AMERICAN ASSOCIATION
OF STATE HIGHWAY AND
TRANSPORTATION OFFICIALS
AASHTO

Guide Specifications for Highway Construction

2020
10th Edition

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TABLE OF CONTENTS

PREFACE

This is the tenth edition of the AASHTO Guide Specifications for Highway Construction. These specifications have been developed by the AASHTO Committee on Construction and are intended to complement the specifications for major structures and bridges, which are covered by the *AASHTO LRFD Bridge Construction Specifications*.

The tenth edition of the AASHTO Guide Specifications provides guidance for developing transportation contract specifications. This edition has a number of updates including a focus on electronic submittals, updated environmental requirements, and revised materials specifications. The AASHTO, ASTM, and additional documentation references have also been updated to reflect the most current versions.

The many differences in climate, geology, geography, customs, statutes, and regulations make a national construction specification practically impossible. However, to provide for easier cross-referencing from state to state or with other agencies, this guide provides uniformity of nomenclature, format, methods of measurement, basis of payment, and method of tests. The guide specifications provide the specification writer with information and topics to be covered and expounded on in a detailed project construction specification.

The guide specifications divisions are subdivided into Description, Materials, Construction Requirements, Method of Measurement, and Basis of Payment. Items shown in brackets, such as [50], throughout the guide specifications are suggested values and should be changed, when necessary, to meet the requirements of the various agencies or project conditions.

Some sections of the guide specifications may be written in a manner to appear as absolute and definite. This is not intended to be the only approach to the content of the section, but to provide a detailed example of the topic.

AASHTO guide specifications are updated and republished periodically. The updated versions provide the user with products, systems, and specification topics that have been used since the last edition.

AASHTO

DIVISION 100
GENERAL PROVISIONS

SECTION 101
GENERAL INFORMATION, DEFINITIONS, AND TERMS

101.1 VOICE/MOOD

This guide specification book uses the active voice, imperative mood when describing the Contractor's responsibilities. For example,

Active Voice/Imperative Mood: Provide competent supervision.

The subject of a sentence written in the active voice/imperative mood is not explicitly stated. In these Specifications, the implied subject of such a sentence is typically the Contractor, although in certain situations, the subject may also be a vendor, fabricator, or manufacturer engaged by the Contractor to supply material, products, or equipment for use on the project. Prior to award of a contract, the imperative statements are directed to the bidder; it is only after the contract has been awarded that the imperatives are directed to the Contractor.

Sentences defining the actions or responsibility of the Agency or its representatives are generally written in active voice/*indicative* mood. For example,

Active Voice/Indicative Mood: The Engineer will provide results of acceptance tests within five days of the test.

101.2 REFERENCES, ACRONYMS, MEASUREMENT UNITS, AND SYMBOLS

A. *References.* Section and Subsection titles and headings provide reference only, not interpretation.

A cross-reference to a specific Subsection of these Specifications includes all general requirements of the Section of which the Subsection is a part.

Unless specified by year or date, cited publications refer to the most recent issue, including interim publications, in effect on the bid closing date.

B. *Abbreviations and Acronyms*. Interpret abbreviations and acronyms used in the contract as follows:

Table 101.2-1. Acronyms and Abbreviations Used in Specifications

Acronym or Abbreviation	Full Name or Meaning
AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
AGC	Associated General Contractors of America
AIA	American Institute of Architects
AISI	American Iron and Steel Institute
ANLA	American Nursery and Landscape Association
ANSI	American National Standards Institute
AREMA	American Railway Engineering and Maintenance-of-Way Association
ARTBA	American Road and Transportation Builders Association
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
ASLA	American Society of Landscape Architects
ASTM	American Society for Testing and Materials
AWPA	American Wood-Preservers' Association
AWWA	American Water Works Association
AWS	American Welding Society
FHWA	Federal Highway Administration
FSS	Federal Specifications and Standards (General Service Administration)
ISO	International Organization for Standardization
LRFD	Load and Resistance Factor Design
MIL	Military Specifications
MUTCD	*Manual on Uniform Traffic Control Devices (for Streets and Highways)*
OSHA	Occupational Safety and Health Administration
PTI	Post-Tensioning Institute
SAE	Society of Automotive Engineers
SSPC	Society for Protective Coatings
UL	Underwriters Laboratories Inc.

C. *Measurement Units.* These Specifications provide measurements in both the inch-pound units of U.S. customary measure and in the International System of Units (abbreviated as SI, and known commonly in the United States as the metric system). Inch-pound units appear first, followed by metric units inside parentheses.

The Agency will identify the system of measurements that will be used on a particular project. Do not mathematically convert units from one system of measure to another; the Agency does not intend for the values to be interchangeable.

D. *Measurement Symbols.* To specify sizes, dimensions, and similar properties, the Agency will use symbols for units of measure, as shown in Table 101.2-2.

Table 101.2-2. Measurement Symbols

Inch-Pound Units (U.S. Customary System)			SI (International System) Units (Metric)	
Symbol	Unit Name	Measurement	Symbol	Unit name
		Length		
mil	mil (0.001 inch)		μm	micrometer
in.	inch		mm	millimeter
ft	foot			
yd	yard		m	meter
mi	mile		km	kilometer
		Area		
in^2	square inch			
yd^2	square yard			
mi^2	square mile		km^2	square kilometer
acre	acre			
		Volume		
gal	gallon		mL	milliliter
$in.^3$	cubic inch		L	liter
ft^3	cubic foot		m^3	cubic meter
yd^3	cubic yard			
		Weight (Mass)		
oz	ounce		g	gram
lb	pound		kg	kilogram
kip	1,000 pounds			
ton	ton, short (2000 lb)		Mg	Megagram

Inch-Pound Units (U.S. Customary System)			SI (International System) Units (Metric)	
Symbol	Unit Name	Measurement	Symbol	Unit name
		Force		
lb	pound		N	newton
kip	1000 pounds		kN	kilonewton
		Pressure, Stress		
psi	pounds per square inch		Pa	pascal
ksi	kips per square inch		kPa	kilopascal
			MPa	megapascal
		Energy		
ft-lb	foot-pound		J	joule
		Illumination		
fc	foot candle		lx	lux
		Time		
s	second		s	second
min	minute		min	minute
h	hour		h	hour
d	day		d	day
		Temperature		
°F	degree Fahrenheit		°C	degree Celsius

101.3 DEFINITIONS

Acts of God. Earthquake, tidal wave, tornado, hurricane, or any other cataclysmic phenomenon of nature beyond the control of the Agency and Contractor.

Actual Cost. Contractor's actual cost to provide labor, material, equipment owned or invoiced rental, and administrative overhead necessary for the work.

Addendum. Contract revision developed between advertising and opening proposals.

Advertisement. Public announcement requesting bids for specified work or materials.

Agency. The State Highway or Transportation Department, Commission, or other organization, constituted under State or Commonwealth laws, that administers highway or transportation work.

Award. Agency acceptance of proposal.

Bid Documentation. All writings, working papers, computer printouts, charts, and data compilation containing or reflecting bidder's information, data, or calculations used to determine the bid proposal. Bid documentation material used to select a proposal includes the following:

- equipment rates,
- overhead rates and related time schedules,
- labor rates,
- efficiency or productivity factors,
- arithmetic extensions, and
- subcontractor and material supplier quotations.

Reference all manuals used to determine the bid proposal, including name, date, and publisher. Bid Documentation excludes any Agency documents provided to the Bidder for use in preparation of the bid proposal.

Bid Documentation Escrow. Preserving successful bid documents as specified in Subsection 103.8.

Bidder. An individual or legal entity submitting a proposal for advertised work.

Bridge. Structure and supports constructed over a depression or obstruction, such as water, highway, or railway, with a track or passageway to carry traffic or other moving loads and a length of at least 20 ft (6 m) measured along the center of the roadway or railroad between abutment undercopings or extreme ends of openings for multiple boxes.

Calendar Day. Every day shown on the calendar, beginning and ending at midnight.

Change Order. Written order to the Contractor detailing changes to the specified work quantities or modifications within the scope of the original contract.

Completion. Contractor completes all specified work satisfactorily and executes and delivers all required documents, certificates, and proofs of compliance.

Construction Limits. Established boundaries within the highway right-of-way or construction easements that define the construction area. Also referred to as the *roadway*.

Contract. Written agreement between the Agency and the Contractor detailing the obligations of each to perform the prescribed work. The contract includes the invitation for bids, addenda, proposal, contract form, contract bonds, standard specifications, supplemental specifications, special provisions, standard plans, notice to proceed, and change orders and supplemental agreements that are required to complete the work.

Contract Bonds. Approved security, on the Agency's form, executed by the Contractor and its surety or sureties, guaranteeing completion of the specified work.

Contract Pay Item. Specific work unit for which the contract provides a price.

Contract Time. Date by which work is to be completed, or number of working days or calendar days allowed to complete the contract. Complete contract work on or before the specified calendar date even if that date is a Saturday, Sunday, or holiday specified in the definition for *Holidays*.

Contractor. Individual or legal entity contracting with the Agency to perform the work.

County. The largest State administrative division used to designate or identify the location of the proposed work.

Culvert. A structure not classified as a bridge providing an opening under the roadway.

Days. Calendar days.

Delay. An event, action, force, or factor causing the work to extend beyond the specified contract time.

A. *Excusable Delay.* A critical delay that is beyond the Contractor's control, not the fault or responsibility of the Contractor, or could not reasonably have been foreseen by the Contractor for which a time extension may be granted.

B. *Compensable Delay.* An excusable delay for which the Contractor may be entitled to additional compensation as specified in Subsection 108.6.

C. *Noncompensable Delay.* An excusable delay for which the Contractor is not entitled to additional compensation.

D. *Nonexcusable Delay.* A delay that was within the Contractor's control, was the fault or responsibility of the Contractor, or could have reasonably been foreseen by the Contractor and for which there is no monetary compensation or time extension.

Differing Site Conditions. Subsurface or latent physical conditions at the project site that

A. Differ significantly from those indicated in the contract, or

B. Present unknown physical conditions of an unusual nature that differ significantly from those normally encountered and generally recognized as inherent in the nature of the work required.

Engineer. The Chief Engineer of the Agency acting directly or through an authorized representative responsible for engineering and administrative supervision of the contract.

Equipment. All machinery, tools, and apparatus, and the fuels, lubricants, batteries, and other supplies and parts needed to use, operate, and maintain these items for use in constructing and completing the work.

Extra Work. Work within the intended scope of the contract but beyond or varying from that originally provided for, and that the Agency later finds essential for the satisfactory completion of the project.

Force Account. A method of payment for work performed by the Contractor at the Engineer's direction, calculated as specified in Subsection 109.4.

Geotextile. Any permeable knitted, woven, or nonwoven textile material integral to a project, structure, or system.

Highway, Street, or Road. General term indicating a public way used by vehicles and pedestrians. Includes entire area within the right-of-way.

Holidays. The following are official holidays used to determine working days: [include Holidays]

Incentive/Disincentive Provisions. Predetermined additions to or subtractions from the contract price for each day work is completed ahead of or behind specific milestone, phase, or contract completion date.

Inspector. The Engineer's authorized representative assigned to inspect work and materials.

Invitation for Bids. Advertisement requesting proposals for work or materials. The invitation for bids estimates quantities and location of the work specified or the character and quantity of materials to be furnished and the time and place of proposal opening.

Laboratory. Agency testing laboratory or other designated testing laboratory.

Major and Minor Contract Items. Major individual bid items having an original value equal to or more than [10] percent of the original contract amount; all others are minor.

Materials. Substances specified for use in project construction.

Notice to Proceed. Written direction to the Contractor to begin work, including the date from which project time will be charged.

Pavement Structure. Combination of surface course, base course, and when specified, subbase, placed on a subgrade to support the traffic load and distribute it to the roadbed.

A. *Surface Course.* Pavement structure layer(s) designed to accommodate the traffic load. The top layer resists skidding, traffic abrasion, and the disintegrating effects of climate and is sometimes called the Wearing Course.

B. *Base Course.* One or more layers of specified material of designed thickness placed on a subbase or subgrade to support a surface course.

C. *Subbase.* One or more layers of specified material of designed thickness placed on a subgrade to support a base course.

D. *Subgrade.* Top surface of a roadbed upon which the pavement structure, shoulders, and curbs are constructed.

E. *Subgrade Treatment.* Stabilization of roadbed material.

Plans. Contract drawings showing location, type, dimensions, and details of specified work.

Prequalification Questionnaire. Specified forms used to furnish required information about the bidder's ability to perform and finance the work.

Profile Grade. Trace of a vertical plane intersecting the top of the proposed wearing surface, usually along the longitudinal centerline of the roadbed. Profile grade indicates either elevation or gradient of such trace according to the context.

Project. The specific section of the highway or property on which construction is to be performed together with all improvements to be constructed under the contract.

Proposal. A bidder's written offer, on Agency-furnished forms, to perform the stated work at the quoted prices.

Proposal Form. Prescribed form on which the bidder submits his/her offer.

Proposal Guaranty. The security furnished with a proposal to guarantee that the bidder will enter into the contract upon proposal acceptance.

Resident Engineer. Field representative of the Engineer who directly supervises contract administration.

Responsible Bidder. Bidder that the Agency determines has the skill, ability, and integrity to perform the project.

Responsive Bid. A bid meeting all requirements of the invitation for bids.

Resources. The labor, equipment, and material necessary to perform work on a contract bid item or other element of work.

Right-of-Way. Land, property, or interest therein acquired for or devoted to transportation purposes.

Roadbed. Graded portion of a highway, within top and side slopes, prepared as a foundation for the pavement structure and shoulders.

Roadbed Material. Material in cuts, embankments, and in embankment foundations below the subgrade surface that supports the pavement structure.

Roadside Development. Items necessary to preserve or replace landscape materials and features, including the following:

A. plantings and other improvements,

B. ground cover to preserve and enhance the appearance and stability of the highway right- of-way, and

C. acquired easements for scenic improvements.

Shoulder. Portion of the roadway contiguous to the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses.

Sidewalk. Portion of the right-of-way constructed exclusively for pedestrian use.

Sieve. U.S.A. Standard Sieve, as defined in ASTM E11. Measure percent passing sieve sizes by weight.

Significant Change in Work. Modification that (1) changes the character of the work materially in kind or nature from the original contract, or (2) results in a major work item increasing in excess of 125 percent or decreasing to less than 75 percent of the original contract quantity.

Specifications. Compilation of provisions and requirements to perform prescribed work.

A. *Standard Specifications.* Book of specifications approved for general application and repetitive use.

B. *Supplemental Specifications.* Approved additions and revisions to the Standard Specifications.

C. *Special Provisions.* Revisions to the Standard and Supplemental Specifications applicable to an individual project.

Specified Completion Date. Date on which the project is specified for completion.

Stabilization. Modification of soils or aggregates by incorporating materials that will increase load-bearing capacity, firmness, and resistance to weathering or displacement.

Standard Plans. Detailed drawings approved for repetitive use.

State or Commonwealth. A body politic, especially one constituting a nation. Example: The State or Commonwealth of ____ acting through its authorized representatives.

Structures. Bridges, culverts, catch basins, drop inlets, retaining walls, cribbing, manholes, endwalls, buildings, sewers, service pipes, underdrains, foundation drains, and similar features that may be encountered in the work.

Subcontractor. Individual or legal entity to which a Contractor sublets part of the work.

Substantial Completion. The point at which the project is complete such that it can be safely and effectively used by the public without further delays, disruption, or impediments. For conventional bridge and highway work, *substantial completion* is the point at which all bridge deck, parapet, pavement structure, shoulder, permanent signing and markings, traffic barrier, and safety appurtenance work is complete.

Substructure, Bridge. All of the structure below the bearings of simple and continuous spans, skewbacks or arches, and tops of footings of rigid frames, including backwalls, wingwalls, and wing protection railings.

Superintendent. The Contractor's authorized representative responsible for and in charge of the work.

Superstructure, Bridge. The entire structure except the substructure.

Supplemental Agreement. Written agreement signed by the Agency and the Contractor to perform work beyond the scope, but in conjunction with, the original contract.

Supplemental Plans. Plans developed and submitted by the Contractor to supplement the Agency's plans. Supplemental plans include drawings, details, and calculations, such as shop drawings; erection, falsework, framework, or cofferdam plans; bending diagrams for reinforcing steel; trade literature; and other supplemental design sheets or similar data that the Contractor must submit to the Engineer.

Surety. Legal entity or individual, other than the Contractor, executing a bond furnished by the Contractor.

Township, Town, City, or District. Subdivision of the county or borough designating or identifying the project location.

Traveled Way. Portion of the right-of-way designated for vehicle use, excluding shoulders and auxiliary lanes.

Unbalanced Bid, Materially. Bid generating a reasonable doubt that award to the bidder submitting a mathematically unbalanced bid will result in the lowest ultimate cost.

Unbalanced Bid, Mathematically. Bid containing lump sum or unit bid items that do not include reasonable labor, equipment, and material costs plus a reasonable proportionate share of the bidder's anticipated profit, overhead costs, and other indirect costs.

Work. The elements and activities necessary to complete a project (including labor, materials, equipment, and the interim products and stages attained in the course of reaching completion).

Work Order. Written directive from the Engineer to the Contractor to perform changed work, extra work, or other additional work within the scope of the contract. A change order establishes any adjustments to compensation or time because of a work order.

Working Day. Any calendar day *except*:

A. Saturdays, Sundays, and contract-designated holidays;

B. Days on which conditions identified in the contract require suspension of construction operations;

C. Days on which inclement weather or conditions beyond the Contractor's control prevent the involvement of at least [75] percent of the normal daily labor and equipment force necessary to control construction operation for at least [60] percent of the daily hours routinely worked, including days on which the inclement weather conditions prevent work from beginning at the regular time and the crew is dismissed, regardless of whether or not conditions change or improve for the rest of the day.

SECTION 102
BIDDING REQUIREMENTS AND CONDITIONS

102.1 PREQUALIFYING BIDDERS

Meet Agency requirements for prequalification before submitting a proposal on projects requiring prequalification. Unless already prequalified, submit prequalification information at least [10] calendar days before submitting a proposal.

Prequalify at least once each year.

Based on submission of additional favorable reports or evidence of unsatisfactory performance, the Agency can change a bidder's prequalification status.

102.2 PROPOSAL FORM CONTENT

A. To obtain a proposal form, prequalify as specified in Subsection 102.1, unless the advertisement indicates that prequalification will not be required. Request bid package and instructions from the Agency. The electronic proposal form does not contain the special provisions, specifications, plans, and other Contract documents. These documents are included by reference. Pay the advertised fee to the Agency for each proposal form and reference documents.

B. The Agency's proposal form will state or include the following:

   1. Project location and description;
   2. Estimate of item quantities and materials to be furnished;
   3. Schedule of items for unit bid pricing;
   4. Schedule for completing work;
   5. Proposal guaranty amount;
   6. Date, time, and location of proposal opening;
   7. Basis for proposal comparison, if it is other than total cost; and
   8. Contract requirements not contained in the standard specifications.

All papers bound with or attached to the proposal form, all plan specifications, and other documents designated in the proposal form are part of the proposal.

102.3 ISSUING PROPOSAL FORMS

Request bid package and instructions from the Agency.

Pay the advertised fee to the Agency for each proposal form and each set of plans.

The Agency may disqualify a bidder as non-responsible or refuse to issue a proposal form for any of the following reasons:

A. Prequalification information reveals a lack of competency and a lack of adequate machinery, plant, and other equipment.

B. Award of additional work could impede or prevent timely completion of work currently under contract.

C. Failure to pay or settle all outstanding labor and material bills for a contract current at the time proposal is issued.

D. Noncompliance with any prequalification regulations.

E. Default under previous contracts or debarment from bidding on Agency contracts.

F. Unsatisfactory performance on previous or current contract(s).

G. Serious misconduct that would adversely affect the ability to perform future work.

H. There is evidence of collusion among bidders. Collusion participants are not recognized as bidders for future work until they are requalified.

I. Failure to reimburse the Agency for monies on previously awarded contracts, including those where the prospective bidder is a party to a joint venture.

102.4 INTERPRETING BID PROPOSAL QUANTITIES

Submit unit bid prices for the estimated quantities. These quantities may increase, decrease, or be eliminated under the contract.

The Agency will pay for the actual quantities of work performed and accepted or materials furnished under the contract.

102.5 EXAMINING DOCUMENTS AND WORK SITE

Carefully examine the contract documents and perform a reasonable site investigation before submitting a bid proposal. Submitting a proposal is considered an affirmative statement that the bidder has examined the site and is satisfied as to the character, quality, quantities, and conditions to be encountered in performing the work. A reasonable site investigation includes investigating the project site, borrow sites, hauling routes, and all other locations related to the performance of the work.

When available, the Agency may include in the contract documents or make available to bidders for review at the designated Agency location, one or more of the following:

A. All Agency boring logs and other records of subsurface investigation,

B. Record drawings, or

C. Results of other preliminary investigations.

A reasonable site inspection includes review of these documents. Such information is for the bidder's general knowledge only and is not a substitute for the bidder's own investigation, interpretation, or judgment.

The Agency is bound only by written statements or representations and descriptions of conditions and work. No oral explanations or instructions are binding.

Submit requests for explanations of proposal documents in adequate time to allow an Agency reply before the proposal opening date. The Agency will respond to requests to all prospective bidders before the specified time for opening proposals.

Immediately notify the Agency of any obvious error, omission, or ambiguity in the bid package. The Agency will review the error, omission, or ambiguity and issue an addendum to all prospective bidders, as appropriate. The Contractor's duty to disclose obvious errors and omissions is a legal requirement. Knowingly withholding information regarding an obvious error or omission, or intentionally misrepresenting an item of Work for financial or competitive gain may result in civil or criminal penalties.

102.6 PREPARING THE PROPOSAL

Submit proposals on Agency-provided or Agency-approved forms. If hard copy, make all entries legible in ink or type. Specify a unit price in words or numbers, or both, if required, for each pay item for which a quantity is given. Show the product of the respective units and quantities in the appropriate column. The unit price prevails if a discrepancy exists between the unit price and the item's total price. The unit price in words prevails if a discrepancy exists between the unit price in words and the unit price in numbers.

For electronic bidding, use the electronic proposal form in the Agency's bidding system. When regular bid items have corresponding alternate items, select the bid item or group of items to be used for the bid tabulation. Acknowledge all addenda listed in the Agency's bidding system.

Provide the total of all unit price and quantity products where required on the form.

Submit bids on all alternates when the proposal contains alternates for various items. Contract award will be made on the alternate selected by the Agency. Submit all Agency addendum provisions to the proposal. Provide on the submitted proposal the signature of a representative authorized to execute bid proposals. Provide the name and address of the individual signing the proposal as well as the following names and addresses, as applicable:

Type of Bidder	Names and Office Addresses Required
Individual	Individual
Partnership	Each member of the partnership
Joint Venture	Each member or officer of firms represented
Corporation	Corporate name and address

102.7 IRREGULAR PROPOSALS

The Agency will consider a proposal to be irregular and will reject such a proposal as nonresponsive if:

A. The proposal is not properly signed by an authorized representative of the bidder.

B. The proposal is not submitted on the proper form (or format if computer generated).

C. The proposal omits a unit and total price for any estimated pay item, except for authorized alternate bid items.

D. Unauthorized additions, conditional or alternate bids, or other irregularities make the proposal incomplete, indefinite, or ambiguous.

E. Added provisions reserve the bidder's right to accept or reject an award or to enter into a contract following award. This does not exclude a bid limiting the maximum gross award amount acceptable to any one bidder at any one bid letting. The Agency selects all awards.

F. If required, the proposal lacks bid escrow documentation.

G. The proposal fails to furnish properly executed proposal guaranty of the character and amount required.

H. An individual, firm, or corporation under the same or different name submits more than one proposal for the same work.

I. The bidder fails to sign the non-collusive bidding certification.

J. The bidder fails to acknowledge addenda.

K. The proposal is mathematically and materially unbalanced. A mathematically unbalanced bid contains lump sum or unit price items that do not include reasonable labor, equipment, and material costs plus a reasonable proportionate share of the Bidder's overhead costs, other indirect costs, and anticipated profit. A Materially Unbalanced Bid is when the Agency determines that an award to the Bidder submitting a Mathematically Unbalanced Bid will not result in the lowest ultimate cost to the Agency.

L. The proposal fails to meet any other material requirement of the invitation for bids.

102.8 PROPOSAL GUARANTY

Make the proposal guaranty unconditionally payable to the Agency. Provide the guaranty in one of the following forms:

A. Properly executed project bid bond on the Agency form;

B. Cashier's check,

C. Certified check,

D. Bank money order, or

E. Bank draft with the bid proposal.

Ensure that the proposal guaranty form is complete and is furnished by the Surety and the Proposal Guaranty has a Power of Attorney executed by the Surety. For an electronic bid, provide a bid bond by a licensed Surety using the electronic registry service approved by the Agency. If the Agency invites alternate Bids and the Bidder elects to Bid more than one alternate, the Bidder may submit one Proposal Guaranty in the amount required for a single alternate. The Proposal Guaranty covers each individual Bid.

102.9 PROPOSAL DELIVERY

For hard copy proposals:

A. Place proposals in a sealed envelope plainly marked to indicate contents.

B. Address to the Agency in care of the official whose office is to receive the proposal. The title and address of the official designated to receive proposals is (Agency to designate).

C. File before the specified time and at the specified location.

D. For proposals using electronic bidding:

E. Submit proposals using the AASHTO "Expedite Bid" software and "Bid Express" website or electronic bid system provided by the Agency.

F. Digitally sign the electronic bid.

If Proposals are received after the specified submission deadline or not prepared and submitted in accordance with the Proposal requirements, the Agency will return Proposals to the bidder unopened.

102.10 REVISING OR WITHDRAWING PROPOSALS

For hard copy bids, write, fax, or telegram revision or withdrawal requests to the Agency before the time set for receiving proposals.

If revising an electronic bid, make desired changes in the Department's bidding system up until the time and date set for the opening of bids. The last bid submitted will be used for tabulation purposes.

If withdrawing an electronic bid, submit an electronic or written request to withdraw a bid before the time and date set for the opening. The Agency will not accept oral requests. An electronic request must be made using the Agency bidding system.

102.11 COMBINATION OR CONDITIONAL PROPOSALS

Submit proposals for projects either in combination or separately, as requested. The Agency will consider only proposal combinations that it specifies. The Agency will write separate contracts for each individual project included in combination awards.

102.12 PUBLIC OPENING OF PROPOSALS

The Agency will open proposals and read publicly at the time and place indicated in the advertisement.

102.13 RESERVED

102.14 MATERIALS GUARANTY FOR THE SUCCESSFUL BIDDER

Furnish a complete statement of the origin, composition, and manufacture of materials to be used in the work. Include samples for compliance testing, as requested.

102.15 CERTIFYING NONCOLLUSIVE BIDDING

Submit the following certification on Agency forms:

EXAMPLE:

Noncollusive Bidding Certification.

By submission of this bid Proposal, each bidder, and each person signing on behalf of a bidder, certifies as to its own organization, under penalty of perjury, that to the best of their knowledge and belief:

1. The prices in this bid Proposal have been arrived at independently without collusion, consultation, communication, or agreement with any other bidder or with any competitor for the purpose of restricting competition.
2. Unless required by law, the prices that have been quoted in this bid Proposal have not been knowingly disclosed and will not knowingly be disclosed by the bidder, directly or indirectly, to any other bidder or competitor prior to opening of Proposals.
3. No attempt has been made or will be made by the bidder to induce any other person, partnership, or corporation to submit or not to submit a Proposal for the purpose of restricting competition.
4. The signers of this Proposal hereby tender to the Agency this sworn statement that the named Contractor(s) has not, whether directly or indirectly, entered into any agreement, participated in any collusion, or otherwise taken any action to restrain free competitive bidding in connection with this Proposal.

The Agency will not consider a bid proposal for award nor will it make any award where there has not been compliance with the statements in the certification above.

The fact that a bidder (1) has published price lists, rates, or tariffs covering items being procured; (2) has informed prospective customers of proposed or pending publication of new or revised price lists for such item; or (3) has sold the same items to other customers at the same prices being bid, does not constitute a disclosure within the meaning of Part 2 of the certification above.

SECTION 103
CONTRACT AWARD AND EXECUTION

103.1 CONSIDERATION OF PROPOSALS

Bid results are public information.

Summation of the unit item prices and estimated quantities is the Agency's basis for comparing bid proposals. Unit prices govern if discrepancies exist between unit bid prices and extensions.

The Agency may reject bid proposals, waive technicalities, or advertise for new proposals in the best interest of the Agency. The bidder may request withdrawal of a bid after bid opening by:

A. Submitting a notarized affidavit within 24 hours after bid opening that declares a clerical or mathematical error in bid preparation,

B. Submitting original work sheets used in bid preparation along with affidavit,

C. Describing specific error(s) in detail, or

D. Verifying that error is of a significant monetary effect in the amount of three percent or greater of the total for all items of the bid proposal.

The bidder may not request bid withdrawal for judgmental errors.

103.2 AWARDING THE CONTRACT

The Agency will award the contract within [30] calendar days to the lowest responsible, qualified bidder with the lowest responsive bid. Written notice by registered mail or other receipt acknowledgment procedure will advise the successful bidder of proposal acceptance and contract award.

The Agency and the successful bidder may mutually agree to extend the time within which the award is made.

103.3 CANCELING THE AWARD

The Agency may cancel a contract award before execution without liability.

103.4 RETURNING PROPOSAL GUARANTY

Except for those of the two lowest bidders, the Agency will return all proposal guaranties within [7] calendar days following the opening and checking of the proposals. The Agency will return the retained proposal guaranties of the two lowest bidders (1) after a satisfactory bond is furnished and the contract is executed, or (2) if the Agency approves the request to withdraw the bid as specified in Subsection 103.1. An alleged error in preparing the proposal will not release a bidder from the bidding obligation unless the Agency returns the proposal guaranty.

103.5 CONTRACT BOND

Furnish an executed performance bond and a payment bond in a sum equal to the contract amount. Use a form acceptable to the Agency. If the surety or bonding company fails or becomes insolvent, within [10] calendar days of the failure or insolvency, file a new bond(s) in the amount designated by the Agency.

103.6 EXECUTING AND APPROVING THE CONTRACT

Return the signed contract and contract bond to the Agency within [15] calendar days of notice of the award. The bidder may withdraw the bid without penalty if the Agency has not executed the contract within [30] calendar days of receiving the signed contract and bonds. A contract is considered awarded only after it is fully executed by all parties.

103.7 FAILURE TO EXECUTE CONTRACT

The Agency may cancel the notice of award and keep the proposal guaranty if the successful bidder fails to execute the contract and file acceptable bonds within [15] calendar days after the notice of the award. The Agency may then award the contract to the next lowest responsible bidder or re-advertise the work.

103.8 ESCROW OF BID DOCUMENTATION

If specified, submit with the bid proposal a legible copy of the documentation used to prepare the proposal. Meet the following:

A. *Submitting and Returning Bid Documentation.* Submit bid documentation in a sealed container clearly marked “Bid Document” and labeled with the bidder’s name and address, submission date, project number, and contract number. The Agency will return sealed containers of all but the two lowest bidders within seven days of contract award. The Agency will return the sealed container of the remaining unsuccessful bidder within seven days of contract execution.

B. *Affidavit.* In addition to bid documentation, submit a signed and certified affidavit that lists each bid document submitted by author, date, nature, and subject. The affidavit must attest that

1. The affiant has examined the bid documentation and that the affidavit lists all documents used to prepare the bid.

2. The sealed container contains all such bid documentation.

C. *Duration and Use.* After executing the contract, the Agency and the Contractor must jointly deliver the sealed container and affidavit to a bank or other Agency-designated bonded document depository for safekeeping in a safety deposit box, vault, or other secure accommodation.

The document storage agreement must indicate that the bid documentation and affidavit will remain in escrow during the life of the contract or until the Contractor notifies the Agency of its intent to file a claim or initiate contract-related litigation against the Agency. Such action is sufficient ground for the Agency to obtain the release and custody of the escrowed bid documentation. Absent a claim or notice of the Contractor's intent to file a claim, the Agency will direct the depository to release the sealed container to the Contractor provided the Contractor signs the final standard release form.

Certifying that the materials in escrow represent all documentation used to prepare the bid waives the Contractor's rights to use bid documentation other than those in escrow, should contract disputes arise.

D. *Refusal or Failure to Provide Bid Documentation.* Failure to provide bid documentation renders the bid nonresponsive.

E. *Confidentiality of Bid Documentation.* Materials held in escrow remain the property of the Contractor unless the Agency receives the Contractor's notification of intent to file a claim or litigation ensues. If either occurs, the materials become the property of the Agency until the claim is resolved or litigation is concluded. Originals and copies of escrow materials will be returned to the Contractor once litigation is concluded, outstanding claims are resolved, or final release is executed. The Agency will make every reasonable effort to ensure the confidentiality of bid documentation.

F. *Cost and Escrow Instruction.* The Agency will pay to store all escrowed materials and will provide escrow instructions to the depository.

G. *Payment.* Include within the overall contract bid price all costs to comply with this subsection.

SECTION 104
SCOPE OF WORK

104.1 CONTRACT INTENT

The intent of the contract is to provide requirements for the construction and completion of the Work in accordance with the Plans, Specifications, and all other Contract Documents and define the roles and obligations of the Agency and Contractor regarding the construction, execution, and completion of the Work.

104.2 REVISIONS

A. *General.* The Agency reserves the right to revise the contract at any time. These revisions do not invalidate the contract or release the surety, and the Contractor agrees to complete the contract as revised. Do not proceed with the revised work without the Engineer's written authorization. Upon receiving written approval, proceed immediately with the revised work.

The Agency will only consider requests from the Contractor for a revision to the contract amount or time if the Contractor first notifies the Engineer as specified in Subsection 104.3.

If the Engineer determines that a revision is necessary, the Agency will revise the contract time as specified in Subsection 108.6 and will pay for the revised work at the contract unit bid prices unless the Contractor's cost of production or the character of the work is materially changed, in which case the Agency may revise the contract as specified in Subsection 109.4. The Agency will not pay for lost or anticipated profits resulting from a revision to the contract.

If the Engineer decides that a potential contract revision identified by the Contractor is not necessary, and the Contractor does not agree with the Engineer's decision, the Contractor may pursue a claim as specified in Subsection 105.18.

B. *Differing Site Conditions.* If either of the following conditions is encountered during the progress of the work, immediately notify the Engineer of the conditions as specified in Subsection 104.3 before they are disturbed and before performing or continuing with the affected work:

1. A subsurface or latent physical condition differing materially from those indicated in the contract; or

2. An unknown physical condition of an unusual nature, differing materially from those ordinarily encountered and generally recognized as inherent in the work provided for in the contract.

C. *Significant Changes in the Character of Work.* The Engineer may alter contract quantities, the work, or both as necessary to satisfactorily complete the project. If such alternations significantly change the character of the work, the Agency will make appropriate adjustments to the contract as specified in Subsections 108.6 and 109.4.

Consider either of the following to be a "significant change":

1. When the character of the work as altered differs materially in kind or nature from that involved or included in the original proposed construction; or

2. When the quantity of a major item of work is increased in excess of 125 percent or decreased below 75 percent of the original contract quantity. Any allowance for an increase in quantity applies only to that portion in excess of 125 percent of original contract item quantity, or in the case of a decrease below 75 percent, to the actual amount of work performed.

Before performing significantly changed work, reach agreement with the Agency concerning the basis for the adjustment as specified in Subsections 109.4 and 108.6.

If the alterations do not significantly change the character of the work specified in the contract, the Agency will pay for the altered work at the contract unit price.

If the Contractor disagrees as to whether an alteration constitutes a significant change, use the notification procedures specified in Subsection 104.3.

D. *Suspension of Work Ordered by the Engineer.* If the Engineer suspends or delays all or any portion of the work for an unreasonable period of time (not originally anticipated, customary, or inherent to the construction industry), and the Contractor believes that additional compensation, contract time, or both is due because of the suspension or delay, notify the Engineer as specified in Subsection 104.3.

The Engineer will evaluate the Contractor's request. If the Engineer agrees that the cost, time, or both, required for the performance of the contract has increased due to the suspension or delay and the suspension or delay was caused by conditions beyond the control of and not the fault of the Contractor, its suppliers, or subcontractors at any approved tier, and not caused by weather, the Engineer will revise the contract as specified in Subsections 108.6 and 109.4.

The Agency will not grant or consider contract revisions based on an Engineer-ordered suspension

1. without a timely written notice as specified in Subsection 104.3;
2. to the extent that performance would have been suspended or delayed by any other cause;
3. for which an adjustment is provided or excluded under any other term or condition of the contract; or
4. that includes profit.

E. *Extra Work.* When necessary or desirable to complete the project, the Engineer may direct the Contractor to perform unforeseen work for which there is no pay item or unit price in the contract. The Agency will pay for such work as specified in Subsection 109.4.

F. *Eliminated Items.* The Agency may partially or completely eliminate contract items. The Agency will reimburse the Contractor for costs incurred before notification of the elimination as specified in Subsection 109.5.

104.3 CONTRACTOR NOTIFICATION

The Engineer will only consider requests for contract revisions when the Contractor meets the notification procedures in this subsection.

A. *Initial Oral Notification by Contractor.* Provide immediate oral notification to the Engineer upon discovering a condition that may require a revision to the contract. Do not start or continue an activity or item of work for which a contract revision may be necessary without authorization from the Engineer.

B. *Written Notice by Contractor.* If the Engineer has not yet resolved the issue, provide the following information, in writing, within [5] calendar days of the oral notification:

   1. A description of the situation, including the time and date the situation was first identified, and the location of the situation, if appropriate.

   2. An explanation of why the situation represents a change to the contract, with references made to the pertinent portions of the contract.

   3. A statement of the revisions considered necessary to the contract price(s), delivery schedule(s), phasing, and time. Because of its preliminary nature, the Agency recognizes that this information may rely on estimates.

   4. An estimate of the time within which the Agency must respond to the notice to minimize cost, delay, or disruption.

   Written notice is required for consideration of contract revisions. Failure to provide written notice to the Agency will constitute a waiver of the Contractor's entitlement to a contract revision for additional compensation or a time extension.

   After notifying the Engineer, and if the Agency provides no directions to the contrary, continue to perform the work to the extent possible under the contract.

C. *Written Acknowledgement by Engineer.* The Engineer will provide written acknowledgement of the Contractor's written notice.

D. *Written Response by Engineer.* Within [10] calendar days of receiving the Contractor's written notice, the Engineer will provide a written response that includes one of the following:

   1. A confirmation of the change and, when necessary, direction on how the work will proceed.

   2. A denial of the request for a contract revision, which will include references to the contract as to why the issue does not represent a change.

   3. A request for additional information stating the specific information needed and the date by which it must be received. The Agency will respond to additional information within [10] calendar days of receipt.

104.4 MAINTAINING TRAFFIC

Keep the road open to traffic during the work or provide adequate detour roads as specified or directed. Furnish, install, and maintain traffic control devices as specified in the approved traffic management plan, Section 618, and the *Manual on Uniform Traffic Control Devices (for Highways* *and Streets)* (MUTCD). Maintain the portion of the project open to the public in a condition that safely and adequately accommodates traffic. Construct and maintain all necessary accesses to parking lots, garages, businesses, residences, farms, and other features as may be necessary. The Agency will pay for traffic control devices under Section 618. Allowable additional compensation for maintenance includes:

A. *Special Detours.* When the contract includes "Maintenance of Detours" or "Removing Existing Structures and Maintaining Traffic," include in bid all costs to construct, maintain, and remove detours, including the costs to construct and remove temporary bridges and accessory features. The Agency will provide right-of-way for temporary highways or bridges designated in the contract.

B. *Maintaining Traffic during Work Suspension.*

   1. *Suspensions Ordered by the Engineer.* Prepare the project for traffic flow as directed during anticipated work suspensions. The Agency will maintain temporary roads and project sections during work suspensions. Resume maintenance for the entire project once work resumes. Replace or repair all work or materials lost or damaged during the suspension. If the reason for the suspension is beyond the control and without the fault of the Contractor, the Agency will pay for the cost of additional work to resume operations at contract unit prices or as extra work.

   2. *Other Work Suspensions.* Maintain the roadway to accommodate traffic, at no cost to the Agency, during suspensions resulting from any of the following:

      a. seasonal or climatic conditions,

      b. failure to correct unsafe conditions for workers or the general public,

      c. failure to perform work directed by the Engineer, or

      d. other circumstances caused by the Contractor.

C. *Maintenance Directed by the Engineer.* Special maintenance is work that is not included in the contract but that is defined and directed by the Engineer to benefit the traveling public. The Agency will pay based on the unit price or as specified in Subsections 109.3 or 109.4.

104.5 RIGHTS IN AND USE OF MATERIALS FOUND ON THE PROJECT

Obtain approval before using excavated materials found in other parts of the project. The Agency will pay for both the excavation of these materials at the contract unit price and for the pay item for which the material is used.

Replace the removed material, when directed, with acceptable materials at no cost to the Agency. Compact replacement material to the density requirements specified for roadway embankment construction. Obtain written permission before excavating or removing material from within the right-of-way that is outside the grading limits.

Unless otherwise specified in the contract, salvageable material is the property of the Contractor.

104.6 CLEANUP

Before final inspection and acceptance, remove all rubbish, debris, materials, temporary structures, and equipment from the highway, borrow pits, and all areas used to perform the work. The final cleanup cost is incidental to other items.

104.7 RESTORING SURFACES OPENED BY PERMIT

Allow individuals, firms, or corporations with authorized permits to enter the project to construct or reconstruct utility service.

When directed by the Engineer, repair work damaged by permit holder actions to the original standard. The Agency will pay for repair work at contract unit prices or as extra work.

104.8 RAILWAY–HIGHWAY PROVISIONS

The Agency will coordinate with the railway for new or existing crossings necessary for designated hauling across railway tracks. To use crossings other than those designated in the contract, make arrangements with the railway at no cost to the Agency.

Perform work on the railway right-of-way without interfering with trains or railway company traffic and in compliance with requirements set by the railway for flagging, right-of-entry agreements, and protection of crossings. Coordinate all work crews and schedules for work conducted concurrently with the railway company work. Furnish insurance for work on railway right-of-way as specified in the contract and railway requirements.

104.9 CONSTRUCTION OVER OR ADJACENT TO NAVIGABLE WATERS

Conduct work over, on, or adjacent to navigable waters without interfering with free waterway navigation. Comply with permits issued by the U.S. Coast Guard or the U.S. Army Corps of Engineers, and obtain and comply with other permits as identified in the contract.

104.10 CONTRACTOR'S RESPONSIBILITY FOR WORK

Protect project work from damage whether or not related to performing the work, except as specified in Subsection 104.4(B)(1), until written acceptance of the project as defined in Subsection 105.17.

Rebuild, repair, restore, and make good all losses, injuries, or damage, under the control of the Contractor, at no cost to the Agency. Rebuild, repair, restore, and make good all losses, injuries, or damage, not under the control of the Contractor, under agreed unit prices or as extra work under Subsection 109.4. Items not under the control of the Contractor are acts of God, or acts of the public enemy or of governmental authorities.

During work suspensions, ensure that there is no damage to the project, provide for normal drainage, and erect necessary temporary structures, signs, or other facilities. Maintain all newly established plantings, seedings, and sodding and protect new tree or other designated vegetative growth in acceptable condition. Bear responsibility for costs incurred in periods of suspension defined in Subsection 104.4(B)(2).

104.11 ENVIRONMENTAL PROTECTION

Comply with all Federal, State, and local laws and regulations controlling environmental pollution. Prevent pollution of streams, lakes, ponds, and reservoirs with sediment, fuels, oils, bitumens, chemicals, or other harmful materials. Prevent atmospheric pollution from particulate and gaseous matter. Ensure that any work has appropriate erosion and sediment control measures in place to prevent discharge into bodies of water.

Ford or work in streams only as allowed by permit. Ensure that any work results in minimal stream siltation.

Use a dike or barrier to prevent sediment from work areas or pits located in or adjacent to streams from entering the stream.

Treat water used to wash aggregate or from other operations that produce sediment by filtration, settling basins, or other methods that reduce sediment concentrations to the level of the stream or lake into which it is discharged.

Meet requirements for temporary and permanent erosion and sediment controls as specified in Section 207.

104.12 CONTRACTOR PROPOSALS FOR VALUE ENGINEERING

The Contractor and the Agency will share equally the savings resulting from a Value Engineering Change Proposal (VECP) offered by the Contractor and approved by the Agency.

Base contract bid prices on actual work rather than on VECPs that are subject to Agency approval. If a VECP is rejected, complete the contract as bid.

The Agency will notify the Contractor within five working days if the response time requested in the Contractor's submittal does not allow sufficient time for review. The Agency may consider a noncompensable delay adjustment to the contract based on the additional review time necessary and its effect on the Contractor's schedule.

The Contractor shall have no claim against the Agency for compensable or noncompensable delay if the Agency fails to respond within the time indicated in Subsection 104.12(B)(5) because additional information requested from the Contractor is necessary to complete the review.

A. The Agency will consider VECPs that may potentially result in savings without damaging essential functions and characteristics of the facility. These include, but are not limited to, service life, economy of operation, ease of maintenance, desired appearance, and safety.

B. *Submitting VECPs.* Submit the following materials and information with each VECP:

1. A statement that the submission is a VECP.
2. A description of the existing work and the proposed changes for performing the work. Include a discussion of the comparative advantages and disadvantages of each.
3. A complete set of plans and specifications showing proposed revisions to the original contract.
4. A detailed cost estimate for performing the work under the existing contract and under the proposed change.
5. A time frame within which the Agency must make a decision.
6. A statement of the probable effect the proposal would have on the contract completion time.
7. A description of any previous use or testing of the proposal, including the conditions and results. If the proposal was previously submitted on another Agency project, provide the dates, project numbers, and the Agency's action on the proposal.

C. *Conditions.* The Agency will only consider VECPs that meet the following conditions:

1. VECPs, regardless of their approval by the Agency, apply only to the current contract and become the property of the Agency. Impose no use or disclosure restrictions on the VECP. The Agency may duplicate or disclose any data necessary to use the VECP. The Agency may apply a VECP for general use on other contracts without obligation to the Contractor. This provision does not deny rights provided by law with respect to patented materials or processes.
2. The Agency may reject a proposal if it contains certain revisions that the Agency is already considering or has already approved for the contract without obligation to the Contractor.
3. The Contractor has no claim to additional costs or delays, including development costs, loss of anticipated profits, or increased material or labor costs, if the VECP is rejected.
4. The Agency will decide whether or not to consider a VECP. The Agency may reject a VECP that requires excessive review, evaluation, or investigation, or that is inconsistent with project design policies or criteria.
5. The Engineer may reject unsatisfactory work resulting from an approved VECP. Remove rejected work and reconstruct under the original contract without reimbursement for the work performed under the VECP or for its removal. Reimbursement for approved modifications to the VECP to adjust to field or other conditions is limited to the total amount payable for the work under the contract bid prices. Rejection or limitation of reimbursement is not a basis for any claim against the Agency.

6. Use only proven features that have been employed under similar conditions or projects acceptable to the Agency.

7. The Agency will reject VECPs that provide equivalent options to those already in the contract.

8. The Agency will only consider VECPs generating sufficient savings.

9. The Agency will reject VECPs that change only pavement thickness or type, or both thickness and type.

10. The Agency will disqualify VECPs if requests for additional information are not met in a timely manner. This includes field investigation results and surveys, design computations, and field change sheets for proposed design changes.

D. *Payment.* VECPs accepted in whole or in part will be by change order. Payment will be as follows:

1. The contract will incorporate changes in quantities of unit bid items, new agreed price items, or both, as appropriate.

2. The Agency will pay for the cost of the revised work directly. The Agency also will pay the Contractor 50 percent of the savings between the cost of the revised work and the original bid price.

3. Costs to develop, design, and implement the VECP are excluded from reimbursement.

4. Only the Contractor may submit VECPs and be reimbursed for savings. Subcontractors may submit VECPs only through the Contractor.

SECTION 105
CONTROLLING WORK

105.1 ENGINEER'S AUTHORITY

The Engineer decides all questions regarding the quantity, quality, and acceptability of materials furnished and work performed, work progress, contract interpretation, and acceptable contract fulfillment.

A. The Engineer will suspend the work wholly or in part for the Contractor's failure to:

1. Correct conditions unsafe for project personnel or the public;

2. Complete contract provisions; or

3. Comply with the Engineer's direction.

B. The Engineer may also suspend work wholly or in part for:

1. Necessary periods caused by unsuitable weather;
2. Conditions unsuitable for conducting work; or
3. Any other condition or reason considered to be in the Agency's interest.

105.2 PLANS AND WORKING DRAWINGS

The Agency will provide at least two sets of plans.

Steel bridge plans show only general features.

Supplement plans with Working Drawings that include shop and erection drawings, associated trade literature, calculations, schedules, manuals, and similar documents to detail required work not included in the plans. Furnish Working Drawings to the Agency. The contract will explain Agency actions following its receipt of this information.

The Contract may require the Contractor to submit electronic Working Drawings for the performance of the work. Submit Working Drawings electronically to the Engineer in high resolution PDF format; prepare drawing details in accordance with conventional detailing practices and follow Agency guidelines for electronic working drawing submittals. If the PDF format is found to be unacceptable, at the request of the Engineer, provide paper copies of the Working Drawings with drawings on 11-by-17-in. sheets and calculations or text on $8^1/_2$-by-11-in. sheets.

Keep one complete set of plans, including workings drawings, on the project site at all times. The contract price includes the cost of furnishing working drawings.

105.3 CONFORMANCE WITH PLANS AND SPECIFICATIONS

Perform work and furnish materials to meet contract requirements.

If a contract item fails to meet contract requirements but is adequate to serve the design purpose, the Engineer will decide the extent to which the work will be accepted and remain in place.

The Engineer will document the basis of acceptance by change order and will adjust the contract price.

If a contract item does not meet specified requirements and results in work that does not serve the design purpose, remove and replace the defective work or correct the work at no cost to the Agency.

If there are contract provisions allowing acceptance of a contract item that does not comply with the minimum requirements, the appropriate Subsections on measurement and payment will include pay adjustment factors reflecting the payment to be made for the accepted work.

105.4 COORDINATING PLANS, SPECIFICATIONS, SUPPLEMENTAL SPECIFICATIONS, AND SPECIAL PROVISIONS

All supplementary documents are essential parts of the contract and a requirement occurring in one is binding as though occurring in all. They are complementary and provide and describe the complete contract. If there is a discrepancy, the governing ranking is:

Dimensions	Information
1. Plan	1. Special Provisions
2. Calculated	2. Plans
3. Scaled	3. Supplemental Specifications
	4. Standard Specification
	5. Standard Plans
	6. Information received at mandatory prebid meetings

The Contractor may not take advantage of any apparent contract error or omission. Notify the Engineer promptly of any omissions or errors so that necessary corrections and interpretations can be made.

105.5 CONTRACTOR COOPERATION

The Engineer will supply at least two sets of Contracts. Keep at least one set on the project at all times.

Give the project the constant attention necessary to promote progress of the work, and cooperate with Agency inspectors and other contractors.

Employ a competent superintendent who is experienced with the work being performed and is capable of reading and understanding the contract documents. The superintendent shall act as the authorized agent of the Contractor, having full authority to execute instructions and directions from the Engineer or authorized Agency representatives without delay. Ensure the superintendent is accessible to the Engineer at all times. Supply all necessary resources to complete the contract, regardless of the amount of work sublet.

Provide a superintendent who speaks and understands English, and maintain at least one other responsible person who speaks and understands English on the project during all working hours.

105.6 PRECONSTRUCTION CONFERENCE

Immediately after awarding the Contract but before the Contractor begins work, submit to the Engineer a complete and practical plan of operations that provides for the orderly and continuous performance of the Work. The Engineer will call a preconstruction conference at a place the Engineer designates in order to go over the construction aspects of the project. Attend this meeting, along with the Agency staff and the various utility companies or railroads that will be involved with the road construction.

Furnish a list of proposed subcontractors and material suppliers at or before the Preconstruction Conference. Ensure that all subcontractors have a safety program or participate in that of the Contractor. The Contractor is responsible for worksite safety and conducting all operations to protect the workers engaged in duties connected with the Work.

If the Contractor fails to provide the required submissions at or before the Preconstruction Meeting, the Engineer may order the meeting suspended until they are furnished. Do not begin the Work until the meeting is reconvened and concluded or the Engineer gives specific written permission to proceed.

105.7 PARTNERING

To facilitate this contract, the Agency offers to participate in partnering with the Contractor. Partnering draws on the strengths of each organization to identify and achieve reciprocal goals. Partnering strives to resolve problems in a timely, professional, and non-adversarial manner. If problems result in disputes, partnering encourages, but does not require, alternative dispute resolution instead of the formal claim process. Partnering does not alter the terms and conditions of the contract. The objective is effective and efficient contract performance to achieve a quality project within budget and on schedule.

Acceptance of this partnering offer by the Contractor is optional, and the partnership is bilateral.

Informal partnering does not make use of a facilitator, while formal partnering uses the services of a facilitator (internal or external). If the partnering offer is accepted, mutually agree with the Engineer on the level of organizational involvement and the need for a partnering facilitation. Engage the facilitator and other resources for key Contractor representatives and the Engineer to attend a partnering and team-building workshop usually between the time of award and the Notice to Proceed. Hold additional partnering update meetings upon mutual agreement.

The direct cost of partnering facilities, professional facilitation, copying fees, and other miscellaneous costs directly related to partnering meetings will be shared by the Contractor and the Agency. The Agency will reimburse the Contractor for 50 percent of the agreed costs incurred for the partnering process.

105.8 COOPERATING WITH UTILITIES

The contract will show all utility items to be relocated or adjusted by utility owner(s), others, or the Contractor.

The Agency requires utility owners and others to adjust utility fixtures and appurtenances shown in the plans. The location shown on the plans for utilities are provided by utility owners and may not be exact, especially with regard to underground installations. Use work procedures that consider the potential of inaccurate locations. Cooperate with the utility owners to remove, rearrange, or both remove and rearrange the underground or overhead utilities to avoid service interruption or duplicate work by the utility owner.

Use work procedures that protect utilities or appurtenances that remain in place during construction.

The Agency will notify utility companies, pipeline owners, or other utility agencies affected by the work to ensure that all utility adjustments, within or adjacent to the construction limits, are made as soon as possible.

Notify the appropriate utility authorities of any service interruption resulting from breakage within the construction limits. Cooperate with authorities until service is restored. Work around fire hydrants only after obtaining approval by the local fire authority and only after making provisions for continued service.

Correct and pay for repairs to damaged utilities that result from carelessness or omission. Restore damaged facilities to the preexisting condition.

The Engineer will decide whether to adjust or relocate utility facilities or appurtenances found but not noted in contract documents. The Engineer will also make necessary arrangements with the utility owner or the Contractor if the necessary work is not shown in the contract. Sections 104, 108, or both, will be used for compensable or noncompensable adjustments to the contract because of revised or extra work.

105.9 COOPERATION BETWEEN CONTRACTORS

The Agency may contract for and perform other work on or near the project site.

Cooperate with other contractors working within the limits of the same project. Conduct work without interrupting or inhibiting the progress or completion of work by other contractors.

Each contractor accepts all liability, financial or otherwise, in connection with the contract. Each contractor protects and saves harmless the Agency from any damages or claims caused by inconvenience, delay, or loss from the presence and work of other contractors working within the same project limits.

Coordinate and sequence the work with other contractors. Arrange, place, and dispose of materials without interfering with the operations of other contractors on the same project.

105.10 CONSTRUCTION STAKES, LINES, AND GRADES

The contract specifies who will provide construction stakes, lines, and grades.

A. *Agency-Provided Construction Stakes, Lines, and Grades.* The Engineer will set construction stakes to establish centerline control points (Begin Project, End Project, PIs, PTs, etc.) and benchmarks at appropriate intervals along the line of the project to facilitate the proper layout of the work.

Determine the meaning of all stakes, indicated measurements, and marks before beginning work. Use these stakes and marks as the field control to perform the work.

Preserve all stakes and marks. The cost of replacing disturbed stakes and marks will be deducted from contract payment.

The Agency ensures the accuracy of surveyed lines, slopes, and grades. The Agency assumes no responsibility for staking delays unless the Engineer is notified [10] calendar days before the Contractor begins work on an item and 48 hours if stakes are subsequently needed.

B. *Contractor-Provided Construction Stakes, Lines, and Grades.* Perform the construction engineering, necessary calculations, and staking of the work, including:

1. Reestablish survey points and centerlines.
2. Reference control points, when necessary.
3. Run a level circuit to check or reestablish plan benchmarks.
4. Set stakes for construction limits, right-of-way including station identification stakes at [100-ft (30-m)] intervals and all locations where a change in right-of-way width occurs, drainage items, slopes, pavement structure, embankment and subgrade controls, bridge control points for vertical and horizontal alignment of all components, and any other stakes necessary to control lines and grades.

Furnish all stakes, templates, straightedges, and other devices necessary to check, mark, and maintain points, lines, and grades. Ensure that contract staking conforms to standard procedures used by Agency engineering personnel. Use of GPS/GIS technology that provides equivalent control points, lines, and grades can be furnished if acceptable to the Engineer.

Run the level circuit to check plan benchmarks for the full length of road construction projects. On bridge construction projects, ensure that the level circuit includes four benchmarks, i.e., two on each side of each structure if possible.

The Engineer will make all measurements and surveys that involve determining final pay quantities. The Contractor is responsible for the final accuracy of construction.

Maintain orderly and clear field notes in standard field notebooks consistent with standard engineering practices and that meet the Agency's notebook procedures. Use standard field books furnished by the Agency. Allow Agency personnel to inspect these field books at any time. The books become Agency property once work is completed. Electronically collected field data developed consistent with standard industry practice may be submitted if acceptable to the Engineer.

Supervise construction engineering personnel and correct any errors, at no additional cost to the Agency.

Include the cost of performing layout work as described above in the contract unit prices for the various items of work that require layout.

C. *Contractor-provided Stakeless Instrumentation.* If specified, submit a comprehensive written Work Plan to the Engineer using a Global Navigation Satellite System (GNSS), Robotic Total Station (RTS) equipment, or a Real-time Kinematic (RTK) system for Agency review and acceptance at the preconstruction conference or at least 30 days before starting work. Update the plan as necessary during construction and notify the Agency of all changes. Describe in the Work Plan how Automated Machine Guidance technology will be used on the project. At a minimum, include the following in the Work Plan:

1. Designate which portions of the Contract will be done using GNSS-enabled Automated Machine Guidance and which portions will be constructed using conventional survey methods.
2. Describe the manufacturer, model, and software version of the equipment.
3. Provide information on the qualifications of Contractor staff. Include formal training and field experience. Designate a single staff person as the primary contact for GNSS or RTS technology issues.
4. Describe how project control will be established. Include a list and map showing control points enveloping the site.
5. Describe site calibration procedures. Include a map of the control points used for site calibration and control points used to validate the site calibration. Describe the frequency of site calibration and how site calibration will be documented.
6. Describe the quality control procedures for verifying mechanical calibration and maintenance of construction and guidance equipment. Include the frequency and type of verification performed to ensure the constructed grades conform to the Contract Documents.

Provide equipment that meets the requirements of the Department's Survey and Mapping Specifications. Provide equipment, software, and all three-dimensional models needed to verify layout, perform check sections, and document pay items.

Train the Engineer on how to use the provided equipment and software and provide technical assistance during the duration of the Work. Upon completion of the Work, the electronic equipment, computer, and software will remain the property of the Contractor.

105.11 AUTHORITY AND DUTIES OF THE RESIDENT ENGINEER

As the direct representative of the Agency, the Resident Engineer has immediate charge of the engineering details of each construction project and is responsible for contract administration. The Resident Engineer can reject defective material and suspend work being performed improperly.

105.12 DUTIES OF THE INSPECTOR

Agency inspectors are authorized to examine all work performed and materials furnished, including the preparation, fabrication, or manufacture of the materials to be used. The inspector can reject work or materials until the issues can be referred to and decided by the Engineer.

Inspectors may not alter or waive contract provisions, issue instructions contrary to the contract, or act as foremen for the Contractor.

105.13 INSPECTING WORK

The Engineer may inspect, at any time, all materials and all parts of the work. Ensure safe access to all parts of the work and provide information and assistance to the Engineer to ensure a complete and detailed inspection.

The Engineer may order work performed or materials used without supervision or inspection by an authorized Agency representative to be removed and replaced at no cost to the Agency.

Remove and uncover portions of finished work, as directed. Once inspected, restore work to contract requirements. If the uncovered work is found acceptable, the Agency will pay for the uncovering, removing, and restoring of that work as extra work. If the work is found unacceptable, the Contractor will pay for the uncovering, removing, and restoring of that work.

If the Engineer fails to reject defective work or materials, whether from lack of discovery of such defect or for any other reason, such initial failure to reject in no way prevents the later rejection when such defect is discovered, or obligates the Agency to final acceptance. The Agency is not responsible for losses suffered due to necessary removals or repairs of such defects.

When a government agency, utility, or railroad company is to accept or pay a portion of the contract cost, that organization's representatives may inspect the work. Inspections by such organizations do not make them a party to the contract and do not interfere with the rights of parties to the contract.

105.14 REMOVING UNACCEPTABLE AND UNAUTHORIZED WORK

The Engineer will consider work that fails to meet the contract requirements to be unacceptable, unless accepted under Subsection 105.3.

Remove and replace unacceptable work before final acceptance.

Work performed contrary to Engineer's instructions, work beyond plan limits, or extra work performed without the Engineer's permission is excluded from pay consideration. The Agency may order this work removed, restored, or replaced by others at the Contractor's expense.

105.15 LOAD RESTRICTIONS

Observe legal load restrictions when hauling equipment or materials on public roads beyond project limits. A special permit does not relieve the Contractor of liability for damage resulting from moving equipment or materials.

Obtain the Engineer's written permission to exceed legal load limits within the project limits. Do not operate equipment or haul loads that may damage structures, roadway, or any construction. Obtain the Engineer's approval to haul materials over completed work within the project limits. Do not operate vehicles or equipment on hydraulic cement concrete construction before the minimum curing time has passed or the specified strength is obtained.

105.16 MAINTENANCE DURING CONSTRUCTION

Maintain the project site in a satisfactory condition until the project is accepted. Maintenance encompasses continuous and effective work conducted daily.

The Engineer will notify the Contractor immediately of failure to meet these conditions. The Engineer will maintain the project if the Contractor fails to remedy unsatisfactory maintenance within 24 h after receiving the notice. The entire maintenance cost will be deducted from monies due the Contractor or will be owed by the Contractor.

Maintain previously constructed work when the contract involves placing material on, or the use of a previously constructed subgrade, base course, pavement, or structure.

The cost to maintain work during construction until final acceptance is incidental to the bid price for other work items.

105.17 OPENING PROJECT SECTIONS TO TRAFFIC

The Engineer may order that certain sections of the project be opened to traffic before the work is completed or accepted. This action does not constitute acceptance of the work or waive any contract provisions.

The Agency will pay to maintain those sections of roadway opened to traffic and will compensate the Contractor for costs incurred as specified in Subsection 109.4. A change order will stipulate compensation for additional expense and additional time, if any, as long as the ordered opening to traffic is not the result of Contractor fault or inactivity.

If the Contractor is late in completing features of the work according to the contract or progress schedule, the Engineer will give written notice establishing a time period for completing these features. The Engineer may order all or a portion of the project opened to traffic if the Contractor fails to complete or make a reasonable effort to complete the late work. The Contractor remains liable or responsible for maintaining the work and shall conduct the remaining construction operations with minimum interference to traffic without additional compensation.

105.18 FURNISHING RIGHT-OF-WAY

The Agency will secure right-of-way before construction begins, unless specified otherwise.

105.19 PROJECT ACCEPTANCE

Final acceptance will not occur until completion of the project as specified in Subsection 101.3.

The contract time may be stopped, at the Contractor's request and at the Engineer's discretion, without all required documents, certificates, or proofs of compliance. Promptly provide the exempted documents, certificates, or proof of compliance when the contract time ends. Final acceptance and payment depends on executing all required documents. (NOTE: This action depends, however, on establishing that the Contractor could not reasonably or in good faith provide some of the required compliance documentation for material before its use in the project.)

When a contract time ends, promptly provide the exempted documents, certificates, or proof of compliance. Final acceptance and payment depends on executing all required documents and delivering them to the Engineer.

A. *Partial Acceptance.* When a unit or portion of the project such as a structure, an interchange, or a section of road or pavement is complete, the Contractor may request a partial final inspection of that work. If the Engineer finds that the unit is complete to contract requirements, the unit may be accepted as complete. Partial acceptance neither voids nor alters any contract terms or waives any other remedy to which the Agency is entitled by law or in equity.

B. *Project Acceptance.* The Engineer will conduct a final inspection after receiving notice of project completion from the Contractor. If the Engineer finds all work to be completed in accordance with the contract, the inspection will constitute the final inspection and the Engineer will provide written notice of the final acceptance effective on the date of the final inspection.

Final Inspection does not waive any available rights or remedies of the Department, nor divest the Contractor of any responsibility for compliance with the contract or liability for damages. If unsatisfactory or incomplete work is found, the Engineer will issue instructions for necessary corrections to this work. Comply immediately with the instructions. When the deficiencies are corrected, the Engineer will conduct another inspection, which will constitute the final inspection, and will provide the Contractor with written notification of final acceptance.

105.20 CLAIMS FOR ADJUSTMENT

Notify the Engineer in writing of any intent to file a claim for additional compensation for work or material as specified in Subsection 104.3 before beginning or continuing affected work.

The Engineer will respond as described under Subsection 104.3(D). Work closely with the Engineer during the notification, review, and evaluation period to try to resolve the contract question and avoid further claims.

The Contractor waives any claim for additional compensation if the Engineer is not notified or is not given sufficient access to obtain a strict accounting of the Contractor's actual costs. Notifying the Engineer and the Engineer's accounting of costs are not substantiation of the claim's validity. The Agency will revise the contract only if the claim is found to have merit.

A. *Claim Submittals.* Provide sufficient detail in claim submittals to enable the Engineer to understand the basis for entitlement and the resulting costs. Include the following information with each claim submitted:

   1. Detailed statement providing all necessary dates, locations, and work items affected by the claim.

   2. The date on which actions or conditions resulting in the claim occurred or became evident.

   3. A copy of the Notice of Potential Claim form (available from the Agency) filed by the Contractor.

   4. Name, title, and activity of each Agency employee familiar with the facts that are the basis of the claim.

   5. Name, title, and activity of each Contractor employee familiar with the facts that are the basis of the claim.

   6. The specific contract provisions that support the claim and a statement of why they support it.

   7. Identification of pertinent documents and the substance of any material oral communications relating to the claim.

   8. A statement regarding whether the additional compensation or time extension is warranted based on contract provisions or an asserted breach of the contract.

   9. For time extension requests, an analysis of the construction schedule that specifies the specific days and the basis for the claim.

   10. Amount and specifics of additional compensation sought. Failure to submit a claim before final payment constitutes a waiver of all claims.

B. *Required Certification of Claims (for Contractor or Subcontractor as appropriate).* Include with the claim submittal a written certification, under oath, that attests to the following:

   1. The claim is made in good faith.

   2. Supporting data is accurate and complete to the Contractor's knowledge and belief.

   3. The Claimant understands and agrees that claim must fully conform to the requirements of Sections 104, 108, and 109.

4. The claim amount accurately reflects the Contractor's or Subcontractor's actual incurred cost. Use the Agency's CERTIFICATE OF CLAIM form (suggested) for the certification:

   EXAMPLE:

   Under the penalty of law for perjury or falsification, the undersigned,

   ___________________________,

   (Name)

   ___________________________ or

   (Title)

   ____

   (Company)

   hereby certifies that the claim for extra compensation and time, if any, made herein for work on this contract is a true statement of the actual costs incurred and time sought, and is fully documented and supported under the contract between the parties. To the extent the project contains federal funding, the United States False Claims Act (31 USC Sec 3729 et seq.), the Contractor or Subcontractor certifies that the above statements and supporting data are made in full compliance with the federal statute.

   ____

   (Dated, signed, and notarized)

C. *Document Retention.* Keep full and complete records of the costs and additional time incurred for each dispute for a period of at least three years after the date of final payment or until the dispute is resolved, whichever is greater. Provide adequate facilities, acceptable to the Engineer, for an audit during normal business hours. Also guarantee that the wage, payroll, and cost records of all Subcontractors and all lower tier Subcontractors will be retained and open to similar inspection or audit for the same period of time. The audit may be performed by employees of the Agency or by an auditor under contract with the Agency. Allow the Engineer or Department Auditor to examine and copy those records and all other records required by the Engineer to determine the facts or contentions involved in the dispute.

D. *Reviewing Claims.* The Agency will review all claims filed regardless of whether or not the claim is part of a suit pending in the courts. The review may begin within [10] calendar days of receiving written notice. The Contractor, Subcontractor(s), or supplier(s) shall cooperate with the Agency and provide, at minimum, access to the following documents:

   1. daily time sheets and foreman's daily reports;
   2. union agreements, if any;
   3. insurance, welfare, and benefits records;

4. payroll register;
5. earnings records;
6. payroll tax returns;
7. material invoices, purchase orders, and all material and supply acquisition contracts;
8. material cost distribution worksheets;
9. equipment records (list of company equipment, rates, etc.);
10. vendor rental agreements and Subcontractor invoices;
11. subcontractor payment certificates;
12. canceled checks (payroll and vendors);
13. job cost report;
14. job payroll ledger;
15. general ledger, general journal (if used), and all subsidiary ledgers and journals together with all supporting documentation pertaining to entries made in these ledgers and journals;
16. cash disbursements journal;
17. financial statements for all years reflecting the operations on this project;
18. income tax returns, whether such records are maintained by the company involved, its accountant, or others;
19. depreciation records on all company equipment;
20. all other documents used to develop costs for the Contractor's internal purposes to establish the actual cost of owning and operating equipment;
21. all documents that reflect the actual Contractor profit and overhead during the contract performance and each of the five years before starting this project;
22. all documents related to preparing the Contractor's bid, including final documents on which the bid was based, unless all such documents were placed in escrow as specified in Subsection 103.8; and
23. worksheets used to prepare the claim and establish cost components for claim items including, but not limited to, labor, benefits and insurance, materials, equipment, Subcontractors, and all documents that confirm time periods, individuals involved, and the hours and rates for the individuals.

105.21 ADMINISTRATIVE CLAIMS AND DISPUTE RESOLUTION PROCESS

The Agency's dispute resolution policy promotes a cooperative attitude between the Engineer and Contractor. Emphasis is placed on resolving issues while still current, at the project level or through the partnering process. Open sharing of information is encouraged by all parties involved so the information provided completely and accurately reflects the issues and facts.

If an issue cannot be resolved through the normal administrative change processes in Sections 104, 108, or 109, initiate the Contract claim procedure by submitting a claim to the Engineer. The disputes process provides for three levels of internal review and decision-making: Step 1) Project level, Step 2) District or Regional level, and Step 3) Claims Review Board hearing or nonbinding ADR process.

Whenever an issue is elevated to a dispute, the parties shall exhaust the Department's Administrative Claims and Dispute Resolution process before filing a legal action. Following these procedures will not otherwise compromise the Contractor's right to seek relief in a Court with legal jurisdiction.

All parties to the dispute must adhere to the Dispute Resolution and Administrative Claim process and timelines. Do not contact Agency personnel who are to be involved in a Step 2 or Step 3 review until a decision has been issued by the previous level. Agency personnel involved in Step 2 or Step 3 reviews will not consider a dispute until the previous level has properly reviewed the dispute and issued a decision.

Step 1: Project level. The Agency will establish the specific ground rules and timelines for meetings with the Contractor to discuss the claim and complete its review of the claim. The Agency will review the claim and provide a written determination of merit within 30 calendar days; however, if the claim issues are more complex, either party may request additional time to prepare or review the claim documentation. The Agency's written decision will include a summary of relevant facts, contract provisions supporting the determination, and if applicable, the analysis of claimed extension of time and requested compensation for delay.

Step 2: District/Regional Office. If the dispute is not resolved at the project-level, submit a written request to escalate the dispute to the Step 2 District or Regional level within seven (7) calendar days of the Agency's written decision. Within fourteen (14) calendar days of submitting the request for a Step 2 meeting, submit three (3) complete copies of the Dispute Documentation. This documentation should comply with the claim submittal requirements, and include any additional information provided at project-level claim review meetings, and provide an enhanced narrative with sufficient description and information to enable understanding by a third party who has no knowledge of the dispute or familiarity with the project. The Engineer will in turn provide all documentation relied upon to support its written decision.

After allowing at least fourteen (14) calendar days for the Contractor to review the Engineer's Dispute Documentation, the District/Region will conduct the Step 2 meeting with Contractor personnel who are authorized to resolve the dispute. The District/Region will issue a written

Step 2 decision to the Contractor within fourteen (14) calendar days of the meeting. If the dispute is not resolved, the Contractor may escalate the dispute to Step 3.

At any time, the parties may agree to proceed through a non-binding Alternative Dispute Resolution (ADR) Process. The parties will choose an ADR method practiced by the Agency and allowed by law.

Step 3: Alternative Dispute Resolution or Claims Review Panel. If the dispute is not resolved by the District/Region review, submit a written Notice of Intent to File a Claim to the Central Office Division of Construction within fourteen (14) calendar days of receipt of the Step 2 decision. Include the Contractor's request for either: A) Alternative Dispute Resolution (ADR) or B) a Claim Review Panel hearing on the claim. ADR mediation processes may use an independent project neutral or a three-party Dispute Review Board.

A. *Dispute Review Board*:

A Dispute Review Board (DRB) is an independent third-party panel that will provide specialized expertise in technical areas and administration of construction contracts. The DRB will assist in and facilitate the timely and equitable resolution of disputes between the Agency and the Contractor in an effort to avoid animosity and construction delays, and to resolve disputes as close to the project level as possible. The DRB shall serve as an independent and impartial entity.

The DRB will consider disputes referred to it and furnish recommendations to the Contracting Agency and Contractor to assist in the resolution of the differences between them. The DRB will participate in regular DRB meetings, provide an independent view of the dispute, and if requested, render non-binding formal or informal advisory recommendations of issues brought before them based upon the analysis of contract provisions, facts, circumstances as presented by the parties, and applicable law.

DRB members shall be trained in the DRB process and especially knowledgeable in the type of construction involved in the Project and discharge their responsibilities impartially and independently.

DRB Membership

The Board shall consist of one member selected by the Contracting Agency and one member selected by the Contractor, with these two members to select the third member.

The first two members shall be mutually acceptable to both the Contracting Agency and the Contractor. If one or both of the two members selected are not acceptable to the Contracting Agency or Contractor, another selection shall be made.

The Contracting Agency and Contractor shall each select their respective Board member and negotiate an agreement, separate and apart from this Contract, with their respective Board member within 14 calendar days after the parties have agreed to establish a Board, as outlined in Subsection 105.21.

The agreements with these two Board members will contain language imposing the "Scope of Work" and "Suggested Operating Procedures" for DRB's. These negotiated agreements shall also include clauses that require the respective selected members to immediately pursue selection of a third member. The third Board member will complement the first two by furnishing a needed expertise, and will facilitate the Board's operations.

If a member of the DRB needs to be replaced, the replacement member will be appointed in the same manner as the replaced member was appointed. The appointment of a replacement Board member will begin promptly upon determination of the need for replacement and shall be completed within 30 calendar days.

Service of a Board member may be terminated at any time with not less than 30 calendar days' notice as follows:

1. The Agency may terminate service of the Agency-appointed member.
2. The Contractor may terminate service of the Contractor-appointed member.
3. The third member's services may be terminated by agreement of the other two members.
4. Termination of a member will be followed by appointment of a substitute as specified above.

No DRB member shall have a financial interest in the Contract, except for payments for services on the DRB. Compensation for the Board members, and the expenses of operation of the Board, shall be shared by the Contracting Agency and Contractor. The Agency and Contractor will indemnify and hold harmless DRB Members from and against all claims, damages, losses, and expenses, including but not limited to, attorney's fees arising out of and resulting from the actions and recommendations of the Board.

Disputes Review Board Procedures

The DRB, the Agency, and the Contractor shall develop by agreement the DRB's rules of operation and procedures to be followed for the Project. DRB members will keep current on the progress of the project by quarterly visits to the project, joint meetings with the Agency and the Contractor, and review of project information. The frequency of project site visits and meeting shall be agreed by the Agency, Contractor, and DRB members.

The DRB will provide recommendations concerning:

1. Contract interpretation.
2. Entitlement to additional compensation or time for performance.
3. The amount of additional compensation or time for performance following a recommendation of entitlement by the Board provided that (1) the parties were not able to reach a resolution as to the amount of the equitable adjustment or time; (2) the Engineer has made a unilateral determination of the amount of compensation for time; and (3) the Contractor has protested the Engineer's unilateral determination.

4. Other subjects mutually agreed by the Contracting Agency and Contractor to be a Board issue.

Once the Board is established, the dispute resolution process shall be as follows:

1. Board hearing dates will be scheduled by agreement of the parties.
2. The Contractor and the Agency will each offer evidence. Either party furnishing any written evidence or documentation to the DRB will furnish copies of information to the other party a minimum of 15 calendar days prior to the DRB hearing date for the dispute.
3. After the hearing is concluded, the DRB will meet and make recommendations supported by two or more members. The DRB recommendations will be submitted as a written report to both parties based on the relevant Contract Provisions, facts, and circumstances involved in the dispute. The DRB will make every effort to reach a unanimous decision. If this proves impossible, the dissenting member may prepare a minority report.
4. Within 30 calendar days of receiving the DRB recommendations, the Agency and the Contractor will respond to the other in writing signifying that the dispute is either resolved or remains unresolved.

In the event the Board's recommendations do not lead to resolution of the dispute, all written recommendations, including any minority reports, will be admissible as evidence in any subsequent litigation. If the DRB does not resolve the dispute, the Contractor may initiate a legal action pursuant to state statutes.

B. *Claims Review Panel Hearing:*

1. The review board may request that the Contractor and the District or Region submit additional evidence or documents related to the claim. The review panel will consider both parties' written and oral submissions, and may consider other relevant information in the project records.
2. The review panel will conduct a hearing with the Contractor and the District or Region. Before the hearing, the department will distribute written ground rules for the hearing to both parties.
3. The review panel may affirm, overrule, or modify, in whole or in part, the District/Region's decision or the Engineer's decision. The review panel will render a decision within 60 calendar days from the date of the appeal.

   Within 14 calendar days of the review panel's decision, the Contractor may accept or reject the review panel decision in writing. If the Contractor does not respond within 14 calendar days, the review panel's decision is final.
4. If the Contractor disagrees with the review panel's decision, the Contractor may initiate a legal action pursuant to state statutes.

SECTION 106
CONTROLLING MATERIAL

106.1 SUPPLY SOURCE AND QUALITY REQUIREMENTS

Use only materials that meet contract requirements. Notify the Engineer of the proposed source of materials to be used prior to their delivery. The Engineer may conditionally approve materials at the supply source. Correct, to the satisfaction of the Engineer, or remove conditionally approved materials incorporated into the work that subsequently fail to meet contract requirements. Unless otherwise specified, use new materials for the work.

Buy America. Comply with the latest provisions of Buy America as listed at 23 CFR 635.410. Use steel or iron materials manufactured in the United States except when:

- The cost of materials, including delivery, of steel or iron products manufactured outside the United States does not exceed 0.1 percent of the total Contract cost or $2,500, whichever is greater;
- The product meets standards for the FHWA Manufactured Products Waiver for certain manufactured products'
- The Contract contains an alternate item for a foreign source steel or iron product and the Contract is awarded based on the alternate item; or
- The materials are temporarily installed.

Submit a notarized Buy America certification from the supplier with the proper attachments for verification of compliance.

Manufacturing is any process that modifies the chemical content, physical shape or size, or final finish of a product. Manufacturing begins with initial melting and mixing and continues through fabrication (cutting, drilling, welding, bending, etc.) and coating (paint, galvanizing, epoxy, etc.).

106.2 LOCAL MATERIALS SOURCES

The Agency may designate possible sources of local materials. Calculate the amount of equipment and work necessary to produce a material that meets specifications using these sources. Expect variations in material quality within the deposits. Procure material from designated portions of the deposit. The Engineer will reject material if it is unacceptable or fails to meet contract requirements.

The Agency may acquire and make available the right to take materials from designated sources, including the right to use the property as specified, or for plant site, stockpiles, and haul roads. If the Agency chooses to use this procedure, the contract will define the acquisitions and rights provided.

If material is obtained from sources not designated in the contract, acquire the rights to take materials from these sources and pay all related costs, including those for increased haul length and for exploring and developing sources.

Use material from other than designated sources only after Agency tests indicate that the material is of equal or better value than the Agency-designated source and after its conditional acceptance is received. Locate borrow pits, gravel pits, and quarry sites out of sight of the highway.

The Contractor is cautioned regarding the potential to encounter contaminated soils within the excavation areas. If encountered, avoid incorporating contaminated soils within the limits of the project.

Excavate pits and quarries so that no water collects or stands on the site. Return the work site to a neat, presentable condition following the work.

For Contractor-acquired rights to borrow sources, perform required grading and reclamation, as required under the agreement with the property owner, when work is completed. Final project acceptance requires receipt of a written release from the property owner indicating that the Contactor has satisfied all agreement conditions.

106.3 SAMPLES, TESTS, AND CITED SPECIFICATIONS

Incorporate into the work only material that has been inspected, tested, and accepted by the Agency. Remove unacceptable materials from the site at no cost to the Agency.

Unless otherwise designated, the Agency will perform testing at its expense using the most recent standard test methods of the Agency, or AASHTO or ASTM tests in effect at the time the job is advertised.

Test method precedence is as follows:

A. The Agency's Standard Materials Test Methods

B. AASHTO

C. ASTM

An Agency representative will perform or observe sampling and sample splitting of materials.

The Agency can retest and reject materials conditionally accepted at the source. Materials designated for use can be inspected, tested, or rejected before or during incorporation into the work. Copies of any or all test results are available upon request.

106.4 CERTIFICATE OF COMPLIANCE

The contract or the Agency's materials and testing schedule will designate materials or assemblies that can be incorporated into the work with certificates of compliance, signed by the manufacturer, stating that they meet contract requirements. Clearly identify each lot of certified materials or assemblies delivered to the work site, and ensure that the certificate of compliance accompanies each delivery and identifies the specification requirement satisfied.

The Agency may sample and test materials or assemblies used on the basis of certificates of compliance. The Agency will reject materials not meeting contract requirements.

106.5 QUALIFIED PRODUCTS LIST

The Agency may use Qualified Product Lists (QPL) for approval of manufactured materials. The Agency Materials Office will maintain the QPL and the standard procedure for the QPL process. The QPL identifies the approved products, the applicable Specification Section, and the basis for acceptance at the project level.

To qualify for continued listing on the QPL, products may be sampled and tested for conformance to the Standard Specifications. The Agency reserves the right to make revisions to the QPL at any time. When a material requires QPL acceptance, only provide materials listed on the QPL at the time of delivery of the material to the project. Provide the Engineer documentation according to the Agency's standard procedure that, at the time of delivery, the material provided is on the QPL.

106.6 PLANT INSPECTION

The Agency may inspect materials at the acquisition or manufacturing source for compliance with specified manufacturing methods. Material samples will be obtained and tested for compliance with quality requirements.

Meet the following conditions if inspection is at the plant:

A. Cooperate fully and assist the Engineer during the inspection.

B. Ensure the Engineer has full access to all parts of the plant used to manufacture or produce materials.

C. If specified, provide a building, located at the plant, for use by the Engineer, as required in Subsection 106.7.

D. Provide and maintain adequate safety measures.

E. Equip crushing or screening facilities with automatic or semiautomatic mechanical sampling devices.

The Agency may retest materials conditionally approved at the source prior to incorporation into the work and will reject material not meeting contract requirements.

106.7 LABORATORY

At the plant site facility, furnish the field laboratory in which the Agency may house testing equipment and perform required tests.

106.8 FOREIGN MATERIALS

Unless otherwise noted in the contract, all testing is to be performed within the United States and witnessed by the Engineer. When specified, arrange and pay for any additional required testing that the Agency is unequipped to perform. If materials or processes require the performance or witnessing of testing at a foreign source, reimburse the Agency for all foreign inspection expenses.

Submit with each lot of foreign material a certificate of compliance as specified in Subsection 106.4. Attach certified mill test reports to certificates of compliance for specified materials.

Accompany all structural materials with mill test reports and certificates of compliance.

To ensure delivery of uniform material that meets requirements, the Agency will accept structural materials requiring mill test reports only from domestic manufacturers or manufacturers with proven plant quality control.

Quality control is established by submitting detailed written proof or through Agency inspection.

106.9 STORING AND HANDLING MATERIALS

Store and handle materials to preserve their quality and fitness for the work. Transport bulk materials in a manner that prevents loss or segregation after loading and measuring.

Store materials so that they can be easily inspected and retested as specified in Subsection 106.3. Obtain approval to store materials and Contractor's plant and equipment on the right-of-way.

Additional storage space is at the Contractor's expense and option. Obtain owner's or lessee's written permission before storing material on private property. Furnish copies of the permission to the Engineer, if requested.

Restore storage and plant sites to their original condition at no cost to the Agency.

106.10 UNACCEPTABLE MATERIALS

The Engineer will reject all materials not meeting contract requirements. Remove rejected material immediately unless the Engineer approves defect corrections.

106.11 AGENCY-FURNISHED MATERIAL

Agency-furnished material will be delivered to or made available to the Contractor at locations specified in the contract.

Include the cost of handling and placing Agency-furnished material in the contract items in which they are used. After delivery, assume responsibility for delivered materials. The Agency will make deductions for the cost of shortages, deficiencies, and damage that may occur to the material after delivery. The Agency will also deduct demurrage charges resulting from the Contractor's failure to accept material delivered as scheduled.

SECTION 107
LEGAL RELATIONS AND RESPONSIBILITY TO THE PUBLIC

107.1 LAWS, RULES, AND REGULATIONS TO BE OBSERVED

Observe and comply with all of the following that affect the conduct of work on the project, have jurisdiction or authority over the work, or that affect individuals engaged or employed on the project:

1. Federal and State laws;
2. Local laws and ordinances; and
3. Regulations, orders, and decrees of bodies or tribunals having any jurisdiction or authority.

Protect and indemnify the Agency and its representatives against any claim or liability originating from violating any of the above items by the following companies or employees of the following companies:

1. the Contractor;
2. Subcontractor(s) at any tier;
3. suppliers of materials or services; or
4. any others engaged by the Contractor.

Comply with all Federal, State, and local laws and regulations governing environmental protection, as specified in Subsections 104.9, 104.11, and 107.13.

Comply with all Federal, State, and local health official rules and regulations governing health and safety. Ensure no Contractor or Subcontractor(s) employee is required to work in or under conditions that are unsanitary, hazardous, or dangerous to health or safety. Admit to the work site any inspector with proper credentials from OSHA or other legal Agency responsible for health and safety administration.

Comply with all laws and ordinances, as well as Title 29, Title 30, and the Code of Federal Regulations Part 1926—Safety and Health Regulations for Construction (OSHA), whichever is more restrictive, when using, handling, loading, transporting, and storing explosives and blasting agents.

Comply with all Federal, State, and local laws, rules, and regulations that govern unlawful employment practices including discrimination based on race, religion, color, sex, or national origin and that define actions required for Affirmative Action and Minority (Disadvantaged) Business programs.

Perform work within or adjacent to a State or National Forest under regulations of the State Fire Marshall, Conservation Commission, Forestry Department, or authority with jurisdiction to protect forests. Immediately notify the Engineer in writing upon discovering any discrepancy or inconsistency between the contract and any law, ordinance, regulation, or order, except as noted in Subsection 107.4.

107.2 PERMITS, LICENSES, AND TAXES

Acquire all permits and licenses; pay charges, fees, and taxes; and give all notices necessary to perform the work. Include these costs in the appropriate unit prices bid for the contract items.

107.3 PATENTED DEVICES, MATERIALS, AND PROCESSES

Provide proof of legal agreement with the patentee or owner, if necessary, for use of a design, device, material, or process covered by letters, patents, or copyrights.

Indemnify and save harmless the Agency and any affected third party or political subdivision from claims of infringement on patents, copyrights, or trademarks.

Indemnify the Agency for costs, expenses, and damages, which it may be obligated to pay as a result of an infringement during the conduct of the work or after the project is completed.

107.4 FEDERAL-AID PARTICIPATION

Federal requirements of a federally assisted contract supersede conflicting provisions of state or local laws, rules, or regulations.

When the Federal Government participates in the cost of the contract, proceed with the work under the supervision of the Agency, but subject to the inspection and approval of appropriate Federal officials. Note, however, that the U.S. Government is not a party to the contract and will not interfere with the rights of contract parties.

107.5 PUBLIC CONVENIENCE AND SAFETY

Store materials and conduct work with minimal obstruction to traffic. Ensure the safety and convenience of the public and property as provided under Subsection 104.4. Follow the safety provisions of all applicable laws, rules, codes, and regulations.

107.6 BARRIERS, BARRICADES, AND WARNING SIGNS

Provide, erect, and maintain traffic control devices to protect the work and public safety. Use barriers and barricades to delineate highway sections closed to traffic. Illuminate obstructions during darkness and provide warning signs to control and direct traffic.

Erect warning signs for work that may interfere with traffic or where new work crosses or coincides with an existing road. Place and maintain warning signs according to the project traffic management plan. Obtain approval before dismantling or removing traffic control devices.

Ensure traffic control devices meet the MUTCD and Section 618.

107.7 USING EXPLOSIVES

Ensure that the use of explosives does not endanger life, property, or new work. Assume liability for property damage, injury, or death resulting from the use of explosives.

Notify property owners and public utility companies in the vicinity of the proposed detonation before using explosives.

107.8 PROTECTING AND RESTORING PROPERTY AND LANDSCAPE

Preserve public and private property during the work. Ensure that the Engineer affirms the location of monuments and property line markers before they are moved, disturbed, or damaged.

Assume liability for any damage to public or private property resulting from defective work or materials, or non-execution of the contract. Maintain liability until the project is accepted.

Restore damaged property to a condition similar or equal to that existing before the damage at no cost to the Agency.

107.9 CULTURAL RESOURCES

When construction operations encounter possible artifacts of historical or archaeological significance, immediately suspend operations in the area and notify the Engineer.

107.10 COMPLIANCE WITH FEDERAL ENDANGERED SPECIES ACT AND OTHER WILDLIFE REGULATIONS

The Federal Endangered Species Act requires that the Agency investigate the potential impact to a threatened or endangered species prior to initiating an activity performed in conjunction with a highway construction project. If the Agency's investigation determines that there is a potential impact to a protected, threatened or an endangered species, the Agency will conduct an evaluation to determine what measures may be necessary to mitigate such impact. When mitigation measures or special conditions, or both, are necessary, these measures and conditions will be addressed in the Plans or in permits.

107.11 DISCOVERY OF AN UNMARKED HUMAN BURIAL

When an unmarked human burial is discovered, immediately cease all activity that may disturb the unmarked human burial and notify the Engineer. Do not resume activity until specifically authorized by the Engineer.

107.12 PROTECTING FORESTS

Obey all laws and regulations that govern work within or adjacent to State or National Forests. Keep the project site orderly and clean. Comply with permit requirements and obtain other permits as identified in the contract.

Prevent and assist with the suppression of forest fires. Cooperate with responsible forestry officials.

107.13 ENVIRONMENTAL PROTECTION

Schedule and conduct construction operations to prevent, control, minimize, or abate pollution of air, land, and water in accordance with Subsection107.1—Laws, Rules, and Regulations to Be Observed. Obtain permits in accordance with Subsection 107.2—Permits, Licenses, and Taxes.

A. *Hazardous Material.* Immediately suspend work and notify the Engineer if any abnormal condition is encountered or exposed that indicates the presence of a hazardous material or toxic waste. The Engineer will conduct a documented inspection of the area. Do not resume work in the affected area until approved. Continue work in other areas of the project unless otherwise directed.

   Treat abnormal conditions, such as the presence of barrels or chemical containers, obnoxious odors, a rainbow-colored sheen on surface water or soil, excessively hot earth, smoke, or any other condition indicating a hazardous material or toxic waste, with extreme caution.

   Meet the requirements and regulations of the applicable State agency when disposing of hazardous material or toxic waste. Perform this work under Subsection 109.4.

B. *Water Protection.* Take all precautions and actions to prevent pollution of groundwater and surface water with any particulate or liquid matter that may be harmful to fish, wild life, and public health or may cause a public nuisance. Continue work in other areas of the project unless otherwise directed.

C. *Minimize the crossings of streams and rivers with hauling equipment.* Clear the crossings of temporary construction and restore to pre-disturbed conditions as soon as practical after use. Minimize water pollution from haul roads, work platforms, temporary earth fills, and other temporary construction used to facilitate bridge or culvert construction.

D. *Land Protection.* Minimize erosion on the project. The Department will consider all areas within the grading construction limits, exclusive of roadbed areas, that grading or grubbing operations have rendered natural vegetation ineffective as being exposed to probable erosion until such time that the Contractor completes final surface finishing and turf establishment operations.

E. *Air Protection.* Take actions to minimize pollution of air with particulate matter that may harm public health or create a public nuisance.

F. *Excessive or Unnecessary Noise.* Minimize noise throughout all phases of the Work. Exercise particular and special efforts to avoid the creation of unnecessary noise impact on adjacent noise sensitive receptors in the placement of non-mobile equipment such as air compressors, generators, pumps, etc. Place mobile and stationary equipment to cause the least disruption of normal adjacent activities.

107.14 STORM WATER MANAGEMENT AND EROSION CONTROL

When required by Contract, obtain and adhere to the NPDES Storm Water Permit for Construction Activity from the State Pollution Control Agency. Implement a Storm Water Pollution Prevention Plan (SWPPP), including the following:

- Temporary and permanent sediment and erosion control measures,
- Ponds,
- Drainage facilities,
- Earthwork operations,
- Topsoil,
- Turf establishment, and
- Other features requiring a SWPPP.

Minimize vehicle tracking of sediment or soil off site at locations where vehicles exit the Project Site onto paved surfaces. Remove tracked sediment from paved surfaces that do not drain back into the Project Site. Retrieve sediment that has left the right-of-way unless the Project has received approval or certification for depositing fill into surface waters. Remove sediment deposited in drainage ways or catch basins, and stabilize the areas where sediment removal results in exposed soil.

Incorporate temporary or permanent stabilization on exposed slopes into the erosion and sediment control schedule.

Prepare and submit a weekly schedule of proposed erosion and sediment control activities including the following:

1. Proposed erosion and sediment control installations and the installation time,
2. Areas ready for permanent turf establishment and the Work time frame,
3. Grading operations and how the Contractor will incorporate the erosion control into the Work,
4. Findings of erosion and sediment control inspections with recommended repair or maintenance required on erosion or sediment control Best Management Practices (BMP) and completion date, and
5. Proposed erosion control measures during work suspensions.

Provide a Site Management Plan (SMP) as shown on the Plans, or within 10 calendar days of receipt of written notice from the Engineer, for construction operations within 1 mi [1.6 km] of surface waters or Areas of Environmental Sensitivity (AES). In the SMP, detail the schedule of work, materials, and equipment along with stormwater or pollutant management BMPs to complete the work and protect the surface waters or AES. Do not start work in the affected areas until the Engineer approves the SMP.

Maintain and implement a quality control plan for sediment and erosion control to include the following:

1. Adherence to permit requirements related to the Work;
2. Conducting weekly inspections of Sediment control BMPs;
3. Developing and maintaining the inspection log with dates and times;
4. Incorporating temporary or permanent erosion control into the Work and stabilizing disturbed areas with mulch, seed, or vegetative cover on a section by section basis;
5. Maintaining temporary sediment control devices; and
6. Removing temporary sediment control devices after use.

107.15 RESPONSIBILITY FOR DAMAGE CLAIMS; INSURANCE

To the fullest extent as permitted by law, indemnify and save harmless the Agency, the State, and all its representatives, employees, municipalities, counties, public utilities, any affected railroad or railway companies, and any fee owner from whom a temporary Right-of-Way was acquired for the Project from all actions, suits, and claims from injury or damage to persons or property resulting from any negligent act or omission by the Contractor, its subcontractors, or agents in the prosecution or safeguarding of the work. Upon request, furnish the Agency a certified copy of the following policies including the provisions establishing premiums.

A. Obtain and maintain insurance liability for damages imposed by law, of the kinds and amounts specified from insurance companies authorized to do business in the State until project acceptance. Ensure coverage of all operations under the contract, whether performed by the Contractor or Subcontractor at any tier.

B. Before execution of the Contract, furnish certificates of insurance for the following, on Agency-approved forms, prior to beginning work;

    1. Workers' compensation insurance, according to prevailing laws for all employees. The Agency shall also require Subcontractors to provide workers compensation insurance in accordance with the State statutory requirements and the following:

        a. Employers Liability including Stop Gap Liability for monopolistic states. Provide the following minimum

        b. Limits unless otherwise stated in the special provisions:

            i. $100,000 – Bodily Injury by disease per employee,

            ii. $500,000 – Bodily Injury by disease aggregate, and

            iii. $100,000 – Bodily Injury by accident.

        c. All States Coverage,

        d. If applicable, Longshore and Harbor Workers Compensation Act (USL&H), Maritime, Voluntary, and Foreign Coverage, and

        e. Waiver of subrogation in favor of the Agency.

        If the Contractor is self-insured for its obligation under the Workers Compensation Statutes in the jurisdiction where the Project is located, provide the Agency with a Certification of the Authority to Self-Insure.

    2. Commercial and general liability insurance in the following amounts:

        a. General aggregate limit:

            i. $2,000,000 Per occurrence,

            ii. $2,000,000 Annual aggregate, and

            iii. $2,000,000 Annual aggregate applying to products and completed operations.

b. Coverages: The Contractor shall provide the following types of coverage:

   i. Premises and Operations Bodily Injury and Property Damage;

   ii. Personal and Advertising Injury;

   iii. Products and Completed Operations Liability;

   iv. Contractual Liability as provided in ISO form CG 00 01 (Ed. 0 4 13) or latest;

   v. Pollution exclusion with standard exception as per ISO Commercial General Liability Coverage Form – CG 00 01 (Ed. 0 4 13) or latest;

   vi. Explosion, Collapse, and Underground (XCU) perils;

   vii. Broad Form PD;

   viii. Independent Contractors – Let or Sublet Work;

   ix. Waiver of subrogation in favor of the Department;

   x. Agency named as an Additional Insured, by endorsement, ISO Forms CG 2010 and CG 20 37 or their equivalent for claims arising out of the Contractor's negligence or the negligence of those for whom the Contractor is responsible; and

   xi. Coverage under the General Liability Policy(s) of the Contractor will be as broadly construed for the Owner as is available to the Contractor.

3. Automobile Liability Insurance:

   a. Maintain the following insurance coverages for liability arising out of the operations, use, or maintenance of all owned, non-owned, and hired automobiles:

      i. Owned automobiles,

      ii. Non-owned automobiles,

      iii. Hired automobiles, and

      iv. Waiver of subrogation in favor of the Agency.

4. Minimum Limits of Liability:

   Provide a minimum limit of liability of at least $2,000,000 Per Occurrence Combined Single Limit for Bodily Injury and Property Damage.

107.16 THIRD-PARTY BENEFICIARY CLAUSE

This contract does not create anyone as a third-party beneficiary or authorize anyone not a party to the contract to maintain an action for damages under contract provisions.

107.17 PERSONAL LIABILITY OF AGENCY EMPLOYEES

The Agency's authorized representatives act solely as representatives of the Agency when conducting and exercising power or authority granted them under the contract.

There is no liability on them either personally or as Agency employees.

107.18 NO WAIVER OF LEGAL RIGHTS

Final acceptance does not preclude the Agency from correcting any measure, estimate, or certificate made before or after contract completion. The Agency may recover from the Contractor, surety, or both, overpayments upheld for failure to fulfill contract obligations. A waiver on the part of the Agency of any breach of the contract is not a waiver of any other or subsequent breach.

Assume liability for latent defects, fraud, or such gross mistakes as may amount to fraud, or as regards the Agency's right under any warranty or guaranty without prejudice to the terms of the contract.

SECTION 108
PROSECUTION AND PROGRESS

108.1 SUBLETTING THE CONTRACT

Obtain the Agency's written permission before subletting, selling, transferring, assigning, or disposing of any portion of the contract(s). Perform at least [30] percent of the total contract work unless otherwise specified less the total contract amount of those items designated as "specialty items," which may be subcontracted without regard to the [30] percent limitation. Be responsible for any subcontract or contract transfer under the contract and bonds.

108.2 SCHEDULES

A. *General*. Provide all resources to complete the work. Provide a schedule using the bar chart method as specified in Subsection 108.2(B), *except* when the contract specifies a schedule using the critical path method (CPM), in which case, meet the requirements of Subsection 108.2(C). With the Engineer's approval, the Contractor may provide a CPM schedule in place of the bar chart schedule. Plan and schedule the project to meet contract-required milestone and final completion dates.

   At least [10] calendar days before the preconstruction meeting, submit to the Engineer for review an initial progress schedule that meets the requirements specified in Subsection 108.2(B) or 108.2(C), as applicable. The Engineer and Contractor will review the initial schedule at the preconstruction meeting. Within [5] work days after the preconstruction meeting, the Engineer will accept the Contractor's initial schedule or request additional information. The type of information requested may include estimated manpower, equipment, unit quantities, and production rates used to determine the duration of an activity or item or work. Provide the requested information and resubmit the revised initial schedule within [5] work days after receiving the Engineer's request.

The Engineer will use the schedule to monitor progress of the work. The Engineer will accept or reject the initial schedule based solely on completeness; acceptance does not modify the contract or constitute endorsement or validation by the Engineer of the Contractor's logic, activity durations, or assumptions in creating the schedule. The Agency may withhold monthly progress payments until the Engineer accepts the initial schedule.

Submit a schedule update to the Engineer on the first working day of each month, or as requested by the Engineer. The Agency may withhold monthly progress payments if schedules are not updated as specified or requested.

B. *Early Completion*. The Contractor may decide to submit an Early Completion Schedule showing completion of all work prior to the Contract Completion Date. If accepted, the Engineer will initiate a change to the Contract Completion Date to reflect the early finish date. The amended Completion Date will be effective upon execution of the change and all contract provisions concerning the Completion Date such as incentives, disincentives, excusable delays, compensable delays, and liquidated damages will be measured against the amended Completion Date. The Contractor may elect not to amend the Completion Date; however, in so doing, the Contractor waives its rights to delay damages for not meeting the projected early Completion Date.

C. *Bar Chart Method.* Use this scheduling method when specified.

1. *Initial Bar Chart Progress Schedule.* At least [10] calendar days before the preconstruction meeting, submit to the Engineer for review an initial bar chart progress schedule that includes the following:

    a. Activities that describe the essential features of the work, activities that might delay contract completion, and critical activities;

    b. The planned start and completion dates for each activity, the duration of each activity (stated in work days, and with activities of more than 15 work days in duration broken into two or more activities distinguished by location or some other feature), and the sequencing of all activities;

    c. The quantity and estimated daily production rate for controlling activities;

    d. An indication of how the schedule accommodates adverse weather days for each month;

    e. Dates related to the procurement of materials, equipment, and articles of special manufacture;

    f. Dates related to the submission of working drawings, plans, and other data specified for review or approval by the Agency;

g. Dates related to Agency inspections;

h. Dates related to specified activities by the Agency and third parties; and

i. A narrative report that describes the proposed work sequence, lists the work days per week, department-specified holidays, number of shifts per day, and number of hours per shift. For calendar day and completion date contracts, provide the estimated number of adverse weather days for each month consistent with the monthly-anticipated adverse weather days.

2. *Project Schedule Updates.* Conduct job site meetings with the Engineer to verify schedule accuracy. Hold meetings monthly or as required by the complexity of the project. Update the schedule as required to reflect actual work modifications and progress and to document approved contract revisions. Include the actual start and finish of each activity, percentage complete, and the remaining duration of activities started and still ongoing. Submit [2] copies of the schedule update to the Engineer for review within [48] hours of the job site meeting.

3. *Schedule Revisions.* The Engineer may request a Revised Update Schedule when any of the following events occur:

a. The project has experienced a change that affects controlling items of Work.

b. The sequence of Work is changed from that in the approved schedule.

c. The project is significantly delayed.

d. The Engineer has granted an extension of Contract Time.

Submit the Revised Update Schedule within 7 calendar days of receiving a written request, or when an update is required by any other provision of the Contract.

D. *Critical Path Method (CPM).* Use this scheduling method when specified. Develop a CPM schedule using computerized scheduling software that is compatible with that used by the Agency.

1. *Initial Work Plan.* Prepare and complete a schedule for the first [60] calendar days of work that meets the requirements for an initial bar chart as specified in Subsection 108.2(B)(1). With prior approval, the Engineer may accept activity durations of more than 15 working days. Include a summary bar chart schedule for the balance of the project; activity durations on the summary chart may exceed 15 working days. Submit an updated version of the bar chart every [14] calendar days, until the Agency accepts the initial CPM schedule.

2. *Initial CPM Schedule.* Within [30] calendar days after providing the initial bar chart, submit an initial CPM schedule to the Engineer for review. Define and sequence activities so as to accurately describe the entire project and to meet contract requirements with respect to the scope of work, phasing, accommodations for traffic, and interim, milestone, and project completion dates. Use working days to create the schedule, beginning with the date of the notice to proceed.

a. *CPM Schedule Requirements*. Ensure that the CPM schedule identifies and conforms to the following:

   i. Planned start and completion dates for each activity;

   ii. Duration of each activity (stated in work days, and with activities of more than 15 work days in duration broken into two or more activities distinguished by location or some other feature);

   iii. Finish-to-start relationships among activities, without leads or lags, unless otherwise approved by the Engineer;

   iv. Interim, milestone, and project completion dates specified in the contract as the only constraints in the schedule logic;

   v. The quantity and estimated daily production rate for critical activities;

   vi. Activities related to the procurement of materials, equipment, and articles of special manufacture;

   vii. Activities related to the submission of working drawings, plans, and other data specified for review or approval by the Engineer;

   viii. Activities related to Agency inspections; and

   ix. Activities related to specified activities by the Agency and third parties.

b. *Use of Float*. The Contractor acknowledges that all float (including Total Float, free Float, and Sequestered Float) is a shared commodity available to the Project and is not for the exclusive benefit of any party; float is an expiring resource available to accommodate changes in the Work, however originated, or to mitigate the effect of events that may delay performance or completion of all or part of the Work.

   Do not sequester or suppress float by including logical relationships that provide no tangible or sequential value between unrelated activities or that require completion of an activity that could otherwise continue beyond a successor's start or finish dates.

c. *CPM Schedule Submission Requirements*. Provide the following items with each schedule submission. Submit [1] paper copy and [1] electronic copy of the schedule to the Engineer.

   i. A logic diagram in color, depicting no more than 50 activities on each 11 by 17 in. [280 by 430 mm] sheet, and with each sheet including title, match data for diagram correlation, and a key.

   ii. Tabular sorts of activities by early start, predecessor and successor, work area by early start, and total float;

   iii. 60-day look-ahead bar charts by early start; and a

iv. Narrative report indicating the workdays per week, holidays, number of shifts per day, number of hours per shift, and how the schedule accommodates adverse weather days for each month.

3. *Schedule Updates.* Update the schedule on a monthly basis to show current progress. Include the following with each update:

   a. Actual start and finish dates of each activity or remaining durations of activities started but not yet completed; and a

   b. Narrative report describing progress during the month, shifts in the critical activities from the previous update, sources of delay, potential problem areas, work planned for the next update period, and changes made to the CPM schedule. Changes include additions, deletions, or revisions to activities due to the issuance of a contract revision, changes to an activity duration, changes to relationships between activities, or changes to the planned sequence of work or the method and manner of its performance.

   Submit the updated schedule electronically to the Engineer. Also provide [1] paper copy of tabular sorts by total float and activity by early start.

4. *Schedule Revisions.* Submit a revised schedule when changes in construction phasing and sequencing occur or other changes that cause a deviation from the current project schedule. Any revisions to the schedule must be listed in the monthly update narrative with the purpose of the revision and description of the impact on the project schedule's critical path and project completion date. Create the schedule revision using the latest update before the start of the revision. Circumstances that may require a revised schedule include the following:

   a. A delay (actual or projected) to scheduled milestone or project completion dates;

   b. A difference between the actual sequence or duration of work and that depicted in the schedule; and

   c. Issuance of a contract revision that, by adding, deleting, or revising activities, changes the planned sequence of work or the method and manner of its performance.

   Prepare and submit the revised schedule within [10] calendar days after the Engineer's request. Within [10] calendar days of receipt, the Engineer will accept the revised schedule, reject the revised schedule, or request additional information.

   Address the reasons for rejection or submit the information requested no more than [10] calendar days after the Engineer's request.

5. *Impact Schedule.* Prepare an Impact Schedule in order to:

   a. Quantify the effects of any contemporaneous or prospective impacts to the Progress Schedule,

   b. Establish the need for a time extension to a Milestone; and

c. Negotiate at the Department's request a potential Contract Revision document that changes the planned sequence of Work or the method and manner of its performance.

The standard for preparation of the Impact Schedule is specified in Subsection 108.6. The requirement to prepare an Impact Schedule is not a directive by the Agency to accelerate the Work but rather a directive for the Contractor to demonstrate the effects of impacts to the accepted schedule update.

108.3 LIMITING OPERATIONS

Minimize interference with traffic during performance of the work. Stage work as specified in the contract.

108.4 CHARACTER OF WORKERS

Provide the resources necessary to complete all contract work as specified. Ensure workers have the experience and skills to perform assigned work.

Remove from the project any employee(s) who performs the work in an unskilled manner or who is intemperate or disorderly. Return these employees to the project only with the Engineer's written permission.

The Engineer may suspend work for the Contractor's failure to remove any employee(s) or to furnish suitable and sufficient personnel to perform the work.

108.5 METHODS AND EQUIPMENT

Use equipment of the size and mechanical condition necessary to produce the specified work. Ensure that the equipment does not damage the roadway, adjacent property, or other highways.

Request permission in writing to use methods or equipment other than those specified; describe the proposed methods and equipment to be used and the reasons for the change. Perform work according to the original basis of payment and contract time. Discontinue use of alternate methods or equipment when work does not meet contract requirements. Remove and replace or repair deficient work at no cost to the Agency.

108.6 DETERMINING COMPENSATION AND CONTRACT TIME EXTENSION FOR EXCUSABLE DELAYS

Request an extension in contract time for excusable delays under this Subsection. Meet Subsection 105.20 documentation requirements.

A. *Time Impact Analysis.*

Evaluate delays and calculate the appropriate time extension for excusable delays in accordance with the Association for the Advancement of Cost Engineering, International (AACEI)

Recommended Practice No. 52R-06, Time Impact Analysis as Applied in Construction. A time impact analysis (TIA) is an evaluation of the effects of impacts on the project using the accepted CPM project schedules.

Use the schedule that has a data date closest to and before the event. Prepare an impacted schedule by incorporating the impact into the accepted schedule. Identify the impact as either a discrete activity or a set of activities. The impact may consist of added or deleted activities or existing activities with changed logic or durations. If the impact schedule shows that incorporating the event modifies the critical path and scheduled completion date of the accepted schedule, the difference between scheduled completion dates of the schedules will be equal to the adjustment of Contract time.

Establish the status of the project after the impact's effect has ended and provide details identifying any mitigating actions or circumstances used to keep the project ongoing during the impact period.

The Engineer will review the Contractor's evaluations and calculations and determine the time extension and compensation due, if any. The Engineer will measure extensions to the Contract Time in working days for Working Day Contracts and in calendar days for Completion Date and Calendar Day Contracts.

The Agency will relieve the Contractor from associated liquidated damages, as specified in Subsection 108.8, if the Department extends the Contract Time.

File written requests with the Engineer within [7] calendar days of receiving contract time charges on working day contracts. Document asserted discrepancies in the time assessed. Failure to file a protest is acceptance of the time assessments.

B. *Excusable Delays.*

1. *Noncompensable Delay.* Unforeseen and unanticipated delay caused by acts of God, acts of the public enemy, fires, floods, epidemics, quarantine restrictions, strikes, freight embargoes, unusually severe weather, or delays not resulting from the Contractor's or Agency's fault or negligence. The Agency will not grant additional compensation.

2. *Compensable Delay.* Delay caused by Agency action or inaction or under the Agency's control, including delays resulting from change orders, differing site conditions, work suspensions caused by conditions beyond the control of the Contractor, defective specifications, lack of site access, and delayed shop drawing approval. For such compensable delays, the Agency may grant additional time and compensation as specified in Subsection 109.10.

Provide a written request to the Engineer within [5] calendar days of the occurrence of a delay detailing the reasons for a time extension and additional compensation, if appropriate.

Maintain daily records of all nonsalaried labor, material costs, station locations, and equipment expenses for all operations affected.

Prepare and submit to the Engineer weekly written reports that contain

1. Number of days of delay;

2. Summary of all delayed operations or those that will be delayed;

3. Explanation of how the Agency's action or omission delayed each operation, if appropriate, and an estimation of the time necessary to complete the project; and

4. Itemization of all extra costs incurred:

    a. Document how the extra costs relate to the delay and how they are calculated and measured.

    b. Identify all affected nonsalaried project employees for whom costs are being compiled.

    c. Summarize equipment time charges; identify equipment by manufacturer's number.

Meet with the Agency the first working day of each week to compare the previous week's daily records with those maintained by the Agency.

File written notice within [10] calendar days documenting disagreement between Agency and Contractor calculation of weekly delay costs. Failure to file written notification is interpreted as evidence that Agency records are accurate.

No costs allegedly incurred before notification of delay are allowed.

C. *Concurrent Delays.* Concurrent delays are separate delays to critical activities that occur at the same time. When a non-compensable delay is concurrent with a compensable delay, the Contractor is entitled to an extension of Contract Time, but not entitled to compensation.

D. *Procedures Following Completion of Work Allegedly Delayed.* Submit a written report to the Engineer within [15] calendar days of completing the project or phase of work allegedly delayed. Include the following information in the report:

1. Description of the operations delayed with supporting documentation and explanation of the reason for the delay.

2. As-built chart or time impact analysis depicting how the operations were delayed.

3. Item-by-item measurement and explanation of extra costs requested for reimbursement because of the delay, if applicable.

Provide an accountant's certification of all costs included in the report.

The Agency will respond in writing within [60] calendar days of receipt of the Contractor's submission.

For compensable delays, the Agency will grant compensation as specified in Subsection 109.10.

108.7 INCENTIVE OR DISINCENTIVE FOR EARLY COMPLETION

Meet contract incentive or disincentive provisions.

For each calendar day the project or phase is open to unrestricted continuous traffic before or after the specified completion time established in the contract, the Agency will increase or decrease payment by the amount specified.

"Unrestricted continuous traffic" means that the affected lanes are open to unrestricted traffic flow with the specified striping and safety features in place.

The Engineer will determine when the work stage or project is complete to open the roadway to unrestricted continuous traffic.

The Agency will pay for incentives or deduct disincentives, as appropriate, in the current progress payment schedule. The Agency may assess liquidated damages, as specified in Subsection 108.8, concurrently with disincentives if they are not based on duplicate costs.

Submit a certified check to the Agency for the difference between disincentive assessments and contract retainage when disincentives exceed retainage. Submit check within [30] calendar days of payment notice.

Request time extensions only for documented industry-wide labor disputes or material delivery delays.

108.8 FAILURE TO COMPLETE ON TIME

The Agency will deduct specified liquidated damages from progress payments or retainage for each working day or calendar day the contract remains incomplete after the contract completion date, including approved time extensions. In view of the difficulty in making a precise determination of actual damages incurred, the Agency will assess a daily charge not as a penalty but as liquidated damages to compensate for the additional Agency costs incurred due to the failure to complete on time.

In suits involving assessment or recovery of liquidated damages, the reasonableness of daily charges will be presumed and the amount assessed will be in addition to every other remedy enforceable at law, in equity, by statute, or under the Contract.

Work continued after the specified contract completion time or approved time extensions does not waive the Agency's contract rights.

The Agency may suspend time charges on calendar day and working day contracts once the work is substantially complete. Complete all remaining work with diligence.

108.9 CONTRACT DEFAULT

The Agency may declare the Contractor to be in default if the Contractor

A. Fails to begin work in the time specified;

B. Fails to perform the work with sufficient resources to ensure the timely completion of the work;

C. Fails to meet contract work requirements or neglects or refuses to remove and replace rejected materials or unacceptable work;

D. Stops work;

E. Fails to resume stopped work after receiving notice to proceed;

F. Becomes insolvent or bankrupt, or commits related acts; is nonresponsive to final third-party judgments; or makes an assignment for the benefit of creditors;

G. Fails to comply with labor provisions, minimum wage payments, or EEO contract requirements;

H. Is party to fraud, or

I. Repeatedly fails to make payment in accordance with the Contract to subcontractors or suppliers for labor or materials.

The Engineer will notify the Contractor and the surety in writing for conditions determined to be in default.

Failure to correct the delay, neglect, or default within [10] calendar days after the Engineer's written notice authorizes the Agency to prosecute the work. The Agency may appropriate or use all materials and equipment at the project site and enter into an agreement for completing the contract. The Agency may purchase from the Contractor, at actual cost, acceptable materials acquired for use on the project and not yet included in the work.

The Agency will determine the method to complete the contract.

All costs and charges incurred by the Agency, including the cost of completing the work under the contract, will be deducted from monies owed or that may be owed the Contractor. Should the expense exceed the sum that would have been payable under the contract, the Contractor and surety are liable for the difference.

If a Contract default is later determined to be without cause, the default of the Contractor will revert to a Termination for Public Convenience as allowed in Subsection 108.10 and damages to which a Contractor may be entitled following improper default termination are limited to the amounts specified in Subsection 108.10.

108.10 TERMINATION FOR PUBLIC CONVENIENCE

A. *General.* The Agency may terminate the contract in whole or in part for

1. Executive Orders of the President or State Governor, or

2. Court restraining orders based on acts or omissions of persons or agencies other than the Contractor.

3. Conditions are determined to be in the best interest of the Agency because of but not limited to the following:

   a. Lack of funding or a funding reallocation that prevents the completion of the Work as planned,

   b. Discovery of significant hazardous material problems,

   c. Right-of-Way acquisition problems, or

   d. Utility conflicts that would cause substantial delays or expense to the Contract.

Specifics on the termination and the effective date will be detailed in a Notice of Termination.

B. *Submittals and Procedures.* Upon receipt of a Notice of Termination, immediately

1. Stop work as specified.

2. Place no further subcontracts or order materials, services, or facilities, except as approved to complete any remaining portion of the contract.

3. Terminate all subcontracts to the extent they relate to terminated work.

4. Settle all outstanding liabilities and termination settlement proposals.

5. Transfer title and deliver the following to the Agency:

   a. Fabricated or partially fabricated parts, work in process, completed work, supplies, and other material produced or acquired for the work terminated; and

   b. Completed or partially completed plans, drawings, information, and other property required to be furnished to the Agency if the contract had been completed.

6. Complete work not terminated.

7. Coordinate a time and date with the Engineer to inventory materials obtained but not yet used for the project.

8. Take all necessary or directed action to protect contract-related property that is in the possession of the Contractor and in which the Agency has or may have an interest.

C. *Settlement Provisions.* Accept final payment for:

1. Completed work items at the contract bid price.

2. Eliminated work as specified in Subsection 109.5.

3. Partially completed work at agreed prices or as follows: Submit a claim for additional damages or costs not covered above or elsewhere in the contract within [60] days of the

termination date. Furnish cost documentation. Exclude anticipated profits on work not completed. Ensure the claim is less than the total contract price, reduced by the amount of previous payments, and the contract price of non-terminated work. Following Agency agreement with claimed costs, the Agency will amend the contract and make payment.

D. *Disputed Settlement.* If the Agency does not agree with the costs claimed by the Contractor, the Agency will make payment as follows, but without duplicating any amounts agreed upon under Subsection 108.10(C):

1. For contract work performed before the termination date, the total of

   a. The cost of work completed.

   b. The cost of settling and paying termination settlement proposals under terminated subcontracts properly chargeable to the termination portion of the contract if not included in Subsection 108.10(D)(1)(a).

   c. Profit on Subsection 108.10(D)(1)(a), determined by the Agency to be reasonable. The Agency will exclude profit under this subdivision if the Contractor's costs for work performed exceed the bid item payments made.

2. Reasonable settlement costs of terminated work, including

   a. Accounting, legal, clerical, and other expenses reasonably necessary to prepare termination settlement proposals and support data;

   b. Subcontract termination and settlement (excluding the amounts of settlement); and

   c. Storage, transportation, and other costs incurred that are reasonably necessary to preserve, protect, or dispose of the termination inventory.

3. Except for normal spoilage and to the extent that the Agency accepts the risk of loss, the Agency will exclude the fair value of destroyed, stolen, or damaged material.

4. The following will be deducted to arrive at the amount owed the Contractor:

   a. All unliquidated advance or other payments under the terminated portion of the contract;

   b. Any Agency claim against the Contractor under the contract; and

   c. The agreed upon price, or the proceeds from the sale of, materials, supplies, or other items acquired and sold by the Contractor but not covered by or credited to the Agency.

E. *Partial Termination.* File a proposal with the Agency for an adjustment of the price(s) of the continued portion of the contract within [90] days of the effective termination date. Provide supporting information. The Agency will make any agreed upon adjustment.

The Agency may establish terms and conditions for making partial payments against costs incurred by the Contractor for the terminated portion of the contract.

Provide access to all project cost records for Agency audit. Request approval to maintain photographs, microphotographs, or other accurate reproductions rather than original records and documents.

If the Agency issues a termination of the Contract or portion thereof, the Agency relieves the Contractor of its obligation to perform such portions of the Contract. The Agency does not relieve the Contractor of its responsibilities for the Work completed before the termination, or the Contractor's Surety of its responsibilities for any just claims arising out of the performance of the Work before the termination.

SECTION 109
MEASUREMENT AND PAYMENT

109.1 MEASURING QUANTITIES

To measure completed work, the Engineer will use the United States customary measure or International System of Units (SI), as specified in the contract. The units of the two systems are not equal and are not interchangeable within a contract.

The Engineer will determine quantities of materials the Contractor furnishes and the work the Contractor performs using measurement methods and computations conforming to sound engineering practice. The Engineer will determine quantities of acceptable Work using Plan Dimensions for Contract items designated as "P" in the Statement of Estimated Quantities shown on the Plans. Otherwise, the Engineer will field measure quantities of Work performed or use a combination of Plan dimensions and field dimensions,

The Engineer will measure actual quantities of work completed as described in the measurement subsections for individual pay items. The Agency will make payment based on these actual measured quantities. Accept estimated quantities designated in the contract to be used as final payment quantities for final payment, unless revised by approved change order.

The Engineer will measure completed work as follows:

A. *Lump Sum or Each.* Consider "lump sum" or "each" payment as full compensation for all resources necessary to complete the work.

B. *Length.* The Engineer will measure items paid by the linear foot (meter) or inch (millimeter) along the finished surface of the item.

C. *Area.* The Engineer will use horizontal longitudinal and plan (neat) transverse measurements for surface area computations. The Engineer will not deduct individual fixtures having an area of 10 $ft.^2$ (1 m^2) or less.

D. *Volume.* The Engineer will measure structures using plan (neat) or approved change order dimensions.

The Engineer will use the "Average End Area Method from Cross Sections" to compute excavation, compaction, or stockpile volumes. The cross-section method is used when a site needs to be formally documented by cross sections. Alternatively, use the "Surface to Surface Volumes from Digital Terrain Models" (DTM) method. The DTM method is more applicable to small and less linear sites. Surface to Surface Volume comparisons don't allow for haul distance comparison. If average haul needs to be recalculated, use the cross-section method.

For material specified for measurement by loose volume in the vehicle, haul the material in vehicles approved by the Engineer. The Engineer will measure materials at the point of delivery. Ensure the body shape of the vehicle allows contents to be accurately and readily measured. Load and level vehicles to their water level capacity.

If the contract allows, the Engineer may weigh materials and convert the mass to volume using specified conversion factors.

The Engineer will measure water to the nearest 250 gal (1000 L) with calibrated tanks, distributors, or water meters.

The Engineer will measure bituminous materials by the gallon or ton (liter or megagram).

The Engineer will measure volumes at 60°F (16°C), or will correct volumes to the volume at 60°F (16°C) according to ASTM D1250 or ASTM D633.

The Engineer will use net certified scale weights, or weights based on certified rail car volumes, as a basis for measurement. The Engineer will correct for bituminous material lost, wasted, or otherwise not incorporated in the work.

When bituminous materials are shipped by truck or transport, the Engineer will correct net certified weights or volumes for loss or foaming when computing quantities.

The Engineer will measure timber by the thousand feet board measure (cubic meter), based on nominal widths and thicknesses and individual maximum lengths.

E. *Weight (Mass).* The Engineer will use certified scales to determine weight (mass).

The Engineer may accept certified "car weights" for material shipped by rail, except for material to be subsequently processed in mixing plants.

Obtain certified haul truck tares as specified. Ensure that each haul truck displays a legible identification mark.

The Engineer will measure cement by the pound or ton (kilogram or megagram).

The Engineer will accept nominal weight (mass) or dimensions for standard manufactured items unless otherwise specified. The Engineer will accept industry- established manufacturing tolerances, unless otherwise specified.

The Engineer will measure aggregate weight (mass) in the saturated surface dry condition.

Furnish, erect, and maintain weigh systems tested and certified by ______ (contracting Agency to complete), or use certified permanently installed commercial scales. Provide certifications after each setup and before use or as requested by the Engineer. Seal the weigh system after certification and display certification stamp. Ensure weigh systems are accurate to within ±0.5 percent of the correct weight throughout the range of use.

Provide uniformly graduated scale intervals not to exceed 0.01 times the nominal rated scale capacity, or 1 lb (0.5 kg), whichever is less. Use only mechanical or electronic scales.

Arrange beams, dials, platforms, and other scale equipment for safe and convenient viewing by the operator and inspector.

Maintain 10 standard 50-lb weights (22.5-kg masses) or other approved devices to test scales.

Service and test scales for accuracy before use at a new site. Install and maintain platform scales with the platform level and with rigid bulkheads at each end.

Correct quantities of materials received on scales found to be outside of specified tolerances based on the last documented test within specified tolerances.

F. *Time.* The Engineer will measure equipment rental in hours of actual working time and necessary traveling time within the project limits as specified in Subsection 109.4(C)(4).

G. *Plan Quantities.* If the Agency places a "P" designation on individual Contract Items or specific portions of Contract Items in the Statement of Estimated Quantities on the Plans, the Agency will use the Plan dimensions to calculate the pay quantity for that Contract Item. The Agency will limit use of the "P" designated quantities to Contract Items with specified dimensions and controlled by field checks during, or after construction. The Engineer will determine the quantities of Contract Items that do not have a "P" designation using field measurements required by the Contract, unless otherwise agreed in writing.

The Engineer will adjust a "P" designated quantity if the Engineer revises the dimensions of the Work or decides the "P" designated quantity is incorrect. The Engineer will only adjust quantities for the revised or corrected portions of the "P" designated Contract Item.

109.2 SCOPE OF PAYMENT

The Agency will pay for the quantity of work acceptably completed and measured for payment as specified in the measurement Subsection for each pay item. Payment of the contract unit price is full compensation for all resources necessary to complete the item of work under the contract.

Assume liability for risk, loss, damage, or expense resulting from the work, subject to Subsection 107.18.

109.3 COMPENSATION FOR ALTERED QUANTITIES

Accept payment for work quantities that vary from contract quantities at the original contract unit prices. Request cost adjustment under Subsections 104.2 and 108.10.

109.4 EXTRA WORK AND FORCE ACCOUNT WORK

If the Agency revised the contract under Subsection 104.2, the Agency will pay for the work by one of the following methods:

A. *Contract Unit Prices.* The Engineer will use the contract unit prices if they are representative of the work to be performed.

B. *Negotiated Prices.* The Engineer and Contractor may negotiate new unit or lump sum prices before the work is performed by using one or more of the following methods:

   1. Original Contract Unit Prices for similar Contract Items adjusted for increased or decreased Material costs;

   2. State-wide average unit prices awarded for the Contract Item(s) as listed in the Agency's annual summary of Contracts;

   3. The average of unit prices awarded on three different projects of similar work and quantity;

   4. Unit prices computed by the Office of Estimating; or

   5. Cost analysis of labor, material, equipment, and markups as allowed in Subsection 109.4(C).

C. *Force Account.* The Agency may direct the Contractor to perform work on a force account basis, which will be compensated as follows:

   1. *Labor.* For the actual time labor and foremen are engaged specifically on force account work, the Agency will pay the cost of those employees' wages at the rates agreed to in writing prior to beginning work. The Agency will not pay for general superintendence.

      The Agency will include the actual costs paid for subsistence and travel allowances, health and welfare benefits, pension fund benefits, or other benefits required by a collective bargaining agreement or other employment contract applicable to the class of labor employed.

      The Agency will apply an additional [35] percent of the above sum for project overhead and profit.

   2. *Bond, Insurance, and Tax.* The Agency will pay the actual cost, plus [10] percent, for property damage, liability, and worker's compensation insurance premiums, unemployment insurance contributions, and social security taxes. Furnish evidence of the actual rate(s) paid.

   3. *Materials Costs.* For materials accepted by the Engineer and used in force account work, the Agency will pay the actual invoiced delivery costs plus [15] percent.

4. *Equipment and Plant*. For the approved use of Contractor-owned machinery or special equipment other than small tools, obtain the hourly rates from the latest edition of the identified equipment rental rate guide.

   The Contractor shall apply, and the Agency will confirm, rental rates identified in the guide as follows:

   a. Use hourly rates, determined by dividing the monthly rate by 176.

   b. The number of hours to be paid for on a force account activity is the number of hours that the equipment or plant is actually used.

   c. Use the rates in the guide in effect on the first day work is performed on the force account activity throughout the performance period of the force account work.

   d. Do not apply an area adjustment. Use rate adjustment tables to correct for equipment life.

   e. Base overtime calculations on Subsection 109.4(C)(4)(a).

   f. Include estimated operating costs for each hour the equipment or plant is in operation. Do not include idle time, regardless of cause, except as provided for in Subsection 109.4(C)(4)(g).

   g. For equipment that remains on a standby basis at the request of the Engineer, the Agency will pay for idle time at one-half the rate established in Subsection 109.4(C)(4)(a). The Agency will not pay for standby time on a day that the equipment operates for eight or more hours. For equipment operating less than eight hours on a normal workday, the Agency will limit standby payment to the hours that, when added to the operating hours for that day, equals eight hours. The Agency will not make standby payment for days not normally considered a work day.

   h. Calculate transportation costs to move equipment or plant to or away from the site.

   i. Include the cost of fuel, oil, lubrication, supplies, small tools, necessary attachments, repairs, overhaul and maintenance, depreciation, storage, overhead, profits, insurance, and all incidentals in the rates established above.

   Obtain the Engineer's approval for rates exceeding those outlined above.

   The Agency will not pay for (1) time lost for equipment breakdowns, (2) time spent to repair equipment, or (3) time exceeding 24 h after Engineer notification that equipment is no longer needed.

   Obtain written agreement before using equipment not included in the rental rate guide.

   These provisions only apply to equipment and plant owned directly by the Contractor or by entities associated with the Contractor or its parent company.

Before using the rented equipment on the work, inform the Engineer of the need to rent the equipment and of the rate to rent that equipment. The Agency will reimburse the Contractor for rental equipment based on actual work time and transportation to and from the work site, provided the Contractor submits a copy of a paid invoice for the rental expense incurred.

The Agency will reimburse the Contractor for transportation charges to and from the work site provided (1) equipment is obtained from the nearest approved source, (2) return charges do not exceed delivery charges, (3) haul rates do not exceed established rates of licensed haulers, and (4) equipment units are unavailable on or near the project.

Submit invoices for all charges by individuals or firms other than the Contractor.

5. *Subcontracting.* If a subcontractor performs force account work, the Agency will pay the approved Subcontractor invoice plus [5] percent for administrative costs.

6. *Cost Records.* Obtain Engineer's daily approval of cost records.

7. *Statements.* Furnish a weekly itemized cost statement to the Engineer. Detail as follows:

    a. Name, classification, date, daily hours, total hours, rate, and extension for each laborer and foreman.

    b. Designation, dates, daily hours, total hours, rental rate, and extension for each unit of equipment.

    c. Quantities of materials, prices, and extension.

    d. Materials transportation costs.

    e. Property damage, liability, and workers' compensation insurance premiums, unemployment insurance contributions, and social security costs.

    Support statements with accompanying certified payrolls and invoices for all materials used and transportation charges. Furnish an affidavit for materials taken from the Contractor's stock and not specifically purchased for the work; certify origin, quantity used, price, and transportation cost.

    Accept the total payment as provided for above as full compensation for the work.

109.5 ELIMINATED ITEMS

Accept the Engineer's authority to eliminate contract items found to be unnecessary to complete the work. The Agency will reimburse the Contractor for direct costs incurred before notification of elimination as follows:

A. Restocking charges supported by paid invoices and an additional 5 percent markup on the compensation for overhead and profit.

B. The cost of material transferred to the Agency in lieu of restocking or disposal. The allowed compensation is the paid invoice cost plus 15 percent markup, but no more than the unit bid price for the item involved.

C. Hauling costs, if not included in restocking charges, for returned material and for material delivered to the Agency.

109.6 PROGRESS PAYMENTS

Bid project assuming monthly progress payments. The Agency will base progress payments on the Engineer's estimate of the value of work performed and materials placed under the contract and for materials delivered as specified in Subsection 109.7.

Expect no progress payment when the total value of the work completed since the last estimate is less than [$1,000].

Bid project based on a retainage of [5] percent of the value of the completed work to a maximum of [3] percent of the original contract amount. The Agency will not release retainage until final acceptance of the work.

109.7 PAYMENT FOR MATERIAL ON HAND

The Agency may make partial payment for materials designated for incorporation into the work that

A. Meet contract requirements;

B. Are delivered and stockpiled at the project site or other approved location;

C. Are to be stored more than 90 days;

D. Are supported by copies of material purchase orders, paid invoices, or receipt of delivery; or

E. Are not living or perishable.

Partial payments will be limited to the appropriate value of the contract unit price. Provide copies of paid invoices within [30] days of receipt of partial payment. Acknowledge that approval of partial payment for stockpiled materials is not final acceptance of the materials.

109.8 PAYMENT OF WITHHELD FUNDS

Request payment of withheld progress payments in writing. Accompany request with verification of escrowed deposit of securities eligible for investment in State funds or bank certificates of deposit. Meet the following conditions:

A. Assume all expenses in connection with escrow deposits.

B. Ensure securities or certificates of deposit are acceptable to the Agency.

C. Ensure securities or certificates of deposit have a value of at least 100 percent of the retained amount to be paid to the Contractor under this Section.

D. Enter into an escrow agreement acceptable to the Agency.

E. Obtain the written consent of the surety to the agreement.

109.9 ACCEPTANCE AND FINAL PAYMENT

Accept the Engineer's final estimate of work under Subsection 105.19 or file a formal objection to the quantities within [30] calendar days. Submit objections in writing and provide sufficient detail to permit final adjudication.

Expect final payment to reflect the entire sum due minus all previous payments, retainage, deductions, and corrections.

109.10 COMPENSATION FOR PROJECT DELAYS

A. *Allowable Delay Costs.* The Contractor may only recover compensable delay costs for the following:

1. *Extended Field Overhead.* The Agency will pay for extended field overhead costs that include costs for general field supervision, field office facilities and supplies, and maintenance of field operations. General nonsalaried field supervision labor costs include, but are not limited to, field supervisors, assistants, watchman, clerical, and other field support staff. Calculate these labor costs as specified in Subsection 109.4(C)(1). For salaried personnel, calculate the daily wage rate actually paid by dividing the weekly salary by 5 days per week.

2. *Extended Labor.* Compute labor costs during delays as specified in Subsection 109.4(C)(1) for all non-salaried personnel remaining on the Project required under collective bargaining agreements or for other Engineer-approved reasons.

3. *Escalated Labor.* To receive payment for escalated labor, demonstrate that the delay forced the work to be performed during a period when labor costs were higher than planned at the time of bid. Provide adequate support documentation for labor costs, allowances, and benefits.

4. *Materials Escalation or Storage.* The Agency will pay for increased Material costs or Material storage costs if the delay resulted in material cost escalation or extended storage costs. Obtain the Engineer's approval before storing Material due to a delay.

5. *Idle Equipment or Equipment Mobilization and Demobiliziation.* The Agency will pay for equipment, other than small tools, that must remain on the Project during compensable delays at the idle Equipment rate calculated in Subsection 109.4(C). The Agency will pay the Contractor's transportation costs to remove and return Equipment not required on the Project during compensable delays.

6. The Agency will pay an additional [10] percent markup for items 1 through 5 for which there is no specific allowance.

Document all costs claimed when measuring additional equipment expenses (i.e., ownership expenses) that result directly from a delay caused by the Agency. Use actual records kept in the usual course of business, not equipment rental rate guides, and measure increased ownership expenses according to generally accepted accounting principles.

109.11 DIRECTED ACCELERATION

The Engineer may order the Contractor to accelerate the Work to avoid delay costs or to complete the Project early. The Agency and Contractor will negotiate the acceleration costs.

109.12 INEFFICIENCY

The Agency may compensate the Contractor for inefficiency or loss of productivity resulting from Contract Revisions, directed acceleration, or other causes if adequately supported by an analysis that demonstrates a cause and effect relationship between impacts and productivity losses. Use the Measured Mile analysis, or other reliable methods, comparing the productivity of work impacted by a change to the productivity of similar work performed under unimpacted (unchanged) conditions to quantify the inefficiency.

109.13 UNRECOVERABLE COSTS

The Contractor is not entitled to additional compensation for costs not specifically allowed or provided for in Subsection 109.4, including but not limited to the following items of damages or expense:

A. Profit more than that provided herein;

B. Loss of profit;

C. Home office overhead exceeding that already provided; for example, overhead that the Agency has paid the Contractor for as specified elsewhere in Subsection 109.4.

D. Consequential damages, including, but not limited to, loss of bonding capacity, loss of bidding opportunities, and insolvency;

E. Any indirect costs or expenses; and

F. Attorneys’ fees, claims preparation expenses, or litigation costs.

AASHTO

DIVISION 200
EARTHWORK

SECTION 201
CLEARING AND GRUBBING

201.1 DESCRIPTION

Clear, grub, remove, and dispose of vegetation and debris within designated limits.

201.2 MATERIAL

Reserved.

201.3 CONSTRUCTION

Clear and grub all surface objects, vegetation, trees, stumps, roots, and other debris designated for removal. Mow as required. Undisturbed and sound stumps and nonperishable solid objects more than 3 ft (1 m) below subgrade and embankment slopes may remain in place. Stumps and nonperishable solid objects that extend less than 3 in. (75 mm) above the groundline or low water level may remain if they are outside excavation and embankment areas. Cut stumps flush with or below the final slope line. Preserve trees, shrubs, plants, and other objects designated to remain.

Dispose of material and debris or remove or repurpose materials for recycling. Disposable material and debris may be disposed of by burial at designated locations with at least 12 in. (300 mm) of cover material. Obtain written arrangements with property owners and governmental authorities for disposal locations outside the right-of-way limits. Determine locations for disposal, treatment, or recycling of materials removed from the project site. Move such material from the project site to a state or EPA permitted disposal site, storage treatment, or recycling facility.

Remove low-hanging and unsound branches from remaining trees or shrubs. Use proper tree surgery practices to trim tree branches. Trim branches of trees extending over the roadbed to provide a clear height of at least 20 ft (6 m). Seal the cut or scarred tree or shrub surfaces with an asphaltum base paint made for tree surgery.

201.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. When the Agency will pay for tree and stump removal on an individual unit basis, the Engineer will classify items removed according to the schedule of sizes designated in the contract.

1. *Trees*. The Engineer will classify trees and stumps less than 4 in. (100 mm) in diameter as brush. The Engineer will measure the diameter of trees at a height of 40 in. (1 m) above the ground.

2. *Stumps*. The Engineer will measure stumps by taking the average diameter at the cutoff.

201.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Clearing and grubbing	acre (ha), station, lump sum
(B) Removal of trees or stumps Size __________________	each

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 202
REMOVAL OF STRUCTURES AND OBSTRUCTIONS

202.1 DESCRIPTION

Raze, remove, dispose of, or salvage buildings, fences, structures, pavements, abandoned pipelines or utilities, and other obstructions designated for removal. Backfill resulting cavities.

202.2 MATERIAL

Reserved.

202.3 CONSTRUCTION

A. *General*. Raze, remove, salvage, or dispose of material promptly. Dispose of material as specified in Subsection 201.3. In embankment areas, backfill basements or cavities to the level of the surrounding ground as specified in Subsection 203.3(F).

B. *Removal of Bridges, Culverts, and Other Drainage Structures.* Remove existing substructures to the natural stream bottom. Remove those parts outside the stream to 12 in. (300 mm) below natural ground surface.

C. Dismantle designated Agency-retained material without damage. Match-mark the pieces, transport, and store at designated locations. Remove all other structures from the right-of-way.

D. *Removal of Miscellaneous Material.* Dispose of designated concrete pavement, base course, sidewalks, curbs, gutters, buildings, foundations, slabs, ballast, gravel, bituminous material, and pavement materials as specified in Subsection 201.3. Consider potential for recycling or reuse of materials on site. Use AASHTO R 65 if agency does not have an existing standard in place for a particular application.

   Break concrete selected for use as riprap into pieces less than 150 lb (70 kg). Stockpile or place as directed by the Engineer.

   Store salvageable ballast, gravel, bituminous material, and other pavement material at designated locations. Ensure stored material is free from dirt or foreign matter. Saw concrete pavement, sidewalks, curbs, gutters, and similar structures that will be left in place to a true vertical line or remove to an existing joint.

202.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

202.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Removal of structures and obstructions	lump sum
(B) Removal of ________________	each, ft (km), yd^2 (m^2), yd^3 (m^3)
(C) Recycling and reuse of ________________	each, ft (km), yd^2 (m^2), yd^3 (m^3)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified. The Agency will not make separate payment for excavating, backfilling, and compacting cavities resulting from the removal of structures.

SECTION 203
EXCAVATION AND EMBANKMENT

203.1 DESCRIPTION

Excavate, haul, dispose of, place, recycle or reuse, and compact specified materials necessary to construct the project.

203.2 MATERIAL

Borrow (as specified by Agency).

203.3 CONSTRUCTION

A. *General.* Clear, grub, and remove topsoil before beginning excavation, grading, and embankment operations. Salvage topsoil as specified in Subsection 208.3. Provide a uniform and smooth finish to excavation and embankment surfaces. Obtain the Engineer's approval before wasting excavation material. Excavate and perform embankment operations without disturbing material outside staked construction limits.

   Dispose of surplus or unsuitable excavated material at locations acceptable to the Engineer. Obtain written agreements with property owners and governmental authorities for disposal locations outside the right-of-way limits. Use suitable surplus material to widen embankments and flatten slopes within the right-of-way. This work shall consist of determining locations for disposal, treatment, or recycling of regulated materials removed from the project site. This work shall also consist of loading regulated materials into a vehicle or transport container and the movement of such material from the project site to a state or EPA permitted disposal site, storage treatment, or recycling facility by appropriately trained and licensed personnel.

   Cover rocks and boulders with at least [12 in. (300 mm)] of embankment material. Do not place excess or unsuitable material in wetlands.

   Grade obliterated roadways to restore the original ground contour. Form natural, rounded slopes. Remove and dispose of pavement and base courses as specified in Subsection 202.3(C).

B. *Common Excavation.* Excavate and place or dispose of otherwise unclassified material encountered during excavation.

C. *Rock Excavation.* Remove, as rock excavation, material that cannot be excavated without blasting or using rippers. Include all boulders and detached stones with a volume of 2 yd^3 (1.5 m^3) or more.

Excavate material classified as rock to a depth between [6 to 12 in. (150 to 300 mm)] below the subgrade. Shape the rock surface to drain. Backfill to subgrade as specified in Subsection 203.3(F).

Presplit rock slopes when specified. Plan diameter, spacing, and loading of presplitting holes to produce a neat break. Drill presplitting holes to the full depth of the ledge.

Demonstrate to the Engineer with a 100-ft (30-m) test section that diameter, spacing, and loading will produce an acceptable backslope. Continue presplitting if the backslope is acceptable. Establish test sections until satisfactory results are obtained.

Handle and load explosives according to the manufacturer's recommendations.

D. *Borrow Excavation.* Provide borrow material meeting specifications from off the right- of-way or from outside excavation limits. Make arrangements and pay all costs involved in procuring borrow. Allow the Engineer to cross-section after stripping and before use.

   Furnish a certified hazardous waste site assessment for borrow areas located off the right- of-way. Provide an alternate borrow source or conduct more detailed testing in suspect locations.

   Use suitable and available common and rock excavation before using borrow material. Obtain approval to use borrow in lieu of on-site excavation. Grade borrow areas uniformly to drain.

E. *Unsuitable or Undercut Excavation.* The Engineer will consider excavation unsuitable or undercut if it contains deposits of saturated or unsaturated soil mixtures or organic matter unacceptable for embankment material.

   Remove unsuitable or undercut material encountered in the subgrade. Excavate to the specified depth or as directed by the Engineer. Backfill and compact with approved material as specified in Subsection 203.3(F).

   Dispose of material that cannot be properly stabilized and compacted as specified in Subsection 203.3(A).

F. *Embankment Construction:*

   1. *General.* Embankment construction includes preparing areas upon which embankments are to be placed; placing and compacting approved embankment material within roadways areas to replace unsuitable material; and placing and compacting embankment material in cavities and other depressions within the roadway area.

      Compact lifts in embankment areas, other than rock, to at least [95] percent of the maximum density, as determined by AASHTO T 99 Method C. Increase or decrease moisture content of material to meet the specified density. The Engineer will determine in-place field density according to AASHTO T 191 or T 310.

      Do not use frozen embankment material or place embankment material on frozen ground. Do not place rocks, broken concrete, and other solid materials in embankment areas designated for placing or driving piles.

Construct embankments of acceptable material including reclaimed asphalt pavement (RAP), recycled concrete aggregate (RCA) and portland cement concrete rubble, but containing no muck, stumps, roots, brush, vegetable matter, rubbish, reinforcement bar, or other material that does not compact into a suitable and enduring roadbed. Do not use RAP or RCA in the top 3 feet (0.914 m) of slopes and shoulders that are to be grassed or have other type of vegetation established. Do not use RAP or RCA in stormwater management facility fill slopes.

Use AASHTO R 65 if agency does not have an existing standard in place for a particular application.

2. *Preparation of Embankment Areas.* Remove unsuitable material before constructing embankment.

   Bench when placing embankment on hillsides or against existing embankment with slopes steeper than 6:1 (1:6). Bench continuously in loose lifts of less than [12 in. (300 mm)]. Ensure benches can accommodate placing and compacting equipment. Begin all horizontal cuts at the intersection of the groundline and the vertical side of the previous bench. Step existing slopes to keep the embankment from wedging against structures. Compact excavation from benching with the new embankment material.

   Where the height of the embankment at the subgrade level is to be 4 ft (1.2 m) or less, remove all organic matter from the existing ground surface. Scarify the cleared surface to a minimum depth of [6 in. (150 mm)]. Compact to the specified embankment density. Where the height of the embankment is to be greater than 4 ft (1.2 m), disc all remaining sod thoroughly before constructing embankment.

   Scarify existing roadways containing granular material within 3 ft (1 m) of the subgrade to a depth of [6 in. (150 mm)]. Compact to the specified embankment density.

3. *Embankment Adjacent to Structures.* Compact embankment without applying excessive pressure against structures. Place fill adjacent to the end bent of a bridge only to the bottom of the backwall until the superstructure is in place. Bring up embankment equally on both sides of a concrete wall or box-type structure.

4. *Roadway Embankment.* Place and spread roadway embankment in uniform horizontal lifts of less than [10 in. (250 mm)] loose measurement. Compact to the specified density before placing the next lift. Obtain approval to increase lift thickness. Maintain proper moisture content to achieve the required density and stability.

5. *Rock Embankment.* Place rock embankments in lifts equal to the average rock dimension. Restrict maximum rock dimension to 3 ft (1 m). Distribute spalls and finer rock fragments to level and smooth each lift. Place succeeding lifts to not damage previously completed lifts. Dump rock on the lift being constructed, and push into place. Do not construct rock lifts within [24 in. (600 mm)] of finished subgrade.

Place at least [24 in. (600 mm)] of compacted embankment over structures before placing rock.

6. *Embankment over Wet or Unstable Foundations.* Compact the first layer of fills over swampy or otherwise unstable ground in lifts sufficient to support equipment. Compact uniformly across the area to produce a compacted embankment that does not rut under loaded hauling equipment.

203.4 MEASUREMENT

A. *Contract Quantities.* The Agency will base payment for excavation on the plan quantities in the contract. When revisions to the quantities are measured for payment, the Engineer will use the plan cross sections as the original cross sections.

B. *Measured Quantities.* The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

1. The Engineer will measure volume in its original position.

2. The measurement will include the following:

    a. Slides not attributable to carelessness,

    b. Authorized excavation below grade, and

    c. Unsuitable materials excavated and removed to achieve proper compaction in cut sections and in embankment foundations.

3. The measurement will exclude suitable material temporarily removed and replaced to aid compaction.

4. The Engineer will use alternate measurement methods where the cross-section method is impractical.

203.5 PAYMENT

A. The Agency will consider the following items as incidental to the work:

1. Prewatering of excavation and borrow areas to bring material to the specified moisture content.

2. Presplitting of rock slopes.

B. When the contract does not specifically provide for payment of embankment, the Agency will consider embankment costs as incidental to excavation. Include the cost for benching and recompacting in the unit bid price for excavation.

C. The Agency will pay for the removal of hazardous material as specified in Subsection 109.4.

D. The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Common excavation	yd^3 (m^3)
(B) Rock excavation	yd^3 (m^3)
(C) Unsuitable excavation	yd^3 (m^3)
(D) Borrow excavation	yd^3 (m^3), ton (Mg)
(E) Embankment	yd^3 (m^3)
(F) Linear grading	station, mi (km)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 204
SUBGRADE PREPARATION

204.1 DESCRIPTION

Shape and compact subgrade before placing a base or surface course.

204.2 MATERIAL

Reserved.

204.3 CONSTRUCTION

Shape subgrade for its full width to required grade and cross section. Scarify the top [6 in. (150 mm)] of the subgrade and increase or decrease moisture content to achieve the specified density and stability. Compact to [100] percent of maximum density to allow placement of base or surface course material without rutting or displacing the roadbed.

The Engineer will determine maximum density according to AASHTO T 99 Method C and in- place field density according to AASHTO T 191 or T 310.

Ensure the finished subgrade surface is smooth and conforms to prescribed elevations before constructing the base or surface course. Limit the maximum variation from the subgrade to the prescribed elevation to [0.4 ft (12 mm)].

Correct all finished sections damaged during construction operations at no cost to the Agency.

204.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure the roadbed of divided highways separately.

B. The Engineer will measure the length of ramps and loops between the ends of the exit and entrance noses along the centerline.

204.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Subgrade preparation	station, mi (km), yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 205
RESERVED

SECTION 206
EXCAVATION AND BACKFILL FOR CONDUITS AND MINOR STRUCTURES

206.1 DESCRIPTION

Excavate and backfill for pipe culverts, storm drains, and other minor structures.

206.2 MATERIAL

Backfill (as specified by Agency).

206.3 CONSTRUCTION

Excavate to line and grade shown. Dispose of unsuitable excavated foundation material as specified in Subsection 203.3(A). Use surplus material meeting contract requirements as conduit backfill or as embankment.

Excavate rock, hardpan, and other unyielding material to [12 in. (300 mm)] below the designed grade. Replace excavated material with free-draining material meeting Subsection 703.17(A).

Bed conduit as specified in Subsection 603.3(B).

Distribute backfill in uniform lifts less than [6 in. (150 mm)]. Compact each lift to specified density before placing successive lifts.

Wait [7] days or ensure that a minimum compressive strength of [2,800 psi (19 MPa)] is attained before backfilling against newly constructed masonry or concrete structures.

Remove all sheeting and bracing used in structure excavation after completing the work. Provide shoring and temporary water control as specified in Section 803.

206.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. For minor structures other than conduit, the Engineer will measure vertical planes [12 in. (300 mm)] outside the base of the structure.

B. For conduit, the Engineer will measure parallel vertical planes located [18 in. (450 mm)] outside the horizontal projection of the outside diameter of the pipe.

C. The Engineer will measure structure excavation below the limits of roadway excavation.

D. When structures are placed in embankment sections, the Engineer will use the natural groundline cross section as the uppermost level of computation.

206.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Excavation for ____________________	yd^3 (m^3)
(B) Backfill for ____________________	yd^3 (m^3)
(C) Bedding material	yd^3 (m^3), ton (Mg)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 207
EROSION AND SEDIMENT CONTROL

207.1 DESCRIPTION

Control erosion using berms, dikes, dams, sediment basins, erosion-control mats, netting, gravel, mulches, grasses, slope drains, and other approved erosion control devices or methods.

207.2 MATERIAL

Provide materials as specified in:

Silt Fence	Subsection 705.4
Fertilizer	Subsection 715.3
Fiber Rolls and Socks	Subsection 715.4
Floating Turbidity Curtains	Subsection 715.5
Gravel Bags	Subsection 715.6
Prefabricated Filter Insert	Subsection 715.7
Seed	Subsection 715.8
Sediment Filter Bags	Subsection 715.9
Tackifiers	Subsection 715.10
Temporary Rolled Erosion Control Products	Subsection 715.11
Turf Reinforcement Mats	Subsection 715.12
Mulch	Subsection 715.13
Plant Materials	Subsection 715.14
Erosion Control Materials	Subsection 715.15
Miscellaneous Landscape	Subsection 715.16
Grass Sod	Agency specified

207.3 CONSTRUCTION

A. *Erosion Control Schedule.* Submit schedules identifying temporary and permanent erosion control work. Include the following items in the schedule:

1. Surface area of erodible earth material to be exposed by each earthwork operation.
2. Proposed methods and materials to limit and contain erosion and sedimentation.
3. Proposed materials to be used.
4. Point of incorporation of permanent features.

Begin work only after receiving schedule approval.

B. *Implementation of Erosion and Sediment Control Schedule.* Incorporate into the project all erosion and sediment control measures outlined in the accepted schedule. Provide immediate erosion control measures to prevent contamination of adjacent streams or other watercourses, lakes, ponds, or other areas of impounded water. Use temporary berms, dikes, dams, mats, seeding, and other devices or methods as required.

Coordinate installation of temporary and permanent erosion control features. Incorporate permanent erosion control features into the project as soon as practical. Use temporary erosion control measures to correct conditions unforeseen during the design of the project or for emergency conditions that develop during normal construction.

Coordinate clearing and grubbing and grading operations with incorporation of erosion control features. Provide erosion control measures between successive construction stages. Limit the surface area of erodible earth exposed at one time to [750,000 ft^2 (70,000 m^2)] per equipment spread.

Cease earthwork operations when erosion control features are determined to be inadequate. Resume only after demonstrating effectiveness of erosion control features.

Provide temporary erosion control measures immediately when seasonal limits prohibit permanent measures.

Provide or replace temporary erosion control measures to offset negligence, carelessness, or failure to install permanent erosion control features at no cost to the Agency.

Obtain easements for temporary erosion control work outside the right-of-way when necessary.

C. *Installation of Erosion and Sediment Control Measures.* Construct erosion and sediment control measures in accordance with the following:

1. *Seeding and Mulching.* Apply seed and mulch as specified in Subsection 610.3. Immediately before seeding, till or hand work the ground surface into an even and loose seedbed free of clods, and bring to the desired line and grade. Place topsoil as specified in Section 208 if required. Apply seed and mulch to the prepared area at the rates specified in the contract. Seed and mulch slopes as excavation progresses. If directed by the Engineer, apply temporary seed mixtures to disturbed areas. Mulching may also be used without temporary seeding to temporarily stabilize unprotected erodible areas.

2. *Erosion Control Mats.* Place erosion control mats as specified in Subsection 619.3(A).

3. *Fiber Roving System.* Apply and anchor fiber roving systems as specified in Subsection 619.3(B).

4. *Bales.* Place and anchor bales as specified in Subsection 619.3(C).

5. *Sodding.* Prepare ground surface and place sod as specified in Subsection 619.3(D).

6. *Silt Fence.* Prior to disturbing upslope soils, install silt fence at the locations and to the dimensions shown in the plans. Remove sediment when accumulations reach one-half the ground height of the silt fence. Replace, at no cost to the Agency, sections of silt fence that no longer function due to damage or deterioration.

7. *Temporary Berms.* Construct and compact soil to the dimensions shown on the plans, and grade to drain to the designated outlet.

8. *Erosion Checks.* Construct erosion checks as specified in Section 615.

9. *Sediment Traps, Basins and Dams.* Install prior to disturbing soils in the drainage area. Construct embankment as specified in Subsection 203.3(F). Remove sediment when accumulations reach one-half the storage depth.

10. *Slope Protection.* Construct slope protection as specified in Section 822.

11. *Temporary Slope Drains.* Install temporary slope drains as required to prevent excessive erosion of the slope. Stake the drainpipe to the slope or secure with riprap to prevent movement. Construct temporary berms to intercept runoff and channel the runoff to the slope drain. Place riprap at both ends of the pipe to prevent scour.

D. *Maintenance.* Maintain installed erosion control features until project acceptance. Maintain slopes and repair damaged or failed slopes until project acceptance at no cost to the Agency.

Remove temporary erosion control measures after stabilizing slopes and developing turf to the extent that future erosion is unlikely. Dispose of erosion control measures as specified in Subsection 201.3.

Dispose of trapped sediment removed from erosion and sediment controls as specified in Subsection 203.3(A), or use as fill, if suitable. Consider disposal of removed sediment as incidental to the work.

E. *Qualifications.* Submit the following for approval at least 14 days before earth-disturbing operations begin:

1. Names of personnel responsible for soil erosion and sediment control; and

2. A résumé for each individual describing their knowledge and experience providing erosion and sediment control and pollution prevention on highway or road construction projects for at least five (5) years. Include certifications in those states where applicable.

207.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure, and the Agency will pay for, temporary seeding as specified in Section 610.

B. The Engineer will measure, and the Agency will pay for, erosion control mat, fiber roving, bales, and sod as specified in Section 619.

C. The Engineer will measure silt fence, temporary berms, and slope drains according to the length constructed and accepted. The Engineer will not separately measure support stakes, anchors, and fasteners.

D. The Engineer will measure, and the Agency will pay for, erosion checks as specified in Section 615.

E. The Engineer will measure sediment traps, basins, and dams by the unit. This measure will include all excavation and embankment required to construct the item, as well as the materials used to construct outlet and overflow structures.

F. The Engineer will measure, and the Agency will pay for, permanent slope protection as specified in Section 822.

207.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Silt Fence	ft (m)
(B) Temporary Berms	ft (m)
(C) Slope Drains	ft (m)
(D) Sediment Trap	each
(E) Sediment Basin	each
(F) Dam	each

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

The Agency will not pay for temporary erosion and sediment control measures required due to the Contractor's negligence, carelessness, or failure to install permanent measures as part of the scheduled work.

The Agency will consider erosion control measures required for areas outside the project limits, such as borrow pits, haul roads, plant sites, and storage and disposal areas, as incidental to the work.

SECTION 208
SALVAGING AND PLACING TOPSOIL

208.1 DESCRIPTION

Excavate, salvage, and stockpile topsoil. Place topsoil following grading operations.

208.2 MATERIAL

Provide materials as specified in:

Topsoil	Subsection 715.1

208.3 CONSTRUCTION

Salvage and stockpile topsoil before beginning earthwork operations. Place sediment controls before beginning salvage operations. Stockpile topsoil so as not to interfere with natural drainage or cause off-site sediment damage. Limit stockpile side slopes to a steepness of 2:1 (1:2).

Surround all topsoil stockpiles with sediment controls. Temporarily seed stockpiles within 15 days of formation.

Disc or scarify areas to be topsoiled to a depth of at least [2 in. (50 mm)].

Distribute topsoil evenly to a lightly compacted depth of at least [2 in. (50 mm)] on slopes 3:1 (1:3) or steeper and [4 in. (100 mm)] on flatter slopes. Place during conditions that are favorable for grading, sodding, or seeding.

Correct surface irregularities to prevent the formation of depressions or water pockets. Compact topsoil lightly to ensure contact with the underlying soil and to create a uniform seedbed.

Dispose of excess topsoil as specified in Subsection 203.3(A).

208.4 MEASUREMENT

The Engineer will measure accepted quantities as specified in Subsection 109.1.

208.5 PAYMENT

(Note to Agency: Consider paying for excavation and stockpiling of topsoil under Subsection 203.5.)

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Topsoil excavation and stockpiling	yd^3 (m^3)
(B) Furnishing and placing topsoil	yd^2 (m^2)
(C) Placing stockpiled topsoil	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

AASHTO

DIVISION 300
BASE COURSES

SECTION 301
RESERVED

SECTION 302
RESERVED

SECTION 303
RESERVED

SECTION 304
AGGREGATE BASE COURSE

304.1 DESCRIPTION

Construct an aggregate base course on a prepared subgrade.

304.2 MATERIAL

Provide materials as specified in:

Treated or Untreated Base Course Aggregates, Reclaimed Concrete Aggregate	Subsection 703.3
Water	Subsection 714.1(A)

304.3 CONSTRUCTION

A. *Subgrade Preparation.* Prior to placing new base material or subbase and base course material on the roadbed, complete the subgrade according to the requirements of this Division for the subgrade type specified.

B. *Mixing.* Mix the base course materials by one of the following methods to ensure homogeneous blending and to provide optimum moisture content for compaction:

1. *Stationary Plant Method.* Mix materials in a pugmill. Place the material onto the roadbed immediately after mixing.

2. *Travel Plant Method.* Use a mechanical spreader or windrow-sizing device to place aggregate. Add and thoroughly mix water with the aggregate using a traveling mix plant.

3. *Road Mix Method.* Place and mix aggregate on the roadway using motor graders or similar equipment, adding water during the mixing operation as necessary to provide optimum moisture content.

C. *Placing.* Place base material in uniform lifts of equal thickness. Ensure lifts are at least [3 in. (75 mm)] in depth. Limit maximum lift thickness to [8 in. (200 mm)].

D. *Shaping and Compacting.* Shape aggregate to the required grade and cross section and adjust water to obtain optimum moisture content for compaction. Maintain the surface during compacting to produce a uniform texture and to firmly key the aggregates.

Compact to a minimum of [95] percent of the maximum density as determined by AASHTO T 180 or AASHTO T 99. The Engineer will determine in-place density according to AASHTO T 191 or T 310, correcting for oversized particles as necessary.

Maintain the completed subgrade surface and apply water as needed to prevent checking or raveling.

E. *Surface Tolerance.* Finish the surface so that deviations do not exceed $^1/_2$ in. (15 mm), longitudinal or transverse, when tested according to Subsection 401.3(L)(1).

304.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

304.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Aggregate base course	ton (Mg), yd^2 (m^2), yd^3 (m^3)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 305
SUBGRADE MODIFICATION

305.1 DESCRIPTION

Modify the subgrade by blending the subgrade soil with acceptable aggregates or stabilizing additives. Scarify and compact the subgrade.

305.2 MATERIAL

Provide materials as specified in:

Treated or Untreated Base Course Aggregates	Subsection 703.3
Water	Subsection 714.1(A)

305.3 CONSTRUCTION

In order to provide the required subgrade of acceptable smoothness and thickness, maintain control in the compaction and smoothness of the subgrade. Shape aggregate to the required grade and cross section and adjust water to obtain optimum moisture content for compaction. Maintain the surface during compacting to produce a uniform texture and to firmly key the aggregates.

Compact to a minimum of 95 percent of the maximum density as determined by AASHTO T 180 or AASHTO T 99. The Engineer will determine in-place density according to AASHTO T 191 or T 310, correcting for oversized particles as necessary.

Maintain the completed subgrade surface and apply water as needed to prevent checking or raveling.

305.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

305.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
Aggregate for subgrade modification	ton (Mg), yd^3 (m^3)
Processing for subgrade modification	station, mi (km), yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 306
RECONDITIONING EXISTING BASE AND SURFACE

306.1 DESCRIPTION

Recondition the surface of an existing roadbed and shape the shoulders.

306.2 MATERIAL

Reserved.

306.3 CONSTRUCTION

Scarify the roadbed, including shoulders, to the specified depth and width. Pulverize the scarified material so that a minimum of 95 percent, excluding gravel or stone, passes a 2-in. (50-mm) sieve.

Compact as specified in Subsection 304.3(D).

306.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

306.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Reconditioning existing base and surface	station, mi (km), yd^2 (m^2)

Such payment is full compensation for furnishing all equipment, tools, labor, and incidentals necessary to complete the work as specified.

SECTION 307
LIME-TREATED COURSES

307.1 DESCRIPTION

Construct one or more courses of non-sulfate soil or soil–aggregate mixed with lime and water.

307.2 MATERIAL

Provide materials as specified in:

Cutback Asphalt	Subsection 702.1(B)
Emulsified Asphalt	Subsection 702.1(C)
Water	Subsection 714.1(A)
Hydrated Lime	Subsection 714.3(A)
Quicklime	Subsection 714.3(B)

307.3 CONSTRUCTION

A. Construct according to the class specified.

1. Class 1 stabilization and construction operations:
    a. Spread the first increment of lime.
    b. Perform Initial Mixing.
    c. Cure the mixed material.
    d. Spread the second increment of lime.
    e. Perform final mixing.
    f. Compact to required density and finish.
2. Class 2 stabilization and construction operations:
    a. Spread the specified percentage of lime.
    b. Perform initial mixing.
    c. Cure the mixed material.
    d. Perform final mixing.
    e. Compact to required density and finish.
3. Class 3 stabilization and construction operations:
    a. Spread the specified percentage of lime.
    b. Perform mixing.
    c. Compact to required density and finish.

B. *Preparing the Roadbed.* Grade the roadbed surface to the specified lines, grades, and cross sections. Dispose of excess material as specified in Subsection 201.3.

Prevent water from ponding in the roadbed. Remove and replace unstable subgrade.

C. *Scarifying and Pulverizing.* Scarify the roadbed to the specified depth and width and pulverize the scarified material to 100 percent passing a 3-in. (75-mm) sieve. Remove unsuitable undercut soil and organic materials.

D. *Applying Lime.* Apply hydrated lime or quicklime at the specified rates. Apply hydrated lime as a slurry or in a dry form. Apply quicklime only in a dry form. Mix quicklime thoroughly with the dry roadbed material before adding water; add water to the mixture within 6 of dry mixing.

Operate only essential equipment on the spread lime until mixing is complete. Ensure the lime is uniformly incorporated within ±[0.5] percent of requirement.

Apply lime only on unfrozen foundation and when the temperature in the shade is 40°F (5°C) or higher during application and mixing.

E. *Adding Water.* Add water and thoroughly mix. Ensure moisture content does not exceed 3 percent over the optimum as determined by AASHTO T 99 or AASHTO T 180.

F. *Mixing.* Mix the lime and water into the soil to form a uniform, homogeneous mixture with 100 percent passing a 3-in. (75-mm) sieve. Reshape the mixed layer to the specified line, grade, and cross section. For Class 1 and 2 stabilization, seal the surface with a roller. For Class 3 stabilization, compact and finish.

G. *Curing and Final Mixing (Class 1 and 2 Stabilization).* Cure the mixture at least three days for hydrated lime and two days for quicklime. Keep the stabilized layer moist during curing. Reprocess surfaces that become dusty or dry during the curing period.

After the curing period, scarify the stabilized layers and, for Class 1 stabilization, reapply lime. Remix the layer to the specified moisture content. Continue mixing until 100 percent of the material, except stone and gravel, passes a 2-in. (50-mm) sieve, and 60 percent passes a No. 4 (4.75-mm) sieve. Seal the surface after mixing with a pneumatic-tired roller.

H. *Compacting and Finishing.* Complete final compacting and finishing operations within 12 of the final mixing. Compact the mixture to a minimum of 95 percent of the maximum density as determined by AASHTO T 99 or AASHTO T 180. Remove all equipment imprints and use a pneumatic-tired roller for final finish rolling.

The Engineer will determine in-place density according to AASHTO T 191 or T 310, correcting for oversized particles as necessary.

I. *Surface Tolerance.* Finish the surface so that deviations do not exceed $^1/_2$ in. (15 mm), longitudinal or transverse, when tested according to Subsection 401.3(L)(1).

J. *Protecting and Curing*. Restrict operation of vehicles or equipment on the treated course for a minimum 7-day cure period after final finish rolling. Unless the contract specifies an asphalt curing seal, keep the surface lightly moistened during the curing period to prevent drying.

Apply an asphalt curing seal (prime coat) as specified in Section 405.

Protect and maintain the subgrade surface until covered. Construct at least one course of base or subbase on the treated subgrade before using it for hauling operations.

Protect the course from freezing for at least [5] days after placement.

307.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will use manufacturer's package net weight (mass) to measure sacked lime.

307.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
Lime	ton (Mg)
Processing lime-treated course (Class ____,____ in. (mm) thick)	mi (km), yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

The Agency will base payment for quicklime upon a 90 percent available lime index calculated as percent calcium oxide (CaO) by weight.

The Agency will base payment for hydrated lime upon a 90 percent available lime index calculated as percent calcium hydroxide ($Ca(OH)_2$) by weight.

SECTION 308
CEMENT-TREATED BASE COURSE

308.1 DESCRIPTION

Construct one or more courses of a mixture of portland cement or blended hydraulic cement, soil or soil–aggregate, and water on a prepared foundation. Use with nonsulfate containing soils and water only.

308.2 MATERIAL

Provide materials as specified in:

Portland Cement	Subsection 701.2
Blended Hydraulic Cement	Subsection 701.3
Cutback Asphalt	Subsection 702.1(B)
Emulsified Asphalt	Subsection 702.1(C)
Asphalt Concrete Aggregates	Subsection 703.4
Fly Ash	Subsection 713.3(C)(1)
Ground Granulated Blast Furnace Slag	Subsection 713.3(C)(2)
Water	Subsection 714.1(A)

308.3 CONSTRUCTION

A. *Proportioning.* Obtain approval from the Engineer to substitute fly ash or ground granulated blast furnace slag for cement at cement replacement percentages by weight (mass) not to exceed 35 and 50 percent, respectively.

B. *Construction Methods and Equipment.* Use either the travel plant or central plant method.

1. *Travel Plant Method.* Scarify the existing roadway or other designated material source, and pulverize the scarified material until a minimum of [80] percent passes a No. 4 (4.75-mm) sieve. Remove all material retained on a 3-in. (75-mm) sieve. Remove unsuitable undercut soil and organic material. Blend designated borrow with the scarified material to obtain a uniform mixture. Clean butt joints at existing pavements or structures before mixing.

   Correct soft or yielding subgrade areas. Place and spread pulverized aggregate uniformly to required thickness and width.

   Apply the specified quantity of cement uniformly throughout the material to be stabilized. Replace cement lost before mixing at no cost to the Agency. Ensure the quantity of cement applied is within ±[5] percent of the requirement.

   Blend the materials in a traveling plant mixer. Introduce water uniformly during the mixing cycle. Blend the materials thoroughly to prevent formation of cement balls as water is applied.

   Complete wet mixing, lay down, and finishing operations within 2 after adding cement. Suspend work when windy conditions cause a cement loss.

2. *Central Plant Method.* Proportion and mix the aggregate, cement, and water in a central mixing plant. Equip the plant to feed and meter design batch quantities. Mix until material is uniformly blended.

   Ensure the quantity of cement incorporated is *within* ±[5] percent of the requirement. Reject materials outside of this tolerance.

   Use a mechanical spreader to distribute in a uniform layer. Moisten the subgrade or base before lay down. Begin compaction within 60 minutes of introducing mix water.

C. *Compacting and Finishing.* Compact the mixture to a minimum of [95] percent of the maximum density as determined from a field sample, taken as compaction begins, according to AASHTO T 134. The Engineer will determine in-place field density according to AASHTO T 191 or T 310, correcting for oversized particles as necessary. Ensure that moisture in the completed mixture remains within ±2 percent of the optimum moisture content as determined according to AASHTO T 134. Complete compacting and finishing within 2 after adding water to the mixture. Install a construction joint at the point of removal for any material needing removal.

D. *Surface Tolerance.* Finish the surface so that deviations do not exceed $^1/_2$ in. (15 mm), longitudinal or transverse, when tested according to Subsection 401.3(L)(1).

E. *Protecting and Curing.* Apply a curing seal of cutback or emulsified asphalt immediately after final rolling. Keep the surface moist until the seal is applied.

   Apply the curing seal (prime coat) as specified in Section 405.

   Protect and maintain the subgrade surface until covered. Construct at least one course of base or subbase on the treated subgrade before using it for hauling operations.

   Protect the base course from freezing for [5] days after placement.

F. *Weather Limitations.* Place cement-treated base only when the air temperature is above 40°F (5°C) or if forecast temperatures will remain above 35°F (2°C) for 24 h. Place cement-treated material only on unfrozen subgrade, incorporate only unfrozen aggregate, and do not place during rainy conditions.

308.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure cement-treated base course by the yd2 (m2) or by the individual components for material and processing, as established in the contract.

308.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
Cement-treated course	yd^2 (m^2)
Hydraulic or blended hydraulic cement	ton (Mg)
Aggregate	ton (Mg)
Processing cement-treated base course	station, mi (km), yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 309
PORTLAND OR BLENDED HYDRAULIC CEMENT CONCRETE BASE COURSE

309.1 DESCRIPTION

Construct a portland or blended hydraulic cement concrete base, with or without reinforcement, on a prepared foundation.

309.2 MATERIAL

Provide materials as specified in:

Portland Cement	Subsection 701.2
Blended Hydraulic Cement	Subsection 701.3
Fine Aggregate	Subsection 703.1(A)
Coarse Aggregate	Subsection 703.1(B)
Joint Fillers	Subsection 707.1
Reinforcing Steel	Subsection 711.1
Curing Materials	Subsection 713.2
Air-Entraining Admixtures	Subsection 713.3(A)
Fly Ash	Subsection 713.3(C)(1)
Ground Granulated Blast Furnace Slag	Subsection 713.3(C)(2)
Water	Subsection 714.1(A)

309.3 CONSTRUCTION

A. *Proportioning.* Submit for approval a mix design that represents project production. Obtain approval from the Engineer to substitute fly ash or ground granulated blast furnace slag for cement at cement replacement percentages by weight (mass) not to exceed 35 and 50 percent, respectively.

B. *Construction Methods and Equipment.* Construct as specified in Subsections 501.3(B) through 501.3(K)(4) and 501.3(M) through 501.3(R).

C. *Surface Tolerance.* Finish the surface so that deviations do not exceed $^1/_4$ in. (5 mm), longitudinal or transverse, when tested according to Subsection 401.3(L)(1).

D. *Protecting and Curing.* Protect and maintain the base surface until covered.

E. *Tolerance in Base Thickness.* The Engineer will determine base course thickness as specified in Subsection 501.3(R).

309.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure the completed concrete base course by the yd^2 (m^2) using plan pavement widths.

309.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Portland or blended hydraulic cement concrete base course	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

A. *Price Adjustments:*

1. The Agency will use the unit contract bid price for any course thicker than that specified.

2. The Agency will adjust the unit bid price for deficiencies in average thickness according to the following table:

Table 309.5-1. Price Adjustments for Concrete Base Course Deficiency

Deficiency in Thickness in. (mm)	Price Allowed
0 to 0.20 (0 to 5)	100 percent
0.21 to 0.30 (5.1 to 7.5)	80 percent
0.31 to 0.40 (7.6 to 10)	72 percent
0.41 to 0.50 (10.1 to 12.5)	68 percent
0.51 to 0.75 (12.6 to 19)	57 percent
0.76 to 1. (19.1 to 25)	50 percent
>1.00 (25)	Remove and replace

SECTION 310
LEAN CONCRETE BASE COURSE

310.1 DESCRIPTION

Construct a base course of aggregate, portland or blended hydraulic cement, water, and approved additives on a prepared foundation.

310.2 MATERIAL

Provide materials as specified in:

Portland Cement	Subsection 701.2
Blended Hydraulic Cement	Subsection 701.3
Concrete Aggregates	Subsection 703.1
Curing Materials	Subsection 713.2
Air-Entraining Admixtures	Subsection 713.3(A)
Fly Ash	Subsection 713.3(C)(1)
Ground Granulated Blast Furnace Slag	Subsection 713.3(C)(2)
Water	Subsection 714.1(A)

310.3 CONSTRUCTION

A. *Proportioning.* Submit for approval a mix design that represents project production. Obtain approval from the Engineer to substitute fly ash or ground granulated blast furnace slag for cement at cement replacement percentages by weight (mass) not to exceed 35 and 50 percent, respectively.

Prepare a mix design as specified in Subsection 713.1(A) with:

1. Slump between 1 and 3 in. (25 and 75 mm),

2. Entrained-air content between 4 and 9 percent, and

3. 28-day compressive strength between 750 to 1,500 psi (5. to 10. MPa).

B. *Construction Methods and Equipment*. Meet Subsections 501.3(B) through 501.3(H).

C. *Joints*. Install construction joints where concrete placement operations are interrupted for more than 30 minutes. Place a header to create a vertical face that is perpendicular to the centerline, and use tie bars as needed.

D. *Surface Tolerance*. Finish the surface so that deviations do not exceed $^1/_4$ in. (5 mm), longitudinal or transverse, when tested according to Subsection 401.3(L)(1).

E. *Curing*. Cure as specified in Subsection 501.3(M). In addition, at least 12 but not more than 48 prior to placing the reinforcing steel for the overlying pavement, sweep the base clean and apply a second application of liquid membrane curing compound to the lean concrete base at a rate of application of [1 gal/200 ft^2 (1 L/5 m^2)]. After applying the second application of curing agent (serving as a bond breaker), allow no haul traffic on the lean concrete base.

F. *Protecting*. Restrict operation of traffic and construction equipment on the completed base course for 14 days or until attainment of the specified compressive strength. Protect and maintain the base surface until covered.

G. *Tolerance in Base Thickness*. The Engineer will determine base course thickness as specified in Subsection 501.3(R).

310.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure the completed lean concrete base course by the yd^2 (m^2) using plan pavement widths.

310.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Lean concrete base course	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

The Agency will make price adjustments as specified in Subsection 309.5.

SECTION 311
LIME OR FLY ASH–TREATED COURSES

311.1 DESCRIPTION

Construct one or more courses of a mixture of nonsulfate soil, soil–aggregate or aggregate, with lime or fly ash, and water on a prepared foundation.

311.2 MATERIAL

Provide materials as specified in:

Cutback Asphalt	Subsection 702.1(B)
Emulsified Asphalt	Subsection 702.1(C)
Asphalt Concrete Aggregates	Subsection 703.4
Fly Ash and Other Pozzolans	Subsection 713.3(C)(1)
Water	Subsection 714.1(A)
Hydrated Lime	Subsection 714.3(A)
Quicklime	Subsection 714.3(B)

311.3 CONSTRUCTION

A. *General.* Mix and place soil, lime, fly ash, and water as specified in the applicable provisions of Subsections 307.3(D) through 307.3(H), and Subsections 308.3(B) and 308.3(C).

Prepare material to be cured by performing initial mixing to break down the soil to allow absorption of lime and water during the curing period. Spread the mixture uniformly for the full width specified. Seal with a light, pneumatic-tired roller.

B. *Lime and Water-Mixing Phase.* Scarify or mix the materials to the specified depth and width immediately after applying lime. Mix until 100 percent of the material by dry weight, excluding gravel and stones, passes a 2-in. (50-mm) sieve, and 60 percent passes a No. 4 (4.75-mm) sieve.

C. *Curing Period.* Cure the sealed mixture between 3 and 21 days. Use sprinkling or fogging to keep the partially treated material moist during the curing period.

D. *Fly Ash and Water-Mixing Phase.* Mix immediately after adding fly ash and water to cured material. Mix, spread, compact, and finish as specified in Subsections 308.3(B) and 308.3(C).

E. *Protecting and Curing.* Cure and protect lime-fly ash-treated subgrade and base courses as specified in Subsection 308.3(J).

F. *Surface Tolerance*. Finish the surface so that deviations do not exceed $^1/_2$ in. (15 mm), longitudinal or transverse, when tested according to Subsection 401.3(L)(1).

311.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will use the manufacturer's package net weight (mass) to measure sacked lime or fly ash.

311.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
Lime	ton (Mg)
Fly ash	ton (Mg)
Aggregates	ton (Mg), yd^3 (m^3)
Processing lime–fly ash-treated course (in. (mm) thick)	station, mi (km), yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 312
FLY ASH-TREATED COURSE

312.1 DESCRIPTION

Construct one or more courses of a mixture of soil, fly ash, and water on a prepared foundation.

312.2 MATERIALS

Provide materials as specified in:

Fly Ash	Subsection 713.3(C)(1)
Water	Subsection 714.1(A)

312.3 CONSTRUCTION

A. *Weather Limitations*. Perform fly ash mixing operations when the subgrade is unfrozen or when the air temperature in the shade is equal to or greater than [40°F (4°C)]. Protect the fly-ash-modified subgrade mixture from freezing conditions.

B. *Construction Methods and Equipment*. Mix, spread, compact, and finish as specified in Subsections 308.3(B) and 308.3(C).

C. *Protecting and Curing*. Cure and protect fly ash-treated subgrade and base courses as specified in Subsection 308.3(J).

D. *Surface Tolerance*. Finish the surface so that deviations do not exceed $^1/_2$ in. (15 mm), longitudinal or transverse, when tested according to Subsection 401.3(L)(1).

312.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure fly ash by the ton (Mg) for bulk delivery, and by the manufacturer's package net weight (mass) for sacked fly ash.

312.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
Fly ash	ton (Mg)
Processing fly ash-treated course (___ in. (mm) thick)	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 313
OPEN GRADED BITUMINOUS BASE (OGBB)

313.1 DESCRIPTION

Construct a permeable base course of aggregate and bituminous material mixed in a central plant and spread and compacted on a prepared foundation.

313.2 MATERIALS

Provide materials as specified in:

Asphalt Cements/Binders	Subsection 702.1(A)
Aggregate for Open Graded Bituminous Base	Subsection 703.5

313.3 CONSTRUCTION

A. *Proportioning.* Incorporate asphalt cement, Class PG 64-22, at a percentage by weight (mass) of 2.5 ± 0.3 of the mix.

B. *Equipment.* Produce, heat, mix, haul, spread, compact, and finish the bituminous base course using equipment meeting the requirements of Subsection 401.3(D).

C. *Prime Coat.* Apply prime coat, if required, as specified in Section 405.

D. *Surface Tolerance.* Finish the surface so that deviations do not exceed $^1/_2$ in. (15 mm), longitudinal or transverse, when tested according to Subsection 401.3(L)(1).

E. *Weather Limitations.* Comply with the weather limitations for asphalt concrete specified in Subsection 401.3(B).

F. *Traffic Restrictions and Curing Period.* Do not operate vehicles and construction equipment on the OGBB until the OGBB has cooled to ambient temperature. Minimize traffic on the OGBB after completion of the curing period; obtain the Engineer's approval to use the OGBB as a haul road. Repair damage to the base resulting from the Contractor's operation at no cost to the Agency. Prevent tracking or spillage of soil, mud, or other materials that would compromise the hydraulic efficiency of the base.

G. *Hydraulic Efficiency.* The Engineer will apply 0.26 gal (1 L) of water onto the surface of the OGBB to evaluate whether the water can totally absorb into the base within 15 seconds with no water remaining on the surface. Failure to achieve this performance standard will indicate a contaminated base whose hydraulic efficiency has been severely impaired. Remove and replace such contaminated OGBB to the extent determined by the Engineer at no cost to the Agency. Do not operate hauling equipment on the OGBB during the placement of the overlying pavement.

313.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

313.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Open graded bituminous base	ton (Mg)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 314
OPEN GRADED PORTLAND CEMENT CONCRETE BASE (OGPCCB)

314.1 DESCRIPTION

Construct a permeable base course of aggregate, portland cement concrete, and water mixed in a central plant and spread and compacted on a prepared foundation.

314.2 MATERIALS

Provide materials as specified in:

Portland Cement	Subsection 701.2
Aggregate for Open Graded Portland Cement Concrete Base	Subsection 703.6
Fly Ash	Subsection 713.3(C)(1)
Water	Subsection 714.1(A)

314.3 CONSTRUCTION

A. *Proportioning*. Incorporate a minimum cement content of 7.4 lb/ft^3 (118 kg/m^3). Fly ash may be substituted for up to [25] percent of the required cement, with this substitution in the ratio of 1 lb (1 kg) of fly ash for each 1 lb (1 kg) of cement. Do not use fly ash from [November 1 through April 1]. Ensure that the water cement ratio (w/c) does not exceed 0.45, calculated as follows:

w/c = (weight of water)/(weight of cement + weight of fly ash)

B. *Mixing and Placing*. Mix and place the OGPCCB as specified in Subsection 501.3.

C. *Weather Limitations*. Do not mix or place OGPCCB when either the aggregate or subgrade is frozen. Ensure the air temperature is at least 40°F (5°C) in the shade and rising.

D. *Consolidation of Mixture.* Use vibratory equipment during lay down operations to consolidate the mixture to a minimum of 95 percent of AASHTO T 121M/T 121. Using nuclear gauge testing devices according to AASHTO T 310, the Engineer will determine roadway consolidation of the finished base on the fresh mixture 15 to 30 minutes after lay down.

E. *Water Curing.* Sprinkle the surface of the completed OGPCCB with a fine spray of water every 2 for a period of 8 h. Begin curing the morning after the base has been placed.

F. *Construction Joint.* At the start of the day, or if an unavoidable interruption of operations would form a joint in the base, cut back the edge of the base to leave a vertical face necessary to secure a satisfactory surface. Replace all removed base at no additional cost to the Agency.

G. *Traffic Restrictions and Curing Period.* Do not operate vehicles or construction equipment on the OGPCCB for at least three days after its placement. Do not place overlying pavement on the base until the completion of this curing period. After completion of the curing period, minimize construction traffic on the OGPCCB; obtain the Engineer's approval to use the OGPCCB as a haul road. Repair damage to the base resulting from Contractor's operations at no cost to the Agency. Prevent tracking or spillage of soil, mud, or other materials that would compromise the hydraulic efficiency of the base.

H. *Hydraulic Efficiency.* The Engineer will apply 0.26 gal (1 L) of water on the surface of the OGPCCB to evaluate whether the water can totally absorb into the base within 15 seconds with no water remaining of the surface. Failure to achieve this standard will indicate a contaminated base whose hydraulic efficiency has been severely impaired. Remove and replace contaminated OGPCCB to the extent determined by the Engineer at no cost to the Agency. Do not operate hauling equipment on the OGPCCB during the placement of the overlying pavement.

I. *Surface Tolerance.* Finish the surface so that deviations do not exceed $^1/_2$ in. (15 mm), longitudinal or transverse, when tested according to Subsection 401.3(L)(1).

314.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

314.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Open graded portland cement concrete base	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 315
COLD RECYCLED BITUMINOUS BASE COURSE, COLD IN-PLACE (CIR)

315.1 DESCRIPTION

Construct a cold in-place bituminous base course that uses bituminous material combined with reclaimed asphalt pavement (RAP), reclaimed aggregate material, or virgin aggregates.

315.2 MATERIAL

A. *Reclaimed Material.* Reduce oversized materials until 95 percent of material passes the 2-in. sieve. Incorporate all reclaimed material into the CIR asphalt.

1. *Reclaimed Portland Cement Concrete (RPCC).* As specified in Subsection 703.4(C)(1), the engineer may use reclaimed aggregates from the project or from stockpiles off the project.

2. *Bituminous Material.* Add bituminous material to reclaimed material according to approved mix design, as specified in Subsection 702.1.

3. *Reclaimed Asphalt Pavement (RAP).* Processed paving material containing bitumen and aggregates, as specified in Subsection 702.2(E).

B. *Aggregate.* As specified in Subsections 703.3 and 703.4.

C. *Mixture.* Combine reclaimed material, aggregates, and bitumen according to mix design and at the recommended moisture and emulsion content. Make field adjustments as recommended in the mix design to obtain satisfactory coating and specified compaction.

315.3 CONSTRUCTION

A. *Mixture Design.* Take samples of reclaimed materials, and perform testing to establish the mix design. If the RAP is included in the depth indicated for removal, take separate samples of the RAP from the roadway along with RAP from other sources, RPCC or Aggregate to be used. Establish the mix design according to the Agency specifications for special bituminous mixtures, and submit the mix design for review at least 3 weeks before the planned start of mixture production.

B. *Equipment.* Provide equipment to produce recycled bituminous base course mixture as follows:

1. Provide a self-propelled milling machine with a down-cutting drum, screening or crushing plant, and pugmill mixer. Use pugmill mixer with liquid additive system and spray bar capable of volumetrically controlling liquid additive based on milling depth, milling width, and machine speed.

2. Use equipment capable of automatically metering liquids with a variation of no more than ±2.0 percent by weight of liquids.

3. Maintain all equipment as specified in Subsection 401.3(D).

C. *Weather limitations.* Do not place CIR base when freezing temperatures occur for 24 before paving. With written approval of the Agency, the Engineer may place CIR when no freezing temperatures occur for 24 before paving and when the ambient air temperature is 45˚F and rising.

D. *Compaction.* After processing, uniformly shape and compact the CIR to the lines, grades, and depths indicated. Cure the CIR base as necessary.

315.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

315.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
Cold In-Place Recycled Bituminous Base	yd^2(m^2)
Asphalt Binder for CIR	gal (L)
Course Aggregate	ton (Mg)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 316
SEPARATOR FABRIC FOR BASES

316.1 DESCRIPTION

Furnish and install geotextiles for subgrade separation.

316.2 MATERIALS

Provide materials as specified in:

Separator Fabric	Subsection 705.3

316.3 CONSTRUCTION

A. *Protecting and Storing Geotextiles.* Wrap geotextile in a protective covering to prevent damage during shipping and handling. Label each roll to provide product identification for inventory and quality control. In the field, store the fabric rolls in a manner that protects them from the elements, including ultraviolet radiation.

B. *Preparing the Surface.* Prepare the surface to receive the geotextile to a smooth condition, free of obstructions and debris that may damage the fabric during installation.

C. *Placing Geotextiles.* Place the fabric in the manner and at the locations shown on the plans.

D. *Constructing Seams.* To join separate geotextile sheets, either provide a minimum 18-in. (450-mm) overlap or provide sewn seams. If overlapped, place the fabric so that the preceding roll overlaps the following roll in the direction the base material is being spread. If sewn, ensure the seam strength is at least 70 percent of the required tensile strength of the unaged fabric.

If windy conditions disturb the fabric, secure it by pinning with large nails with washers or by weighting with cover material.

E. *Applying Cover Material.* Cover the fabric with the base material within two weeks of its placement. Apply cover material by back dumping in a manner that prevents slippage of the fabric. Apply a minimum cover of 3 in. (75 mm). Bituminous mix material may be laid by a tracked laydown machine. Fill and compact any rutting that occurs in the base material with appropriate material.

F. *Repairing Damaged Fabric.* Should the geotextile be damaged during construction, repair the torn or punctured section, at no cost to the Agency, using a piece of fabric that is large enough to cover the damaged areas and to meet the overlap requirements.

316.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will not measure overlapped and wasted material for payment.

316.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Separator fabric	yd^2 (m^2)

Such payment is full compensation for furnishing all material, equipment, labor, and incidentals to complete the work as specified.

DIVISION 400
FLEXIBLE PAVEMENTS

SECTION 401
HOT MIX ASPHALT (HMA) PAVEMENTS

401.1 DESCRIPTION

Construct one or more courses of hot mix asphalt (HMA) mixtures on a prepared foundation.

(Note to Contracting Agency: Use statistically-based quality assurance methods in the control and acceptance of HMA mixtures; refer to AASHTO R 9.)

401.2 MATERIAL

Provide materials as specified in:

Portland Cement	Subsection 701.2
Asphalt	Section 702
Reclaimed asphalt pavement	Subsection 702.2(E)
Recycled asphalt shingles	Subsection 702.2(A) and 702.2(E)
Aggregate for Asphalt Base Course and Asphalt Concrete	Subsections 703.4 and 703.7
Mineral Filler	Subsection 703.11
Fly Ash	Subsection 713.3(C)(1)
Lime for Asphalt Mixtures	Subsection 714.3(C)

401.3 CONSTRUCTION

A. *Mix Design*. Develop and submit a job mix formula as specified in Subsection 702.2.

B. *Weather Limitations*.

1. Place HMA mixtures only on dry, unfrozen surfaces and only when weather conditions allow for proper handling and compacting.

2. Meet Table 401.3-1 placement temperatures.

Table 401.3-1. HMA Placement Temperature Limitations

(Note to Agency: Use Agency Requirements.)

Paving Course	Thickness in. (mm)	Minimum Air Temperature °F (°C)	Surface Temperature °F (°C)
Surface	All	50 (10)	55 (13)
Subsurface	Less than 3 (75)	40 (4)	45 (7)
Subsurface	3 (75) or more	30 (0)	35 (2)

C. *Asphalt Mixing Plant.* Meet AASHTO M 156 [as further modified by the Agency].

D. *Equipment:*

1. *Hauling Equipment.* Furnish equipment with tight, clean, smooth metal beds to haul HMA mixture. Keep beds free of petroleum oils, solvents, or other materials that would adversely affect the mixture. Apply a thin coat of approved release agent to beds as necessary to prevent mixture adherence. Be prepared to cover and insulate hauling beds.

2. *Asphalt Pavers.* Provide self-propelled asphalt pavers with activated heated screed assemblies to spread and finish to the specified section widths and thicknesses.

   Ensure the paver's distribution system places the mixture uniformly in front of the screed. Screed or strike-off the surface without tearing, shoving, or gouging the mixture.

   Operate the paver at consistent speeds to apply the material in an even, continuous layer. Avoid stop and go operation.

   Equip pavers with automatic screed controls that are capable of operating from a reference line or a ski and that are capable of operating from either or both sides of the paver. Control the screed to maintain the transverse slope according to plan.

   The Contractor may operate equipment manually in irregularly shaped and minor areas.

   If automatic controls fail, operate equipment manually only for the remainder of the work day and only if specified results are obtained.

   Suspend paving if the specified surface tolerances are not met. Resume only after correcting the situation.

3. *Rollers.* Use rollers capable of reversing without shoving or tearing the mixture. Operate rollers according to manufacturer's recommendations. Equip vibratory rollers with

separate energy and propulsion controls. Select equipment that will not crush the aggregate or displace the mixture.

E. *Preparing Base or Existing Surface.* Clear surface of debris. Apply and cure tack coat before placing the HMA. Apply a tack coat on all curbs, gutters, manholes, or other structure surfaces that will be in contact with the HMA.

Use non-tracking tack for application between May 1 and October 1. Tack coat as specified by the Agency can be used at other times. Conform to Subsection 404 or the non-tracking tack coat material manufacturer's recommendations for equipment requirements.

Repair damaged areas of the tacked surface, and restore the existing pavement or base to a uniform grade and cross section before placing the mix.

F. *Mixing and Holding.* Heat the asphalt mixture within the specified temperature range. Ensure a continuous supply of heated asphalt to the mixer.

Heat and dry aggregates to the required temperature. Avoid damaging or contaminating the aggregate.

Combine and mix the dried aggregates and asphalt to meet the job mix formula. Ensure a minimum of 95 percent uniform coating of aggregates according to AASHTO T 195.

Correct procedures if storing or holding causes segregation, excessive heat loss, or a reduced quality mixture. Dispose of unsuitable mixture.

G. *Pre-Paving Requirements.* Prior to placing any asphalt concrete, produce a sufficient amount of asphalt mix to properly calibrate the plant and procedures using the mix design approved for mainline construction. The Engineer will sample and test the asphalt concrete thus produced for the following:

1. voids in mineral aggregate (VMA);
2. asphalt cement content;
3. gradation; and
4. air voids (lab molded).

Place no asphalt concrete from the startup operation that fails to meet specification requirements on the mainline or the compaction test strips. Instead, continue to make adjustments until all requirements are met. Asphalt concrete not meeting the requirements may be used in the construction of temporary facilities, or, if no temporary facilities are available, it shall become the property of the Contractor.

Include costs of plant startup operations, considering both labor and materials, in the price bid for the mixture in place.

Construct a control strip with production materials and equipment. Select compacting methods to meet the specified density. The Engineer will take random core samples to verify compliance with job mix requirements. Reconstruct the test strip if the job mix formula, the compacting method, or compacting equipment changes, or if results do not meet specifications.

H. *Spreading and Finishing.* Spread and finish the mixture with asphalt pavers to specified grade and thickness.

Offset longitudinal joints [6 to 12 in. (150 to 300 mm)] from the joint in the layer immediately below. Create the longitudinal joint in the top layer along the centerline of two-lane highways or at the lane lines of roadways with more than two lanes.

Hand place material in areas inaccessible to mechanical spreading and finishing equipment.

Maintain a consistent supply of mixture to ensure uninterrupted paving.

Minimize inconvenience to traffic and protect existing and finished surfaces. Leave only short lane sections, normally less than [26 ft (8 m)], where the abutting lane is not placed the same day, unless otherwise specified.

I. *Compacting.* Compact immediately after spreading and before the asphalt mixture falls below the minimum job mix design compaction temperature. Discontinue paving if unable to achieve the specified density before the mixture cools to 175°F (80°C).

Provide the number, weight, type, and sequence of rollers necessary to compact the mixture without displacing, cracking, or shoving. Roll the asphalt mixture parallel to the centerline. Roll the longitudinal joint first, then begin at the outside edge, and continue toward the center. Overlap each pass approximately one-half of the previous roller width. Begin rolling superelevated curves at the low side and continue to the high side, overlapping longitudinal passes parallel to the centerline.

Maintain a uniform nonvibratory roller maximum speed of 3 mph or 264 ft/min (5 km/h or 80 m/min) with the drive wheels nearest the paver. Operate vibratory rollers uniformly at the manufacturer's recommended speed and frequency.

Continue rolling to eliminate all roller marks and to achieve the minimum [92] percent of theoretical maximum density or the recommended [95] percent of laboratory maximum density as determined according to [Agency-specified method].

Maintain the line and grade of the edge during rolling.

Use static steel-wheeled rollers or pneumatic rollers, as specified, on open-graded friction courses. Limit rolling to consolidate and bond the friction course to the underlying course. Avoid excessive rolling.

Prevent the mixture from adhering to the rollers by using very small quantities of detergent or other approved material.

Hand compact areas inaccessible to rollers.

The Engineer will take random test samples from the compacted pavement for the full depth of the course. Fill and compact sample holes immediately after sampling.

At no cost to the Agency, remove and replace mixture that does not meet specification requirements or that becomes contaminated with foreign materials. Remove defective materials for the full thickness of the course by saw cutting the sides perpendicular and parallel to the direction of traffic. Coat saw-cut edges with bituminous materials and replace the defective material with specification materials.

If implementing intelligent compaction, refer to AASHTO PP 81.

J. *Joints.* Protect ends of a freshly laid mixture from damage by rollers. Form transverse joints to expose the full depth of the course. Apply a tack coat on transverse and longitudinal joint contact surfaces immediately before paving. Stagger longitudinal and transverse joints on succeeding lifts approximately 6 in. (150 mm). Use notch wedge joint (versus butt) for lift thicknesses equal to or between 1 in. (25 mm) to 3 in. (75 mm) for improved joint density. Construct all longitudinal joints within 12 in. (300 mm) of the lane lines.

K. *Rumble Strips.* Construct rumble strips on mainline shoulders of highways by cutting $^1/_2$-in. (12.5 mm) deep concave depressions into existing asphalt concrete surfaces. Install rumble strips in accordance with the details of the shoulder or centerline Standard Drawings. Demonstrate the ability to achieve the desired surface alignment, consistency, and conformity with the specifications and the Standard Drawings prior to beginning production work on mainline shoulders.

The test site shall be approximately 25 ft (7.62 m) longitudinally at a location mutually agreed upon by the Contractor and Agency. Coat the entire rumble-strip area with liquid asphalt coating (emulsion) using a pressure distributor following the cutting and cleaning of the depressions of waste material. For rumble strips installed on the shoulder, use an approximate application rate of 0.1 gal/yd^2 (0.45 L/m^2). For rumble strips installed in a new asphalt concrete surface (new construction or overlay) along centerline the, do not seal the rumble-strip area. When the rumble strip is installed along the centerline in an existing asphalt concrete surface (i.e., more than one year since placement), use an approximate application rate of 0.05 gal/yd^2 (0.23 L/m^2). Maintain the application temperature between 160°F (71.1°C) and 180°F (82.2°C). For shoulder rumble strips only, do not extend overspray more than 2 in. (50 mm) beyond the width of the cut depressions and do not come in contact with pavement markings.

L. *Surface Tests.* The Engineer will test pavement surfaces to verify compliance with smoothness requirements.

1. *Method 1—Straightedge.* This method applies to all paving. The Engineer will test the surface with a 10-ft (3-m) straightedge at random locations. The Engineer will identify pavement areas that deviate more than [$^3/_{16}$ in. (5 mm)] from the straightedge as defective work. Remove and replace, grind, or cold mill such areas as directed. Do not surface patch. After the Contractor performs corrective work, the Engineer will retest the area.

2. *Method 2—Profilograph.* The Engineer will test the surface of each designated lane with a profilograph when the following conditions apply:

    a. The pavement layer is placed immediately below friction courses or other special-purpose pavement layers.

    b. On single- or multi-lift construction when: (1) total construction thickness is more than 2.5 in. (65 mm) or milling leveling precedes construction, or (2) design speed for the road will be 40 mph (60 km/h) or higher.

    The Engineer will operate a California-type profilograph, furnished by the Agency, to determine the profile index. The profilograph will record profile results vertically on a 1-in. (25-mm) scale or full scale. The Engineer will move the profilograph along the pavement either manually or by a propulsion unit attached to the assembly at a speed of 3 mph (5 km/h) or less. The Engineer will evaluate profilograph test results using Agency procedure _______based on California Test 526).

    The Engineer will take profiles 3 ft (1 m) from and parallel to each edge for pavement placed at 12 ft (3.6 m) widths. For pavement placed wider than 12 ft

    (3.6 m), the Engineer will take profiles 3 ft (1 m) from and parallel to each edge and each planned lane marking. The Engineer may take additional profiles to define the limits of out-of-tolerance areas.

    The profile will end [15 ft (5 m)] from a bridge approach pavement or ties to existing pavement. The profile will exclude acceleration and deceleration lanes, storage lanes for turns, crossovers, shoulders, side streets or side road connections less than [500 ft (150 m)], or mainline sections less than [50 ft (15 m)].

    The Engineer will test the surface during the initial 650 ft (200 m) of the paving operation and when the Contractor resumes paving operations after a shutdown of [3] months or longer. The Contractor may proceed when the test results indicate an average profile index of [9 in./mi (140 mm/km)] or less.

    The Engineer will determine an average profile index for each day's paving. A day's paving is a minimum of 0.1 mi (100 m) of full pavement width placed per day. Group the results of a daily production less than 0.1 mi (100 m) with the next day's test results. Suspend paving and correct the process if a daily average profile index exceeds 12 in./mi (180 mm/km).

    In order to determine where corrective work or pay adjustments are necessary, the Engineer will evaluate the pavement in 0.1-mi (100-m) sections using the profilograph. Correct all areas within each 0.1-mi (100-m) section with deviations more than [0.4 in./25 ft (10 mm/8 m)]. The Engineer will rerun the surface test for corrected sections to determine a new profile index. Perform additional corrective action to reduce the profile index to meet 100 percent pay criteria or invoke price adjustment, as specified.

Correct by cold milling, grinding, overlaying, or removing and replacing according to the following:

a. *Cold Milling/Grinding.* Cold mill or grind to the required surface tolerance and cross section. Remove and dispose of all waste materials.

b. *Overlaying.* Use specification materials for overlays. Overlay the full width of the underlying pavement surface. Place a minimum recommended overlay thickness of [1.6 in. (40 mm)]. Use only one overlay.

c. *Removing and Replacing.* Replace rejected areas with asphalt concrete pavement materials that meet specification requirements. Test the corrected surface area.

Complete all corrections before determining pavement thickness.

401.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will base quantities of asphalt binder on the theoretical mass incorporated into accepted product as verified by samples taken according to Subsection 702.2(B).

401.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Asphalt Binder	ton (Mg), gal (L)
(B) Plant mix—Type_____	ton (Mg), yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

A. *Price Adjustments:*

The Agency will adjust the unit price according to the schedules provided in Tables 401.5-1 and 401.5-2. The unit bid price adjustments will apply to the total asphalt pavement production represented by the specific profile index.

The Agency will base unit price adjustments for 100 percent pay or pay reductions on the measured profile index after the Contractor has performed corrective work. The Agency will base unit price adjustments for incentives on the initial measured profile index before any corrective work.

Table 401.5-1. Price Adjustment without Incentives

Profile Index in./mi per 0.1-mile section (mm/km/100-m section)	Contract Unit Price Adjustment Percent of Unit Bid Price
Less than 7 (110)	100
Over 7 to 8 (111 to 125)	98*
Over 8 to 9 (126 to 140)	96*
Over 9 to 10 (141 to 155)	94*
Over 10 to 11 (156 to 175)	92*
Over 11 to 12 (176 to 190)	90*
More than 12 (190)	Corrective work required

*Correct deficiencies or accept pay at this percent.

Table 401.5-2. Price Adjustment with Incentives

Profile Index in./mi per 0.1-mile section (mm/km/100-m section)	Contract Unit Price Adjustment Percent of Unit Bid Price
Less than 1 (15)	105
Over 1 to 2 (16 to 30)	103
Over 2 to 3 (31 to 50)	102
Over 3 to 4 (51 to 65)	101
Over 4 to 7 (66 to 110)	100
Over 7 to 8 (111 to 125)	98*
Over 8 to 9 (126 to 140)	96*
Over 9 to 10 (141 to 155)	94*
Over 10 to 11 (156 to 175)	92*
Over 11 to 12 (176 to 190)	90*
More than 12 (190)	Corrective work required

*Correct deficiencies or accept pay at this percent.

SECTION 402
COLD MIX ASPHALT PAVEMENT

402.1 DESCRIPTION

Construct one or more courses of cold mix asphalt mixture on a prepared foundation. Apply a top dressing if specified.

402.2 MATERIAL

Provide materials as specified in:

Asphalt	Section 702
Aggregate for Cold Mix Asphalt Pavement	Subsection 703.8(A)
Aggregate for Top Dressing	Subsection 703.8(B)

402.3 CONSTRUCTION

A. *Weather Limitations*. Place cold asphalt pavement on a dry surface when the surface temperature is above 50°F (10°C).

B. *Equipment*. Meet Subsections 401.3(D)(2) and 401.3(D)(3).

C. *Preparing Existing Surface*. Meet Subsection 401.3(E).

D. *Placement*. Meet Subsections 401.3(H) and 401.3(J). If a top dressing of aggregate is specified, apply at the rate of [5.5 to 13 lb/yd^2 (3 to 7 kg/m^2)], and roll to obtain maximum embedment.

402.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will base quantities of asphalt binder on the theoretical mass incorporated into accepted product as verified by samples taken according to Subsection 702.2(B).

402.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
Cold mix asphalt pavement	ton (Mg), yd^2 (m^2)
Asphalt binder for cold asphalt pavement	ton (Mg), gal (L)
Emulsified asphalt for cold asphalt pavement	ton (Mg), gal (L)
Aggregate top dressing for cold asphalt pavement	ton (Mg), yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 403
ROAD MIX ASPHALT PAVEMENT

403.1 DESCRIPTION

Construct one or more courses of road mix asphalt pavement on a prepared foundation or road surface.

403.2 MATERIAL

Provide materials as specified in:

Asphalt Binder	Subsection 702.1(A)
Road Mix Asphalt Surface Course Aggregates	Subsection 703.2

403.3 CONSTRUCTION

A. *Weather Limitations.* Meet Subsection 402.3(A).

B. *Equipment.* Furnish all equipment to complete the work.

1. *Distributors.* Use a distributor capable of uniformly dispensing asphalt to the required section at a pressure from [0.5 to 2.0 ± 0.02 gal/yd^2 (0.2 to 9.0 ± 0.1 L/m^2)]. Maintain uniform asphalt temperature.

   Equip distributors with a tachometer, pressure gauges, volume-measuring devices or a calibrated tank, tank thermometer, power unit for the pump, and full circulation spray bars adjustable laterally and vertically.

2. *Rollers.* Use rollers as specified in Subsection 401.3(D)(3).

C. *Placing Aggregates for Traveling Mixer or Blade Method.* Place aggregate to be mixed with asphalt material on underlying layer in a uniform windrow(s). Ensure a maximum aggregate moisture content of [2] percent. Instead of aerating and drying the aggregate to meet the required moisture content, the Contractor may use an approved additive designed to prevent stripping of asphalt. Do not use additives with emulsified asphalt binders.

D. *Proportioning and Mixing.* Use a traveling mixer, blade method, or stationary mixer. Avoid cutting into the underlying course or contaminating the mixture with earth or extraneous matter.

1. *Traveling Mixer:*

   a. Use a mixer that thoroughly blends the aggregate and asphalt.

b. Ensure that the mixer introduces a premeasured flow of asphalt binder during the mixing process.

c. Produce a mixture uniform in appearance, texture, asphalt content, and free from pockets of segregated aggregate.

d. Mix until not more than [50] percent of the original volatiles remain in the mix as determined by AASHTO T 110.

2. *Blade Method:*

a. Spread the windrowed aggregate on the prepared underlying layer.

b. Use a pressure distributor to apply asphalt material evenly over the aggregate in successive applications within preset limits.

c. Limit each application of asphalt material to a maximum of [0.5 gal/yd^2 (2.3 L/m^2)].

d. Partially mix asphalt material with the aggregate immediately after each application.

e. Windrow and mix the entire surface course after the last application of asphalt material.

f. Mix by blading from side to side of roadway.

g. Produce a mixture uniform in appearance, texture, asphalt content, and free from pockets of segregated aggregate.

h. Mix until not more than [50] percent of the original volatiles remain in the mix as determined by AASHTO T 110.

3. *Stationary Mixer:*

a. Dry aggregate to ensure a maximum [2] percent moisture content before mixing.

b. Comply with the manufacturer's requirements for applying asphalt material and mixing.

c. Produce a mixture uniform in appearance, texture, asphalt content, and free from pockets of segregated aggregate.

d. Mix until not more than [50] percent of the original volatiles remain in the mix as determined by AASHTO T 110.

E. *Spreading, Compacting, and Finishing.* Use a self-propelled, pneumatic-tired blade grader or a mechanical spreader to disperse the material on accepted underlying course. Do not cut into the underlying course when spreading the windrow. Use a self-propelled, pneumatic-tired roller for initial rolling. Use a three-wheel or tandem-steel wheel roller for final rolling.

Roll parallel to the centerline beginning at the outside edge and continuing toward the center. Overlap each pass approximately one-half of the previous roller width. Roll superelevated curves beginning at the low side and continuing to the high side, overlapping longitudinal passes parallel to the centerline. Terminate each pass at least [3 ft (1 m)] beyond the end of the preceding pass. Achieve the specified density without pulverizing the aggregate or displacing the mixture.

Construct the mixture in two separate lifts if the compacted thickness of the road mix surface is more than 2 in. (50 mm).

Meet required elevations, grades, and sections. Trim edges neatly to line.

Blade all noncompacted material into a windrow at the end of each day's work or when work is interrupted by inclement weather.

F. *Surface Requirements.* Meet Subsection 401.3(L).

403.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will base quantities of asphalt binder on the theoretical mass incorporated into accepted product as verified by samples taken according to Subsection 702.2(B).

403.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Aggregate for road mix	ton (Mg), yd^2 (m^2)
(B) Asphalt binder for road mix	ton (Mg), gal (L)
(C) Emulsified asphalt for road mix	ton (Mg), gal (L)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 404
TACK COAT

404.1 DESCRIPTION

Apply an asphalt binder tack coat to a prepared existing surface.

404.2 MATERIAL

Provide materials as specified in:

Asphalt	Section 702

404.3 CONSTRUCTION

A. *Weather Limitations.* Apply tack coat during dry weather only. Apply non-tracking tack coat between May 1 and October 1.

B. *Equipment.* Meet Subsection 403.3(B) or the non-tracking tack coat material's manufacturer's recommendations. Conform to manufacturer's requirements for the maximum application temperature of liquefied asphalt.

C. *Preparing Existing Surface.* Patch, clean, and remove irregularities from all surfaces to receive tack coat. Remove loose materials.

D. *Applying Asphalt.* Use a calibrated pressure distributor to apply a uniform tack coat. Tack irregular or inaccessible areas using hand-hose application methods.

1. *Tack coat:* Apply at a rate of [0.033 to 0.15 gal/yd^2 (0.15 to 0.70 L/m^2)]. Obtain approval before diluting emulsified asphalt.

2. *Non-tracking tack coat:* Apply at the rate recommended by the manufacturer. This rate is typically between 0.05 to 0.10 gallons per square yard.

Minimize inconvenience to traffic. Maintain one-way traffic without pickup or tracking of asphalt. Adjacent concrete or asphalt concrete surfaces shall show minimal visible evidence and white or yellow pavement markings shall show no visible evidence of the asphalt tack material tracking at the end of the production shift. Tracking of the tack material on pavement markings will require restoration of the markings to their original pre-tack condition. Remove build-up of the tacking material on existing pavement surface.

404.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will not measure water used in the dilution of emulsified asphalt. The Engineer will measure tack coat prior to dilution.

404.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Asphalt binder for tack or non-tracking tack coat materials	ton (Mg), gal (L)
(B) Emulsified asphalt for tack coat	ton (Mg), gal (L)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 405
PRIME COAT

405.1 DESCRIPTION

Apply an asphalt prime coat to a prepared existing surface. Apply blotter material if required.

405.2 MATERIAL

Provide materials as specified in:

Asphalt	Section 702
Blotter Sand	Subsection 703.10

405.3 CONSTRUCTION

A. *Weather Limitations.* Place asphalt on a dry surface, when the surface temperature is above 50°F (10°C), and when weather conditions ensure proper application.

B. *Equipment.* Meet Subsection 403.3(B).

C. *Preparing Existing Surface.* Shape and compact the surface to be primed to the required grade and section. Remove all loose materials immediately before priming.

D. *Applying Asphalt.* Use a calibrated pressure distributor to apply the asphalt in a uniform, continuous spread. Ensure that asphalt application at the junctions of spreads does not exceed the specified amount. Squeegee excess asphalt from the surface. Correct deficient areas. Place building paper over the end of previous applications and begin the new application on the building paper. Apply at a rate of [0.1 to 0.5 gal/yd^2 (0.45 to 2.25 L/m^2)]. Maintain the film for the specified time, unless covered by a subsequent course.

Minimize inconvenience to traffic. Maintain one-way traffic without pickup or tracking of asphalt.

Notes for SI version and conversions: Mg (megagram) and MT (metric ton) are equivalent and Mg will be used throughout this publication to denote the quantity. Conversions in [brackets] are soft conversions.

E. *Applying Blotter Sand*. Apply blotter sand to absorb excess asphalt if required to open roadway to traffic before complete penetration and cure.

405.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure prime coat by the amount of residual asphalt.

405.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Asphalt binder for prime coat	ton (Mg), gal (L)
(B) Cutback asphalt for prime coat	ton (Mg), gal (L)
(C) Emulsified asphalt for prime coat	ton (Mg), gal (L)
(D) Blotter sand	ton (Mg), yd^3 (m^3)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 406
EMULSIFIED ASPHALT CHIP SEAL (REVISED)

406.1 DESCRIPTION

Construct a single-application chip seal on a prepared existing surface. Emulsion chip seal is an application of an emulsified asphalt binder covered with an application of clean graded aggregate to an existing asphalt surface. The emulsified asphalt binders may be modified with various polymers such as latex, tire, and natural rubbers. Aggregate must be durable, consisting of crushed stone, gravels, or manufactured aggregates varying in size from $^5/_8$ in. (16 mm) to a minimum of $^1/_4$ in. (6 mm).

This Section is intended to provide information needed for Owners or Contractors to construct emulsified asphalt chip seals. An emulsified asphalt chip seal is the application of emulsified asphalt, followed immediately by a single layer of aggregate chips to a prepared surface.

This Section refers to quality requirements for materials and a design method for chip seals available in other AASHTO documents. However, the main purpose is to provide guidance for the construction of emulsified asphalt chip seals applied in one layer. All units of measurement are expressed in inch-pound units, which are the normal units used in the United States, with SI units in parentheses.

Commentaries are included in this Section to 1) emphasize and further explain the section, 2) present options to be considered by the user, or 3) provide sources of additional information. An example of these commentaries is shown below:

Commentary

This Section covers construction of single-application chip seals. If this process is repeated with another application of emulsified asphalt and another layer of cover aggregate, the process is known as a double chip seal. A triple chip seal would require yet another application of emulsified asphalt and cover aggregate. Other terms have been used referring to chip seals such as "seal coat," "surface treatment," "surface seal," "surface dressing," "sprayed seal," and others. Sometimes, a fog seal is applied over the completed chip seal.

406.2 REFERENCED DOCUMENTS

A. *AASHTO Standards:*

- M 140, Emulsified Asphalt
- M 208, Cationic Emulsified Asphalt
- M 316, Polymer-Modified Emulsified Asphalt
- MP 27, Materials for Emulsified Asphalt Chip Seals
- R 10, Definition of Terms Related to Quality and Statistics as Used in Highway Construction
- R 66, Sampling Asphalt Materials
- R 78, Recovering Residue from Emulsified Asphalt Using Low-Temperature Evaporative Techniques
- R 90, Sampling Aggregate Products
- PP 82, Emulsified Asphalt Chip Seal Design
- T 11, Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
- T 19M/T 19, Bulk Density ("Unit Weight") and Voids in Aggregate
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 44, Solubility of Bituminous Materials
- T 49, Penetration of Bituminous Materials
- T 51, Ductility of Asphalt Materials
- T 59, Emulsified Asphalts
- T 85, Specific Gravity and Absorption of Coarse Aggregate

- T 96, Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- T 104, Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate
- T 111, Mineral Matter or Ash in Asphalt Materials
- T 112, Clay Lumps and Friable Particles in Aggregate
- T 301, Elastic Recovery Test of Asphalt Materials by Means of a Ductilometer
- T 335, Determining the Percentage of Fracture in Coarse Aggregate
- T 350, Multiple Stress Creep Recovery (MSCR) Test of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
- T 382, Determining the Viscosity of Emulsified Asphalt by a Rotational Paddle Viscometer

B. *ASTM Standard:*

- D5624, Standard Practice for Determining the Transverse-Aggregate Spread Rate for Surface Treatment Applications

C. *Federal Highway Administration:*

- FHWA-HIF-12-001, Independent Assurance Programs (2011)
- FHWA-HIF-19-029, Chip Seal Checklist (2019)

D. *Federal Lands Highway Standard:*

- FLH T 508, Flakiness Index Value.

E. *Other Documents:*

- Martin, R. S., Jr. Chip Seal Practice. In *Proc., 26th Paving and Transportation Conference*, Department of Civil Engineering, University of New Mexico, Albuquerque, New Mexico, January, 1989.
- Shuler, S. High Traffic Chip-Seal Construction: The Tulsa Test Road. In *Transportation Research Record No. 1300*. Transportation Research Board, National Research Council, 1991, pp. 116–124.

406.3 TERMINOLOGY

A. *CRS-2P, Polymer Modified.* A cationic rapid-setting emulsified asphalt that includes a polymer modifier typically in the form of a styrene–butadiene latex rubber or a styrene–butadiene or styrene–butadiene–styrene block copolymer-modified base asphalt binder and meets AASHTO MP 27 for emulsified asphalt chip seals.

B. *CRS-2.* A cationic rapid-setting emulsified asphalt without a polymer.

C. *RS-2P, polymer modified.* An anionic rapid-setting emulsified asphalt that includes a polymer modifier typically in the form of a styrene–butadiene latex rubber or a styrene–butadiene or styrene–butadiene–styrene block copolymer-modified base asphalt binder and meets AASHTO MP 27 for emulsified asphalt chip seals.

D. *RS-2.* An anionic rapid-setting emulsified asphalt without a polymer.

E. *HFRS-2P, Polymer Modified.* An anionic high-float rapid-setting emulsified asphalt that includes a polymer modifier typically in the form of a styrene–butadiene latex rubber or a styrene–butadiene or styrene–butadiene–styrene block copolymer-modified base asphalt binder.

F. *HFRS-2.* An anionic high-float rapid-setting emulsified asphalt without a polymer.

G. *CHFRS-2P, Polymer Modified.* A cationic high-float rapid-setting emulsified asphalt that includes a polymer modifier typically in the form of a styrene–butadiene latex rubber or a styrene–butadiene or styrene–butadiene–styrene block copolymer-modified base asphalt binder.

H. *CSS-1h.* A cationic emulsified asphalt that is slow setting and has a hard penetration residual binder residue.

I. *SS-1h.* An anionic emulsified asphalt that is slow setting and has a hard penetration residual binder residue.

406.4 MATERIALS

Provide materials as specified below:

A. *Emulsified Asphalt.* Emulsified asphalt for chip seal shall meet the requirements of AASHTO M 140, M 208, or M 316.

B. *Aggregate.* Chip seal aggregate shall conform to the requirements specified in AASHTO MP 27, Section 6.1, Tables 1 and 2.

C. *Mix Design.* Design the chip seal to determine aggregate spread rate and emulsified asphalt application rate using a design method such as that described by AASHTO PP 82.

406.5 CONSTRUCTION

A. *Equipment.* Furnish the following equipment or equivalent:

1. *Asphalt Distributor.* The asphalt distributor shall be self-propelled with a ground speed control device interconnected with the emulsified asphalt pump such that the specified application rate will be supplied at any speed. The asphalt distributor shall be capable of maintaining the emulsified asphalt at the specified temperature. The spray bar nozzles shall produce a uniform double or triple lap application fan spray, and the shutoff shall be instantaneous, with no dripping. All nozzles shall be oriented at the same angle between 15 and 30 degrees using the wrench supplied by the distributor manufacturer. Each

asphalt distributor shall be capable of maintaining the specified application rate within ±0.015 gal/yd^2 [0.068 L/m^2] for each load.

Commentary

Obtaining a triple overlap from the spray bar is the most desirable arrangement because the emulsified asphalt application will generally be more uniform than with double overlap. However, when equipment is calibrated and set up properly, very acceptable results have been obtained with double overlap.

2. *Aggregate Spreader.* A self-propelled mechanical-type aggregate spreader with a computerized spread control, capable of distributing the aggregate uniformly to the required width and at the designed rate shall be used.

3. *Pneumatic-Tire Rollers.* A minimum of three self-propelled pneumatic-tire rollers capable of ballast loading, either with water or sand, to allow the weight of the machine to be varied from 6 to 8 tons [5.4 to 7.2 Mg] to achieve a minimum contact pressure of 80 lb/in.^{2} (550 kPa) shall be used. The alignment of the axles shall be such that the rear-axle tires, when inflated to the proper pressure, can compact the voids untouched by the front-axle tires. All tires shall be as supplied by the roller manufacturer. Width of the rollers shall exceed 60 in. (1.5 m).

Commentary

Steel-wheel rollers have been used as the final roller on some chip seals with success. The advantage is a more even final elevation. This produces fewer prominent chip edges extruding above the surface, which can be susceptible to snowplow damage. The disadvantage of steel-wheel rollers is the potential for crushing of aggregate chips that cannot withstand the high stress imparted at the steel roll–chip interface. Therefore, if used, steel rollers should be limited to 5 tons [4.5 Mg]. Vibration shall not be used if the rollers are so equipped.

4. *Brooms.* Motorized brooms with a positive means of controlling vertical pressure shall be used to clean the road surface prior to spraying emulsified asphalt. Plastic bristle brooms are required to remove loose aggregate after rolling.

Commentary

Vacuum brooms are preferred in urban or residential areas, but push brooms are acceptable in rural areas where chips being scattered off the roadway do not pose a hazard to pedestrians or vehicles.

5. *Trucks.* Unless otherwise approved, use trucks of uniform capacity to deliver the aggregate. Provide documentation showing measurements and calculation in cubic yards (cubic meters). Clearly mark the calibrated level. Truck size may be limited when shown on the plans.

B. *Equipment Calibration:*

Provide proof of calibration of the asphalt distributor and the aggregate spreader. Conduct calibration no earlier than five days prior to chip seal operations. Submit the results of the calibration procedure to the Engineer.

Flow from each nozzle in the asphalt distributor must be within ±10 percent of the average flow of all nozzles as measured by the procedure as described in NCHRP Report 680, Chapter 7 (Shuler et al., 2011).

Uniformity of the aggregate applied transverse to the pavement centerline shall be in accordance with ASTM D5624. Tolerance for each pad tested for transverse spread rate shall be ±10 percent of the average of the total transverse rate.

Commentary

Calibration is very important to assure the quantity of emulsified asphalt and aggregate applied to the pavement is correct. Although many modern asphalt distributors and aggregate spreaders are computer controlled, calibration is required to tell the computer how much emulsified asphalt is being applied. This quantity must be checked prior to spraying emulsified asphalt and spreading aggregates and checked against the quantity the computer (if the distributor is so equipped) indicates is being applied.

1. *Asphalt Distributor:*

All nozzles shall be the same size, provide the same flow rate, be oriented in the same direction, and be the same distance above the pavement.

Commentary

The distributor truck applies emulsified asphalt to the pavement surface. This application must be done uniformly both transverse and longitudinal to the centerline of the pavement to provide the proper emulsified asphalt layer necessary for proper aggregate chip adhesion.

When lower application rates are determined necessary or shown in the plans, smaller nozzles shall be inserted in the spray bar where the emulsified asphalt rate is reduced.

Commentary

Due to minor rutting or heavy truck traffic, it may be desirable to reduce the emulsified asphalt application rate in the wheel paths.

a. *Nozzle Angle:*

Nozzles shall be positioned at an angle of 15 to 30 degrees from the horizontal of the spray bar in accordance with the manufacturer's recommendation. All nozzles shall spray a full fan except for the right and left edge nozzles. The right and left edge nozzles shall be adjusted to a half fan such that the spray stays to the inside of the spray bar.

Commentary

The next step in calibrating the distributor is adjustment of the spray bar nozzle angles. Each nozzle has a slot cut across the face of the nozzle. When the nozzle is threaded into the spray bar, the slot should all be positioned at an angle of 15 to 30 degrees to the direction of the spray bar as shown in Figure 406.5-1. This angle provides the best position for achieving uniformity in the spray and the triple overlap coverage. The angle should be adjusted using the wrench supplied with the distributor. This wrench is designed, when used properly, to set the correct angles for each nozzle. Any wrench that fits the hexagonal nozzle can adjust the nozzle angle, but correctness of the angle would have to be visually verified.

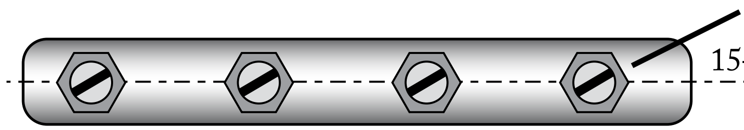

Figure 406.5-1. Spray Bar Nozzle Orientation in Spray Bar

b. *Spray Bar Height.* The spray bar height must be adjusted so that the emulsified asphalt provides exactly two or three overlaps across the entire spray width.

Commentary

Streaking of the emulsified asphalt will occur if the spray bar is set too high or too low as shown in Figures 406.5-2 and 406.5-3.

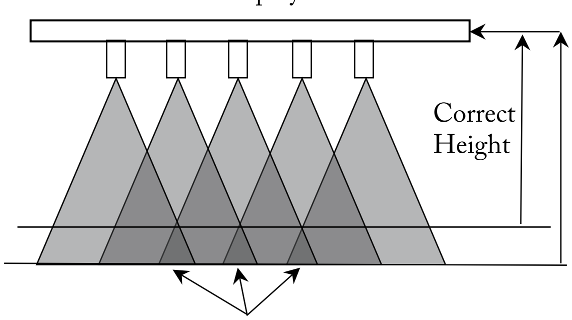

Figure 406.5-2. Streaks with Spray Bar Too High for Double Overlap

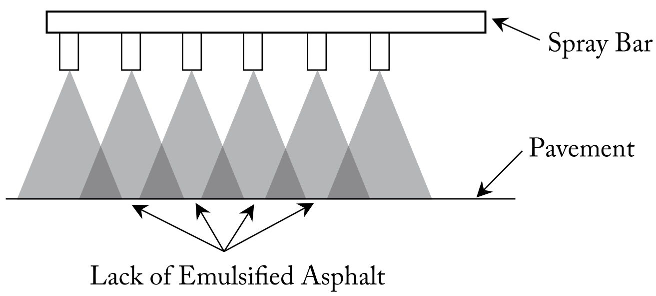

Figure 406.5-3. Streaks with Spray Bar Too Low for Double Overlap

To avoid this streaking, the bar must be adjusted to the correct height. This adjustment process is accomplished by shutting off nozzles to determine where the spray pattern contacts the pavement as shown in Figures 406.5-4 and 406.5-5.

c. *Bar Height Adjustment to Achieve Double Lap*

Every other nozzle shall be turned off when a double lap application is desired, as shown in Figure 406.5-4. The distributor operator shall spray emulsified asphalt onto the pavement surface for as short an interval as possible while an observer watches where the emulsified asphalt hits the pavement from each nozzle left open. If there is overlap of emulsified asphalt from adjacent nozzles, the bar is too high. If there is a lack of emulsified asphalt from adjacent nozzles, the bar is too low.

Once it is confirmed the bar height is correct, the nozzles that were turned off should be turned back on and a double application of emulsified asphalt will result when spraying resumes.

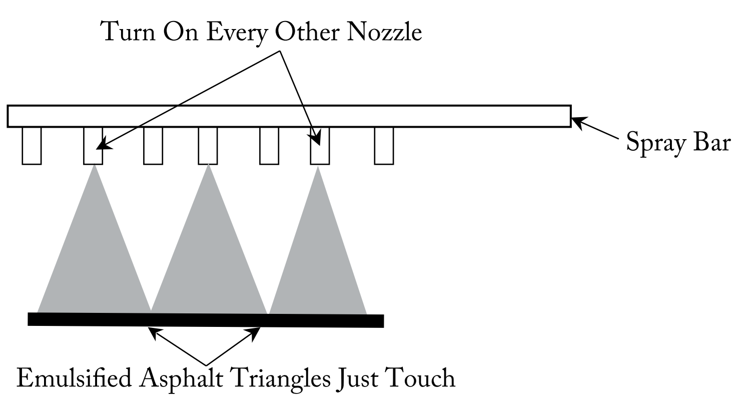

Figure 406.5-4. Adjustment of Spray Bar Height for Double Overlap

d. *Triple Lap Application Bar Height Adjustment*

Every third nozzle shall be turned off when a triple lap application is desired, as shown in Figure 406.5-5. The distributor operator shall spray emulsified asphalt onto the pavement surface for as short an interval as possible while an observer watches where the emulsified asphalt hits the pavement from each nozzle left open. If there is overlap of emulsified asphalt from adjacent nozzles, the bar is too low. If there is a lack of emulsified asphalt from adjacent nozzles, the bar is too high.

Once it is confirmed the bar height is correct, the nozzles that were turned off should be turned back on and a triple application of emulsified asphalt will result when spraying resumes.

As the distributor empties during spraying, the bar height will rise. However, this is not usually enough to cause significant streaking worth adjustment of the spray bar.

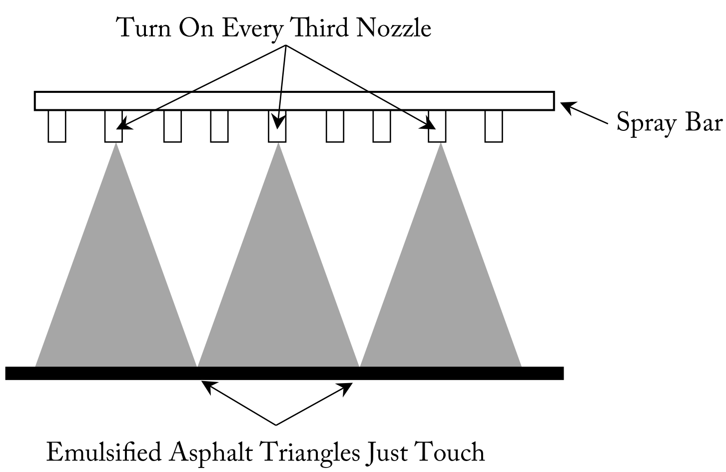

Figure 406.5-5. Adjustment of Spray Bar Height for Triple Overlap

e. *Transverse Flow Rate.* The flow rate across the spray bar shall be uniform, with each nozzle spraying within ±10 percent of the average flow rate.

Commentary

A uniform flow rate is achieved by measuring the width of the slot in the nozzle and by measuring the orifice diameter. Also, some nozzles are labeled by the manufacturer. Manufacturers supply a list of nozzles in the owner's document describing which nozzles shall be used for various application rates or on a placard mounted on the equipment.

However, nozzles of the same apparent size have been measured with different flow rates. Therefore, it is recommended that all nozzles be checked for flow rate before chip seal operations begin. This is easily accomplished by fabricating a flow apparatus (Martin, 1989). This apparatus consists of a pipe to which each nozzle, in turn, can be fitted on one end and a water *source can be fitted on the other end. The flow of water through each nozzle shall be measured by the volume captured in a 1-gal (4-L) container within a set time period. This shall be done for each nozzle to be used on the project. If the flow rate of any nozzle is greater than ±10 percent of the average of all the nozzles to be used, such nozzle shall be discarded or modified to flow within the 10 percent tolerance.*

Determination of uniform lateral flow from the spray bar is determined by collecting a measured volume of emulsified asphalt in containers placed under each nozzle. This process is practical using standard 6-in. by 12-in. (150-mm by 300-mm) concrete cylinder molds lined with 1 gal (4 L) resealable freezer bags. The cylinder molds can be reused and the freezer bags discarded appropriately with the contents.

f. *Longitudinal Flow Rate.* The longitudinal flow rate shall be accomplished by measuring the volume of emulsified asphalt in the distributor before and after spraying enough emulsified asphalt to reduce the volume of emulsified asphalt in the distributor by 70 to 90 percent.

Commentary

The longitudinal flow rate must be measured with all nozzles inserted in the distributor bar. First, the quantity of emulsified asphalt in the truck must be determined. Although there is a volume indicator on the rear of most modern distributors, these are not calibrated in small enough increments to be of use for longitudinal flow rate calibration and shall not be used for this purpose. Instead, the dipstick supplied with the distributor must be used. This dipstick is usually carried on the top of the tank near the inspection hatch. Prior to shooting emulsified asphalt, take a volume reading with the dipstick.

Pay attention to how the dipstick is used. Many dipsticks are not intended to be submerged in the emulsified asphalt but instead are inserted into the top of the tank only until the tip of the dipstick touches the surface of the emulsified asphalt. Then, the volume in the tank is read by indexing the top of the inspection cover to the reading on the dipstick.

Record this volume as "beginning volume." Set up the truck to shoot emulsified asphalt and shoot a minimum of 3000 ft by 12 ft (1000 m by 3.6 m) of emulsified asphalt at the design rate using the gallon per minute pump flow volume and truck speed required by the manufacturer to attain this flow rate. Take a second dipstick reading. Record this reading as "ending volume." Subtract ending volume from beginning volume and record this as "volume used." Determine the area of emulsified asphalt sprayed. Divide volume used by the area sprayed in square yards (square meters). This is the gallons per square yard (liters per square meter) applied to the pavement. This value shall then be compared to the distributor computer, if equipped, to evaluate the accuracy of the computer. A correction factor may then be applied to the computer output, if needed, and used for the remainder of the day. This calibration shall be accomplished each day.

An example of this calibration is presented below:

Given:

1800-gal (6800-L) capacity asphalt distributor

12-ft (3.6-m) wide spray width

Trial spray distance = 3630 ft (1100 m)

0.32 gal/yd^2 (1.45 L/m^2) design spray rate

Dipstick reading beginning volume = 1765 gal (6584 L)

Dipstick reading ending volume = 265 gal (1003 L)

Calculations:

Check to see if enough volume shot. 1765–265 = 1500 gal (6584–1003 = 5581 L)

1500/1765 (5581/6581)= 85 percent > 70 percent and < 90 percent.
OK; enough applied to be valid

Calculate spray rate = 1500 gal / (12 × 3630/9) = 0.31 gal/yd^2
5581 L / (3.6 m × 1100 m) = 1.41 L/m^2

Therefore, decrease distributor speed, or recalibrate computer and recheck.

2. *Aggregate Spreader*

   a. *Transverse Spread Rate:*

   The aggregate spread shall be uniform across the veil and within ±10 percent of the average spread rate. Various methods of calibrating this equipment have been used and the ASTM D5624 procedure can be effective.

   Commentary

   A visual assessment of the lateral distribution of chips is a good place to start the process since non-uniform distribution can easily be seen. The veil of chips deposited on the pavement from the spreader box can be viewed from behind, with the spreader moving away from the observer, or from the front. Either position for the observer is adequate for viewing how uniformly the veil of chips is falling out of the spreader box. However, viewing from either front quarter affords the observer a better view of the entire spreader width and is, of course, safer than directly in front of the spreader. Any variation in light passing through the veil of aggregate indicates variation in application rate. More light means a lack of aggregate. Variation in light means the machine shall be stopped, the gates on the spreader contributing to the non-uniformity adjusted, and the trial rerun. This procedure provides adjustment to the transverse spread rate. Then, to obtain an objective means of measuring the amount of aggregate being deposited, ASTM D5624 is a good procedure to use.

b. *Longitudinal Spread Rate.* The longitudinal spread rate shall be uniform and be within ±10 percent of the design spread rate.

Commentary

Once the transverse spread rate is adjusted, the longitudinal rate can be adjusted. This is also done visually, at first.

Evaluating the quantity of aggregates being placed is important after the rate is established. This provides a quantitative baseline for future work. The best method to accomplish this evaluation is by weighing the aggregate spreader before and after applying the aggregate and calculating the spread rate based on the area covered. This is often not practical. Therefore, a suitable alternative is estimating the quantity of aggregates spread over a known area by knowing the weight of each transport truck supplying the spreader and dividing the estimated weight of aggregate spread by the area covered for that load.

An example follows:

Given:

Trucks loading the aggregate spreader are 12-ton (11 Mg) capacity tandem dumps

12-ft (3.6-m) wide pavement

28 lb/yd^2 (15.42 kg/m^2) design spread rate

Calculations:

Check Truck No. 1

Load = 23,803 lb (10,806 kg)

Spreader distance = 640 ft (195.2 m)

Rate = 23,803/(640 × 12/9) = 27.9 lb/yd^2
(10,806/(195.2 × 3.6) = 15.38 kg/m^2)

Check Truck No. 2

Load = 23,921 lb (10,860 kg)

Spreader distance = 634 ft (193.4 m)

Rate = 23,921/(634 × 12/9) = 28.3 lb/yd^2
(10,860/(193.4 × 3.6) = 15.60 kg/m^2)

Check Truck No. 3

Load = 23,848 lb (10,826 kg)

Spreader distance = 639 ft (194.9 m)

Rate = 23,848/(639 × 12/9) = 28.0 lb/yd²
(10,826/(194.9 × 3.6) = 15.43 kg/m²)

Average Rate = (27.9 + 28.3 + 28.0) / 3 = 28.1 lb/yd²
((15.38 + 15.60 + 15.43) / 3 = 15.47 kg/m²)

No adjustment needed since measured rate is within 1 percent of design.

Compensation for moisture on the aggregate must be considered when calibrating spreaders. The above example indicates no adjustment is needed since the measured spread rate is within 0.10 lb/yd² (0.05 kg/m²) of the design spread rate. However, if the aggregate above had contained as much as 1.02 percent moisture that was unaccounted for, the application rate would have been too low.

C. *Preconstruction Meeting.* Coordinate a preconstruction meeting prior to construction with the Engineer to discuss the following topics:

1. Construction process;
2. Quality control plan; required to be submitted;
3. Mix design; required to be submitted;
4. Materials control;
5. Materials measurement;
6. Equipment calibration; required to be submitted;
7. Traffic control plan;
8. Equipment/process overview;
9. Inspection;
10. Test strip;
11. Unique project conditions;
12. Project documentation; and
13. Expectations.

D. *Road Surface Preparations:*

1. *Cleaning Pavement.* Clean the roadway surface by sweeping no more than 30 min prior to application of the emulsified asphalt and aggregate. However, this 30-min window may be extended if authorized by the Engineer in cases where extending the time does not jeopardize a clean surface prior to chip seal operations. Sweep the pavement with a motorized broom to remove loose material. Clean depressions not reached by the motorized

broom with a hand broom. Clean the outer edges of the pavement to be sealed including an adjacent paved shoulder.

2. *Protecting Accessories.* Cover utility castings (e.g. manholes, gate valve covers, catch basins, sensors) to prevent coating with emulsified asphalt. Suitable covering includes plywood disks, kraft paper, roofing felt, or other approved methods. Remove the protective coverings before opening the road to traffic.

3. *Stripe Removal.* Thermoplastic pavement markings shall be removed by grinding or other approved methods prior to chip seal operations. Other pavement markings may be left in place.

Commentary

If the edge stripes and center lane stripes are worn, removal may not be necessary or, if in doubt, applying a fog seal to the stripes prior to chip sealing has been demonstrated as effective for maintaining good chip seal adhesion. Stop bars and turn arrows should always be removed.

E. *Application:*

1. *Weather Limitations.* Construct chip seal per the following conditions:

   a. Ambient and pavement surface temperatures shall be 50°F (10°C) and rising.

   b. Application of the chip seal shall be only during daylight hours.

   c. Suspend chip sealing if the pavement surface temperature exceeds 140°F (60°C).

   d. The road surface shall be dry to damp.

2. *Test Strip.* Construct a test strip on or near the project site. Construct the test strip under similar placement conditions of time of day, temperature, and humidity as expected for the duration of the project. The test strip shall be a minimum of 500 ft (150 m) in length and shall be constructed with the job mix proportions, materials, and equipment to be used on the project. Adjustments to the mixture formula shall be permitted provided they do not exceed the values stated in the mix design. The Agency shall evaluate the test strip to determine whether project specifications are met. If specifications are not met, additional test strips will be constructed until specifications are met, at no additional cost to the Agency.

3. *Application of Emulsified Asphalt:*

   Apply the emulsified asphalt at the rate determined by the design. This rate shall be within ±5 percent of the chip seal design rate. After applying the emulsified asphalt, place the cover aggregate at the design application rate. Adjust the rate of application, if necessary, so that some emulsified asphalt can be seen between the aggregate chips, but not so much that aggregate chips adhere to the pneumatic rollers. Inspect the aggregate in the wheel paths for proper embedment. Embedment shall be 50 to 60 percent after rolling. Make additional adjustments to the rate of application during the project, if needed.

The temperature of the emulsified asphalt at the time of application shall be above 120°F (50°C).

Commentary

If the temperature is lower than 120°F (50°C), there is risk of less material being applied than desired due to high viscosity.

The longitudinal construction joint for a single-course chip seal must coincide with the painted lane line or the outside edge of the shoulder. There shall be no overlap of the longitudinal construction joint for a single-application chip seal.

4. *Application of Cover Aggregate.* Provide uniformly moistened aggregates that are damp at the time of placement. Damp aggregates shall be saturated but surface dry with approximate moisture content between 1 and 3 percent depending on the aggregate absorption capacity.

Commentary

This moisture content makes the chips appear as though they have a matte or satin finish, and not glossy, using a painting analogy. A damp aggregate draws emulsified asphalt into the aggregate pores, thus providing better adhesion once the emulsified asphalt has set.

For non-modified emulsified asphalts like RS-2 or CRS-2, begin spreading chips into the fresh emulsified asphalt when a few chips cast by hand stick to the emulsified asphalt and do not roll over. This shall be done well before the emulsified asphalt begins to break or set, but not immediately after spraying unless temperature, wind, or high demulsibility demand it. This practice may not be necessary for emulsified asphalts that are polymer modified. Polymer-modified emulsified asphalts are highly adhesive immediately after spraying and chips do not tend to roll over after spreading. Therefore, for polymer-modified emulsified asphalts, chips should be spread immediately after spraying the emulsified asphalt.

The application rate of the chips shall be similar to the design rate. This is a rate where immediately upon dropping the chips, the appearance of the surface has some emulsified asphalt showing between the chips. In fact, the chip quantity should seem somewhat inadequate. The chip spread rate should not be low enough to cause pickup problems on rubber-tire rollers. However, the rate should be such that a small decrease in rate would cause pickup. Emulsified asphalt should be visible between the aggregates upon dropping them and before rolling. If all emulsified asphalt is covered before rolling, there is an excess of chips and the rate shall be reduced. It is the responsibility of the construction superintendent to achieve this application rate.

The speed of the spreader shall be restricted to prevent the aggregates from rolling over. Starting and stopping of the spreader should be minimized. The edges of the aggregate applications shall be sharply defined. Previously used aggregates from sweeping may not be returned to the stockpile or the spreader for reuse.

Commentary

Although a design was done in the laboratory to determine the aggregate application rate, adjustments are almost always needed in the field. This should be done during the first day of construction *to make sure the aggregate quantity is correct. This is best done by observing the appearance of the aggregates after they have been dropped into the emulsified asphalt, but before rolling. Some emulsified asphalt should be visible between most of the aggregates. If emulsified asphalt cannot be seen between the aggregates, the rate is too high. Conversely, too much emulsified asphalt showing through between the aggregate will cause pickup on rubber tires.*

5. *Transverse Paper Joints.* When beginning a new application of the chip seal transversely abutting the previously placed chip seal, use a transverse paper joint so excess asphalt and chips are not placed at the joint. The transverse paper joint shall be formed by placing 36-in. (1-m) wide kraft paper on top of the previously applied chip seal so the edge of the paper aligns with the joint that will be formed when the previously placed chip seal meets the newly applied chip seal. The asphalt distributor shall begin applying emulsified asphalt by starting the application on top of the kraft paper. After the asphalt distributor moves forward and over the joint, the paper shall be removed.

   Commentary

   Ideally, the paper should also be placed at the end of the distributor shot as well. This creates a clean edge with the correct emulsified asphalt and aggregate quantity at the joint. The placement of the paper is calculated based on the emulsified asphalt shot rate and the quantity of emulsified asphalt in the distributor. The distance the asphalt distributor travels before encountering the paper and turning off the bar should be approximately equivalent to 80 percent of the distributor tank volume. This assures the distributor does not spray until empty which can result in less emulsified asphalt applied than desired at the end of the shot.

6. *Rolling Operations.* Complete the first roller pass as soon as possible but not longer than 2 min after applying the aggregate. Proceed in a longitudinal direction at a speed less than or equal to 3 mph (5 km/h). Three complete roller passes of the aggregate chips are required as a minimum. One pass is defined as the roller moving over the aggregates in a single direction. Ensure the rolling is completed quickly enough to embed the aggregate, before the emulsified asphalt breaks, and no longer than 15 min after the emulsified asphalt is sprayed. Position the rollers in echelon so the entire width of the pavement lane is covered in one pass of the rollers.

   Commentary

   If desired, final rolling may be accomplished using the steel-wheel roller in one pass. The asphalt distributor and aggregate spreader speed may have to be reduced if the rolling operations cannot be accomplished before the emulsified asphalt breaks.

7. *Sweeping.* Excess aggregate shall be swept off the new surface in accordance with Table 406.5-1.

Table 406.5-1. Sweeping Sequence

Chip Seal Class[a]		
I	II	III
Within 24 h after rolling	No later than the following morning	Before traffic is allowed without traffic control

[a] Class I is less than 500 annual average daily traffic (AADT), Class II is 501 to 5000 AADT, and Class III is greater than 5000 AADT.

Do not sweep embedded aggregate until at least 85 percent of the total moisture present in the chip seal has evaporated or aggregates may become dislodged. Moisture present consists of moisture in the aggregate chips and moisture present in the emulsified asphalt. Moisture content shall be determined by the procedure reported in NCHRP Report 680 (Shuler et al., 2011). Resweep areas the day after the initial sweeping. The Contractor shall dispose of the surplus cover aggregate in a manner satisfactory to the Agency. In no case shall the excess aggregates swept from the surface exceed 10 percent of the total amount placed. If this quantity is exceeded, work shall cease until an adjustment is made to reduce the spread rate to be within tolerances.

8. *Traffic Control*

Traffic may be allowed onto the fresh chip seal after rolling is completed and before sweeping in accordance with Table 406.5-2. Before allowing traffic on the newly placed chip seal, ensure that at least 85 percent of the total moisture present in the chip seal has evaporated or aggregates may become dislodged.

Table 406.5-2. Timing for Traffic

Chip Seal Class[a]		
I	II	III
Traffic controlled with speed limit signs	Traffic controlled with pilot cars	Traffic controlled with pilot cars

[a] Class I is less than 500 AADT, Class II is 501 to 5000 AADT, and Class III is greater than 5000 AADT.

A pilot car shall be used on two-lane roadways during construction and until the roadway and shoulders have been swept free of loose aggregate.

9. *Protection of Motor Vehicles.* The Contractor is responsible for claims of damage to vehicles until the roadways and shoulders have been swept free of loose aggregate and permanent pavement markings have been applied. If permanent pavement markings are to be applied by Agency forces, the Contractor's responsibility ends after completion of the chip seal and placement of temporary pavement markings.

10. *Fog Seal*

If, in accordance with the plans, a fog seal is applied to the surface of the completed chip seal, spray the fog seal after sweeping and before placement of permanent pavement markings, but not sooner than 24 h after final rolling. Refer to Section 410 for specific requirements for application of fog seal over chip seals.

Commentary

Fog seals are applied to the surface of completed chip seals for two reasons: 1) The dark color provides more contrast to pavement markings, and 2) the fog seal provides a slight increase in binder residue to increase chip retention.

A fog seal may also be applied to recent hot mix asphalt patches in the pavement to be chip sealed. These fresh hot mix patches can be more absorptive than the surrounding pavement due to higher air void content. The fog seal helps prevent the new chip seal emulsified asphalt from being absorbed into the substrate unevenly.

11. *Sequence of Work:*

Construct the chip seal so that adjacent lanes are sealed on the same day when possible. If the adjacent lane(s) has not been sealed, sweep all loose aggregate from the unsealed lane(s) before traffic is allowed on the surface without traffic control.

Permanent pavement markings shall not be placed for 24 h after placing the chip seal when no fog seal is applied.

If fog seal is used, the permanent pavement markings shall not be placed before three days have elapsed for waterborne pavement marking or ten days for other types of markings.

Commentary

The chip seal will usually cure within 24 h under dry conditions and temperatures above 60°F (16°C). The fog seal can be applied after the chip seal coat is cured. The fog seal will usually cure within 2 h under dry conditions and temperatures above 60°F (16°C). Interim pavement markings can be placed after the fog seal cures. Do not allow traffic on the fog seal until cured.

F. *Quality Assurance:*

1. *General:*

a. The chip seal contractor (the Contractor) shall establish, implement, and maintain a QC program to control all equipment, materials, workmanship, and processes during chip seal construction. The Contractor's QC program shall include preconstruction activities including chip seal design, site preparation, material handling and transportation, and stockpiling. The program shall include procedures required for sampling, testing, inspection, monitoring, documentation, and corrective action procedures during transport, stockpiling, placement, and finishing operations.

b. A written quality control plan shall be developed which details the Contractor's QC program that meets the requirements of these specifications. The QC plan shall be contract specific and signed by the Contractor's representative. Chip seal construction shall not proceed without Agency acceptance of the QC plan and QC personnel present on the job. Failure to comply with these provisions will result in shutdown of the operation until the Contractor's operation is in compliance.

2. *Definitions:*

a. **Agency.** A state highway agency, other agency, or owner responsible for the final acceptance of the project.

b. **Calibration.** Any calibration, standardization, check, or verification as required by the test method or standard.

c. **Contractor.** The prime contractor who has ultimate control of the project.

d. **Supplier.** One who produces the final product materials (i.e., aggregates and asphalt emulsion) used on the project.

e. **Standard.** Any standard, specification, test method, practice, or other document utilized to achieve compliance with the contract.

f. **Testing Lab.** The laboratory conducting quality control tests (Contractor or Supplier) and acceptance tests (Agency).

3. *Personnel:*

a. *Responsibilities and Requirement of QC Staff.* At a minimum, provide the name of the person responsible for each position listed below, including their telephone number, email, and their qualifications/certifications.

i. *QC Plan Manager.* The person responsible for the execution of the QC plan and liaison with the Agency. This person shall be on the job and have the authority to stop or suspend construction operations.

ii. *QC Technicians.* The person(s) responsible for conducting QC tests and inspection to implement the QC plan. QC technicians shall have Level 2 aggregate testing certification from the American Concrete Institute (ACI), or other certification program approved by the Agency.

b. *Certified Contractor Staff.* At a minimum, one crew member (project manager or other with decision-making authority) possessing a valid chip seal certification shall always be on the job while the chip seal is being constructed. The chip seal certification is administered by the National Center for Pavement Preservation (NCPP) on behalf of AASHTO TSP·2 (Transportation System Preservation Technical Services Program).

4. *QC Testing Laboratories and Equipment:*

   a. The laboratory that performs the QC for production can be either qualified or Agency approved. The Contractor shall provide the name of the Agency-approved lab for all tests within the relevant scope of testing.

   b. Testing and sampling equipment and measuring devices shall meet the requirements of the specified standards and test methods. The lab shall maintain records of the calibration and maintenance of all sampling, testing, and measuring equipment, and all documents required by the Agency.

   c. Placement Equipment Calibration. Prior to the commencement of work, the asphalt emulsion distributor and aggregate spreader shall be calibrated in the presence of the Agency representative utilizing the materials to be used on the project. Calibration will be performed consistent with procedures in FHWA-HIF-19-029, Chip Seal Checklist (2019).

5. *QC Activities.* QC activities shall include monitoring, inspection, sampling, and testing. The Contractor's QC activities shall cover all aspects that affect the quality of the materials and workmanship of the chip seal. If there is no Agency-specific requirement, the minimum QC activities and frequencies required are listed as follows:

   a. Component materials;

   b. Transportation material handling;

   c. Mix design by a qualified lab;

   d. Test strip construction and assessment;

   e. Placement and finishing;

   f. Performance; and

   g. Review of material certifications supplied by vendors and suppliers.

Table 406.5-3. Minimum Aggregate QC Requirements

Process Control Test	Test Method	Minimum Frequency
Gradation[a]	AASHTO T 11 or AASHTO T 27	Prior to construction for design, then once per day of placement and every change of source
Unit Weight	AASHTO T 19M/T 19	Prior to construction for design, then every change of source
Bulk Specific Gravity	AASHTO T 85	Once, prior to construction for design, then every change of source
Aggregate Absorption	AASHTO T 85	Once, prior to construction for design, then every change of source
L.A. Abrasion	AASHTO T 96	Once, prior to construction for design, then every change of source
Soundness	AASHTO T 104	Once, prior to construction for design, then every change of source
Deleterious Material	AASHTO T 112	Once, prior to construction, then every change of source
Fractured Faces	AASHTO T 335	Once, prior to construction, then every change of source
Flakiness Index	FLH T 508	Prior to construction for design, then every other day of placement or change of source
Application Rate	Truckload Yield Check, Tarp on Roadway	Once at startup each production day

[a] Aggregate samples will be taken at the project stockpile site using AASHTO R 90 Method B. Gradation test results should be provided within 24 hours.

Table 406.5-4. Minimum Asphalt Emulsion QC Requirements

Process Control Test	Test Method	Minimum Frequency
Tests on Emulsion[a]		
Viscosity	AASHTO T 59 or T 382	Once per 200 tons (180 Mg) of material placed
Temperature	N/A	Once delivery tanker
Particle Charge	AASHTO T 59	Prior to loading emulsion distributor
Demulsibility	AASHTO T 59	Once per 200 tons (180 Mg) of material placed
Sieve	AASHTO T 59	Once per 200 tons (180 Mg) of material placed
Storage Stability	AASHTO T 59	Once per 200 tons (180 Mg) of material placed
Residue[b]	AASHTO R 78	Once per 200 tons (180 Mg) of material placed
Application Rate	Computer Printout, Volumetric Measurement, Plate on Roadway	Once at startup each production day, then each 500 tons (450 Mg) of aggregate placed
Tests on Residue		
Solubility	AASHTO T 44	Once per 200 tons (180 Mg) of material placed
Penetration	AASHTO T 49	Once per 200 tons (180 Mg) of material placed

Continued on next page

Table 406.5-4. Minimum Asphalt Emulsion QC Requirements | Continued

Process Control Test	Test Method	Minimum Frequency
Ductility	AASHTO T 51	Once per 500 tons (450 Mg) of material placed
Ash Content	AASHTO T 111	Once per 200 tons (180 Mg) of material placed
Elastic Recovery	AASHTO T 301	Once per 500 tons (450 Mg) of material placed
MSCR, Jnr, % Recovery	AASHTO T 350	Once per 500 tons (450 Mg) of material placed

[a] A material certification from the supplier shall be provided with each delivery tanker. Asphalt emulsion samples will be taken at the point of delivery from the delivery tanker using AASHTO R 66.

[b] Determined by either AASHTO T 59 or Agency-approved method.

6. *Contractor's Quality Control Plan.* The Contractor shall submit a written, project-specific, signed QC plan to the Agency for acceptance at least 15 days prior to placement. The QC plan shall detail the Contractor's plans, policies, procedures, and organization deemed necessary to measure and control materials, equipment, and the chip seal placement process.

   The QC plan shall be maintained to reflect the current status of the operations. Changes must be approved by the Agency prior to implementation.

   At a minimum, the QC plan shall detail the following:

   a. *Scope of the QC Plan.* Reference all applicable specifications.

   b. *Definitions.* Terms used in the QC plan shall be clear and distinct.

   c. *QC Organization.* Include a QC organizational chart identifying all personnel responsible for implementing the QC plan and how they integrate and communicate within the Contractor's management structure and the Agency's. Include a list of QC personnel with their names, qualifications, responsibilities, certifications, telephone numbers, and email addresses.

   d. *QC Testing Facilities and Equipment.* Include the location and qualifications of QC testing facilities, and a listing of all QC testing equipment with the frequency of calibration and verification.

   e. *Materials Control.* Include the sources of all materials used in construction of the chip seal. Describe stockpile management practices, including segregation mitigation, loading, and transport procedures.

   f. *QC Activities.* Describe QC activities deemed necessary to control all aspects of chip seal construction. Include the locations, methods, frequency, and personnel responsible for conducting QC sampling, testing, and inspection. Identify lot/sublot sizes, sample identification system, and sampling storage/retention procedures.

   g. *Chip Seal Placement and Workmanship.* Describe methods, equipment, and materials for construction of the chip seal. Identify methods to ensure proper workmanship:

i. Equipment calibration for distributor and aggregate spreader.

ii. Monitoring application rates.

iii. Ensuring proper spread patterns:

a) Proper embedment without excessive or inadequate aggregate;

b) Emulsion drilling or flushing;

c) Longitudinal joint overlap; and

d) Transverse joints.

iv. Rolling operations, proper number of passes, and coverage.

v. Sweeping operations and schedule.

vi. Method to control traffic.

h. *Documentation.* Describe testing procedures and determine when corrective action is required. The Contractor will provide examples of reporting forms, production QC test results, daily production records, non-conformance reports, and document retention details.

i. *Non-Conformance and Corrective Action.* Establish and maintain an effective and positive system for controlling non-conforming materials as indicated by inspection and test results. Investigate the cause of any non-conformance to prevent recurrence and take prompt corrective action to correct conditions that have resulted, or could result, in the incorporation of non-conforming materials into the work. All non-conforming materials shall be positively identified to prevent use and intermingling with conforming materials. Include procedures and personnel responsible for directing corrective action including suspension of work and disposal or reworking of non-conforming materials. Detail how the results of QC inspections and tests will be used to determine corrective actions, define rules to gauge when a process is out of control, and select the associated corrective action to be taken. At minimum, establish corrective action procedures for each control requirement listed above.

7. *Records and Documentation.* The Contractor shall maintain complete records of all QC tests and inspections.

All QC test results shall be submitted to the Agency within 24 h of completion of application as requested. A material certification shall be submitted from each supplier for each batch of material delivered to the jobsite, including test results.

The QC records shall contain all test and inspection reports, forms and checklists, equipment calibrations, supplier material certificates, and non-conformance and corrective action reports. The QC records shall indicate the nature and number of observations made, the number and type of deficiencies found, the quantities conforming and non-conforming, and the nature of corrective action taken as appropriate for materials as well as workmanship. The QC records shall always be available to the Agency and shall be retained for the life of the contract. The Contractor's documentation procedures will be subject to approval by the Agency prior to the start of work, and to compliance checks by the Agency during the progress of the work.

8. *Compliance with Specifications.* At the conclusion of the project, the Contractor shall attest in writing to the Agency that the chip seal has been constructed in accordance with and meets the requirements of the specifications.

G. *Agency Acceptance:*

1. *General.* As the owner of the final chip seal, the Agency must ensure the Contractor has constructed the project in accordance with the specifications. The Agency will conduct acceptance sampling, testing, and inspections consistent with AASHTO R 10. The Agency may conduct verification testing if QC results are used for acceptance.

2. *Acceptance Activities:*

    a. Assure the Contractor has followed the approved QC plan.

    b. *Materials.* Monitor all Contractor QC testing.

    c. Agency to sample and test:

        i. *Aggregate.* Gradation, moisture content, and deleterious materials, once per day or at the discretion of the Agency.

        ii. *Asphalt Emulsion.* Once per project or at the discretion of the Agency.

        Note: Actual frequency and lot size will be per each Agency's frequency guide schedules for verification, sampling, and testing.

    d. Traffic control conforms to plans and specifications and complies with the *Manual on Uniform Traffic Control Devices*.

    e. *Surface Preparation.* Monitor and approve sweeping methods; verify surface is clean and dry, and inlets and manhole covers are protected.

    f. *Calibration.* Witness the calibration of the asphalt emulsion distributor and aggregate spreader.

    g. *Asphalt Emulsion Distributor.* Verify equipment has been calibrated and is in proper operating condition. Monitor for an even application of material.

    h. *Aggregate Spreader.* Verify equipment has been calibrated and is in proper operating condition. Monitor for an even application of material. Ensure spreader is proper distance from asphalt distributor.

i. *Pneumatic Rollers.* Verify equipment is in proper operating condition and rollers are positioned in echelon so the entire width of the pavement lane is covered. Roll three complete passes over the aggregate, with one pass defined as the roller moving over the chips in either direction.

j. *Sweepers.* Verify equipment is in proper operating condition. Ensure loose material is removed without damaging fresh chip seal.

k. *Application Rates.* Monitor and verify correct application rates of asphalt emulsion and cover aggregate.

l. *Production Inspection.* To be completed after final sweeping to check for unacceptable conditions, such as:

   i. Bleeding/flushing.

   ii. Raveling/stone loss.

   iii. Crushed/broken aggregate.

   iv. Excessive longitudinal joint overlap.

   v. Transverse joint overlap.

H. *Independent Assurance Program (IA):*

1. The IA program shall follow Tech Brief: Independent Assurance Programs, FHWA-HIF-12-001 (2011) and shall be the responsibility of the Agency or Owner. The IA Program consists of activities that are an unbiased and independent evaluation of all the observations, sampling and testing procedures, and equipment used in the acceptance program. The IA Program is staffed by qualified Agency personnel or an accredited laboratory not involved with acceptance testing. It ensures the sampling and testing is performed correctly and the testing equipment used in the program is operating correctly and remains calibrated. It involves a separate and distinct schedule of sampling, testing, and observation. The results of the IA testing shall not be used for material acceptance.

406.6 MEASUREMENT

The Engineer will measure work acceptably completed as specified below:

A. *Emulsified Asphalt.* Emulsified asphalt will be measured for chip seal by volume at 60°F (16°C).

B. *Aggregate.* Aggregate will be measured based on the area of pavement surfaced.

Commentary

Aggregate can be paid for by the ton as well. This is easier to verify but results in an incentive to place more aggregate than necessary. Applying too much aggregate is poor practice and results in dislodgement of the embedded aggregate.

406.7 PAYMENT

Payment for chip seals can be done by either paying for the materials in unit costs, or for the completed chip seal by area of pavement sealed.

Commentary

The advantage of payment by the square yard for a completed chip seal is simplicity if the area is easily defined. The disadvantage is that an incentive is created to reduce material quantities. Reduced emulsified asphalt quantities can lead to chip loss and vehicle damage.

A. *Payment by Unit Price.* The Agency will pay for accepted quantities at the contract price as follows:

1. Payment for the accepted quantity of emulsified asphalt and aggregate for chip seal (including any required additives) at the contract bid price of measure is compensation in full for all costs of furnishing and applying the material as specified.

2. Payment will be made in accordance with the schedule set forth below at the contract bid price for the specified unit of measure.

Item No.	Item	Unit
State ##	Emulsified asphalt for chip seal	gal (L)
State ##	Aggregate for chip seal	tons (Mg)
State ##	Diluted emulsified asphalt for fog seal, if used	gal (L)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

B. *Payment for Completed Chip Seal:*

1. Payment for the accepted quantity of the chip seal at the contract bid unit price of measure is compensation in full for all costs of furnishing and applying the material as specified, including cleaning the existing pavement; stationing; purchase of aggregate; delivery of aggregate; and all labor, equipment, and materials necessary for the placement of the chip seal for full lane coverage, sweeping of any loose aggregate after construction, and other requirements as specified.

2. Payment shall be made in accordance with the schedule set forth below at the contract bid price for the specified unit of measure.

Item No.	Item	Unit
State ##	Chip seal	yd^2 (m^2)
State ##	Diluted emulsified asphalt for fog seal, if used	gal (L)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 407
HOT-APPLIED ASPHALT CHIP SEAL

407.1 DESCRIPTION

Construct a single-layer, hot-applied chip seal on a prepared existing surface. This Section is intended to provide information needed for Owners or Contractors to construct hot-applied asphalt chip seals. A hot-applied asphalt chip seal is the application of hot-applied asphalt binder, followed immediately by an application of a single layer of precoated aggregate.

This guide specification refers to quality requirements for materials and a design method for chip seals available in other AASHTO documents. However, the main purpose is to provide guidance for the construction of hot-applied asphalt chip seals applied in one layer.

All units of measurement are expressed in inch-pound units in accordance with U.S. practice. SI units are given in parentheses.

Commentaries are included in this guide specification to 1) emphasize and further explain the section, 2) present options to be considered by the user, or 3) provide sources of additional information. An example of these commentaries is shown below:

Commentary

This guide specification covers construction of single-application chip seals. If this process is repeated with another application of hot asphalt and another layer of cover aggregate, the process is known as a double chip seal. Other terms have been used referring to chip seals such as "seal coat," "surface treatment," "surface seal," "surface dressing," "sprayed seal," and others. Sometimes, a fog seal is applied over the completed chip seal.

407.2 REFERENCED DOCUMENTS

A. *AASHTO Standards:*

- M 140, Emulsified Asphalt
- M 208, Cationic Emulsified Asphalt
- M 316, Polymer-Modified Emulsified Asphalt
- M 320, Performance-Graded Asphalt Binder
- M 332, Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test
- R 90, Sampling Aggregate Products
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 96, Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

- T 301, Elastic Recovery Test of Asphalt Materials by Means of a Ductilometer
- T 335, Determining the Percentage of Fracture in Coarse Aggregate

B. *ASTM Standards:*

- D5624, Standard Practice for Determining the Transverse-Aggregate Spread Rate for Surface Treatment Applications
- D6114/D6114M, Standard Specification for Asphalt-Rubber Binder

C. *Federal Lands Highway Standard:*

- FLH T 508, Flakiness Index Value.

D. *Federal Highway Administration:*

- FHWA-HIF-19-029, Chip Seal Checklist (2019)

E. *Texas Department of Transportation:*

- *Seal Coat and Surface Treatment Manual*, 2017. Available from http://onlinemanuals.txdot.gov/txdotmanuals/scm/scm.pdf

F. *Other Documents:*

- Shuler, S., A. Epps-Martin, T. Lord, and D. Hoyt. *National Cooperative Highway Research Program Report 680: Manual for Emulsion-Based Chip Seals for Pavement Preservation*, Chapter 7. National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, DC, 2011.

407.3 TERMINOLOGY

Three broad classes of asphalt binders are used in hot-applied chip seals. They include asphalt–rubber, rubber-modified asphalt, and performance-graded (PG) binders. The latter two are PG graded.

A. Asphalt–Rubber Binder. A blend of coarse crumb rubber and an asphalt binder, meeting the requirements of ASTM D6114/D6114M. The binder shall include at least 15 percent crumb rubber and can be as high as 22 percent.

B. Rubber-Modified Asphalt. A blend of fine rubber and an asphalt binder mixed at an asphalt terminal. The binder may also include polymers. This product is also referred to as a terminal blend. This product includes a minimum of 5 percent crumb rubber, but can contain as much as 18 percent. There is no national specification for these products.

C. Performance-Graded (PG) Hot-Applied Binders. These binders shall meet the requirements of AASHTO M 320. An unmodified or a modified binder could be used in a chip seal application.

D. Emulsified asphalts for fog seals, if used, include:

1. **CSS-1h.** A slow-setting cationic emulsified asphalt that has a residual binder residue with lower penetration than CSS-1.

2. **SS-1h.** A slow-setting anionic emulsified asphalt that has a residual binder residue with lower penetration than SS-1.

Commentary

In colder environments, a CRS-1h has been used to get a faster set.

407.4 MATERIALS

A. *Asphalt Binder.* Provide materials as specified below:

1. *Asphalt–Rubber Binder.* This binder shall meet all the requirements of ASTM D6114/D6114M. It is a combination of asphalt binder, extender oil, and crumb rubber modifier (CRM). If used, the asphalt modifier (or extender oil) shall be from 2.5 to 6.0 percent by weight of the asphalt binder in the asphalt–rubber binder.

   The asphalt binder (and, if used, the asphalt modifier) must be combined with the CRM at the asphalt–rubber binder production site. The asphalt binder and asphalt modifier blend must be from 350 to 425°F [177 to 218°C] when the CRM is added. Combined ingredients must be allowed to react at least 45 min at temperatures from 350 to 400°F [177 to 204°C], except the temperature shall not be higher than 10°F (5.5°C) below the actual flashpoint of the asphalt–rubber binder. After reacting for at least 45 min, the asphalt–rubber binder must comply with the requirements shown in ASTM D6114/D6114M.

   Commentary

   Because of the high temperatures used with hot-applied binders, health and safety issues are of more concern.

2. *Rubber-Modified Asphalt.* Provide materials as specified below:

   a. This binder shall consist of a PG asphalt binder with a minimum of 5 percent scrap tire rubber and 2 percent styrene–butadiene–styrene (SBS) block copolymer blended at a terminal. The binder needs to meet the requirements of AASHTO M 320 and exhibit an elastic recovery greater than 60 percent when tested in accordance with AASHTO T 301. The actual PG grading of the rubberized asphalt would be per the design or as specified.

Commentary

In Arizona, Texas, and California, this product is often referred to as a terminal blend. The CRM content may vary from 5 percent to 18 percent or more.

3. *PG Asphalt.* Provide materials as specified below:

   a. These binders shall meet the requirements of AASHTO M 320 or M 332 with exhibit elastic recovery greater than or equal to 60 percent when tested in accordance with AASHTO T 301. The performance grade to be used shall be determined by the Engineer or Contractor.

   Commentary

   Both polymer-modified and unmodified binders can be used. Agencies shall designate the grade commonly used in their state.

B. *Granulated Rubber:*

1. Crumb rubber shall be vulcanized rubber using an ambient temperature processing of scrap tires. Granulated rubber shall meet the requirements given in ASTM D6114/D6114M.

2. The use of rubber from multiple sources is acceptable provided that the overall blend of rubber meets the specified gradation. Certification of the gradation and quality of the rubber shall be provided by the rubber supplier.

Commentary

The crumb rubber gradations used vary between states. Also, for asphalt rubber, most states use a binder that does not contain any extender oil or high natural rubber, while some use a binder that does contain both.

C. *Aggregate:*

1. Chip seal aggregate shall be durable, uniform in quality, and free from wood, bark, roots, and other deleterious materials. Gradations and quality requirements are specified in Table 407.4-1 where all percentages are by weight. The aggregate gradation to be used will be as shown in the plans or other contract documents. Gradation A is for asphalt rubber while gradation B is for rubberized and performance-graded asphalts. All aggregate retained on the No. 4 screen shall be crushed by mechanical means and meet the requirements shown in Table 407.4-2.

Table 407.4-1. Chip Seal Aggregate Gradations

Sieve Size	A Asphalt Rubber % passing	B RMA and PG Asphalts % passing
$^{3}/_{4}$ in. (19 mm)	100	—
$^{1}/_{2}$ in. (12.5 mm)	95–100	100
$^{3}/_{8}$ in. (9.5 mm)	70–100	70–100
No. 4 (4.75 mm)	0–15	0–15
No. 8 (2.36 mm)	0–5	0–5
No. 16 (1.18 mm)	—	—
No. 30 (600 µm)	—	—
No. 50 (300 µm)	—	—
No. 200 (75 µm)	0–1	0–1

Table 407.4-2. Fracture and Abrasion Requirements

Property	Chip Seal Class[a]		
	I	II	III
Fracture, 1 Face, % min AASHTO T 335	70	85	95
Fracture, 2 Faces, % min AASHTO T 335	60	80	90
Los Angeles Abrasion, max. % loss, AASHTO T 96	37	35	30
Flakiness Index, max. % FLH T 508	25	20	17

[a] Traffic Class I is less than 500 AADT, II is 501 to 5000 AADT, and III is greater than 5000 AADT.

Prior to placing, the aggregate shall be uniformly precoated with a performance-graded asphalt that meets the requirements of AASHTO M 320 or M 332 and is typically used by the Agency based on climate. The precoating shall be accomplished by mixing at a central hot mix plant. The binder shall have a minimum temperature of 250°F [121°C] at the time of precoating with approximately 0.40 to 0.80 percent asphalt cement, by weight of the aggregate. The end result shall be a dust-free aggregate.

407.5 CONSTRUCTION

A. *Weather Limitations.* Construct chip seal per the following conditions:

1. Ambient or pavement surface temperatures shall be 50°F [10°C] and rising.

2. Suspend chip sealing if the pavement surface temperature exceeds 140°F [60°C].

3. The road surface shall be dry and swept clean of dirt and debris.

B. *Mix Design:*

1. *Asphalt Rubber.* Design of the rubberized asphalt chip seal surface treatment shall be the responsibility of the Contractor using a method approved by the Agency. The application rate of the asphalt rubber is normally from 0.6 ± 0.1 gal/yd^2 (2.7 ± 0.5 L/m^2). The application rate of the precoated aggregate is normally between 30 to 40 lb/yd^2 (15–20 kg/m^2). No later than two weeks before work commences, the Contractor shall submit for the approval of the Engineer the chip seal design, which specifies the additives for the asphalt rubber, the binder profile for the product showing the physical properties, application rate of the asphalt rubber, and the source, composition, and application rate of the cover aggregate. Samples of each material shall be included with the submittal. Once the materials and design are approved, no substitution will be permitted unless approved by the Engineer. The supplier of the binder shall certify the percent of granulated rubber in the blend and whether the blend includes an extender oil. The temperature of the asphalt cement shall be between 350 and 425°F [177–218°C] at the time the CRM is added. The components shall be mixed together in the blender and reacted for a minimum of 1 h. The temperature of the binder shall be above 350°F [177°C] during the reaction period.

   Commentary

   Most blending units have a mass flow meter capable of measuring and recording the total quantity of asphalt binder in tons. The quantity of ground rubber shall be determined by weight utilizing either a hopper equipped with load cells or a feeder equipped with belt scales. The total weight in tons and percentage of ground rubber based on total asphalt rubber binder shall be recorded. All data shall be reported to the awarding authority. As part of the blending operation, a dedicated asphalt rubber reaction/heated storage tank with proper heating and mixing capabilities is required.

2. *Rubber-Modified Asphalt (RMA).* The chip seal design shall follow the method approved by the Agency. If none is available, the Kirby method in the Texas Seal Coat Manual (2017) shall be used. The application rate of the binder is normally in the range of 0.50 ± 0.10 gal/yd^2 (2 ± 0.5 L/m^2). The Engineer will specify the exact application rate based on the aggregate texture and absorption and the existing surface condition. Aggregate application rates should be in the range between 25 and 35 lb/yd^2 (15 and 25 kg/m^2).

3. *PG asphalts.* The chip seal design shall follow the method approved by the Agency. If none is available, the Kearby method in the Texas Seal Coat Manual (2017) shall be used. The application rate of the binder will be 0.30 ± 0.10 gal/yd^2 [1.35 ± 0.45 L/m^2]. The Engineer will specify the exact rate based on the surface and the characteristics of the aggregate material. Aggregate application rates shall be 20 to 30 lb/yd^2 [10.9 to 16.3 kg/m^2] for conventional aggregates or as directed by the Engineer.

C. *Preconstruction Meeting.* Coordinate a preconstruction meeting prior to construction with the Engineer to discuss the following topics and document delivery schedule:

1. Construction process;

2. Quality control plan, required to be submitted;
3. Mix design, required to be submitted;
4. Materials control;
5. Materials measurement;
6. Equipment calibration, required to be submitted;
7. Traffic control plan;
8. Equipment/process overview;
9. Inspection;
10. Test strip;
11. Unique project conditions;
12. Project documentation; and
13. Expectations.

D. *Road Surface Preparations:*

1. *Cleaning Pavement.* Clean the roadway surface by sweeping no more than 30 min prior to application of the hot asphalt and chips. This 30-min window may be extended if authorized by the Engineer in cases where extending the time does not jeopardize a clean surface prior to chip seal operations. Sweep the pavement with a motorized broom to remove loose material. Clean depressions not reached by the motorized broom with a hand broom. Clean the outer edges of the pavement to be sealed.

2. *Protecting Accessories.* Cover utility castings (manholes, gate valve covers, catch basins, sensors, etc.) to prevent coating with asphalt binder. Suitable coverings include plywood disks, Kraft paper, roofing felt, or other approved methods. Remove the protective coverings before opening the road to traffic.

3. *Traffic Markings Removal.* Pavement markings shall be removed by grinding or other approved methods prior to chip seal operations.

E. *Equipment:*

1. *Blending Unit.* A mechanical blender for proper proportioning and thorough mixing of the asphalt-cement and granulated rubber is required to produce the asphalt–rubber binder. This unit shall be equipped with: asphalt mass flow meter (gallons) (liters); a flow rate meter (gallons per minute) (liters per minutes); a positive displacement auger to feed the rubber properly to the mixing chamber at the specified rate; and a static motionless mixer or a blending tank with a high-speed mixer. The blender shall have a separate asphalt binder feed pump and finished product pump to maximize production, and shall be capable of

providing 100 percent proportional blend at any given time during the blending cycle; supporting documentation from the manufacturer shall be submitted to the Engineer.

Commentary

A blending unit shall not be required for terminal blends.

2. *Asphalt Distributor.* The asphalt distributor shall be self-propelled with a ground speed control device interconnected with the asphalt pump such that the specified application rate will be supplied at any speed. The asphalt distributor shall be capable of maintaining the asphalt binder at the specified temperature. For asphalt rubber applications, the asphalt distributor shall be equipped with internal mixing capabilities. The spray bar nozzles shall produce a uniform triple lap application fan spray, and the shutoff shall be instantaneous, with no dripping. All nozzles shall be oriented at the same angle between 15 and 30 degrees using the wrench supplied by the distributor manufacturer. Each pressure distributor shall be capable of maintaining the specified application rate within ±0.015 gal/yd^2 [±0.068 L/m^2] for each distributor load.

3. *Aggregate Spreader.* A variable width, self-propelled mechanical-type aggregate spreader with a computerized spread control capable of distributing the aggregate uniformly to the required width and at the designed rate shall be used. The spreader shall be a self-propelled type mounted on pneumatic-tired wheels capable of an application width of 14 ft (4.2 m) or greater.

4. *Pneumatic-Tire Rollers.* A minimum of three self-propelled pneumatic-tire rollers capable of ballast loading, either with water or sand to allow the weight of the machine to be varied from 6 to 12 tons [5.4 to 10.9 Mg] to achieve a minimum contact pressure of 80 lb/in.^{2} [550 kPa] shall be used. The alignment of the axles shall be such that the rear-axle tires, when inflated to the proper pressure, can compact the voids untouched by the front-axle tires. All tires shall be as supplied by the roller manufacturer. Width of the rollers shall exceed 60 in (1.5 m).

Commentary

Steel-wheel rollers have been used as the final roller on some chip seals with success. The advantage is a more even final elevation. This produces fewer prominent aggregate edges extruding above the surface which can be susceptible to snow plow damage. The disadvantage of steel-wheel rollers is the potential for crushing of aggregate that cannot withstand the high stress imparted at the steel roll–chip interface. Therefore, if used, steel rollers should be limited to 5 tons (4.5 Mg). Vibration shall not be used if the rollers are so equipped.

5. *Brooms.* Motorized brooms with a positive means of controlling vertical pressure shall be used to clean the road surface prior to spraying the asphalt binder. Plastic bristle brooms are required to remove loose aggregate after rolling.

Commentary

Vacuum brooms or pickup sweepers are preferred in urban or residential areas, but push brooms are acceptable in rural areas where chips being scattered off the roadway do not pose a hazard to pedestrians or vehicles.

6. *Trucks:*

   a. *Asphalt–Rubber Binder.* All trucks for the asphalt–rubber binder shall be equipped with internal agitation and heating capabilities. Trucks for the other binder types do not require these capabilities unless separation is an issue.

   b. *Aggregate.* Trucks for hauling aggregate shall be rear discharge equipped with a device to lock onto the hitch at the rear of the aggregate spreader to prevent spillage. Sufficient hauling vehicles shall be available to ensure continuous operations of the distributor and the aggregate spreader.

F. *Equipment Calibration:*

The Contractor shall provide proof of calibration of the asphalt distributor and the aggregate spreader. The asphalt distributor shall be calibrated prior to the job. The asphalt application rate will be verified on a daily basis as calculated by dividing the total gallons (liters) of asphalt by the total area treated. The Contractor shall submit the results of the calibration procedure to the Engineer.

Flow from each nozzle in the pressure distributor must be within ±10 percent of the average flow of all nozzles as measured by the procedure described in NCHRP Report 680, Chapter 7 (Shuler et al., 2011).

Uniformity of the aggregate applied transverse to the pavement centerline shall be judged using ASTM D5624. Tolerance for each pad tested for transverse spread rate shall be ±10 percent of the average of the total transverse rate.

Commentary

Calibration is very important to assure the quantity of asphalt and chips applied to the pavement are correct. Although many modern asphalt distributors and aggregate spreaders are computer controlled, calibration is required to tell the computer how much asphalt is being applied. This quantity must be checked prior to spraying asphalt and spreading aggregate and checked against the quantity the computer (if the distributor is so equipped) indicates is being applied.

1. *Asphalt Distributor:*

   All nozzles shall be the same size, provide the same flow rate, be oriented in the same direction, and be the same distance above the pavement.

   Commentary

   The distributor truck applies hot asphalt to the pavement surface. This application must be done uniformly both transverse and longitudinal to the centerline of the pavement to provide the proper hot asphalt layer necessary for aggregate adhesion.

   When lower application rates are determined to be necessary or are shown in the plans, smaller nozzles shall be inserted in the spray bar where the asphalt rate is reduced.

Commentary

To lower the risk to bleeding in areas with minor rutting or heavy truck traffic, it may be desirable to reduce the asphalt application rate in these areas.

a. *Nozzle Angle:*

Nozzles shall be positioned at an angle of 15 to 30 degrees from the horizontal of the spray bar in accordance with the spray bar manufacturer's recommendation. All nozzles shall spray a full fan except for the right and left edge nozzles. The right and left edge nozzles shall be adjusted to a half fan such that the spray stays to the inside of the spray bar.

Commentary

The next step in calibrating the distributor is adjustment of the spray bar nozzle angles. Each nozzle has a slot cut across the face of the nozzle. When the nozzle is threaded into the spray bar, the slot should all be positioned at an angle of 15 to 30 degrees to the direction of the spray bar as shown in Figure 407.5-1. This angle provides the best position for achieving uniformity in the spray and the triple overlap coverage.

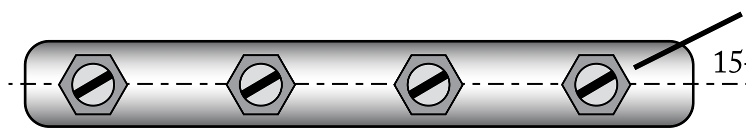

Figure 407.5-1. Spray Bar Nozzle Orientation in Spray Bar

The angle at which the nozzles are positioned shall be adjusted using the wrench supplied with the distributor. However, in cases where this wrench is unavailable, a wrench that fits the hexagonal nozzle will suffice but the angle must be judged visually.

Commentary

The angle should be adjusted using the wrench supplied with the distributor. This wrench is designed, when used properly, to set the correct angles for each nozzle. Any wrench that fits the hexagonal nozzle can adjust the nozzle angle but correctness of the angle would have to be visually verified.

All nozzles fitted to the spray bar shall be full fan nozzles except for the right and left edge nozzles. These nozzles shall be half fan nozzles adjusted so the spray from the nozzle remains to the inside of the spray bar.

b. *Spray Bar Height:*

The spray bar height must be adjusted so that the asphalt provides exact coverage across the entire spray width in two or three overlaps.

Commentary

Streaking of the emulsified asphalt will occur if the spray bar is set too high or too low, as shown in Figures 407.5-2 and 407.5-3.

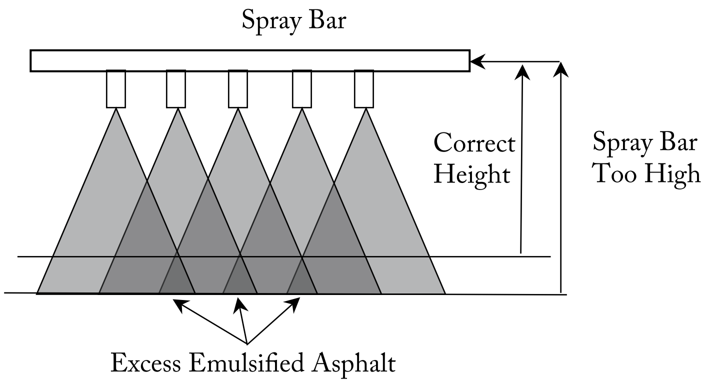

Figure 407.5-2. Streaks with Spray Bar Too High for Double Overlap

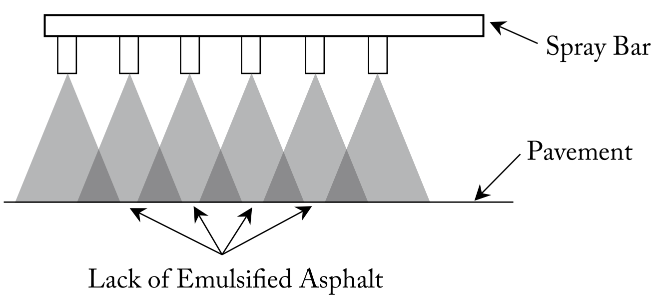

Figure 407.5-3. Streaks with Spray Bar Too Low for Double Overlap

To avoid this streaking, the bar must be adjusted to the correct height. This adjustment process is accomplished by shutting off nozzles to determine where the spray pattern contacts the pavement, as shown in Figures 407.5-4 and 407.5-5.

c. *Bar Height Adjustment to Achieve Double Lap:*

Every other nozzle shall be turned off when a double lap application is desired, as shown in Figure 407.5-4. The distributor operator shall spray asphalt onto the pavement surface for as short an interval as possible while an observer watches where the asphalt hits the pavement from each nozzle left open. If there is overlap of asphalt from adjacent nozzles, the bar is too high. If there is a lack of asphalt from adjacent nozzles, the bar is too low.

Once it is confirmed that the bar height is correct, the nozzles that were turned off can be turned back on and a double application of asphalt will result when spraying resumes.

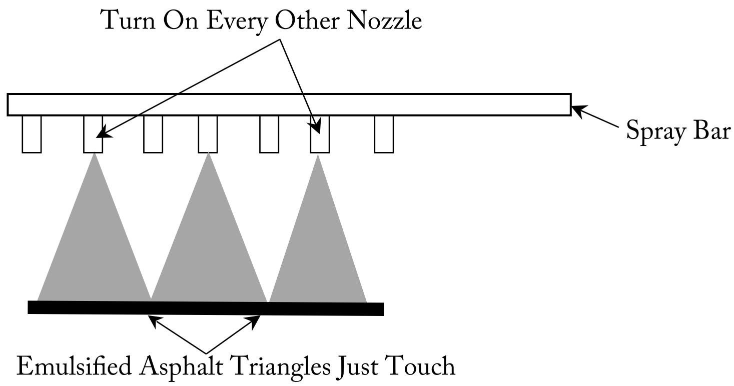

Figure 407.5-4. Adjustment of Spray Bar Height for Double Overlap

d. *Triple Lap Application Bar Height Adjustment:*

Every third nozzle shall be turned off when a triple lap application is desired as shown in Figure 407.5-5. The distributor operator shall spray asphalt onto the pavement surface for as short an interval as possible while an observer watches where the asphalt hits the pavement from each nozzle left open. If there is overlap of asphalt from adjacent nozzles, the bar is too high. If there is a lack of asphalt from adjacent nozzles, the bar is too low.

Once it is confirmed the bar height is correct, the nozzles that were turned off can be turned back on and a triple application of asphalt will result when spraying resumes.

As the distributor empties during spraying, the bar height will rise. However, this is not usually enough to cause significant streaking worth adjustment of the spray bar.

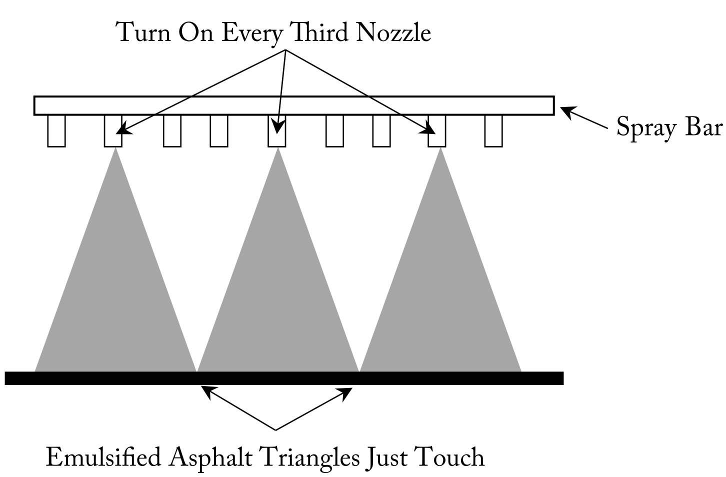

Figure 407.5-5. Adjustment of Spray Bar Height for Triple Overlap

e. *Transverse Flow Rate.* The flow rate across the spray bar shall be uniform with each nozzle spraying within ±10 percent of the average flow rate.

Commentary

A uniform flow rate is achieved by measuring the width of the slot in the nozzle the diameter of the orifice. Also, some nozzles are labeled by the manufacturer. Manufacturers supply a list of nozzles in the owner's document describing which nozzles shall be used for various application rates or on a placard mounted on the equipment.

However, nozzles of the same apparent size have been measured with different flow rates. Therefore, it is recommended that all nozzles be checked for flow rate before chip seal operations begin. This is easily accomplished by fabricating a flow apparatus. This apparatus consists of a pipe to which each nozzle, in turn, can be fitted on one end and a water source can be fitted on the other end. The flow of water through each nozzle shall be measured by the volume captured in a 1-gal (4-L) container within a set time period. This shall be done for each nozzle to be used on the project. If the flow rate of any nozzle is greater than ±10 percent of the average of all the nozzles to be used, such nozzle shall be discarded, or modified to flow within the 10 percent tolerance.

Determination of uniform lateral flow from the spray bar is determined by collecting a measured volume of asphalt in containers placed under each nozzle. This process is practical using standard 6-in. by 12-in. (150-mm by 300-mm) concrete cylinder molds lined with 1-gal (4-L) resealable freezer bags. The cylinder molds can be reused and the freezer bags discarded appropriately with the contents.

f. *Longitudinal Flow Rate.* The longitudinal flow rate shall be accomplished by measuring the volume of asphalt in the distributor before and after spraying enough asphalt to reduce the volume of asphalt in the distributor by 70 to 90 percent.

Commentary

The longitudinal flow rate must be measured with all nozzles inserted in the distributor bar. First, the quantity of asphalt in the truck must be determined. Although there is a volume indicator on the rear of most modern distributors, these are not calibrated in small enough increments to be of use for longitudinal flow rate calibration and shall not be used for this purpose. Instead, the dipstick supplied with the distributor must be used. This dipstick is usually carried on the top of the tank near the inspection hatch. Prior to shooting asphalt, take a volume reading with the dipstick.

Pay attention to how the dipstick is used. Many dipsticks are not intended to be submerged in the asphalt but instead are inserted into the top of the tank only until the tip of the dipstick touches the surface of the asphalt. Then, the volume in the tank is read by indexing the top of the inspection cover to the reading on the dipstick.

Record this volume as "beginning volume." Set up the truck to shoot asphalt and shoot a minimum of 3000 ft by 12 ft (1000 m by 3.6 m) of asphalt at the design rate using the gallon (liter) per minute pump flow volume and truck speed required by the manufacturer to attain this flow rate. Take a second dipstick reading. Record this reading as "ending volume." Subtract *ending volume from beginning volume and record this as "volume used." Determine the area of asphalt sprayed. Divide volume used by the area sprayed in square yards (square meters). This is the gallons per square yard (liters per square meter) applied to the pavement. This value shall then be compared to the distributor computer, if equipped, to evaluate the accuracy of the computer. A correction factor may then be applied to the computer output, if needed, and used for the remainder of the day. This calibration shall be accomplished each day.*

An example of this calibration is presented below:

Given:

1800-gal (6800-L) capacity asphalt distributor

12-ft (3.6-m) wide spray width

Trial spray distance = 3630 ft (1100 m)

0.32 gal/yd^2 (1.45 L/m^2) design spray rate

Dipstick reading beginning volume = 1765 gal (6584 L)

Dipstick reading ending volume = 265 gal (1003 L)

Calculations:

1. *Check to see if enough volume shot. 1765–265 = 1500 gal (6584–1003 = 5581 L)*
2. *1500/1765 (5581/6584) = 85 percent >70 percent and <90 percent.*
   OK, enough applied to be valid
3. *Calculate spray rate = 1500 gal / (12 × 3630/9) = 0.31 gal/yd^2*
   (5581 L / (3.6 m × 1100 m) = 1.41 L/m^2)

Therefore, decrease distributor speed, or recalibrate computer and recheck.

2. *Aggregate Spreader:*

   a. *Transverse Spread Rate.* The aggregate spread rate shall be uniform across the veil and within ±10 percent of the average spread rate.

   Commentary

   Various methods of calibrating this equipment have been used and the ASTM D5624 procedure can be effective. However, a visual assessment of the lateral distribution of aggregate is a good place to start the process since non-uniform distribution can easily be seen. The veil of aggregate deposited on the pavement from the spreader box can be viewed from behind, with the spreader moving away from the observer, or from the front. Either position for the observer is adequate for viewing how uniformly the veil of aggregate is falling out of the spreader box. However, viewing from either front quarter affords the observer a better view of the entire spreader width and is, of course, safer than directly in front of the spreader. Any variation in light passing through the veil of aggregate indicates variation in application rate. More light *means a lack ofaggregate. Variation in light means the machine shall be stopped, the gates on the spreader contributing to the non-uniformity adjusted, and the trial rerun. This procedure provides adjustment to the transverse spread rate. Then, to obtain an objective means of measuring the amount of aggregate being deposited, ASTM D5624 is a good procedure to use.*

b. *Longitudinal Spread Rate.* The longitudinal spread rate shall be uniform and be within ±10 percent of the design spread rate.

Commentary

Once the transverse spread rate is adjusted, the longitudinal rate can be adjusted. This is also done visually, at first. Begin spreading aggregate into the fresh asphalt when a small quantity of aggregate cast by hand sticks to the asphalt and does not roll over. This shall be done well before the asphalt begins to cool, but not immediately after spraying unless temperature and wind demand it.

The application rate of the aggregate shall be similar to the design rate. This is a rate where, immediately upon dropping the aggregate, the appearance of the surface has some asphalt showing between the aggregates. In fact, the aggregate quantity should seem somewhat inadequate. The aggregate spread rate should not be low enough to cause pickup problems on rubber-tire rollers. However, the rate should be such that a small decrease in rate would cause pickup. Asphalt should be visible between the aggregates upon dropping and before rolling. If all asphalt is covered before rolling, there is an excess of aggregate and the rate shall be reduced. It is the responsibility of the construction superintendent to achieve this application rate.

Evaluating the quantity of aggregate being placed is important after the rate is established. This provides a quantitative baseline for future work. The best method to accomplish this evaluation is by weighing the aggregate spreader before and after applying the aggregates and calculating the spread rate based on the area covered. This is often not practical. Therefore, a suitable alternative is estimating the quantity of aggregates spread over a known area by knowing the weight of each transport truck supplying the spreader and dividing the estimated weight of chips spread by the area covered for that load.

An example follows:

Given:

Trucks loading the aggregate spreader are 12-ton (11-Mg) capacity tandem dumps

12-ft (3.6-m) wide pavement

28 lb/yd^2 (15.42 kg/m^2) design spread rate

Calculations:

1. *Check Truck No. 1*
    a. *Load = 23,803 lb (10,806 kg)*
    b. *Spreader distance = 640 ft (195.2 m)*

c. Rate = 23,803/640 × 12/9 = 27.9 lb/yd² (10,806/(195.2 × 3.6) = 15.38 kg/m²)

2. Check Truck No. 2

a. Load = 23,921 lb (10,860 kg)

b. Spreader distance = 634 ft (193.4 m)

c. Rate = 23,921/634 × 12/9 = 28.3 lb/yd² (10,860/(193.4 × 3.6) = 15.60 kg/m²)

3. Check Truck No. 3

a. Load = 23,848 lb (10,826 kg)

b. Spreader distance = 639 ft (194.9 m)

c. Rate = 23,848/639 × 12/9 = 28.0 lb/yd² (10,826/(194.9 × 3.6) = 15.43 kg/m²)

4. Average Rate = (27.9 + 28.3 + 28.0) / 3 = 28.1 lb/yd²
((15.38 + 15.60 + 15.43) / 3 = 15.47 kg/m²)

5. No adjustment needed since measured rate is within 1 percent of design.

Compensation for moisture on the aggregate must be considered when calibrating chip spreaders. The above example indicates no adjustment is needed since the measured spread rate is within 0.10 lb/yd² (0.05 kg/m²) of the design spread rate. However, if the aggregate above had contained as much as 1.02 percent moisture that was unaccounted for, the application rate would have been too low.

G. *Test Strip.* A test strip shall be constructed on or near the project site. Construct the test strip under similar placement conditions of time of day, temperature, and humidity as expected for the duration of the project. The test strip shall be a minimum of 500 ft (150 m) in length and shall be constructed with the job mix proportions, materials, and equipment to be used on the project. Adjustments to the mixture formula shall be permitted provided they do not exceed the values stated in the mix design. The Agency shall evaluate the test strip to determine whether project specifications are met. If specifications are not met, additional test strips will be constructed until specifications are met, at no additional cost to the Agency.

H. *Application of Asphalt Binder:*

1. Apply the asphalt binder at the rate determined by the design. This rate shall be within ±5 percent of the chip seal design rate. After applying the binder, place the cover aggregate at the design application rate. Adjust the rate of application, if necessary, so that some binder can be seen between the aggregate chips, but not so much that aggregate chips adhere to the pneumatic rollers. Inspect the aggregate in the wheel paths for proper embedment. Embedment shall be 50 to 70 percent after rolling. Make additional adjustments to the rate of application during the project, if needed.

2. The temperature of the binder asphalt at the time of application shall be as recommended by the Contractor and approved by the Engineer. Recommended application temperatures are given in Table 407.5-1.

Table 407.5-1. Suggested Application Temperatures as a Function of Binder Type

Binder Type	Minimum Application Temperature
Asphalt Rubber	375°F [190°C]
Rubber-Modified Asphalt	350°F [177°C]
PG Asphalt Polymer Modified	325°F [163°C]
PG Asphalt Non-Modified	275°F [135°C]

Commentary

If the temperature is lower than 275˚F [135˚C], there is risk of less material being applied than desired due to high viscosity.

The longitudinal construction joint for a single-course chip seal must coincide with the painted lane line or the outside edge of the shoulder. There shall be no overlap of the longitudinal construction joint for a single-application chip seal.

I. *Application of Aggregate:*

1. Aggregates shall be applied immediately after applying the hot asphalt at the design rate using uniformly precoated aggregates heated to 175 to 225˚F (80 to 107˚C) at the time of placement. The longitudinal spread rate shall be measured by placing one measuring pad in front of the spreader at 500-ft intervals for 1,500 ft (150 m intervals for 450 m).

2. The speed of the spreader shall be restricted to prevent the aggregates from rolling. Starting and stopping of the spreader shall be minimized. The edges of the aggregate application shall be sharply defined. Previously used aggregates from sweeping shall not be returned to the stockpile or the spreader for reuse.

Commentary

Although a design was done to determine the aggregate application rate, adjustments are almost always needed in the field. This should be done during the first day of construction to make sure the aggregate quantity is correct. This is best done by observing the appearance of the aggregates after they have been dropped into the asphalt but before rolling. Some asphalt should be visible between the aggregates. If asphalt cannot be seen between the aggregates, the rate is too high. Conversely, too much asphalt showing through between the aggregates will cause pickup on rubber tires.

J. *Transverse Paper Joints.* When beginning a new application of the chip seal transversely abutting the previously placed chip seal, a transverse paper joint shall be used so excess asphalt and chips are not placed at the joint. The transverse paper joint shall be formed by placing 36-in. (1-m) wide kraft paper on top of the previously applied chip seal so the edge of the paper aligns with the joint that will be formed when the previously placed chip seal meets the newly applied chip seal. The asphalt distributor shall begin applying asphalt binder by starting the application on top of the kraft paper. After the distributor moves forward and over the joint, the paper shall be removed.

Commentary

Ideally, the paper should also be placed at the end of the distributor shot as well. This creates a clean edge with the correct asphalt and chip quantity at the joint. The placement of the paper is calculated based on the binder shot rate and the quantity of binder in the distributor. The distance the distributor travels before encountering the paper and turning off the bar should be approximately equivalent to 80 percent of the distributor tank volume. This assures the distributor does not spray until empty, which can result in less asphalt applied than desired at the end of the shot.

K. *Rolling Operations.* Complete the first roller pass as soon as possible but not longer than 2 min after applying the aggregate. Proceed in a longitudinal direction at a speed of 5 to 7 mph (8 to 11 km/h). Three complete roller passes over the aggregate are required. One pass is defined as the roller moving over the aggregate in a single direction. Ensure the rolling is completed quickly enough to embed the aggregate, before the binder cools, and no longer than 15 min after the binder is applied. Position the rollers in echelon so the entire width of the pavement lane is covered in one pass of the rollers.

Commentary

If desired, final rolling may be accomplished using the steel-wheel roller in one pass.

L. *Sweeping.* The removal of loose aggregate material shall commence after final rolling is completed such that the aggregate is not displaced and the asphalt surface is not damaged.

M. *Traffic Control.* The treated roadway shall not be used by the Contractor or its agents until it has been established by the Engineer that the roadway will not be damaged or marred under the action of traffic. The Contractor shall use signs or other traffic control devices to prevent traffic operating on the newly placed chip seal. Any damage to the hot-applied chip seal shall be repaired by the Contractor at no additional cost to the Agency.

N. *Protection of Motor Vehicles.* The Contractor shall be responsible for claims of damage to vehicles until the roadways and shoulders have been swept free of loose aggregate and permanent markings have been applied. If permanent pavement markings are to be applied by Agency forces, the Contractor's responsibility ends after completion of the chip seal.

O. *Fog Seal.* If, in accordance with the plans, a fog seal is applied to the surface of the completed chip seal, spray the fog seal after sweeping and before placement of permanent pavement markings, but not sooner than 24 h after final rolling. Refer to Section 410 for specific requirements for application of fog seal over chip seals.

Commentary

Fog seals are applied to the surface of completed chip seals for two reasons: 1) The dark color provides more contrast to pavement markings, 2) the fog seal provides a slight increase in binder residue to increase aggregate retention.

A fog seal may also be applied to recent hot mix asphalt patches in the pavement to be chip sealed. These fresh hot mix patches can be more absorptive than the surrounding pavement due to higher air void content. The fog seal helps prevent the new chip seal asphalt from being absorbed into the substrate unevenly.

P. *Sequence of Work.* Construct the chip seal so that adjacent lanes are sealed on the same day when possible. If the adjacent lane(s) has not been sealed, sweep all loose aggregate from the unsealed lane(s) before traffic is allowed on the surface without traffic control. The permanent pavement markings shall not be placed for three days after placing the fog seal for waterborne pavement marking or ten days for other types of markings.

Commentary

The chip seal will usually cure within 24 h under dry conditions and temperatures above 60°F (16°C). The fog seal can be applied after the chip seal coat is cured. The fog seal will usually cure within 2 h under dry conditions and temperatures above 60°F (16°C). Interim pavement markings can be placed after the fog seal cures. Do not allow traffic on the fog seal until cured.

Q. *Reserved (Quality Assurance)*

R. *Quality Control:*

1. *General:*

   a. The Contractor is responsible for quality control (QC) of the materials and workmanship and shall submit a QC plan for verifying the quality of the materials and workmanship. The Contractor's QC plan shall include but is not limited to sampling, testing, inspection, monitoring, documentation, and corrective action procedures during transport, stockpiling, and placement operations.

   b. A written quality control plan (QCP) shall be developed which details the Contractors' QC program that meets the requirements of these specifications. The QCP shall be contract specific and signed by the Contractors' representative. Chip seal construction shall not proceed without Agency acceptance of the QCP and QC personnel present on the project. The Contractor shall, at a minimum, provide the name of the person responsible for each position listed below, including their telephone number, email, and their qualifications/certifications.

   c. Failure to comply with these provisions will result in shutdown of the operations until such time as the Contractor's operations are in compliance.

2. *Personnel.* QC staff requirements and responsibilities shall include the following as a minimum:

   a. *QCP Manager.* The person responsible for the execution of the QCP and liaison with the Agency. This person shall be on the project and have the authority to stop or suspend construction operations.

b. *QC Technicians.* The person(s) responsible for conducting QC tests and inspection to implement the QCP. QC technicians shall have Level 2 Aggregate Testing Certification from the American Concrete Institute (ACI) or other accrediting body approved by the Agency.

c. *Certified Crew Members.* Three crew members (job foreman, aggregate spreader operator, and asphalt distributor operator), at a minimum, shall possess a valid chip seal certification and be on the project at all times the chip seal is being constructed. The chip seal certification is administered by the National Center for Pavement Preservation (NCPP) on behalf of AASHTO TSP·2 (Transportation System Preservation Technical Services Program).

3. *Testing Facilities and Equipment:*

a. The laboratory that performs the QC for production can be either qualified or Agency approved. The Contractor shall provide the name of the Agency-approved lab for all tests within the relevant scope of testing.

b. Testing and sampling equipment and measuring devices shall meet the requirements of the specified standards and test methods. The lab shall maintain records of the calibration and maintenance of all sampling, testing, and measuring equipment, and all documents required by the Agency.

c. *Placement Equipment Calibration.* Prior to the commencement of work, the asphalt emulsion distributor and aggregate spreader shall be calibrated in the presence of the Agency representative utilizing the materials to be used on the project. Calibration will be performed consistent with procedures in FHWA-HIF-19-029.

4. *Materials Testing.* Chip seal aggregates and asphalt binders shall be tested for compliance with the specifications. Only asphalt binders from certified or approved sources shall be allowed.

a. *Chip Seal Aggregate Method A or Method B:*

i. *Stockpile.* Aggregate samples shall be taken at the project stockpile site using AASHTO R 90 Method B a minimum of once per day of placement and for every change of source. Samples shall be tested in accordance with AASHTO T 27 to determine compliance with Table 407.4-1 requirements. The testing rate for quality values in Table 407.4-2 shall be once per source. If the material is hauled to a temporary stockpile on the project, sample and test the temporary stockpile. OR

ii. *Hopper during Construction.* Aggregate samples shall be taken from the hopper of the aggregate spreader a minimum of once per day of placement or every change of source. Samples shall be tested in accordance with AASHTO T 27 to determine compliance with Table 407.4-1 requirements. The testing rate for quality values in Table 407.4-2 shall be once per source.

b. *Asphalt Rubber.* For safety reasons, sampling shall be completed at the point of manufacture, at either the terminal or field blending unit. Testing and reporting shall be completed on these samples. At a minimum, the following data shall be reported for all samples:

i. Total quantity of binder in tons;

ii. Tons (Mg) and percentage of ground tire rubber based on total asphalt rubber binder; and

iii. ASTM D6114/D6114M-certified test results.

c. *Rubber-Modified Asphalt:*

i. Only asphalt binder from a certified or approved source is allowed for use.

ii. Verify the RMA meets specifications by obtaining a certificate of compliance for each load provided.

d. *Performance Graded Asphalts:*

i. Only PG asphalt binder from a certified or approved source is allowed for use.

ii. Verify the PG binder meets specifications by obtaining a certificate of compliance for each load provided.

e. *Emulsified Asphalt for Fog Seal:*

i. If required, only emulsified asphalt from certified or approved sources is allowed for use. Verify the asphalt(s) meet the specifications by obtaining certificates of compliance from the supplier.

ii. Verify the application rate of the emulsified asphalt by dividing the volume of emulsified asphalt used by the area chip sealed each day. Allowable variation is ±5 percent of the application rate adjusted from the design quantity. Provide material certification and quality control test results for each batch of emulsified asphalt used on the project. Include the supplier name, plant location, asphalt grade, and batch number on all reports.

5. *Calibration of Equipment and Workmanship.* Describe the equipment and methods used to calibrate the chip spreader and asphalt distributor including:

a. *Longitudinal Application Rates:*

b. *Transverse Application Rates.* Describe the process to be used to ensure:

i. Good workmanship, including asphalt transverse application uniformity;

ii. Transverse joint construction technique;

iii. Longitudinal and transverse joints construction techniques;

iv. Monitoring methods for application rates to minimize bleeding, aggregate loss, and streaking;

v. Rolling operations detailing rolling pattern and number of passes or coverages;

vi. Sweeping operations and schedule; and

vii. Method of controlling traffic.

6. *Documentation.* Describe the documentation and reporting procedures for all QC activities. Include samples of all QC test forms, and inspection and test reports.

7. *Records and Documentation:*

   a. The Contractor shall maintain complete records of all QC tests and inspections.

   b. All QC test results shall be submitted to the Agency as required or at the end of the contract. A material certification shall be submitted from each supplier for each batch of material delivered to the project, including test results.

   c. The QC records shall contain all test and inspection reports, forms and checklists, equipment calibrations, supplier material certificates, and non-conformance and corrective action reports. The QC records shall indicate the nature and number of observations made, the number and type of deficiencies found, the quantities conforming and non-conforming, and the nature of corrective action taken as appropriate for materials as well as workmanship. The QC records shall be available to the Agency at all times, and shall be retained by the Contractor for the life of the contract. The Contractor's documentation procedures shall be subject to approval by the Agency prior to the start of work, and to compliance checks by the Agency during the progress of the work.

8. *Compliance with Specifications.* The Contractor shall attest in writing to the Agency that the chip seal has been constructed in accordance with and meets the requirements of the specifications at the conclusion of the project.

S. *Agency Acceptance:*

1. *General.* The Agency will conduct acceptance sampling, testing, and inspection activities to ensure material quality, correct application rates, rolling, sweeping, and traffic control are within specification requirements. These activities will be done randomly by the Agency.

2. *Acceptance Activities:*

   a. *Materials Testing:*

      i. *Asphalt Binders.* Sample the first shipment and provide one sample for every 50,000 gal (approximately 200 tons) (190,000 L (approximately 180 Mg)) thereafter. Testing of the binders shall be in accordance with AASHTO M 320 or M 332.

ii. *Aggregate:*

Sample aggregate taken from the project stockpile or the aggregate spreader hopper once per day. Samples shall be stored and tested for gradation at the discretion of the Agency. If the results vary from the requirements of AASHTO T 27 Tables 2 and 3, a price reduction shall be applied per the Schedule of Price Reduction prepared by the Agency.

Price adjustments are not included in this guide since most agencies do not use them for this type of treatment.

iii. *Fog Seal Emulsion* (if used). Sample the first shipment and provide one sample for every 50,000 gal (approximately 200 tons) (190,000 L (approximately 180 Mg)) thereafter. Testing of emulsified asphalts shall be in accordance with AASHTO M 140, M 208, and M 316.

b. *Equipment.* All equipment to be used on the project shall be evaluated by the Agency to assure that it is in acceptable operating condition and calibrated correctly, and that it shall provide the quantities of material specified.

c. *Final Inspection.* A final inspection shall be done to assure that no bleeding or flushing, excessive chip loss, or crushing of aggregate has occurred. Longitudinal and transverse joints shall be inspected to assure that no excessive overlap has occurred.

407.6 MEASUREMENT

The Engineer shall measure work acceptably completed as specified below:

A. *When Payment Is by Unit Price:*

1. *Asphalt Binders.* Asphalt binders used for the chip seal will be measured by volume at 60°F (16°C).

2. *Aggregate.* Aggregate will be measured by the area of pavement surfaced.

3. *Fog Seal.* Emulsified asphalt used in the fog seal will be measured by volume at 60°F (16°C).

Commentary

Aggregates can be paid for by the ton, as well. This is easier to verify, but results in an incentive to place more aggregates than necessary. Applying too much aggregate is poor practice and results in dislodgement of embedded aggregates. Also, paying by the ton will result in unnecessary additional cost.

407.7 PAYMENT

Payment for chip seals can be done by either paying for the materials in unit costs, or for the completed chip seal by area of pavement sealed.

Commentary

The advantage of payment by the square yard for a completed chip seal is simplicity if the area is easily defined. The disadvantage is that an incentive is created to reduce material quantities. Reduced asphalt quantities can lead to aggregate loss and vehicle damage.

A. *Payment by Unit Price.* The Agency shall pay for accepted quantities at the contract price as follows:

1. Payment for the accepted quantity of asphalt binder and aggregate for chip seal (including any required additives) at the contract bid price of measure is compensation in full for all costs of furnishing and applying the material as specified.

2. If used, payment for the accepted quantity of the fog seal at the contract bid price of measure is compensation in full for all costs of furnishing and applying the material as specified.

3. Payment shall be made in accordance with the schedule set forth below at the Contract bid price for the specified unit of measure.

Item No.	Item	Unit
State ##	Hot asphalt for chip seal	gal (L)
State ##	Aggregate for chip seal	tons (Mg)
State ##	Diluted emulsion for fog seal, if used	gal (L)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified, including cleaning the existing pavement; stationing; purchase of aggregate; delivery of aggregate; and all labor, equipment, and materials necessary for the placement of the chip seal for full lane coverage, sweeping of any loose aggregate after construction, and other requirements as specified.

B. *Payment for Completed Chip Seal:*

1. Payment for the accepted quantity of the chip seal at the Contract bid unit price of measure is compensation in full for all costs of furnishing and applying the material as specified.

2. Payment shall be made in accordance with the schedule set forth below at the Contract bid price for the specified unit of measure.

Item No.	Item	Unit
State ##	Chip seal	yd^2 (m^2)
State ##	Diluted emulsion for fog seal, if used	gal (L)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 408
MICROSURFACING

408.1 DESCRIPTION

This Section is intended to provide information needed for Owners or Contractors to construct microsurfacing. A microsurfacing is the application of a mixture containing polymer-modified emulsified asphalt, mineral aggregate, mineral filler, water, and other additives that are properly proportioned, mixed, and spread on a paved surface. Microsurfacing shall be constructed on a prepared surface.

This Section refers to quality requirements for materials and a design method for microsurfacing available in other AASHTO documents. However, the main purpose of this specification is to provide guidance for the construction of microsurfacing.

Commentaries are included in this Section to emphasize and further explain the section, present options to be considered by the user, or provide sources of additional information.

408.2 REFERENCED DOCUMENTS

A. *AASHTO Standards:*

- M 140, Emulsified Asphalt
- M 208, Cationic Emulsified Asphalt
- M 316, Polymer-Modified Emulsified Asphalt
- MP 28, Materials for Microsurfacing
- PP 83, Microsurfacing Design
- T 11, Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
- T 27, Sieve Analysis of Fine and Coarse Aggregates

B. *Other Documents:*

- Gransberg, D. *National Cooperative Highway Research Program Synthesis 411: Microsurfacing.* Transportation Research Board, National Research Council, Washington, DC, 2010.
- *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD), 10th ed. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 2009.

408.3 TERMINOLOGY

A. CQS-1P. A quick-setting cationic polymer modified emulsified asphalt.

B. CQS-1hP. A quick-setting cationic polymer modified emulsified asphalt with a harder asphalt residue than CQS-1P.

408.4 MATERIAL

A. *Emulsified Asphalt.* Emulsified asphalt for microsurfacing shall meet the requirements of AASHTO MP 28. The emulsified asphalt properties are determined by the Agency utilizing regional climatic and traffic conditions. Only emulsified asphalt from certified or approved sources is allowed. Each load of emulsified asphalt shall have a certificate of compliance/analysis, which is to be submitted to the Agency daily.

Commentary

The base asphalt used for microsurfacing emulsified asphalt might be a PG 64-22, which is acceptable in moderate to warm climates, whereas in colder climates a PG 58-28 might be more appropriate.

B. *Aggregate.* Mineral aggregates for microsurfacing shall meet the requirements of AASHTO MP 28.

Commentary

The Type II gradation is used mainly on roads and streets to correct moderate surface defects, fill surface voids, and serve as as a wearing surface for medium to heavy traffic. The Type III gradation is used on collectors, arterials, and major highways to improve friction and durability. Rut fill courses using the rut box are recommended to be a Type III. The Type II gradation is a better choice if traffic noise is a concern.

C. *Mineral Filler.* Mineral filler for microsurfacing shall meet the requirements of AASHTO MP 28.

Commentary

Portland cement or aluminum sulfate are the typical mineral fillers used in microsurfacing. The amount to be used is determined by the requirements of the mix design.

D. *Water.* Water for microsurfacing shall meet the requirements of AASHTO MP 28.

Commentary

The amount of water used in microsurfacing is based on the requirements of the mix design. Adjustments to the water content may be made based on field conditions; however, adjustments that negatively affect mix properties or aesthetics shall not be permitted.

E. *Additives.* Additives used in microsurfacing shall meet the requirements of AASHTO MP 28.

Commentary

Additives to control the set of the mixture are applied during placement and are designed to perform with the system. They are typically used when either placement conditions are very warm or the aggregate reactivity requires them to delay premature breaking of the mixture.

408.5 CONSTRUCTION

A. *Weather Limitations.* Microsurfacing shall not be applied if either the pavement temperature or the air temperature is below 50°F (10°C) and falling, but may be applied when both pavement and air temperatures are above 45°F (7°C) and rising. No material shall be applied when rain is expected before the mix is cured. No material is to be applied if temperatures below 32°F (0°C) are expected within 24 h.

B. *Mix Design.* The mix design shall be prepared by an AASHTO-accredited laboratory following AASHTO PP 83 and shall be approved or accepted by the Agency prior to equipment calibration and before beginning the work. Field adjustments to the design are permitted if they are within the overall tolerances set forth in the job mix formula.

C. *Preconstruction Meeting.* Coordinate a preconstruction meeting prior to construction between the Agency and the Contractor to discuss the following topics:

1. Construction process;
2. Quality control plan;
3. Mix design;
4. Materials control;
5. Materials measurement;
6. Equipment calibration;
7. Traffic control plan;
8. Equipment/process overview;
9. Inspection;
10. Test strip;
11. Unique project conditions;
12. Project documentation;
13. Expectations: and
14. Schedule.

Commentary

Unique project conditions can be cul-de-sacs; ramps; shoulders; and excessively rich, flushed, or bleeding surfaces.

D. *Road Surface Preparation:*

1. Clean the pavement surface of all loose material and vegetation, and remove lane striping and thermoplastic pavement markings and other objectionable materials immediately before applying the microsurfacing. Allow all pavement surface cracks to dry thoroughly, if water is used, before applying the microsurfacing mixture. Cover service entrances (e.g., manhole covers, valve boxes) with an approved method. Remove loose aggregate and dried or broken mixture caused by the operation of the equipment.

2. Allow crack sealant material to cure for a minimum of 30 days on pavement surfaces that have been crack sealed before application of the microsurfacing. Waive this requirement if a compatible crack sealant is used that does not require a cure time.

   Commentary

   The sealant should be an asphalt-based material to be compatible. It should be designed to be used under the location and climatic conditions of the project.

3. Apply a tack coat, if required by the Agency, using an emulsified asphalt (an SS, CSS, or microsurfacing grade) meeting the requirements of AASHTO M 140, M 208, or M 316. Dilute the asphalt emulsion for the tack coat with three parts water to one part emulsified asphalt as approved by the Engineer. Apply the diluted tack coat at the rate of 0.05 to 0.10 gal/yd^2 (0.23 to 0.45 L/m^2). Allow the tack to cure sufficiently before the application of the microsurfacing.

   Commentary

   Additional surface preparation items to include are herbicide treatment, oil spot removal, removal of shoulder clippings, and removing raised reflectorized pavement markings. Cracks 0.25 in. (6 mm) or wider shall be sealed. Overbands on the surface shall not exceed 4 in. (100 mm) in width and shall not be greater than $^1/_8$ in. (3 mm) thick. Tack coat is used prior to microsurfacing by a number of agencies. However, if tack coat use is specified in the design, it is applied to an existing surface that is either moderately raveled or composed of a material such as concrete or brick about which there are concerns that the microsurfacing will not properly bond. Tack coats are not recommended to be placed on leveling courses of microsurfacing nor on rut filling. The Contractor should not tack more area than what they plan to pave that day. Tacked areas that are not covered at the end of the paving day should be addressed to prevent slippery pavement surfaces.

E. *Equipment:*

1. *Mixing Equipment:*

   a. Mix materials in a specifically designed paver, either truck-mounted or continuous run machines, as required by the Agency. The paver shall be a continuous-flow mixing unit able to accurately proportion and deliver the aggregate, emulsified asphalt, mineral filler, water, and additives through a revolving multi-blade, double-shafted mixer. The paver shall have enough storage capacity for all the mixture ingredients to maintain an adequate supply to the mixing chamber.

b. The continuous-run machine shall be equipped to provide the operator with full control of the forward and reverse speeds during application. It shall be equipped with opposite-side driver stations to assist in alignment. The self-loading device, opposite-side driver stations, and forward and reverse speed controls shall be of original-equipment-manufacturer design.

c. If a continuous-run machine is required by the Agency to reduce construction joints, use a paver capable of loading materials while continuing to apply microsurfacing.

Figure 408.5-1. Continuous Front-Loaded Self-Propelled (Left) and Truck-Mounted (Right) Microsurfacing Mixing Machines (*Gransberg, 2010*)

Commentary

Truck-mounted machines are generally used for residential streets and locations where construction joints are not undesirable. Continuous-run machines are generally used for arterials, collectors, highways, and airfield applications.

2. *Proportioning Devices.* The paver shall have controls to meter each individual material into the mixing chamber. The rates of the emulsified asphalt and mineral filler addition shall be interconnected or linked to the aggregate delivery system such that the ratios of these materials remain fixed to the job mix formula during the project.

   Note: The verification of material rates and proportions is generally accomplished during the calibration of the machine and should be conducted in the presence of the Agency representative.

3. *Spreading Equipment.* A spreader box shall be equipped with spiral augers that are fixed inside of the box. The spreader box shall be equipped with a front seal to eliminate any loss of the mixture and an adjustable rear seal to control the application rate of the material. The spreader box and rear seal shall be designed to ensure the delivery of a uniform

mixture to the secondary strike-off. The box shall be capable of shifting laterally to compensate for variability in the geometry of the pavement.

4. *Secondary Strike-Off.* The spreading equipment shall be equipped with a secondary strike-off with the same leveling adjustment capabilities as the spreader box to provide a satisfactory surface texture. The secondary strike-off shall be made of neoprene rubber or burlap drag depending on the type of texture required by the Agency.

5. *Rut Filling:*

   a. A rut box specifically designed and manufactured to fill individual ruts shall be provided for each designated wheel track. Rut boxes are used when filling ruts 0.5 in. (12.5 mm) or more in depth. Where ruts exceed 1.0 in. (2.5 mm), multiple passes with the rut box may be necessary.

   b. The rut boxes shall be 5 to 6 ft (1.5 to 1.8 m) wide with a dual chamber and an inner "V" configuration of augers to channel the large aggregate toward the center of the rut and the fines to the edges of the rut. The box shall be equipped with a dual strike-off plate to control the width and depth of the rut fill. All rut filling material should cure under traffic for at least 24 h before additional material is placed.

   c. When ruts depths are less than 0.5 in. (12.5 mm), a full-width scratch course may be applied with the spreader box using a metal or stiff rubber strike-off.

   Commentary

   For every inch of microsurfacing mix, add $^1/_8$ in. (3 mm) to $^1/_4$ in. (6 mm) as a crown to allow for compaction under traffic.

6. *Brooms.* Motorized brooms shall have a positive means of controlling vertical pressure and be capable of cleaning the road surface prior to placing microsurfacing.

7. *Rolling.* Where required by the Agency, a self-propelled, 10-ton (0.9-Mg) (maximum) pneumatic tire roller equipped with a water spray system shall be used. All tires shall be inflated per the manufacture's specifications.

   Commentary

   Rolling of microsurfacing is typically not required except for airfield applications and parking lots or when extreme heat causes a tender mat. When required, the minimum tire pressure should be 90 psi (620 kpa) unless otherwise recommended by the equipment manufacturer. Do not roll until the mat is cured sufficiently to prevent damage; this is typically the morning following application.

F. *Paver Calibration:*

1. Calibrate the paver to be used for the placement of microsurfacing in the presence of the representative from the Agency according to the method recommended by the paver manufacturer.

2. Each paver shall be calibrated prior to the beginning of each project for each aggregate type, or as required by the Agency. The calibration procedure shall include a metered verification for each material used. No paver will be permitted to work until the calibration has been completed and accepted.

G. *Test Strip.* A test strip shall be constructed on or near the project site. If near the site, the pavement conditions must be similar. Construct the test strip under similar placement conditions of time of day, temperature, and humidity as expected for the duration of the project. The test strip shall be a minimum of 500 ft (150 m) in length and shall be constructed, after completion of the calibration, with the job mix proportions, materials, and equipment to be used on the project. Adjustments to the mixture formula shall be permitted provided they do not exceed the values stated in the mix design. The test strip shall be evaluated by the Agency to determine whether project specifications are met. If specifications are not met, additional test strips will be constructed until specifications are met, at no additional cost to the Agency.

Note: The purpose of a test strip is to assure that adequate workmanship, aesthetics, and cure time of the mixture are achievable when applied with the personnel, equipment, and materials intended for use during execution of the project. The requirement for a test strip and an explanation of any specific evaluation methods that will be used should be outlined in the project plans.

H. *Application of Mixture:*

1. For mix consistency and performance, adjustments to the job mix formula are allowed and must remain within the tolerances set forth in the mix design.

2. Wet the surface of the pavement by fogging a fine mist of water ahead of the spreader box when necessary or helpful to promote bonding or reduce surface temperature. The rate of application shall not result in pooling of water on the surface to be paved.

3. In irregular areas not accessible to the spreader box, use hand tools to provide a complete and uniform coverage. These areas shall be cleaned and lightly dampened before placing the mix. The finished texture shall be uniform and have a neat appearance.

4. Where required in the plans, use the rut box to fill ruts and depressions equal to or greater than 0.5 in. (12.5 mm). For ruts of less than 0.5 in. (12.5 mm), a full-width scratch course using the conventional spreader box is acceptable. Where ruts exceed 1 in. (25 mm), multiple passes with the rut box may be necessary.

5. All rut filling shall be allowed to cure under traffic for at least 24 h before the final surface course is placed. Mixtures for filling ruts shall meet the requirements of Type III in AASHTO MP 28. The mixture must meet the longitudinal and transverse profile noted in the project plans.

6. When required in the plans, roll pavement surfaces with a minimum of two full coverage passes after the mixture has cured to the point where it will not be damaged by the roller following the requirements of Subsection 408.5(E)(7).

7. Areas including service entrances, gutters, and intersections shall be cleaned of any debris associated with the placement of the microsurfacing daily. At the direction of the Engineer, sweep raveled aggregate.

   Commentary

   A mist of water also assists with pick-up of crack sealant.

I. *Aggregate Stockpiling, Testing, and Moisture Control:*

1. The gradation of the aggregate stockpile shall not vary by more than the stockpile tolerance from the mix formula while also remaining within the specification grading band. Sampling and testing of the aggregate shall be a minimum of one per each 500 tons (450 Mg) with a sample consisting of three test portions tested in accordance with AASHTO T 27 and T 11.

2. Stockpile moisture can vary due to weather conditions and the Contractor shall take the necessary precautions to protect the aggregate stockpiles and, if necessary, rework the stockpiles to reach an acceptable moisture content as defined in the mix design.

3. The aggregate shall be handled in such a manner as to prevent segregation, mixing of the various materials or sizes, and contamination with foreign materials. The grading of aggregates proposed for use and as supplied to the project shall be uniform. Suitable equipment of acceptable size shall be furnished by the Contractor to maintain the stockpiles and prevent segregation of aggregates. The aggregate shall be passed over a scalping screen immediately prior to transfer to the microsurfacing mixing machine (not prescreened) to remove oversized material.

   Commentary

   For example, the gradation for Type III microsurfacing aggregate is 45 to 70 percent passing of the # 8 sieve (2.36 mm) with a ±5 percent stockpile tolerance. If the mix design shows the Type III aggregate to be 62 percent passing the # 8 sieve (2.36 mm), the allowable variation is 57 to 67 percent passing. If the percentage passing is 67 percent, the allowable variation is 62 to 70 percent.

J. *Application of Aggregate and Emulsified Asphalt.* Verify the application rate of the aggregate and emulsified asphalt over a known area by using the paver's proportions device meters and calibration documents. Provide material certification and quality control test results for each load of emulsified asphalt used on the project. Include the supplier name, plant location, emulsified asphalt grade, and batch number on all reports.

Commentary

The term "yield checks" is sometimes used by industry to refer to application rate. The overall performance of the microsurfacing is related to the proper application rate of the material. It is recommended that the application rate be verified a minimum of four (4) times per day. The factors determined during the calibration process are necessary for the verification of the application rate. In most cases, application rates are based upon pounds of dry aggregate per square yard.

K. *Workmanship:*

1. When placing microsurfacing, the longitudinal and transverse joints shall be uniform, neat in appearance, and shall not contain material build-up or uncovered areas. Longitudinal joints shall be placed on lane lines, edge lines, or shoulder lines and shall have a maximum overlap of 3 in. (75 mm). Longitudinal joints shall be straight in appearance along the centerline, lane lines, shoulder lines, and edge lines. All transverse joints shall be clean and straight. At the start of each day of production and at approaches, place a 5-ft (1.5-m) minimum width of paper/plastic on the existing pavement. Cover all bridge ends with paper/plastic to ensure no microsurfacing is placed on the bridge. Remove the paper/plastic once the microsurfacing has cured and properly dispose of the excess material from the project site. Place and spread all courses as continuously as possible, keeping the number of construction transverse joints to a minimum. When a construction transverse joint is necessary, the paving box shall be full of material. Do not spread (drag) the remaining material. Once the end of the mat and a straight line is created, the paving box shall be lifted, and the remaining material shall be removed and properly disposed of from the project site.

2. Longitudinal lines at intersections, curbs, shoulders, and street ends shall be straight to provide a good appearance. Longitudinal edge lines shall not vary by more than ±2 in. (50 mm) in 100 linear ft (30 m). If the Contractor is unable to meet this requirement, they shall be required to establish a pilot line.

3. The finished surface shall have a uniform texture free from excessive surface defects, ripples, or drag marks. A single drag mark exceeding 0.5 in. (12.5 mm) in width and 6 in. (150 mm) in length or a total of four drag marks within 100 linear ft (30 m) in a single pass are excessive.

4. The Contractor shall produce neat and uniform longitudinal and transverse joints. Transverse joints shall be constructed as butt-type joints. Joints are acceptable if there is no more than 0.25 in. (6 mm) vertical space for longitudinal joints, and no more than 0.25 in. (6 mm) for a transverse joint between the pavement surface and a 10-ft (3 m) straightedge placed perpendicular to the joint.

5. If these criteria are exceeded, the Contractor shall stop work and correct them.

Commentary

Correction of defects is typically made by applying full-lane-width passes of a sufficient length to promote an aesthetic surface. No partial-width corrections should be permitted.

L. *Opening to Traffic:*

1. Do not allow traffic on the newly completed surface course until the mix has set sufficiently to prevent damage to the mixture as determined by the Contractor. Stopping and starting traffic and turning traffic may require additional curing time. Construct the microsurfacing so that adjacent lanes are placed on the same day when possible.

Barricades, signage, and traffic control shall follow the current *Manual on Uniform Traffic Control Devices* (MUTCD) standards.

2. Place temporary pavement markings after the microsurfacing cures. The permanent pavement markings shall not be placed for 10 to 14 days for waterborne pavement markings or per manufacturer's recommendations for other types.

Commentary

Prior to allowing traffic, the Contractor shall broadcast microsurfacing sand or other approved materials as directed by the Engineer over turnouts, intersections, and crossovers as the microsurfacing cures. Once the microsurfacing has properly cured, sweep all loose sand and debris from the intersections/crossovers, and properly dispose of the material. The Contractor shall repair any damaged areas prior to project completion.

M. *Project Documentation.* The Contractor shall supply daily documentation to the Agency that includes the following:

1. Aggregate used, tons (Mg) (dry);
2. Microsurfacing emulsified asphalt used, tons (Mg);
3. Emulsified asphalt for tack coat used, if specified, tons (Mg);
4. Mineral filler used, pounds (kilograms);
5. Water used in mixture, gallons (liters);
6. Additive used in mixture, gallons (liters);
7. Surface area completed, square yards (square meters);
8. Surface area application rate, dry pounds of aggregate per square yard (dry kilograms of aggregate per square meter); and
9. Percentage of emulsified asphalt based on dry aggregate.

N. *Reserved (Quality Assurance)*

408.6 MEASUREMENT

A. The Engineer will measure work acceptably completed as specified in Subsection 109.1.

B. Emulsified asphalt for microsurfacing shall be measured by the gallon (liter). The Contractor will be required to submit certified bills of lading from the emulsified asphalt manufacturer indicating total gallons (liters) delivered. In addition, the Contractor will be responsible for submitting a way-back ticket representing unused material at the conclusion of the project.

C. Aggregate for microsurfacing shall be measured by the ton (Mg) of dry aggregate used. The aggregate usage shall be determined by using the calibration factors. The mineral filler will be counted by the 94-lb (42.6 kg) sack and will be included in the payment for aggregate.

D. The Engineer shall not measure mix water or water used to pre-wet the pavement surface.

408.7 PAYMENT

A. *The Agency will pay for accepted quantities at the contract price as follows:*

1. Payment will be made in accordance with the schedule set forth below at the contract bid price for the specified unit of measure.

Item No.	Item	Unit
State ##	Aggregate for microsurfacing	ton (Mg)
State ##	Polymer-modified emulsified asphalt for microsurfacing	ton (Mg), gal (L)
State ##	Diluted emulsified asphalt for tack coat	ton (Mg), gal (L)
State ##	Filler	ton (Mg)

2. Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals necessary to complete the work as specified. If the materials placed on the project fail to meet the specification requirements, they shall be repaired, or replaced, by the Contractor to the satisfaction of the Agency at no additional cost to the Agency.

Commentary

Some current specifications require the basis of payment be by the square yard (square meter) of material placed because it is easy to measure. If the application rate specified is not verified by the Agency, it is possible they can get an application that is deficient in thickness or low in binder content. Some agencies measure the placement by the amount of material placed by the ton (Mg), but they must monitor the materials by using the measurements provided by the mixing device.

SECTION 409
COLD MILLING ASPHALT PAVEMENT

409.1 DESCRIPTION

Cold mill and remove existing asphalt pavement.

409.2 MATERIAL

Reserved.

409.3 CONSTRUCTION

A. *Milling Equipment.* Use self-propelled milling equipment capable of maintaining accurate cut depth and slope. Ensure the equipment can accurately and adequately establish profile grade and control cross slope. Equip the milling machine with integral material pickup and truck discharges, if specified. Ensure the milling machine has effective means for dust control.

B. *Milling.* Cold mill the existing pavement to the specified profile grade and cross section. Taper the transverse joint at the end of each day's run. Unless specified otherwise, dispose of the reclaimed pavement in a manner approved by the Engineer.

C. *Surface Tests.* Meet the specified surface tolerance, as verified using a 10-ft (3-m) rolling straightedge operated parallel to centerline. Ensure no variation greater than ($^1/_4$ in. (6 mm)).

409.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

409.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Cold milling asphalt pavement	yd^2 (m^2), ton (Mg), mi (km), station
(B) Cold milling ______ in. (mm) depth	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 410
EMULSIFIED ASPHALT FOG SEAL (NEW)

410.1 DESCRIPTION

This Section is intended to provide information needed for Owners or Contractors to construct emulsified asphalt fog seals. An emulsified asphalt fog seal is the application of emulsified asphalt, either diluted or undiluted, to a prepared pavement surface and may be followed immediately by a light application of blotter aggregate. Fog seals are intended as a barrier to air and water infiltration of a pavement surface, to arrest low-severity raveling, or to create color contrast between traffic markings and the paved surface.

This Section refers to quality requirements for materials and methods used to construct fog seals.

All units of measurement are expressed in inch-pound units, with SI units given in parentheses.

Commentaries are included in this Section to emphasize and further explain the section, present options to be considered by the user, or provide sources of additional information. An example of these commentaries is shown below:

Commentary

This Section covers construction of emulsified asphalt fog seals that are often used on emulsified asphalt, hot-applied chip seals, or on newly placed hot mix asphalt in accordance with AASHTO M 318. The fog seal will help blacken the chip seal and also help with rock retention.

410.2 REFERENCED DOCUMENTS

A. *AASHTO Standards:*

- M 140, Emulsified Asphalt
- M 208, Cationic Emulsified Asphalt
- M 316, Polymer-Modified Emulsified Asphalt
- M 318, Standard Specification for Glass Cullet Use for Soil-Aggregate Base Course
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 304, Uncompacted Void Content of Fine Aggregate

B. *ASTM Standard:*

- D5624, Standard Practice for Determining the Transverse-Aggregate Spread Rate for Surface Treatment Applications

C. *Other Document:*

- Martin, R. S., Jr. Chip Seal Practice. *Proc., 26th Paving and Transportation Conference*, Department of Civil Engineering, University of New Mexico, Albuquerque, New Mexico, January 1989.

410.3 TERMINOLOGY

A. CSS-1h. A cationic emulsified asphalt that is slow setting, low viscosity, and has a residual binder residue with lower penetration than CSS-1, which can use a softer and higher-penetration residual asphalt.

B. SS-1h. An anionic emulsified asphalt that is slow setting, low viscosity, and has a residual binder residue with lower penetration than SS-1, which can use a softer and higher-penetration residual asphalt.

410.4 MATERIALS

A. *Emulsified Asphalt*. Emulsified asphalt for fog seals shall meet the requirements of AASHTO M 140 or M 208. Fog seal emulsified asphalt may be diluted with water prior to application but must be diluted at the emulsified asphalt plant and not diluted in the construction field. The residual asphalt content shall not be less than 28 percent by weight of the total mixture.

Commentary

Emulsified asphalts diluted with water can be less stable than the emulsified asphalt concentrate that was diluted. Maximum shelf life expectancy of the diluted emulsified asphalt is two days unless otherwise noted by the manufacturer. Most manufacturers recommend using diluted emulsified asphalt on the same day it is diluted.

B. *Blotter Aggregate.* When blotter aggregate is used in fog seals, the aggregate size to be used will be as shown in the plans or other contract documents or the requirements shown in Table 410.4-1. Aggregate shall be crushed by mechanical means and shall have a minimum void content of 45 percent as determined by AASHTO T 304. The normal application rate for blotter aggregate can vary from 1 to 3 lb/yd^2 (0.5 to 1.6 kg/m^2).

Table 410.4-1. Blotter Aggregate

Sieve Size, T 27	Passing, percent
No. 8 (2.36 mm)	100
No. 16 (1.18 mm)	50–85
No. 30 (600 μm)	25–60
No. 50 (300 μm)	5–30
No. 200 (75 μm)	0–10

Commentary

Blotter aggregate is sometimes used to absorb any excess emulsified asphalt that may occur on the pavement surface due to over-application or because of pooling in low areas of the pavement. The normal application rate is 1 to 3 lb/yd^2 (0.5 to 1.6 kg/m^2).

410.5 CONSTRUCTION

A. *Weather Limitations:*

1. Construct fog seal per the following conditions:

   a. Ambient or pavement surface temperatures shall be 60°F (16°C) and rising;

   b. Application of the fog seal shall be only during daylight hours;

   c. The road surface shall be dry;

   d. Temperatures below 40°F (4°C) are not anticipated for at least 24 h after application;

e. Sustained winds are less than or equal to 10 mph (16 km/h); and

f. Application shall be completed at least 2 h before sunset.

2. Suspend fog seal operations when rain is expected before the fog seal emulsified asphalt can set.

Commentary

A skirt can be attached to the asphalt distributor if winds are above 10 mph (16 km/h) to prevent the emulsified asphalt from blowing onto passing vehicles.

B. *Application Rate.* The emulsified asphalt application rate for the fog seal shall be between 0.015 gal/yd^2 [0.068 L/m^2] of residual asphalt binder for dense graded asphalt pavements to 0.039 gal/yd^2 [0.177 L/m^2] for chip seals with aggregates larger than $^1/_2$ in. (12.5 mm). Target rates are shown in Table 410.5-1 for four types of typical pavement surfaces. The actual rate used for a specific pavement shall be determined using a test strip or by the ring test described below.

Table 410.5-1. Initial Target Fog Seal Application Rate

US Standard Version

Surface Type	Residual Rate, gal/yd^2	Undiluted, gal/yd^2 [a]	Diluted 1:1, gal/yd^2
Dense-Graded Asphalt Mixture	0.015–0.021	0.025–0.035	0.05–0.07
Open-Graded Asphalt Mixture	0.021–0.027	0.035–0.045	0.07–0.09
Chip Seal (<1/2 in. top agg. size)	0.027–0.033	0.045–0.055	0.09–0.11
Chip Seal (≥1/2 in. top agg size)	0.029–0.039	0.055–0.065	0.11–0.13

[a] The undiluted application rate assumes an emulsified asphalt residual binder content of 60 percent and a water content of 40 percent.

SI Version

Surface Type	Residual Rate, L/m^2	Undiluted, L/m^2 [a]	Diluted 1:1, L/m^2
Dense-Graded Asphalt Mixture	0.068–0.095	0.113–0.158	0.023–0.032
Open-Graded Asphalt Mixture	0.095–0.122	0.158–0.204	0.032–0.407
Chip Seal (<1/2 in. top agg. size)	0.122–0.149	0.204–0.249	0.407–0.498
Chip Seal (≥1/2 in. top agg size)	0.149–0.177	0.249–0.294	0.498–0.589

[a] The undiluted application rate assumes an emulsified asphalt residual binder content of 60 percent and a water content of 40 percent.

C. *Ring Test:*

1. *Sample Selection.* Sweep the section of road to be fog sealed clean of debris and dust.

2. *Test Procedure:*

a. Draw three 6-in. [152.4-mm] diameter circles on the swept pavement.

b. Select three target application rates and translate them to the required volume of emulsified asphalt from Table 410.5-2.

c. Label each circle with its application rate.

d. Use a 10-mL graduated cylinder to pour the required amount of emulsified asphalt into the center of each circle. Evenly distribute the material within the circle.

e. The ideal application rate will evenly and completely cover the pavement within the circle, with no emulsified asphalt draining outside.

f. Record the optimal application rate.

Table 410.5-2. Amount of Emulsified Asphalt for Ring Test

gal/yd^2	mL (6-in. circle)
0.05	4.2
0.06	5.0
0.07	5.8
0.08	6.6
0.09	7.4
0.10	8.3
0.11	9.1
0.12	10.0
0.13	12.8

All design work will be carried out using the emulsified asphalt to be used on the job site or using equivalent material from the same source and having substantially the same material properties.

Commentary

The ring test is especially recommended when the pavement surface to be fog sealed is tight and dense and excess emulsified asphalt could result.

D. *Preconstruction Meeting.* Coordinate a preconstruction meeting prior to construction with the Engineer to discuss the following topics:

1. Mix design, required to be submitted;

2. Materials control;

3. Materials measurement;

4. Equipment calibration, required to be submitted;

5. Traffic control plan;

6. Equipment/process overview;
7. Inspection;
8. Test strip;
9. Unique project conditions;
10. Project documentation; and
11. Expectations.

E. *Road Surface Preparations:*

1. *Cleaning Pavement.* Clean the roadway surface by sweeping no more than 30 min prior to application of the emulsified asphalt fog seal. This 30-min window may be extended if authorized by the Engineer in cases where extending the time does not jeopardize a clean surface prior to fog seal operations. Sweep the pavement with a motorized broom to remove loose material. Clean depressions not reached by the motorized broom with a hand broom. Clean the outer edges of the pavement to be sealed, including an adjacent paved shoulder.

2. *Protecting Accessories.* Cover utility castings (e.g. manholes, gate valve covers, catch basins, sensors) to prevent coating with emulsified asphalt. Suitable coverings include plywood disks, kraft paper, roofing felt, or other approved materials. Remove the protective coverings before opening the road to traffic.

F. *Equipment:*

1. *Asphalt Distributor.* The asphalt distributor shall have a ground speed control device interconnected with the emulsified asphalt pump such that the specified application rate will be supplied at any speed. The asphalt distributor shall be capable of maintaining the emulsified asphalt at the specified temperature. The spray bar nozzles shall produce a uniform double lap application fan spray, and the shutoff shall be instantaneous, with no dripping. All nozzles shall be oriented at the same angle between 15 and 30 degrees, using the wrench supplied by the distributor manufacturer and as described below in Subsection 410.5(G).

2. *Blotter Aggregate Spreader.* If a spreader is used, it shall be a self-propelled mechanical-type aggregate spreader with a computerized spread control, capable of distributing the blotter aggregate uniformly to the required width and at the designed rate, shall be used. The spreader shall be mounted on pneumatic-tired wheels.

3. *Brooms.* Motorized brooms with a positive means of controlling vertical pressure shall be used to clean the road surface prior to spraying emulsified asphalt.

Commentary

Vacuum brooms are preferred in urban or residential areas, but push brooms are acceptable in rural areas where debris scattered off the roadway does not pose a hazard to pedestrians or vehicles.

4. *Trucks*. Unless otherwise approved, use trucks of uniform capacity to deliver the aggregate.

G. *Equipment Calibration:*

1. The Contractor shall provide proof of calibration of the asphalt distributor and the aggregate spreader if a blotter aggregate is applied to the fog seal. Calibration shall be conducted no earlier than five days prior to fog seal operations. The Contractor shall submit the results of the calibration procedure to the Engineer.

2. Flow from each nozzle in the asphalt distributor must be within ±10 percent of the average flow of all nozzles as measured by the procedure described below.

3. Uniformity of the blotter aggregate applied transverse to the pavement centerline shall be in accordance with ASTM D5624. Tolerance for each pad tested for transverse spread rate shall be ±10 percent of the average of the total transverse rate.

Commentary

Calibration is very important to assure that the quantities of emulsified asphalt and blotter sand applied to the pavement are correct. Although many modern asphalt distributors and aggregate spreaders are computer controlled, calibration is required to tell the computer how much emulsified asphalt is being applied. This quantity must be checked prior to spraying emulsified asphalt and spreading blotter aggregate and checked against the quantity that the computer (if the distributor is so equipped) indicates is being applied.

4. *Asphalt Distributor:*

a. All nozzles shall be the same size, provide the same flow rate, be oriented in the same direction, and be the same distance above the pavement.

Commentary

The asphalt distributor applies emulsified asphalt to the pavement surface. This application must be done uniformly both transverse and longitudinal to the centerline of the pavement.

b. When lower application rates are determined to be necessary or are shown in the plans, smaller nozzles shall be inserted in the spray bar where the emulsified asphalt rate is reduced.

Commentary

Due to minor rutting or heavy truck traffic, it may be desirable to reduce the emulsified asphalt application rate in the wheel paths.

c. *Nozzle Angle:*

i. Nozzles shall be positioned at an angle of 15 to 30 degrees from the horizontal of the spray bar in accordance with the manufacturer's recommendation. All nozzles shall spray a full fan except for the right and left edge nozzles. The right and left edge nozzles shall be adjusted to a half fan such that the spray stays to the inside of the spray bar.

Commentary

The next step in calibrating the distributor is adjustment of the spray bar nozzle angles. Each nozzle has a slot cut across the face of the nozzle. When the nozzle is threaded into the spray bar, the slots should all be positioned at an angle of 15 to 30 degrees to the direction of the spray bar, as shown in Figure 410.5-1. This angle provides the best position for achieving uniformity in the spray and the triple overlap coverage. The angle should be adjusted using the wrench supplied with the distributor. This wrench is designed, when used properly, to set the correct angles for each nozzle. Any wrench that fits the hexagonal nozzle can adjust the nozzle angle, but correctness of the angle would have to be visually verified.

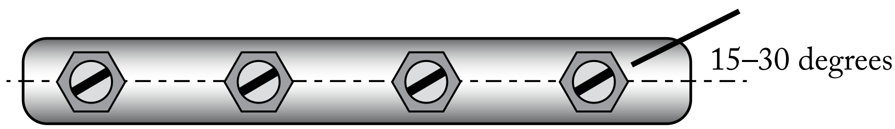

Figure 410.5-1. Spray Bar Nozzle Orientation in Spray Bar

ii. The angle at which the nozzles are positioned shall be adjusted using the wrench supplied with the distributor. However, in cases where this wrench is unavailable, a wrench that fits the hexagonal nozzle will suffice but the angle must be judged visually.

iii. All nozzles fitted to the spray bar shall be full fan nozzles except for the right and left edge nozzles. These nozzles shall be half fan nozzles adjusted so the spray from the nozzle remains to the inside of the spray bar.

d. *Spray Bar Height*. The spray bar height must be adjusted so that the emulsified asphalt provides complete coverage across the entire spray width in two or three overlaps.

Commentary

Streaking of the emulsified asphalt will occur if the spray bar is set too high or too low, as shown in Figures 410.5-2 and 410.5-3.

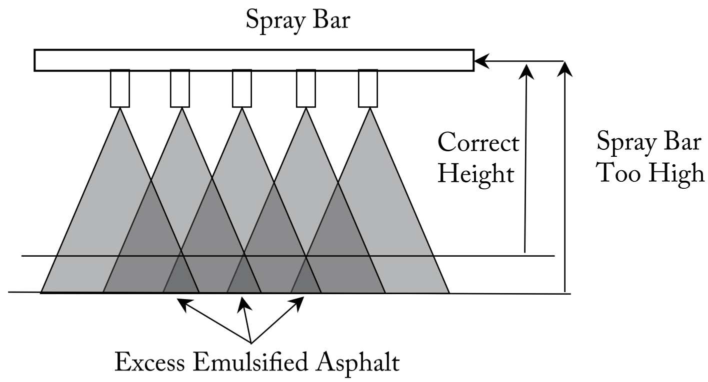

Figure 410.5-2. Streaks with Spray Bar Too High for Double Overlap

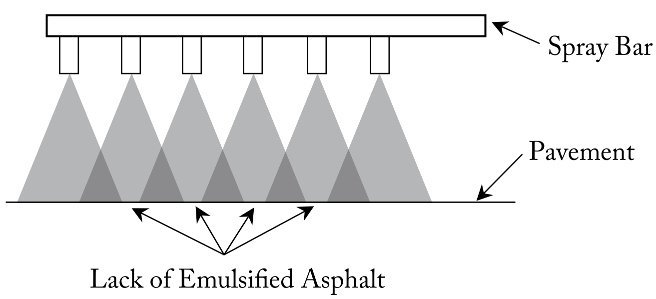

Figure 410.5-3. Streaks with Spray Bar Too Low for Double Overlap

To avoid this streaking, the bar must be adjusted to the correct height. This adjustment process is accomplished by shutting off nozzles to determine where the spray pattern contacts the pavement, as shown in Figures 410.5-4 and 410.5-5.

i. *Bar Height Adjustment to Achieve Double Lap:*

Every other nozzle shall be turned off when a double lap application is desired, as shown in Figure 410.5-4. The distributor operator shall spray emulsified asphalt onto the pavement surface for as short an interval as possible while an observer watches where the emulsified asphalt hits the pavement from each nozzle left open. If there is overlap of emulsified asphalt from adjacent nozzles, the bar is too high. If there is a lack of emulsified from adjacent nozzles, the bar is too low.

Once it is confirmed that the bar height is correct, the nozzles that were turned off can be turned back on and a double application of emulsified asphalt will result when spraying resumes.

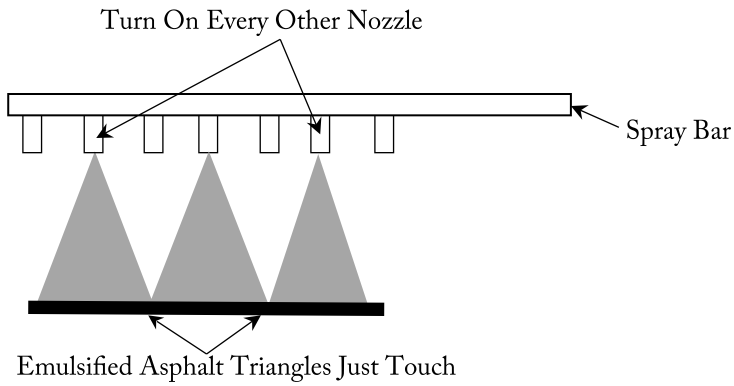

Figure 410.5-4. Adjustment of Spray Bar Height for Double Overlap

ii. *Triple Lap Application Bar Height Adjustment:*

Every third nozzle shall be turned off when a triple lap application is desired, as shown in Figure 410.5-5. The distributor operator shall spray emulsified asphalt onto the pavement surface for as short an interval as possible while an observer watches where it hits the pavement from each nozzle left open. If there is overlap of emulsion from adjacent nozzles, the bar is too high. If there is a lack of emulsified asphalt from adjacent nozzles, the bar is too low.

Once it is confirmed that the bar height is correct, the nozzles that were turned off can be turned back on and a triple application of emulsified asphalt will result when spraying resumes.

As the distributor empties during spraying, the bar height will rise. However, this is not usually enough to cause significant streaking worth adjustment of the spray bar.

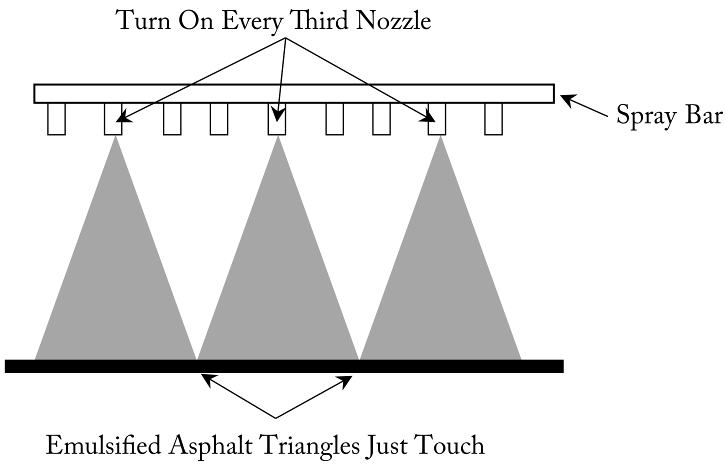

Figure 410.5-5. Adjustment of Spray Bar Height for Triple Overlap

e. *Transverse Flow Rate.* The flow rate across the spray bar shall be uniform with each nozzle spraying within ±10 percent of the average flow rate.

Commentary

A uniform flow rate is achieved by measuring the width of the slot in the nozzle and by measuring the orifice diameter. Also, some nozzles are labeled by the manufacturer. Manufacturers supply a list of nozzles in the owner's document describing which nozzles shall be used for various application rates or on a placard mounted on the equipment.

However, nozzles of the same apparent size have been measured with different flow rates. Therefore, it is recommended that all nozzles be checked for flow rate before fog seal operations begin. This is easily accomplished by fabricating a flow apparatus (Martin, 1989). This apparatus consists of a pipe to which each nozzle, in turn, can be fitted on one end and a water source can be fitted on the other end. The flow of water through each nozzle shall be measured by filling a 1-gal (4-L) container in a measured period. This shall be done for each nozzle to be used on the project. If the flow rate of any nozzle is greater than ±10 percent of the average of all the nozzles to be used, the noncompliant nozzles shall be discarded, or modified to flow within the ±10 percent tolerance.

Determination of uniform lateral flow from the spray bar is determined by collecting a measured volume of emulsified asphalt in containers placed under each nozzle. This process is practical using standard 6-in. by 12-in. (150-mm by 300-mm) concrete cylinder molds lined with 1-gal (4-L) resealable freezer bags. The cylinder molds can be reused, and the freezer bags discarded appropriately with the contents.

f. *Longitudinal Flow Rate.* The longitudinal flow rate shall be accomplished by measuring the volume of emulsified asphalt in the distributor before and after spraying enough emulsified asphalt to reduce the volume of emulsified asphalt in the distributor by 70 to 90 percent.

Commentary

The longitudinal flow rate must be measured with all nozzles inserted in the distributor bar. First, the quantity of emulsified asphalt in the truck must be determined. Although there is a volume indicator on the rear of most modern distributors, these are not calibrated in small enough increments to be of use for longitudinal flow rate calibration and shall not be used for this purpose. Instead, the dipstick supplied with the distributor must be used. This dipstick is usually carried on the top of the tank near the inspection hatch. Prior to shooting emulsified asphalt, take a volume reading with the dipstick.

Pay attention to how the dipstick is used. Many dipsticks are not intended to be submerged in the emulsified asphalt, but instead, are inserted into the top of the tank only until the tip of the dipstick touches the surface of the emulsified asphalt. Then, the volume in the tank is read by indexing the top of the inspection cover to the reading on the dipstick.

- *Record this volume as "beginning volume."*
- *Set up the truck to shoot emulsified asphalt and shoot a minimum of 3000 ft by 12 ft (1000 m by 3.6 m) of emulsified asphalt at the design rate using the gallon per minute pump flow volume and truck speed required by the manufacturer to attain this flow rate.*
- *Take a second dipstick reading.*
- *Record this reading as "ending volume."*
- *Subtract ending volume from beginning volume and record this as "volume used."*
- *Determine the area emulsified asphalt sprayed. Divide volume used by the area sprayed in square yards. This is the gallons per square yard applied to the pavement.*
- *This value shall then be compared to the distributor computer, if equipped, to evaluate the accuracy of the computer.*
- *A correction factor may then be applied to the computer output, if needed, and used for the remainder of the day. This calibration shall be accomplished each day.*

An example of this calibration is presented below:

1800-gal (6800-L) capacity asphalt distributor

12-ft (3.6 m) wide spray width

Trial spray distance = 22500 ft (6800 m)

0.05-gal/yd^2 (0.23 L/m^2) design spray rate

Dipstick reading beginning volume = 1765 gal (6680 L)

Dipstick reading ending volume = 265 gal (1000 L)

Calculations:

1. *Check to see if enough volume shot. 1765–265 = 1500 gal (6680–1000 = 5680 L)*
2. *1500/1765 (5680/6680) = 85 percent > 70 percent and < 90 percent.*
   OK, enough applied to be valid
3. *Calculate spray rate = 1500 gal/(12 × 22500/9) = 0.05 gal/yd²*
   (5680 L/(3.6 m × 6800 m) = 0.23 L/m²)

Therefore, distributor is set up correctly.

5. *Aggregate Spreader:*

   a. *Transverse Spread Rate.* The blotter aggregate shall be uniform when placed on the fog seal to aid in preventing tracking of the emulsified asphalt.

   Commentary

   A visual assessment of the distribution of the blotter aggregate is a good place to start the process, since non-uniform distribution can easily be seen. The veil of blotter aggregate deposited on the pavement from the spreader box can be viewed from behind with the spreader moving away from the observer or from the front. Either position for the observer is adequate for viewing how uniform the veil of blotter aggregate is falling out of the spreader box. However, viewing from either front quarter affords the observer a better view of the entire spreader width and is, of course, safer than directly in front of the spreader. Any variation in light passing through the veil of blotter aggregate indicates variation in application rate. More light means a lack of blotter aggregate. Variation in light means the machine shall be stopped, the gates on the spreader contributing to the non-uniformity adjusted, and the trial rerun. This procedure provides adjustment to the transverse spread rate. Then, to obtain an objective means of measuring the amount of blotter aggregate being deposited, ASTM D5624 is a good procedure to use.

   b. *Longitudinal Spread Rate:*

      i. The longitudinal spread rate shall be uniform and be within ±10 percent of the design spread rate.

      Commentary

      Once the transverse spread rate is adjusted the longitudinal rate can be adjusted. This is also done visually, at first. This shall be done well before the emulsified asphalt begins to break or set, but not immediately after spraying unless temperature, wind, or high demulsibility demand it.

      ii. The application rate of the blotter aggregate shall be similar to the design rate. This is a rate where, immediately upon dropping the blotter aggregate, the appearance of the surface has some emulsified asphalt showing. In fact, the quantity should seem somewhat inadequate. The spread rate should not be low enough to cause pickup problems on rubber-tire rollers. However, the rate should be such that a small decrease in rate would cause pickup. Emulsified asphalt should be visible between the aggregate upon dropping and before rolling. It is the responsibility of the construction superintendent to achieve this application rate.

Commentary

Evaluating the quantity of the blotter aggregate being placed is important after the rate is established. This provides a quantitative baseline for future work. The best method to accomplish this evaluation is by weighing the aggregate spreader before and after applying the blotter aggregate and calculating the spread rate based on the area covered. This is often not practical. Therefore, a suitable alternative includes estimating the quantity of spread over a known area by knowing the weight of each transport truck supplying the spreader and dividing the estimated weight of spread by the area covered for that load.

An example follows:

Given:

Trucks loading the aggregate spreader are 12-ton (11 Mg) capacity tandem dumps

12-ft (3.6-m) wide pavement

28 lb./yd² (15.42 kg/m²) design spread rate

Calculations:

1. *Check Truck No. 1*
    a. *Load = 23,803 lb (10,628 kg)*
    b. *Spreader distance = 6400 ft (1950 m)*
    c. *Rate = 23,803/(6400 × 12/9) = 2.79 lb/yd²*
    (10,628/(1950 × 3.6) = 1.514 kg/m²)
2. *Check Truck No. 2*
    a. *Load = 23,921 lb (10,658 kg)*
    b. *Spreader distance = 6340 ft (1930 m)*
    c. *Rate = 23,921/(6340 × 12/9) = 2.83 lb/yd²*
    (10,658/(1930 × 3.6) = 1.534 kg/m²)
3. *Check Truck No. 3*
    a. *Load = 23,848 lb (10,637 kg)*
    b. *Spreader distance = 6390 ft (1940 m)*
    c. *Rate = 23,848/(6390 × 12/9) = 2.80 lb/yd²*
    (10,637/(1940 × 3.6) = 1.523 kg/m²)

4. *Average Rate = (2.79 + 2.83 + 2.80) / 3 = 2.81 lb/yd²*
((1.514 + 1.534 + 1.523) / 3 = 1.524 kg/m²)

5. *No adjustment needed since measured rate is within 1 percent of design.*

Compensation for moisture on the aggregate must be considered when calibrating spreaders. The above example indicates no adjustment is needed since the measured spread rate is within 0.10 lb/yd² (0.05 kg/m²) of the design spread rate. However, if the above had contained as much as 1.02 percent moisture that was unaccounted for, the application rate would have been too low.

H. *Test Strip.* Construct a 500-ft (150-m) test strip and adjust the application rate as needed to assure a uniform application of the fog seal is applied with no streaking. Apply the fog seal to minimize the amount of overspray and do not allow traffic on the fog seal until it has cured. The application rate shall not result in an excess of emulsified asphalt that could run off the pavement area to be sealed.

Commentary

Care should be taken to ensure the fog seal application rate does not cause a significant reduction in the surface texture of the pavement.

I. *Application of Emulsified Asphalt:*

1. Apply the emulsified asphalt at the rate determined by the test strip or the ring test within ±5 percent. After applying the emulsified asphalt, place the blotter aggregate at an application rate that just covers the emulsified asphalt or is sufficient to blot excess emulsified asphalt.

2. The temperature of the emulsified asphalt at the time of application shall be above 120°F.

Commentary

If the temperature is lower than 120°F (50°C), there is risk of less material being applied than desired due to high viscosity.

3. The longitudinal construction joint for a fog seal must coincide with the painted lane line or the outside edge of shoulder. There shall be no overlap of the longitudinal construction joint.

4. Allow the fog seal to cure undisturbed for at least 2 h or until the emulsified asphalt breaks and is substantially tack free. Cover unabsorbed asphalt with blotter aggregate to protect traffic or minimize rain damage. Remove excess blotter aggregate after the asphalt is absorbed by sweeping.

J. *Application of Blotter Aggregate.* Blotter aggregate shall be used for two purposes: 1) to blot excess emulsified asphalt prior to opening to traffic, and 2) to provide friction. After the emulsified asphalt has been sprayed and has begun to set, apply the blotter aggregates with the aggregate spreader if uniform transverse and longitudinal application on the pavement is required. Blotter aggregates may be applied by hand when localized areas requiring blotting of excess emulsified asphalt are present.

K. *Transverse Paper Joints.* When beginning a new application of the fog seal transversely abutting the previously placed fog seal, a transverse paper joint shall be used so excess asphalt and aggregates are not placed at the joint. The transverse paper joint shall be formed by placing 36-in. (1-m) wide kraft paper on top of the previously applied fog seal so the edge of the paper aligns with the joint that will be formed when the previously placed fog seal meets the newly applied fog seal. The asphalt distributor shall begin applying emulsified asphalt by starting the application on top of the kraft paper. After the distributor moves forward and over the joint, the paper shall be removed.

Commentary

Ideally, the paper should also be placed at the end of the distributor shot as well. This creates a clean edge with the correct fog seal quantity at the joint. The placement of the paper is calculated based on the emulsified asphalt shot rate and the quantity of emulsified asphalt in the distributor. The distance the distributor travels before encountering the paper and turning off the bar should be approximately equivalent to 80 percent of the distributor tank volume. This assures the distributor does not spray until empty, which can result in less emulsified asphalt applied than desired at the end of the shot.

L. *Traffic Control.* Traffic may be allowed onto the newly placed fog seal after the emulsified asphalt has completely set and after blotter aggregates have been applied.

M. *Protection of Motor Vehicles.* The Contractor shall be responsible for claims of damage to vehicles until the roadways and shoulders have been swept free of loose aggregate and permanent pavement markings have been applied. If permanent pavement markings are to be applied by Agency forces, the Contractor's responsibility ends after completion of the fog seal and placement of temporary pavement markings.

N. *Sequence of Work:*

1. Construct the fog seal so that adjacent lanes are sealed on the same day when possible. If the adjacent lane(s) has not been sealed, sweep all loose aggregates from the unsealed lane(s) before traffic is allowed on the surface without traffic control.

2. The permanent pavement markings shall not be placed for three days after placing the fog seal for waterborne pavement marking or ten days for other types.

3. If fog sealing a new chip seal, the fog seal can be applied after the chip seal coat is cured, typically 1 to 2 days after construction.

4. Permanent pavement markings shall not be placed for three days after placing the fog seal.

Commentary

The fog seal will usually cure, or set, within 2 h under dry conditions and temperatures above 60°F (16°C). Interim pavement markings can be placed after the fog seal cures.

O. *Quality Control:*

1. *General:*

    a. The Contractor is responsible for quality control (QC) sampling and testing and shall submit a QC plan including materials and procedures for verifying the quality of the fog seal aggregates and emulsified asphalt(s). The Contractor's QC plan shall include but is not limited to sampling, testing, inspection, monitoring, documentation, and corrective action procedures during transport, stockpiling, and placement operations.

    b. A written quality control plan (QCP) shall be developed, which details the Contractor's QC program meeting the requirements of these specifications. The QCP shall be contract-specific and signed by the Contractor's representative. Fog seal construction shall not proceed without Agency acceptance of the QCP and QC personnel present on the project. Failure to comply with these provisions will result in shutdown of the operations until such time as the Contractor's operations are in compliance.

2. *Personnel.* The QC staff shall include the following as a minimum:

    a. *QCP Manager.* The person responsible for the execution of the QCP and liaison with the Agency. This person shall be on the project and have the authority to stop or suspend construction operations.

    b. *QC Technicians.* The person(s) responsible for conducting QC tests and inspection to implement the QCP. QC technicians shall have Level 2 Aggregate Testing Certification from the American Concrete Institute (ACI) or other accrediting body approved by the Agency.

    c. *Certified Crew Members.* Three crew members (job foreman, aggregate spreader operator, and asphalt distributor operator), at a minimum shall possess a valid fog seal certification and be on the project at all times the fog seal is being constructed. The fog seal certification is administered by the National Center for Pavement Preservation (NCPP) on behalf of AASHTO TSP·2 (Transportation Services Preservation Program).

3. *Testing Facilities and Equipment.* The Contractor shall provide the name of the laboratory conducting QC tests and the laboratory shall be qualified or approved by the Agency for all testing within the relevant scope of testing. Sampling, testing, and measuring devices shall meet the requirements of the specified standards and test methods. The laboratory shall maintain records of the calibration and maintenance of all sampling, testing, and measuring equipment.

4. *Materials Testing.* Blotter aggregate and emulsified asphalt shall be tested for compliance with the specifications as follows:

    a. *Aggregate:*

        i. *Stockpile.* Test the blotter aggregate gradation a minimum of once per day in accordance with AASHTO T 27 to determine compliance with Table 410.5-1 requirements. If the material is hauled from the production site to a temporary stockpile, test at the temporary stockpile.

ii. *Construction.* Test the blotter aggregate gradation from the hopper of the fog spreader a minimum of once per day in accordance with AASHTO T 27 to determine compliance with Table 410.5-1 requirements. The testing rate for quality values shall be once per source.

b. *Emulsified Asphalt:*

i. Only emulsified asphalt from certified or approved sources is allowed for use. Verify the emulsified asphalt(s) meet the specifications by obtaining certificates of compliance from the supplier.

ii. Verify the application rate of the emulsified asphalt by dividing the volume of emulsified asphalt used by the area fog sealed each day. Allowable variation is ±5 percent of the application rate adjusted from the design quantity. Provide material certification and quality control test results for each batch of emulsified asphalt used on the project. Include the supplier name, plant location, emulsified asphalt grade, and batch number on all reports.

5. *Calibration of Equipment and Workmanship.* Describe the equipment and methods used for equipment calibration and workmanship as follows:

a. Longitudinal application rates,

b. Transverse application rates,

c. Asphalt transverse application uniformity,

d. Transverse joint construction technique,

e. Monitoring method for application rates,

f. Sweeping operations and schedule, if aggregate is applied, and

g. Method of controlling traffic.

6. *Documentation.* Describe the documentation and reporting procedures for all QC activities. Include samples of all QC test forms and inspection and test reports.

7. *Records and Documentation:*

a. The Contractor shall maintain complete records of all QC tests and inspections.

b. All QC test results shall be submitted to the Agency as required or at the end of the contract. A material certification shall be submitted from each supplier for each batch of material delivered to the project, including test results.

c. The QC records shall contain all test and inspection reports, forms and checklists, equipment calibrations, supplier material certificates, and non-conformance and corrective action reports. The QC records shall indicate the nature and number of observations made, the number and type of deficiencies found, the quantities conforming and non-conforming, and the nature of corrective action taken as appropriate for materials as well as workmanship. The QC records shall be available to the Agency at all times and shall be retained by the Contractor for the life of the contract. The Contractor's documentation procedures will be subject to approval by the Agency prior to the start of work, and to compliance checks by the Agency during the progress of the work.

8. Compliance with Specifications. The Contractor shall attest in writing to the Agency that the fog seal has been constructed in accordance with and meets the requirements of the specifications at the conclusion of the project.

P. *Agency Acceptance:*

1. *General.* The Agency will conduct acceptance sampling, testing, and inspection activities to ensure that material quality, correct application rates, sweeping, and traffic control are within specification requirements. These activities will be done randomly by the Agency.

2. *Acceptance Activities:*

   a. *Materials Testing:*

      i. *Blotter Aggregate (if used).* Sample blotter aggregate taken from the aggregate spreader hopper once per day. Samples will be stored and tested for gradation at the discretion of the Agency. If the results vary from the requirements of Table 410.5-1, a price reduction will be applied per the Schedule of Price Reduction prepared by the Owner Agency.

      ii. *Emulsified Asphalt.* Sample the first shipment and provide one sample for every 50,000 gal (approximately 200 tons) (190,000 L (approximately 180 Mg)) thereafter. Testing of emulsified asphalts shall be in accordance with AASHTO M 140, M 208, and M 316.

3. *Equipment.* All equipment to be used on the project shall be evaluated by the Agency to assure that it is in acceptable operating condition, that it is calibrated correctly, and that it will provide the quantities of material specified.

4. *Final Inspection.* A final inspection will be done to assure that no bleeding or flushing, excessive fog loss, or crushed aggregate has occurred. Longitudinal and transverse joints will be inspected to assure that no excessive overlap has occurred.

410.6 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

A. *Emulsified Asphalt.* Measure the undiluted emulsified asphalt by volume, at 60°F (16°C).

B. *Blotter Aggregate.* Blotter aggregate will be paid for by the area of pavement surfaced.

410.7 PAYMENT

Payment for fog seals can be done by either paying for the materials as unit costs, or for the completed fog seal by area of pavement sealed.

A. *Payment by Unit Price.* The Agency will pay for accepted quantities at the contract price as follows:

1. Payment for the accepted quantity of emulsified asphalt and blotter aggregate for fog seal (including any required additives) at the contract price of measure is compensation in full for all costs of furnishing and applying the material as specified.

2. Payment will be made in accordance with the schedule set forth below at the contract price for the specified unit of measure.

Item No.	Item	Unit
State ##	Emulsified asphalt for fog seal	gal (L)
State ##	Blotter Aggregate for fog seal	tons (Mg)
State ##	Diluted emulsified asphalt for fog seal, if used	gal (L)

B. *Payment for Completed Fog Seal:*

1. Payment for the accepted quantity of the fog seal at the contract price of measure is compensation in full for all costs of furnishing and applying the material as specified, including cleaning the existing pavement; stationing; purchase of blotter aggregate; delivery of blotter aggregate; all labor, equipment, and materials necessary for the placement of the fog seal for full lane coverage; sweeping of any loose aggregate after construction; and other requirements as specified.

2. Payment will be made in accordance with the schedule set forth below at the contract price for the specified unit of measure.

Item No.	Item	Unit
State ##	Fog seal	yd^2 (m^2)
State ##	Diluted emulsified asphalt for fog seal, if used	gal (L)
State ##	Blotter Aggregate	tons (Mg)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

Commentary

The advantage of payment by the square yard (square meter) for a completed fog seal is simplicity if the area is easily defined. The disadvantage is that an incentive is created to reduce material quantities.

SECTION 411
IN-PLACE COLD RECYCLED ASPHALT PAVEMENT

411.1 DESCRIPTION

Construct an in-place cold recycled asphalt pavement.

411.2 MATERIAL

Provide materials as specified in:

Asphalt Binder	Subsection 702.1(A), or as specified by Agency
Blotter Sand	Subsection 703.10

411.3 CONSTRUCTION

A. *Weather Limitations.* Work when the atmospheric temperature is at least (60°F (15°C)) and when there is no precipitation.

B. *Pulverizing.* Mill and pulverize existing asphalt pavement to the specified depth. Use a self-propelling pulverizing machine capable of maintaining a uniform grade and cross slope. Ensure pulverized material meets the following gradation:

Table 411.3-1. Gradation for Pulverized Material

Sieve Size	Percentage Passing
2 in. (50 mm)	100
$1^1/_2$ in. (38 mm)	100 to 90

Reject pulverized asphalt pavement contaminated with base or subgrade material.

C. *Mixing.* Combine an asphalt binder with the pulverized material at the specified rate, using one of the following methods to ensure a consistent mixture:

1. Incorporate with the liquid used to cool the cutter teeth. Ensure even application across the width of the cut and blend uniformly.

2. Incorporate into the pulverized asphalt windrow with a separate mechanical mixing device and blend uniformly.

3. Incorporate through a paving machine during a combined mixing and placing operation.

   Use a positive displacement pump that meters asphalt binder. Equip the pump with a positive interlock system calibrated to mixing quantities and forward speed. When using an emulsified binding agent, water may be added to assist uniform mixing; add water before or with emulsified binding agent.

D. *Placing and Compacting.* Place the surface course only when the final moisture content of the recycled mixture is less than [$1^1/_2$] percent.

Apply tack, prime, and fog coats to the existing subgrade or surface when specified. Blot excess asphalt with fine sand.

1. *Placing by Blade.* Use self-propelled, pneumatic-tired graders to spread the windrowed material to the required section and grade. Establish a test strip to verify the rolling pattern and maximum placement thickness. Meet density, cross section, and profile grade requirements.

2. *Placing by Paver.* Place the recycled mixture with a self-propelled asphalt paver as specified in Subsection 401.3(D)(2). Spread the material in one or more lifts. Compact as specified.

411.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

411.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) In-place cold recycled asphalt material	station
(B) Asphalt binder agent	ton (Mg), gal (L)
(C) Blotter sand	ton (Mg), gal (L)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 412
SURFACE RECYCLING

412.1 DESCRIPTION

Heat, scarify, rejuvenate, and recompact existing asphalt pavements, and overlay with new asphalt surface mixture.

412.2 MATERIAL

Provide materials as specified in:

Asphalt Binder	Subsection 702.1(A)
Emulsified Asphalt	Subsection 702.1(C)
Asphalt Concrete Aggregates	Subsection 703.4
Blotter Sand	Subsection 703.10
Asphalt Rejuvenating Agent	As specified by Agency

412.3 CONSTRUCTION

A. *Weather and Seasonal Limitations.* Construct between [June 1 and September 1] and when the surface is dry.

B. *Equipment:*

1. *Heater Scarifier.* Furnish a self-propelled, self-contained unit or combination of self- contained units designed to heat and scarify existing pavement to at least [$^3/_4$ in. (20 mm)]. Use an adjustable-width heating unit. Ensure proper combustion without excessive smoke.

2. *Distributor-Paver.* Furnish a single-unit distributor-paver that:

   a. Uniformly distributes rejuvenator at the specified rate onto the scarified material, and

   b. Screeds and finishes as specified in Subsection 401.3(D)(2).

3. *Rollers.* Meet Subsection 401.3(D)(3).

4. *Distributor.* Meet Subsection 403.3(B)(1).

5. *Asphalt Paver.* Meet Subsection 401.3(D)(2).

6. *Heater-Scarifier-Paver.* Furnish a single unit that meets Subsections 412.3(B)(1) and 401.3(D)(2). Provide for uniform distribution of rejuvenating agent at the specified rate.

7. *Heater-Miller-Scarifier-Paver.* Furnish a single unit that meets Subsections 412.3(B)(6) and 409.3(A).

C. *Preparing the Pavement.* Clean the pavement of all foreign material and loose aggregate. Complete specified patching before scarifying.

D. *Heating and Scarifying or Hot Milling.* Heat and scarify or mill existing pavement to a minimum [3/4 in. (20 mm)].

E. *Rejuvenating, Mixing, and Compacting.* Apply rejuvenating agent uniformly to recycled mix. Uniformly mix rejuvenated and virgin asphalt materials, and spread and compact. Meet contract requirements for quantity and temperature of virgin asphalt surface mixture. Compact the remixed material as specified in Subsection 401.3(I).

Meet the following for separate compaction operations:

1. Lay and compact the remixed material to the maximum density as established by a test strip.
2. Maintain the surface until the subsequent overlay with the final asphalt surface mixture.
3. Use blotter sand sparingly in flushed areas.
4. Apply final overlay within 2 weeks of scarifying.
5. Apply a tack coat before placing final overlay.
6. Place and compact the final overlay as specified in Subsection 401.3(I).

A separate compactive effort will not be required if the final mix is added before the remixed material cools below _____ °F (°C) [Agency requirement].

412.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will consider widened or irregular areas as incidental to the length measure.

412.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Surface recycling	station, yd^2 (m^2)
(B) Asphalt rejuvenating agent	ton (Mg), gal (L)
(C) Emulsified asphalt (tack)	ton (Mg), gal (L)
(D) Aggregate for asphalt surface course	ton (Mg)
(E) Blotter sand	ton (Mg), yd^3 (m^3)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 413
FABRIC REINFORCEMENT FOR ASPHALT CONCRETE PAVEMENT

413.1 DESCRIPTION

Apply fabric as a waterproofing and stress-relieving membrane between plant mix asphalt concrete pavement layers.

413.2 MATERIAL

Provide material as specified in:

Fabric Reinforcement for Asphalt Pavement	Subsection 705.2

413.3 CONSTRUCTION

A. *Weather Limitations.* Apply asphalt binders to install fabric only if the air temperature is above 60°F (15°C).

B. *Equipment:*

1. *Distributors.* Meet Subsection 403.3(B)(1). Equip with a hand spray having a single nozzle and positive shut-off valve.

2. *Fabric Laydown Equipment.* Furnish mechanical or manual roll-tension equipment to lay full or partial rolls of fabric without wrinkles and folds.

3. *Miscellaneous Equipment.* Provide hand tools including stiff-bristle brooms to cut and smooth fabric and to apply asphalt binder to joints.

C. *Preparing the Surface.* Remove dirt, dust, water, oil, or other foreign matter from the surface. Fill cracks more than [1/8 in. (3 mm)] wide with crack filler and repair potholes. Cure the crack filler before placing fabric.

D. *Applying Asphalt Binder.* Uniformly apply asphalt binder material over the area to receive fabric. Double application rate along overlap areas.

Ensure a minimum asphalt binder temperature of 290°F (145°C) and a maximum temperature of 325°F (165°C). Use an asphalt distributor to apply the asphalt binder at the recommended rate of [0.20 to 0.35 gal/yd^2 (1.0 to 1.5 L/m^2)]. Hand spray inaccessible areas. Start and stop the distributor over paper or roofing felt to provide neat cut-off lines. Apply the binder [2 to 6 in. (50 to 150 mm)] wider than the fabric width.

Avoid spills.

E. *Placing Reinforcement Fabric*. Place the fabric immediately after applying the asphalt binder. Broom the fabric to remove air bubbles and to maximize contact with the pavement. Flatten wrinkles. Cut, realign, and rejoin any misaligned fabric. Ensure a joint overlap of (2 to 4 in. (50 to 100 mm)). Overlap transverse joints in the direction of paving. Imbed the reinforcement fabric into the asphalt binder and bond to the pavement. Use self-propelled, pneumatic-tired rollers, if required.

F. *Applying Tack Coat*. If required, apply tack coat as specified in Section 404. Do not use cutback asphalt or emulsified asphalt containing petroleum distillate additives.

G. *Placing Pavement Overlay*. Place asphalt concrete pavement overlay as specified in Section 404 immediately after placement of fabric. Repair any damage or disbonding of the fabric reinforcement membrane before and during overlay operations. Spread blotter sand to absorb excess binder that bleeds through the fabric.

Ensure the asphalt paving mixture temperature remains at or below 325°F (163°C) during laydown.

413.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

413.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Fabric reinforcement	yd^2 (m^2)
(B) Asphalt binder	gal (L)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 414
DIAMOND GRINDING FOR PAVEMENT PRESERVATION (NEW)

414.1 DESCRIPTION

A. This Section covers the requirements for diamond grinding pavements during the pavement service life. Diamond grinding for pavement preservation is conducted to improve the ride characteristics, texture, and frictional properties of the roadway surface. The specifications are intended for use when continuous diamond grinding is required. These specifications are applicable to either asphalt concrete or portland cement concrete pavements.

B. This Section is not intended for use with bump grinding, which is conducted during the new construction process to eliminate discrete location roughness.

C. This Section is not intended for application on local streets that contain utilities such as water valves, manholes, and curb and gutter. Often these roadway features as well as intersecting roadway grades prevent achieving the smoothness tolerances.

414.2 REFERENCED DOCUMENTS

A. *AASHTO Standards:*

- R 54, Accepting Pavement Ride Quality When Measured Using Inertial Profiling Systems
- R 56, Certification of Inertial Profiling Systems

B. *ASTM Standard:*

- E1926, Standard Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements

C. *International Grinding and Grooving Association (IGGA):*

- Diamond Grinding Slurry Handling—Best Management Practices

414.3 TERMINOLOGY

A. Definition of Terms Specific to this Section:

1. **Area of Localized Roughness.** Any point exceeding the specification requirements when IRI is computed using a continuous 25-ft (8-m) base line.
2. **Blade Spacing.** The separation between cutting blades mounted in series on the cutting head (measured as the number of blades per foot (blades per meter)) spaced along the grinding equipment drum (rotating shaft). The blade spacing is impacted by the hardness and size of the aggregate material being diamond ground; particularly for concrete pavement.
3. **Diamond Grinding.** The removal of a thin layer of hardened portland cement concrete or asphalt concrete pavement surface using a self-propelled machine outfitted with a series of closely spaced diamond saw blades mounted on a rotating shaft.
4. **Distance Measurement Instrument (DMI).** A device used to measure the longitudinal distance between two points.
5. **Dowel Bar Retrofit (DBR).** The procedure for restoring load transfer across the transverse joint of a portland cement concrete pavement by cutting a slot across the transverse joint,

installing a steel dowel at the appropriate position, and backfilling with high-strength repair material. Typically, three dowels are installed in each wheel path.

6. **Effective Wheelbase.** The effective wheelbase is defined as the distance from the front wheel assembly transverse pivot point to the transverse pivot point of the profile/depth control/ground drive wheels.

7. **Feather Pass.** A grinding transition from the newly ground surface to an existing unground surface, such as a shoulder, intended to provide a smooth change in grade promoting drainage and smoothness onto the unground surface.

8. **Grinding Cutting Head.** The location of diamond blades mounted in a series on the grinding equipment drum (rotating shaft). The cutting head width typically ranges from 3 ft to 4 ft [0.9 to 1.2 m].

9. **Inertial Profiler.** A commercial device produced to measure pavement profile. The device uses an accelerometer to form an inertial reference, a laser-height sensor to measure the pavement surface location relative to that reference, and a DMI to measure the longitudinal distance traveled during the testing. These sensor outputs are used by the equipment to produce the pavement profile.

10. **International Roughness Index (IRI).** A roughness statistic that summarizes the impact of pavement profile on vehicle response for a passenger car, of specified properties, traveling at 50 mph (80 km/h). The IRI is computed from a single longitudinal profile using a quarter-car simulation as described in ASTM E1926.

11. **Mean Roughness Index (MRI).** A roughness statistic calculated by averaging the IRI values computed for the left and right wheel path profiles, respectively.

12. **Pavement Preservation.** In the context of this Section, surface modification of in-service asphalt concrete or portland cement concrete pavements is conducted to improve ride quality, enhance frictional properties, increase texture, improve roadway template, or reduce tire–pavement noise generation. Diamond grinding for these activities is generally conducted as a continuous grinding operation throughout the entire project.

13. **Percent Ride Improvement.** A measure of the change in ride quality as a result of the diamond grinding operation. Percent improvement is determined by measuring the roadway profile before and after the grinding operation. The equation is: Percentage of Improvement = $(S_b - S_a)/S_b \times 100$, where S_b is the smoothness (IRI) before grinding and S_a is the smoothness (IRI) after grinding.

14. **proVAL (Profile Viewing and AnaLysis).** An engineering software application that allows users to view and analyze pavement profiles in many different ways. The software is typically used for analyzing profile features and for computing the IRI, MRI, and HRI (half-car roughness index) values for construction acceptance. The program also computes the localized roughness values and can be used to identify areas where diamond grinding is needed to improve smoothness. This software is provided by the FHWA and is a free download at www.roadprofile.com.

414.4 EQUIPMENT

A. Grinding shall be performed using diamond blades mounted on a self-propelled machine designed for grinding and texturing pavement. The grinding equipment shall be a minimum 35,000 lb [15,890 kg], including the grinding head, and of a size that will grind a strip at least 3 ft [0.9 m] wide. The effective wheelbase of the machine shall be no less than 12 ft [3.66 m].

B. The equipment shall have a positive means of vacuuming the grinding residue from the pavement surface, leaving the surface in a clean, near-dry condition.

C. Grinding equipment that causes raveling, aggregate fractures, or disturbance to the joints shall not be permitted.

D. The equipment shall be maintained to ensure that it is in proper working order.

414.5 CONSTRUCTION

A. The construction operation shall be scheduled and proceed in a manner that produces a neat, uniform finished surface. Full- and partial-depth concrete repairs, slab stabilization, and dowel bar retrofit shall be completed prior to any grinding. Joint sealing shall be completed after the diamond grinding operations.

B. Grind joint or crack faults so there is no more than a $^{1}/_{16}$-in. [1.6-mm] differential between adjacent sides of the joints and cracks.

C. *Lateral Drainage:*

1. Lateral drainage shall be achieved by maintaining a constant cross slope between grinding extremities in each lane. The finished cross slope shall match the pregrind cross slope and shall have no depressions or misalignment of slope greater than $^{1}/_{4}$-in. in 12 ft (5-mm in 3 m) when measured with a 12-ft (3-m) straightedge placed perpendicular to the centerline.

2. Wheel path rutting shall be removed to the Agency or contract plan requirements.

3. Grinding operations shall not consist of simply texturing the wheel path depressions. Areas of deviation shall be reground.

4. Straightedge requirements will not apply across longitudinal joints or outside the ground area.

5. Shoulder, auxiliary, or ramp lane grinding shall transition from the edge of the mainline as required to provide drainage, leaving no more than a $^{3}/_{16}$-in. (5-mm) ridge.

D. Grinding shall begin and end at lines normal to the pavement centerline at the project limits. Passes of the grinding head shall not overlap more than 1 in. (25 mm). No unground surface area between passes will be permitted.

E. *Final Surface Finish:*

1. The grinding process shall produce a pavement surface that meets the contract plan requirements in grade. Ground surface shall be uniform in appearance with longitudinal line-type texture. The line-type texture shall contain corrugations parallel to the centerline and present a narrow-ridge corduroy-type appearance. The peaks of the ridges shall be $^{1}/_{8}$-in. ± $^{1}/_{16}$-in. [3.18-mm ± 1.59-mm] higher than the bottom of the grooves with evenly spaced ridges.

2. It shall be the Contractor's responsibility to select the number of blades per foot (meter) to be used to provide the proper surface finish for the aggregate type and concrete present on the project.

   Note: The number of blades used for grinding will range between 50 to 60 blades per foot (164 to 197 blades per m) as necessary to provide the designated texture. Harder aggregate may require the use of 55 to 60 blades per foot (180 to 197 blades per m).

3. The Engineer may require removal of unbroken fins at the Contractor's expense.

   Note: The project conditions may dictate that the Contractor has to make multiple passes with the equipment to meet the specifications.

4. It is the Contractor's responsibility to determine the proper sequence of operations to meet the specification. If multiple passes of the grinding equipment are required, the area will only be considered for payment once.

5. A minimum of 95 percent of any 100-ft (30-m) section of pavement surface shall be textured. Depressed pavement areas due to subsidence or other localized causes will be exempted from texture and smoothness requirements. The Contractor shall notify the Engineer of depressed areas that should be excluded from the coverage requirement.

F. *Slurry Handling and Removal:*

1. Slurry shall be collected, processed, and disposed of in accordance with applicable local, state, and Federal requirements. The International Grinding and Grooving Association publishes a best practices manual on slurry disposal.

G. *Smoothness Requirements:*

1. An initial MRI representative of portions of the project may be available. When available, this information represents the conditions that existed at the time the survey was made. The Contractor is cautioned to note the survey date, since conditions may have changed over time. This profile is for informational purposes only, to give the Contractor an idea of the conditions that existed at the time of the survey. The Contractor assumes the risk of error if the information is used for any purpose other than as stated. Contractors are responsible for visiting the project site to make their own condition determination prior to bidding.

2. Prior to performing any grinding work, the Contractor shall provide a control profile developed in accordance with AASHTO R 54. Single-point lasers shall not be used. Approved line laser equipment shall be used. All equipment shall have current certification according to the requirements of AASHTO R 56. The Contractor shall measure profiles in both wheel paths and average the resulting IRI to determine acceptance (i.e. MRI). The profiles shall be spaced at 72 in. (1.8 m) from the centerline of the lane being profiled. A guide (positive means for controlling alignment) shall be used to ensure proper alignment of the profile.

3. The control profile will be used to identify the required smoothness for the project, as indicated in Table 414.5-1. The control profile will be obtained after any and all corrective work that impacts the pavement roughness such as slab repairs, DBR, partial-depth repairs, etc. The profile will be obtained in 0.1-lane-mi-long segments (528 ft) (0.161 lane-km-long segment (161 m)) and the location of each segment accurately established, either through stationing or GPS coordinates.

4. The finished surface shall have a final MRI improvement in accordance with Table 414.5-1 and grinding will not be considered acceptable until the smoothness requirements are achieved. Segment locations from the control profile shall match the segment locations tested in the smoothness acceptance measurements.

5. Depressed pavement areas due to subsidence or other localized causes will be excluded from the smoothness requirements. These areas shall be reviewed by the Engineer for approval to exclude.

6. The Contractor shall measure profiles in both wheel paths and average the resulting IRI to determine acceptance (i.e. MRI). The profiles shall be measured 3 ft (1 m) from each lane line. The Contractor shall notify the Agency when profile testing will be conducted. The Contractor shall provide the profile traces to the Agency within 24 h after testing.

7. For roadways with posted speeds less than or equal to 45 mph (70 km/h), the finished ground surface shall not include any bumps exceeding 0.3 in. in 25 ft (8 mm in 8 m). For roadways with posted speeds greater than 45 mph (70 km/h), the localized roughness (IRI) will be less than or equal to 160 in./mi. [2.53 m/km], when determined using the ProVAL Assurance Module with a 25 ft [7.62 m] baseline.

8. The conditions of smaller municipal projects may not be suited for the above type of smoothness requirements. In these cases, the only smoothness requirement may be $^1/_8$ in. variance in a 12-ft (2.6 mm variance in a 3-m) straightedge test.

9. Incentives and disincentives can be used to increase the quality of construction.

10. Agencies are encouraged to develop their own smoothness requirements based on local conditions and pavement performance.

Table 414.5-1. Smoothness Requirements for 40 Percent Improvement

Posted Speed Limit (MPH (km/h))	Existing MRI (in./mile [mm/km])	Required Post Grind MRI (in./mile [mm/km])
<45 (70)	<230 [3.63]	<138 [2.18]
	>230 [3.63]	< 0.6 × (Existing Segment MRI)
>45 (70)	<130 [2.05]	<78 [1.23]
	>130 [2.05]	< 0.6 × (Existing Segment MRI)

414.6 MEASUREMENT

A. Grinding will be measured by the square yard of diamond-ground area. The measurement will be the final textured surface area regardless of the number of passes required to achieve acceptable results. Minor areas of unground pavement within the designated areas to be ground will be included in the measurement.

B. When conditions require a feather pass into the shoulder or the auxiliary or ramp lanes, measurement for payment will be by the square yard (square meter) based on a width of 2 ft (0.6 m) times the length of the required feather pass. The minimum length of feather pass will be 100 ft [30.5 m]. It should be noted that the minimum width is 2 ft [0.6 m], but it may be increased to up to 4 ft [1.2 m] based on site conditions to provide positive cross drainage. The additional feathering width into the shoulder may be required if the shoulder elevation is greater than the mainline pavement elevation, which would then provide for a better cross slope transition to get the water away from the longitudinal joint.

414.7 PAYMENT

A. Grinding will be paid for at the contract price per square yard (square meter). Payment shall be full compensation for all labor, equipment, materials, and incidentals to complete this work, including hauling and disposal of grinding residue.

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AASHTO

DIVISION 500
RIGID PAVEMENT

SECTION 501
PORTLAND CEMENT CONCRETE PAVEMENT (PCCP)

501.1 DESCRIPTION

Construct a portland cement concrete pavement on a prepared subgrade or base course.

501.2 MATERIALS

Provide materials as specified in:

Portland Cement	Subsection 701.2
Fine Aggregate	Subsection 703.1(A)
Coarse Aggregate	Subsection 703.1(B)
Recycled Concrete Aggregate	Subsection 703.1(D)
Load Transfer Devices	AASHTO M 31M/M 31
Joint Filler	Subsection 707.1
Reinforcing Steel	Subsection 711.1
Curing Materials	Subsection 713.2
Air-Entraining Admixtures	Subsection 713.3(A)
Chemical Admixtures	Subsection 713.3(B)
Fly Ash	Subsection 713.3(C)(1)
Ground Granulated Blast Furnace Slag (GGBFS)	Subsection 713.3(C)(2)
Water	Subsection 714.1(A)

501.3 CONSTRUCTION

A. *Mix Design.* Prepare and submit a mix design as specified in Subsection 713.1(A).

B. *Equipment for Mixing and Transporting Concrete.* Provide and maintain in good mechanical condition all equipment and tools for subgrade preparation, concrete batching, paving, finishing, and curing operations.

1. *Batching Plant and Equipment.* Furnish a batching plant with individual bins, weigh hoppers, and scales for each aggregate size used. Include a bin, hopper, and separate scale for each approved cementitious material. Seal and vent weigh hoppers. Equip the batch plant with an accurate, nonresettable batch counter to record the number of proportioned batches produced.

   Ensure that the batch plant site, layout, equipment, and arrangements for transporting the material will provide a continuous concrete supply. Build stockpiles in layers less than 3 ft (1 m) thick. Complete each layer before beginning the next and avoid "coning" over the lower layer. Separate aggregate stockpiles of different sources and gradations.

   Reject segregated aggregates or aggregates mixed with foreign material. For aggregates produced or handled by hydraulic methods or washed aggregates, stockpile or bin to drain for at least 12 before using in the mix, unless shipped by rail in car bodies that allow free drainage. Store aggregates with high or non- uniform moisture content for more than 12 h before use.

   Use hoppers to weigh fine aggregate and each size of coarse aggregate according to job mix quantities. Weigh cement, fly ash, or other cementitious material on separate scales and hoppers with devices that ensure complete discharge of the batches into the batch box or container. Equip batching plants with automatic and interlocked proportioning devices to weigh aggregates and bulk cement.

   Transport aggregates from the batching plant to the mixer in batch boxes, vehicle bodies, or other containers that can carry the required quantities when mixing at the work site. Separate the batches with partitions to prevent spilling between compartments during transport and dumping of the mixture. In order to ensure that the mixer contains the specified amount of cement, establish procedures for bulk cement transfer from the weighing hopper to the transporting container or into the batch for transporting.

   Transport bulk cement to the mixer in tight compartments. Reject a batch of cement mixed with aggregates that is not discharged within $1^{1}/_{2}$ h. Transport sacked cement as allowed on top of the batch mix aggregate.

   Control batching to ensure that required weights (masses) are within 1 percent for cement and 2 percent for aggregates.

   Measure water by volume or weight (mass) within a 1 percent tolerance. Supply an auxiliary tank of comparable volume when measuring by volume, for the weight (mass) required for filling the measuring tank. Ensure that the measuring tank has controls that track the quantity of water in the tank.

Use methods and equipment to add air-entraining agents or other admixtures to within a ±3 percent tolerance of the mix design.

2. *Mixers.* Mount a manufacturer's plate on the mixer that indicates total drum capacity, concrete mixing capacity, and recommended mixing speed of the drum or attached blades. Keep mixers clean and operable. Repair or replace the drum pickup and throw-over blades when they show more than $^3/_4$-in. (20-mm) wear from the original height. Provide, at the concrete plant, a copy of the manufacturer's drum blade design showing the original height and depth dimensions and blade arrangement. Mark blades or drill a $^1/_4$-in. (6-mm) hole near each end and at the midpoint of each blade to show $^3/_4$-in. (20-mm) wear from the new condition.

   a. *Central Plant.* Furnish mixers that thoroughly combine the aggregates, cement, and water and discharge the mixture. Equip mixer with a timing device that automatically prevents discharge during mixing and allows discharge only when mixing is finished. Mix each batch at least 90 seconds. Provide a bell or other audible warning device to sound when the lock is released. Equip the mixer with a counter to record the number of batches mixed.

   Start measuring mixing time when all materials, except water, are in the mixing drum. Mix and deliver ready-mixed concrete according to AASHTO M 157. Post the manufacturer's recommended number of revolutions at mixing speeds on the mixer's mounted serial plate. Reduce the number of revolutions if test data verify that the make and model of the mixer can produce uniform concrete.

   Mix concrete for 90 seconds. Add 4 seconds if timing starts the instant the skip reaches its maximum raised position. End mixing time when the discharge chute opens. Include transfer time in mixing time for multiple drum mixers.

   Reject concrete mixed less than the specified time. Limit drum speed and batch volume to that shown on the manufacturer's standard rating plate posted on the mixer.

   Charge the drum so that some water enters the mixer before the cement and aggregates. Maintain an even flow so that all of the water is in the drum within the first 15 seconds of the mixing period. Keep the drum throat clean to ensure the free flow of materials into the drum.

   After adding the water to the mix, deposit the concrete within 45 minutes if hauled in nonagitating trucks or within 90 minutes if hauled in truck mixers or truck agitators. Reduce the placement time if hot weather or other conditions might cause the concrete to set prematurely. Avoid adding water or other additives to retemper concrete.

b. *Truck Mixers and Truck Agitators.* Furnish truck mixers for mixing and hauling concrete and truck agitators for hauling central-mixed concrete, both of which meet AASHTO M 157.

The Contractor may add water to concrete mixes delivered by transit mix trucks if the specified water to cementitious material ratio is met and the concrete is placed within 45 minutes of the water addition. Do not use concrete that does not meet specified slump and water–cement ratio limits.

c. *Nonagitator Trucks.* Use nonagitating vehicles with smooth, mortar-tight, metal containers that can discharge concrete evenly from the bottom end or side of the container. Provide covers to protect the concrete from hot weather and rain.

3. *Finishing Equipment.* Use slip-form paving equipment or equipment with stationary side forms to construct pavement.

Provide vibrators to consolidate the concrete for the full width. Use either the surface pan type (limited to pavements 8 in. (200 mm) thick or less) or the internal type with either immersed tube or multiple spuds. Ensure that vibrators attached to the spreader or finishing machine, or mounted on a separate carriage, do not touch joints, load transfer devices, the subgrade, or side forms. Limit the minimum vibration frequency, in impulses per minute, of surface vibrators to 3500, tube vibrators to 5000, and spud vibrators to 7000.

Maintain a minimum vibration frequency of 3500 when using spud-type internal vibrators next to the forms.

a. *Slip-Form Method.* Place concrete with a slip-form paver that can spread, consolidate, screed, and finish the freshly placed concrete in one complete pass. Ensure the paver provides a dense, homogeneous pavement, with a surface tolerance that requires minimum hand finishing. Use reference lines outside the finished concrete limits to regulate the paver's alignment and elevation during concrete placing and finishing operations.

b. *Stationary Side-Form Method.* Equip the finishing machine with at least two oscillating-type transverse screeds that can finish the surface to the specified tolerance.

4. *Concrete Saw.* Provide saws to cut joints and backup saws in case of equipment failure. Furnish adequate lighting for night sawing.

5. *Forms.* Furnish 10-ft (3-m) long straight-side forms of at least $^7/_{32}$-in. (5-mm) thick metal. Ensure forms are as deep as the pavement edge is thick, without the horizontal joint. Use only solid forms. Ensure base width equals form depth. Use flexible or curved forms for curves up to 100-ft (30-m) radius. Keep the forms rigid during paving. Extend flange braces outward on the back of the forms to at least two-thirds the height of the form. Remove forms with battered top surfaces or forms that are bent or broken. Maintain the maximum variance of the top form of $^1/_8$ in. (3 mm) in 10 ft (3 m) from a true plane, and

maintain the maximum face variance of $^1/_4$ in. (6 mm) in 10 ft (3 m). Ensure that forms tightly lock together the ends of abutting form sections and are set securely on the grade.

C. *Mixing Limitations.* Ensure adequate natural or artificial light when mixing, placing, or finishing concrete. Place mixed concrete only when its temperature is between 50°F and 85°F (10°C and 30°C).

Stop mixing and concreting operations if shaded ambient air temperature away from artificial heat is 40°F (5°C) or less. Resume operations only when the ambient air temperature is 40°F (5°C) and rising. Place concrete only on unfrozen subgrade. Ensure that no frozen aggregate is in the concrete mix.

Heat aggregates by steam or dry heat before placing in the mixer when unable to sustain the specified concrete temperature range. Use a method that will heat the aggregate mass evenly so as not to injure the materials. Heat water and aggregates to between 70°F and 150°F (20°C and 65°C).

D. *Conditioning Subgrade or Base Course.* Construct subgrade or base course to the specified cross section. Trim high areas and fill and compact low areas to a condition similar to the surrounding grade. Maintain the finished subgrade in a smooth, compact condition and restore disturbed areas prior to placing the pavement.

Keep the subgrade and base course uniformly moist when placing concrete, unless a waterproof cover material is specified.

E. *Preparing the Proper Grade.* Trim beyond the edges of the proposed concrete pavement to hold the forms or slip-form paving equipment. Fill and thoroughly compact all irregularities below the established grade with subgrade or base course material, in lifts of up to $^3/_8$ in. (10 mm), for a width of 16 in. (400 mm) on both sides of the base of the form. Tamp or trim above-grade defects or variations to plan elevation.

F. *Setting Forms.* Compact the foundation under the forms to provide continuous contact with the forms.

Set and check forms before placing concrete to ensure correct form line and grade and to allow continuous concrete placement. Tamp thoroughly the inside and outside edges at the base of the forms. Use three pins for each 10-ft (3-m) section to stake forms in place. Place pins on each side of every joint. Lock form sections to prevent play or movement in any direction. Ensure forms remain true within $^1/_4$ in. (6 mm). Set forms to withstand the impact and vibration of consolidating equipment. Clean and coat forms with an approved form release agent or oil before placing concrete.

Check and correct alignment and grade elevations of the forms immediately before placing concrete. Correct and recheck disturbed forms or unstable subgrade.

G. *Placing and Consolidating Concrete.* Deposit concrete with a minimum of handling. Use a spreading device and mechanically distribute concrete evenly. Place concrete continuously between transverse joints without using intermediate bulkheads. Ensure workers wear clean footwear.

Except for concrete sawing equipment, restrict operation of mechanical equipment on the pavement until after the specified 14-day strength has been obtained. Pave adjacent lanes only after the concrete reaches a flexural strength of [50 psi (345 kPa)] when tested according to AASHTO T 97.

1. *Slip-Form Method.* Vibrate the concrete to consolidate it throughout the depth and width.

   Follow standard paving method requirements or use false forms placed next to the slip forms to place and finish pavement sections that abut other lanes with longitudinal joints. Construct false forms of metal gauge strong enough to maintain the shape and continuity of the form line. Discontinue use of false forms when there is measurable edge slump or misalignment. Limit the maximum length of unbraced false forms to 10 ft (3 m). Keep the false forms in place for at least 90 minutes or until they can be removed without damaging adjacent concrete.

   Use mechanical equipment to place and position pavement reinforcing steel or fabric.

   Spread, consolidate, screed, and float finish the concrete in one pass to lessen the need of hand floating. Operate the slip-form paving equipment in an even forward motion to avoid stop-and-go operation.

   Complete the final finish as specified in Subsection 501.3(K)(7). Attach a burlap drag, if used, to the trailing forms.

   Cure the surface and edges as specified in Subsection 501.3(M). Protect the unhardened concrete edges and surface from rain.

2. *Stationary Side-Form Method.* Use vibrators to consolidate concrete against and along the faces of all forms and the length and both sides of all joint assemblies. Limit vibrator operation to 5 seconds in any location.

   Deposit concrete as near as possible to expansion and contraction joints without disturbing the joint assembly. Do not deposit concrete directly on a joint assembly.

H. *Test Specimens.* Furnish concrete for casting test beams and cylinders and for testing air content and slump.

I. *Striking Off Concrete and Placing Reinforcing Steel.* Strike off concrete in two layers to the cross section shown on the plans. Strike off and consolidate the bottom layer to the depth necessary to place the fabric or reinforcing steel mat directly on the concrete. If the top layer is not placed within 30 minutes of the first layer, remove and replace the lower layer with freshly mixed concrete.

   Position reinforcing steel before placing the concrete when placing concrete in one layer, or use mechanical or vibratory methods after spreading the plastic concrete. Ensure reinforcing steel is free of oil, paint, grease, mill scale, loose or thick rust, or other foreign material.

J. *Joints.* Protect all joints against intrusion of foreign material until sealed.

1. *Longitudinal Joints:*

   a. *Dimensions.* Saw the first cut or insert the joint material to one third of the depth.

   b. *Tiebars.* Place [30-in. (750-mm)] long No. 5 tiebars of Grade 60 steel, spaced [30 in. (750 mm)] center-to-center to one half of the depth of the PCCP. Place tiebars using mechanical equipment or secure them with chains to prevent movement during concrete placement. Ensure that tiebars are placed perpendicular to the face of the joint, centered in the slab depth, and parallel to the finished surface.

   c. *Construction.* Form or saw longitudinal joints in the plastic concrete. Saw the joints within 4 to 24 after placing the concrete and immediately after completing the transverse joints. Allow only the saw on the pavement during sawing operations. Clean joints before curing them. Cure the joints by one of two methods:

      i. *Method 1.* Center a $2^1/_2$-in. (64-mm) wide polyethylene tape, with adhesive material at each edge over the joint, and press into place.

      ii. *Method 2.* Install a rope or rod insert that is nonmetallic, inert, resilient, compressive, nonabsorbent, and nonshrinking along the top of the joint flush with the pavement surface. Spray curing compound over the joint to form a vapor barrier and to touch up areas of curing compound damaged during sawing operations. Use rope or rod that is approximately 25 percent larger than the joint width.

   d. *Sealing.* Seal joints after the curing period and before opening the pavement to traffic. Use sandblasting followed by an oil-free air jet to clean the faces and joint openings before sealing. Seal joints only when they are completely dry. Do not dry joints with a heat lance. Use an approved backer rod to seal the lower portion of the joint groove to a uniform depth to prevent sealant from entering beneath the specified depth. Ensure that backer rod is compatible with the sealant type specified and install according to the manufacturer's recommendations.

      Place hot-poured sealants only when the pavement temperature is above 50°F (10°C).

      Place silicone and cold-applied sealants at the pavement temperatures recommended by the sealant manufacturer. Follow the sealant manufacturer's recommended application rate and cure time when using silicone sealants that require priming of the joint.

      Ensure that the top surface of the joint sealant is $^1/_8$ in. to $^5/_{16}$ in. (3 mm to 8 mm) below the pavement surface.

2. *Contraction Joints.*

   a. *Location and Dimensions.* Form or saw joints as narrowly as possible, to at least one third of the pavement depth; saw a reservoir to provide the correct shape factor.

b. *Load Transfer.* Install load transfer dowel bars of specified grade and size, spaced at [10-ft (3-m)] centers, and secured with a wire basket or implanted mechanically. Place dowel bars one half of the depth parallel to the surface and pavement edge to an alignment tolerance of [±$^1/_4$ in. (±5 mm)]. Vibrate concrete around all dowel bars without misaligning them. Place dowel bars securely to remain in the proper location after the paving train makes its final pass over the joint. Mark the center of the dowel bar assembly on both sides of the pavement slab as a reference to form and saw the contraction joint.

Coat the length of each dowel bar thoroughly with an approved lubricant to prevent concrete cement from sticking to it.

c. *Construction.* Place formed joints while the concrete is plastic. Begin relief-cut joint sawing immediately after the concrete hardens to the stage that it can be sawed without raveling. Saw all joints between 4 and 24 after placing concrete but before uncontrolled shrinkage cracking develops. Avoid uncontrolled cracking before or during joint sawing by moving the operation ahead, and, if necessary, provide additional sawing units to eliminate shrinkage cracking. When early sawing fails to prevent uncontrolled cracking, change the paving operations by forming a contraction joint groove before the initial set of concrete. Allow only concrete saws on the pavement during the sawing operation. Repair uncontrolled cracks at no cost to the Agency by removing and replacing the pavement, including load transfer devices, across the full width of all affected lanes or shoulders and to the nearest transverse joint in each direction.

Wait at least 72 before beginning final or second-step sawing to create the proper sealant reservoir.

d. *Sealing.* Create the required reservoir for the specified sealant by sawing. Place sealant as specified in Subsection 501.3(J)(1)(d).

When using preformed elastomeric seals, apply lubricant-adhesive to the joint faces and sides of the seals to facilitate installation and to secure the seal in the joint. Apply the lubricant-adhesive to the full area of the seal that touches the joint faces. Remove any excess material on top of the joint immediately.

Install preformed seals in a compressed condition with the vertical axis of the seal parallel to the joint faces. Install seals using machines or tools that do not twist, curl, nick, notch, or damage the seal, and that insert the seal so that the seal elongation is no more than 5 percent.

Construct without splicing throughout the limit of the joint.

3. *Expansion Joints.* Construct $^3/_4$-in. (20-mm) wide expansion joints and fill with a continuous preformed material. Depress the material $^3/_8$ in. (10 mm) below the surface.

Use a metal channel to hold the expansion joint material in a vertical position that deviates no more than $^1/_4$ in. (5 mm) from the centerline of the joint. Remove the metal channel after the initial set of the concrete.

Secure dowel bars and preformed material for the load transfer units in place with a metal basket that remains in the pavement. Use a metal dowel cap or sleeve on each dowel bar to adjust to expansion. Equip the cap with a stop to prevent closing during the pavement service. Maintain a 1-in. (25-mm) clearance between the closed end of the cap and the end of the dowel bar to allow future movement of the concrete slab.

4. *Transverse Construction Joints.* Install transverse construction joints at the end of each day's placement. Form bulkheads when stopping the placement in an emergency or at the end of each day's pour.

   In addition to the joints installed at the end of each day's pour, construct transverse construction joints whenever concrete placement stops for more than 30 minutes. If, at the time of interruption, there is not enough concrete to form a 10-ft (3-m) slab, remove concrete to the preceding transverse joint.

K. *Final Strike-Off, Consolidating, and Finishing.*

1. *Sequence.* Order the operation sequentially as follows:

   a. strike-off,

   b. consolidate,

   c. float,

   d. remove laitance,

   e. straightedge, and

   f. final surface finish.

   Provide work bridges or other devices to reach the pavement surface to finish, straightedge, and make corrections.

   Finish the concrete surface without adding additional water.

2. *Finishing at Joints.*

   a. Consolidate concrete next to joints without voids or segregation against the joint material, load transfer devices, joint assembly units, and other devices extending into the pavement. Vibrate the concrete mechanically next to joints.

   b. After placing and vibrating the concrete next to the joints, bring the finishing machine forward without damaging or misaligning the joints.

      If the finishing operation causes concrete segregation, or damage to or misalignment of the joints, stop the finishing machine when the front screed is approximately 8 in. (200 mm) from the joint. Remove the segregated concrete from in front of and off the joint. Lift the front screed and set it directly atop the joint before continuing forward motion. When the second screed is close enough to force excess mortar over the joint, lift the screed and carry it over the joint. For subsequent finishing, the machine may be run over the joint without lifting the screeds if segregation is prevented.

3. *Machine Finishing.*

   a. *Nonvibratory Method.* Use the finishing machine to strike off, screed, and texture the concrete immediately after it is distributed or spread. Avoid damage to, or misalignment of, joint assemblies, reinforcing steel, dowel bars, and other embedded items during finishing. Avoid excessive finishing. Keep top of form free of debris.

      During the first pass of the finishing machine, maintain a uniform ridge of concrete along the entire paving width and ahead of the screed.

   b. *Vibratory Method.* Vibrate as specified in Subsection 501.3(B)(3).

4. *Hand Finishing.* Use hand-finishing methods only under the following conditions:

   a. When mechanical equipment breaks down, stop concrete placement and hand-finish concrete already in place on the grade.

   b. Hand finish narrow widths or irregularly shaped areas that cannot be finished by mechanical equipment. Use a portable screed to strike off and screed the concrete. Provide a second portable screed to strike off the bottom layer of concrete when placing reinforcing steel during two-layer concrete placement methods.

      Use a rigid screed that is made of metal or reinforced with metal and at least 18 in. (0.5 m) longer than the widest part of the slab pour.

      Consolidate the concrete with a hand-operated vibrator.

      Move the screed along the forms in a forward direction that combines a longitudinal and transverse sheering motion without raising either end from the side forms. Repeat this strike-off process until the surface texture is uniform, true to grade and cross section, and free of porous areas.

5. *Floating.* Use a float to achieve the specified grade and surface smoothness after striking off and consolidating the concrete. Use one of the following methods:

   a. *Hand Method.* Use a hand-operated longitudinal float at least 12 ft (4 m) long, 6 in. (150 mm) wide, and stiffened to prevent flexibility and warping. Operate the longitudinal float from foot bridges. Work the float in a sawing motion while holding it in a position parallel to the road centerline and passing it gradually from one side of the pavement to the other. Move ahead, along the centerline of the pavement, advancing no more than one half of the length of the float length. Waste excess water or laitance over the side forms on each pass.

   b. *Mechanical Method.* Furnish a mechanical float that can accurately adjust to the required crown and coordinate with adjustments of the transverse finishing machine.

c. *Alternate Mechanical Method.* Use a machine with a cutting and smoothing float or floats suspended from and guided by a rigid frame mounted on four or more wheels. Maintain constant contact of all four wheels with the forms. Use hand method to fill open-textured areas in the pavement after mechanical floating.

6. *Surface Correction.* Correct surface irregularities while the concrete is plastic, after completing floating and removing excess water and laitance. Fill, strike off, consolidate, and refinish depressions. Cut down and refinish high areas. Smooth the surface across joints to meet specified tolerance.

7. *Final Finish.* Texture the surface without tearing it after the surface sheen disappears.

   Texture the final surface to form an even grooved pattern perpendicular to the centerline. Provide a surface with individual grooves $^1/_{16}$ in. to $^1/_8$ in. (1.5 mm to 3 mm) wide and $^1/_8$ in. to $^3/_{16}$ in. (3 mm to 5 mm) deep, spaced on $^3/_8$-in. to $^3/_4$-in. (10-mm to 20-mm) centers. Use metal tines or finned ball float. Ramps, tapers, and miscellaneous areas may be textured manually.

   Restore pavement texture damaged by rain by grooving while the concrete is in a plastic state. If the concrete has reached its initial set, restore the texture by sawing grooves in damaged areas to specified depth, width, and spacing.

8. *Edging at Forms and Joints.* Tool pavement edges after the final finish along both sides of each slab and on both sides of transverse expansion joints, formed joints, transverse construction joints, and emergency construction joints to the specified radius. Produce a smooth, dense, mortar finish.

   Eliminate tool marks on the slab next to the joints. Avoid disturbing the rounding of the slab corners and remove concrete from the joint filler top. Test the joints with a straightedge before the concrete sets and correct any unevenness between the joints and the adjacent slabs.

L. *Surface Tolerances.* The Engineer will test pavement surfaces as specified in Subsection 401.3(L). If pavement fails to meet the specified surface tolerances, perform corrective work as directed.

M. *Curing.* Cure the concrete for at least 3 days immediately after the finishing operation. Avoid exposing concrete for more than 30 minutes during curing. Use an atomized fog spray to apply water to the surface as an interim cure but only until the final cure is in place.

Fog spray the surface prior to treatment. Treat surfaces exposed during the curing period. Overlap curing blankets at least 8 in. (200 mm), and secure them to rest on the pavement surface. Prevent curing blanket joints from opening or separating. Extend curing blankets 8 in. (200 mm) beyond the pavement edges to cover the sides.

Protect the concrete for at least 10 days or until the concrete achieves a compressive strength of [2,200 psi (15 MPa)] when tested according to AASHTO T 97. Protect the concrete from freezing with blankets, or other materials, when the temperature drops below 35°F (2°C).

Remove and replace all concrete damaged by freezing. Cover and cure the entire surface and edges using any of the following methods:

1. *Impervious Membrane Method.* Apply curing compound only during dry weather.

   Use a fully atomized mechanical sprayer equipped with a tank agitator and wind guard to apply the curing compound at a rate of 1 gal/15 yd^2 (1 L/3.5 m^2).

   Continuously agitate the compound during application, and keep it thoroughly mixed so that the pigment disperses evenly. Hand spray irregular widths, shapes, and surfaces exposed by removing forms.

2. *White Opaque Polyethylene Film.* Meet the requirements of ASTM C171. Extend film beyond the edges of the slab by at least twice the thickness of the pavement edge. Overlap film sheeting by at least 18 in. (450 mm).

3. *Cloth.* Extend cloth such as burlap or cotton beyond the edges of the slab by at least twice the thickness of the pavement edge. Use two layers of cloth. Saturate with water before placing and keep saturated during the curing period.

4. *Waterproof Paper.* Use waterproof paper having a mass of at least 0.4 lb/ft2 (200 g/m2).

N. *Removing Forms.* Keep forms in place for at least 12 and remove carefully to avoid damaging the pavement. Use fresh mortar to repair damaged pavement and honeycombed areas on the edges.

O. *Repairing Defective Pavement Slabs.* Replace all pavement slabs that have uncontrolled cracks as specified in Subsection 501.3(J)(2)(c). If directed by the Engineer, rather than pavement removal and replacement, rout and seal cracks that penetrate the full depth of the pavement.

P. *Protecting the Pavement.* Meet the approved traffic control plan.

Q. *Opening to Traffic.* Allow traffic on the pavement after 14 days or when test specimens, molded and cured according to AASHTO T 23, attain the flexural or compressive strengths specified in Table 713.1-1.

R. *Tolerance in Pavement Thickness.* Determine pavement thickness according to AASHTO T 148.

   Take one core for each lot of 1,000 ft (300 m) per traffic lane. Consider intersections, entrances, crossovers, and ramps as separate lots and determine the thickness of each separately. Consider small irregular unit areas as parts of other lots. Take two additional cores at intervals of at least 300 ft (90 m) to determine the average thickness for that lot when the measure varies between 0.21 in. and 1 in. (5 mm and 25 mm) from the specified thickness.

   Remove the entire unit when any core thickness measurement is deficient by more than 1 in. (25 mm) from the specified thickness.

501.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

501.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit prices as follows:

Pay Item	Pay Unit
(A) Concrete pavement	yd^2 (m^2)
(B) Reinforcing steel	lb (kg), yd^2 (m^2)

A. *Price Adjustments.* The Agency will adjust the contract unit price for surface tolerance deficiencies and incentives as specified in Subsection 401.5.

For thickness deficiencies, the Agency will adjust the contract unit price according to the schedule provided in Table 501.5-1.

Table 501.5-1a. Price Adjustment—Concrete Thickness Deficiency (U.S. Customary Units)

Deficiency in Thickness Determined by Cores (in.)	Contract Price Allowed (percent)
0 to 0.20	100
0.21 to 0.30	80
0.31 to 0.40	72
0.41 to 0.50	68
0.51 to 0.75	57
0.76 to 1.	50
>1	Remove and replace

Table 501.5-1b. Price Adjustment—Concrete Thickness Deficiency (SI Units)

Deficiency in Thickness Determined by Cores (mm)	Contract Price Allowed (percent)
0 to 4	100
5 to 7	80
8 to 10	72
11 to 13	68
14 to 19	57
20 to 25	50
>25	Remove and replace

DIVISION 550
REHABILITATION OF PORTLAND CEMENT CONCRETE PAVEMENT

SECTION 551
CONCRETE PAVEMENT JACKING

551.1 DESCRIPTION

Raise portland cement concrete pavement to the specified elevation and cross slope, and support by drilling and injecting grout under low areas.

551.2 MATERIALS

Provide materials as specified in:

Portland Cement	Subsection 701.2
Limestone Dust	Subsection 703.14
Chemical Admixtures	Subsection 713.3(B)
Fly Ash	Subsection 713.3(C)(1)
Grout for pavement jacking, subsealing, and stabilization	Subsection 713.5(A)
Water	Subsection 714.1(A)

551.3 CONSTRUCTION

A. *Grout Plant*. Use a grout-producing plant having a positive displacement cement injection pump and a high-speed colloidal mixing machine or paddle-type mixer. Operate the colloidal mixing machine at a speed [800 to 2,000 rpm] necessary to create a high- shearing action and to obtain a homogeneous mixture.

Dispose of materials held in the mixer or injection sump pump for more than 1 at approved locations outside the work area at no cost to the Agency.

Measure dry materials by weight (mass). Measure liquids using a volumetric meter. Do not add water to the mix after completing the initial mixing of the grout.

B. *Drilling and Jacking.* Furnish air compressor(s) and rock drill(s) to drill grout injection holes through the pavement and base material. Ensure down-feed pressure is less than 200 psi (1.4 MPa). Drill injection holes to prevent breakout at the bottom of the pavement.

Drill vertical grout injection holes 2 in. (50 mm) or less in diameter. Drill holes to the specified pattern to allow initial spreading of the grout under pressure.

Furnish stringlines to monitor pavement movement during jacking operations. Use an expanding rubber packer that inserts into the injection holes and provides a positive seal at the pavement surface and connects to the discharge hose on the grout plant. Keep the discharge end of the packer or hose above the lower surface of the concrete pavement. When jacking continuously reinforced concrete pavement, pump the grout in a pattern and quantity required to raise the pavement to within $^{1}/_{16}$ in. (1.5 mm) of the stringline grade. When jacking bridge-end panels and jointed pavements, pump the grout in a pattern and quantity required to raise the pavement to within $^{1}/_{8}$ in. (3 mm) of the specified grade. Grade tolerances apply to transverse and longitudinal grades.

Limit continuous pressure during grout injection to 200 psi (1.4 MPa) and allow 300 psi (2.7 MPa) pressure peaks for short periods only. If the pavement is bonded to the subbase, allow brief pressure rises, 10 seconds or less, up to 600 psi (4.14 MPa).

Monitor the pressure as specified in Subsection 552.3(C).

Correct the grade of pavement raised above the specified tolerance by grinding. Remove and replace pavement raised more than $^{3}/_{4}$ in. (20 mm) above the specified grade.

Correct, remove, and replace pavement at no cost to the Agency.

Radial cracks from the grout injection holes will be considered caused by improper injection techniques. For each 9 to 15 ft (2.75 to 4.5 m) of crack measured, the Agency will reduce the pay quantity of grout by 100 lb (45 kg). Remove and replace pavement panels or a part of a panel with more than 15 ft (4.5 m) of new cracks at no cost to the Agency.

Repair cracks that develop between grout injection holes as specified in Section 556. Remove and replace the entire panel or part of the panel if the cracks cannot be repaired.

Perform crack repair, grinding, and panel removal and replacement at no cost to the Agency.

After completing the jacking, seal drill holes flush with the pavement surface with a fast-setting sand–cement mixture.

Note: Agency should specify drill hole fill material.

C. *Weather Conditions.* Perform jacking when the pavement temperature is above [40°F (5°C)] and when the subgrade or subbase is free of frozen material.

D. *Unanticipated Conditions.* Discontinue grout injection at specific locations as determined by the Engineer.

551.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure portland cement by the ton (Mg) incorporated in the grout and pumped under the pavement or pavement structure. The Engineer will reduce the pay quantity of grout as specified in Subsection 551.3(B).

551.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Portland cement for grout	ton (Mg)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 552
SUBSEALING AND STABILIZATION

552.1 DESCRIPTION

Find and fill existing voids in the pavement system by drilling injection holes, placing material, monitoring the pavement profile, testing for deflection after grouting, and resealing pavement joints.

552.2 MATERIALS

Provide materials as specified in Subsection 551.2.

552.3 CONSTRUCTION

A. *Grout Plant.* Meet Subsection 551.3(A) and as follows:

The Contractor may substitute a paddle-type mixer for the high-speed colloidal mixer when using limestone dust grout. Furnish an injection pump with a pressure capability of 250 to 300 psi (1.72 to 2.7 MPa) when pumping a grout slurry mixed to a 12-second flow cone time. Furnish an injection pump that can continuously pump at rates as low as 1.5 gal/min (5.68 L min).

Note: It may be possible to meet the low pumping rate by modifying the system through the addition of a recirculating hose and bypass valve at the discharge end of the system.

B. *Vertical Movement Testing*. Measure slab lift relative to the adjoining shoulder or any two outside slab corners next to a joint, within a tolerance of $^1/_{32}$ in. (0.75 mm). Make lift measurements relative to stable reference points.

Furnish a vehicle with an axle that can be loaded to 9 tons (8,165 kg) evenly distributed between the inside and outside wheel path. Furnish vehicle driver and personnel to operate the static load measuring gauges.

C. *Testing*. Test each joint and slab using static methods performed as follows:

Perform tests between midnight and 10 a.m. Stop testing if there is evidence of slab lockup caused by thermal expansion. Testing may continue after 10 a.m. if the slabs are not interlocked or under compression.

Furnish and maintain two-gauge mounts, with two gauges installed per mount, to detect slab movement under load.

Position a set of gauges with one gauge referenced to the corner of each slab on both sides of the joint near the pavement edge. Zero the gauges with no load on the slab on either side of the joint. Move the test vehicle into a position so the center of the test axle is about 12 in. (300 mm) behind the joint and the outside test wheel is about 12 in. (300 mm) from the pavement edge. Read the back gauge before moving the test truck across the joint and stopping it at a similar position about 12 in. (300 mm) forward of the joint. Read the forward gauge. Repeat this operation for each joint to be tested. The Engineer will read gauges and record the readings. Subseal all slabs with deflection in excess of [0.25 in. (0.625 mm)].

Retest each undersealed slab after the pressure grouting has achieved the required strength. Regrout and retest slabs that deflect more than [$^1/_4$ in. (0.625 mm)].

D. *Drilling and Subsealing*. Drill vertical grout injection holes less than 2 in. (50 mm) in diameter to a depth that penetrates the stabilized base to the subgrade. Drill the holes in the pattern specified. Avoid penetrating the subgrade more than 3 in. (75 mm).

Wash or blow out the holes to make a small cavity to intercept the void structure.

Monitor slab lift during subsealing operations as specified in Subsection 552.3(B). Limit upward movement of the pavement to $^1/_8$ in. (3 mm). Lower an expanding rubber packer connected to the discharge from the grout plant into the hole. Keep the discharge end of the packer or hose above the lower surface of the concrete pavement. Limit continuous pressure to 125 psi (0.862 MPa). Pump grout in each hole until maximum pressure is built up or material flows from hole to hole. Allow a short pressure surge of up to 300 psi (2.7 MPa) when starting to pump grout into the hole to ensure grout penetrates into the void structure. Monitor the grout line pressure. Allow water displaced from the void structure by the grout to flow out freely. Correct subsealing procedures if there is excessive grout loss through cracks, joints, or from back pressure in the hose or in the shoulder area.

Grind pavement raised more than the specified tolerance to bring it to grade, at no cost to the Agency.

E. *Radial Cracks.* If radial cracks develop, the Agency will reduce grout quantities as specified in Subsection 551.3(B).

F. *Transverse Cracks.* Repair transverse cracks that develop between adjacent grout injection holes as specified in Subsection 551.3(B).

G. *Hole Patching.*

Note: Agency should specify drill hole fill material.

H. *Weather Conditions.* Perform subsealing operations only if conditions meet those specified in Subsection 551.3(C).

I. *Unanticipated Conditions.* Discontinue grout injection at specific locations as determined by the Engineer.

J. *Resealing Pavement Joints.* Meet Sections 553, 554, and 555.

552.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. *Testing.* The Engineer will measure preliminary testing performed as specified in Subsection 552.3(C) by the mi (km), station, or joint, as specified, for each lane of roadway tested.

B. *Stability Testing.* The Engineer will measure static testing of slabs performed as specified in Subsection 552.3(C) by the joint. The Agency will make payment only once for each joint.

C. *Holes.* The Engineer will measure holes drilled through the existing concrete slabs by the unit.

D. *Portland Cement for Grout.* The Engineer will measure portland cement for grout as specified in Subsection 551.4(A). The Engineer will not measure material wasted due to excessive grout loss as described in Subsection 552.3(D) or material held for longer than 1 in the mixer or injection sump pump.

E. *Alternate Measurement Method.* If a predetermined hole pattern is used, the Engineer may combine holes and portland cement under Subsections 552.4(C) and 552.4(D) and measure by the yd^2 (m^2). The Engineer will measure by the yd2 (m2) those predetermined areas that are drilled and grouted to the depth and locations specified. The Engineer will measure only the full lane width where holes are drilled and injected with grout material. Length measurement will begin 5 ft (1.5 m) ahead of the first grout hole and continue 5 ft (1.5 m) beyond the last hole drilled and injected. If the distance between holes is 20 ft (6.1 m) or more, the Engineer will deduct areas where grouting has not been performed.

552.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Preliminary testing	mi (km), station, or joint
(B) Stability testing	joint
(C) Holes	each
(D) Portland cement for grout	ton (Mg)
(E) Holes and portland cement per Subsection 552.4(E)	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 553
RESEALING JOINTS—LIQUID SEALANT

553.1 DESCRIPTION

Reseal joints in existing portland cement concrete pavements with liquid sealants.

553.2 MATERIALS

Provide materials as specified in Subsection 707.1.

553.3 CONSTRUCTION

A. *Preparing Joints.* Remove the old sealant or joint insert, and repair, reface, and clean the joint. Provide the proper joint shape factor when installing either a separating or blocking medium and a new sealant.

B. *Equipment.* Follow the manufacturer's equipment recommendations for the specified material. Use a melting kettle with a double boiler and indirect heating, using oil as a heat-transfer medium, for hot-applied sealing compounds. Equip the kettle with a mechanical agitator and a calibrated positive thermostatic temperature control before starting work. Follow the sealant manufacturer's recommendations for application temperature. Furnish insulated hoses and applicator wand.

C. *Removing Joint Insert.* Remove all existing joint inserts and saw the joints to provide clean, vertical faces. Saw cut to provide the width and depth necessary to completely remove the existing joint insert and to provide the specified joint shape for the sealant material.

D. *Removing Existing Sealant.* Use a vertical cutting edge tool to remove all existing sealant from joint faces. The Contractor may use a power-driven concrete saw with diamond or abrasive blades. After cutting the existing sealant free from joint faces, remove the sealant to the depth required to accommodate the separating and blocking medium used and provide the specified depth for installing the new sealant material.

E. *Refacing Joints.* Use a concrete saw with diamond or abrasive blades to remove old sealant from the joint faces and expose clean concrete. Cut the joints to the width and depth necessary to provide the specified shape factor for the joint sealant.

F. *Cleaning Joints before Resealing.* Immediately after the joint refacing operation, thoroughly clean the joint faces and opening using a high-pressure water jet followed by an oil-free air jet. Remove all cuttings or debris remaining on the faces or in the joint opening. Clean the newly exposed joint faces by water blasting or sandblasting until the surfaces are free of saw-cutting fines and traces of old sealant. Just before installing the blocking medium, perform a final joint cleaning with oil-free compressed air that leaves the joint free of sand and water. Follow any additional joint cleaning recommendations of the joint sealant manufacturer. Do not dry joints with a heat lance.

G. *Separating and Blocking Medium.* Plug or seal the lower portion of the joint groove at a uniform depth with a backer rod to prevent entrance of the sealant below the specified depth. Furnish a clean backer rod free of scale, foreign material, oil, or moisture and that is nonabsorbent and compatible with the sealant. Install the backer rod according to manufacturer's recommendations. Determine appropriate backer rod sizing based on joint widths according to the following:

Table 553.3-1a. Backer Rod Sizing (U.S. Customary Units)

Joint Width (in.)	Blocking Media Diameter (in.)
5/16	3/8
3/8	1/2
1/2	5/8
5/8	3/4
3/4	1
1	1 1/4
1 1/4	1 1/2
1 1/2	2

Table 553.3-1b. Backer Rod Sizing (SI Units)

Joint Width (mm)	Block Media Diameter (mm)
8	10
10	12
12	16
16	20
19	25
25	32
32	38
38	50

Do not stretch the backer rod during installation.

H. *Limits of Joint Preparation*. Limit the daily amount of joint preparation work to that which can be completely resealed within a day's production.

I. *Installing Sealants*. Place sealant compound only when the joint is clean and all face surface is dry and dust-free. Place sealant when atmospheric and pavement temperature is at least 50°F (10°C) and rising. Ensure the bond between the concrete and the sealant is established without voids or entrapped air. Ensure the top surface of the sealant material is $^{1}/_{4}$ in. ± $^{1}/_{8}$ in. (6 mm ± 3 mm) below the adjacent pavement surface. Remove all material from the pavement surface after installing sealant.

Cure sealant according to manufacturer's recommendations. Prohibit traffic on the joints during the curing period.

553.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

553.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Resealing transverse joints—liquid sealant	ft (m)
(B) Resealing longitudinal joints—liquid sealant	ft (m)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 554
RESEALING JOINTS—PREFORMED ELASTOMERIC COMPRESSION SEAL

554.1 DESCRIPTION

Reseal joints in existing portland cement concrete pavement with preformed elastomeric compression seals.

554.2 MATERIALS

Provide materials as specified in Subsection 707.1(B).

554.3 CONSTRUCTION

A. *Preparing Joints.* Remove the existing sealant or inserts, reface and clean the joint, and install a seal using a lubricant.

B. *Equipment.* Install the seal using a device that compresses the material without cutting, twisting, distorting, or damaging the seal and that limits seal stretch during installation to 5 percent of the joint length.

C. *Removing Joint Insert.* Remove inserts as specified in Subsection 553.3(C).

D. *Removing Existing Sealant.* Remove existing sealant as specified in Subsection 553.3(D).

E. *Refacing Joints.* Recut the joint faces as specified in Subsection 553.3(E) to widen the joint to the width and depth required for the compression seal.

F. *Repairing Joints.* Repair the joint faces as needed to ensure contact between the compression seal and the concrete. Repair spalled joints as specified in Section 557.

G. *Cleaning Joints before Resealing.* Thoroughly clean the joint immediately after refacing and repair operations. Use a high-pressure water jet or oil-free air jet to remove all cuttings and debris remaining on the face or in the joint opening. Clean the joint-seal contact faces by sandblasting or wire brushing to remove sawing residue and other materials that could prevent a satisfactory bond between the seal and concrete. When the surfaces are thoroughly clean and dry, and before placing the joint sealer, use compressed air to blow out the joint and remove all traces of dust.

H. *Installing Compression Seal.* Install the compression seal in the upright position, free from twisting, distortion, or stretching. Install the compression seal only when the joint face is surface dry and the atmospheric and pavement temperatures are above 32°F (0°C) and rising. Apply a coating of lubricant to the joint reservoir walls and the sides of the preformed compression sealant material. Install the compression seal to a depth of $^1/_4$ in. ± $^1/_{16}$ in. (6 mm ± 1.5 mm) below the concrete surface. For beveled joints, install the seal to a depth of $^3/_{16}$ in. ± $^1/_{16}$ in. (5 mm ± 1.5 mm) below the bottom edge of the bevel.

Base compression seal dimensions on the joint spacing and dimensions shown below.

Table 554.3-1a. Compression Seal Dimensions (U.S. Customary Units)

Joint Spacing (ft)	Minimum Width and Maximum Joint Depth (in.)	Typical Seal Width (in.)
15	$^1/_4 \pm 1^1/_2$	$^7/_{16}$
25	$^5/_{16} \pm 1^1/_2$	$^5/_8$
30	$^3/_8 \pm 2$	$^{11}/_{16}$
40	$^1/_2 \pm 2$	1

Table 554.3-1b. Compression Seal Dimensions (SI Units)

Joint Spacing (m)	Minimum Width and Maximum Joint Depth (mm)	Typical Seal Width (mm)
4.5	6 ± 38	11
7.6	8 ± 38	16
9.1	10 ± 50	17
12.2	12 ± 50	25

Tolerance on all joint widths is $\pm^1/_{16}$ in. (±1.5 mm).

Install the joint seal so that the joint sealer material is stretched no more than 5 percent nor compressed more than 2 percent of the minimum theoretical length.

Splice joint seals according to the manufacturer's recommendations and as follows: (1) Do not splice joint seals within a transverse joint that is less than 24 ft (7.3 m) in length; (2) Transverse joints longer than 24 ft (7.3 m) may contain one splice of the joint seal.

Cure the newly placed sealant material according to the manufacturer's recommendations.

554.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

554.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Resealing transverse joints—neoprene compression seals	ft (m)
(B) Resealing longitudinal joints—neoprene compression seals	ft (m)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 555
RESEALING JOINTS—SILICONE SEALANT

555.1 DESCRIPTION

Reseal joints in existing portland cement concrete pavements with silicone sealant.

555.2 MATERIALS

Provide materials as specified in Subsection 707.1(C).

555.3 CONSTRUCTION

A. *Preparing Joints.* Remove existing sealant or inserts, clean and reface the joint, and install a shaping or blocking medium to produce the proper shape factor in the new joint sealant.

B. *Equipment.* Install the sealant material with a mechanical device equipped with a nozzle shaped to fit inside the joint, and form a uniform bead of the required width and depth between the joint faces.

C. *Removing Joint Insert.* Remove inserts as specified in Subsection 553.3(C).

D. *Removing Existing Sealant.* Remove existing sealant as specified in Subsection 553.3(D).

E. *Refacing Joints.* Reface joints as specified in Subsection 553.3(E).

F. *Joint Shape Factor.* Provide a width-to-depth ratio of 2:1 for joints less than 1 in. (25 mm) wide. Shape the joint reservoir so the sealant material is a minimum of $^1/_4$ in. (6 mm) deep, but not deeper than $^1/_2$ in. (12 mm) for joints up to 1 in. (25 mm) wide. For joints wider than 1 in. (25 mm), limit the depth of sealant to $^1/_2$ in. (12 mm).

G. *Cleaning Joints before Resealing.* Clean joint faces and opening as specified in Subsection 553.3(F).

H. *Separating and Blocking Medium.* Install blocking medium in the joints as specified in Subsection 553.3(G).

I. *Limits of Joint Preparation.* Limit the daily amount of joint preparation work to that which can be completely resealed within a day's production.

J. *Priming.* Prime the joint according to the sealant manufacturer's instructions for proper application rate and time of cure before installing the sealant.

K. *Installing Sealant.* Place the sealant as specified in Subsection 553.3(I), except disregard the temperature requirement.

Tool silicone sealant material that is not self-leveling to force the sealant against the joint surfaces.

555.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

555.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Resealing transverse joints—silicone sealant	ft (m)
(B) Resealing longitudinal joints—silicone sealant	ft (m)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 556
SEALING CRACKS

556.1 DESCRIPTION

Seal cracks in existing portland cement concrete pavements with liquid or silicone sealants.

556.2 MATERIALS

Provide materials as specified in Subsection 707.1.

556.3 CONSTRUCTION

A. *Preparing Cracks.* Remove existing sealant, reface and clean the crack, and install blocking medium to provide the proper shape factor.

B. *Equipment.* Meet Subsections 553.3(B) and 555.3(B). Furnish a concrete saw with a pivotal small-diameter blade that can follow the crack and provide a joint reservoir.

C. *Removing Existing Sealant.* Remove old sealant from the crack as specified in Subsection 553.3(D).

D. *Refacing Cracks.* Use a power-driven concrete saw with small diameter diamond or abrasive blades to reface cracks. Remove old sealant from the crack faces. Widen the crack to the width and depth necessary to produce the specified shape factor.

   Provide a minimum crack reservoir depth of $^3/_4$ in. (20 mm) where crack widths vary and crack faces are raveled and irregular.

E. *Cleaning Cracks*. Meet Subsection 553.3(F).

F. *Repairing Spalls*. Meet Section 557.

G. *Separating Medium*. Meet Subsection 553.3(G) and as follows: (1) For liquid sealants as defined in Section 553, use backer rods having diameters slightly larger than the width of the crack; (2) For silicone sealants as defined in Section 555, nonabsorbent closed cell foam rod is satisfactory.

H. *Installing Sealant*. Meet Subsection 553.3(I) and as follows: Low-severity or hairline cracks that are not spalled do not require sealing.

556.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

556.5 PAYMENT

Accepted quantities, measured as provided above, will be paid for at the contract unit price as follows:

Pay Item	Pay Unit
(A) Sealing cracks—liquid sealant	ft (m)
(B) Sealing cracks—silicone sealant	ft (m)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 557
PARTIAL-DEPTH PATCHING

557.1 DESCRIPTION

Construct partial-depth patches of spalls, potholes, and corner breaks in portland cement concrete pavements.

557.2 MATERIALS

Provide materials as specified in:

Portland Cement	Subsection 701.2
Coarse Aggregate for Concrete	Subsection 703.1(B)
Masonry Mortar Aggregate	Subsection 703.13

Chemical Admixtures	Subsection 713.3(B)
Water	Subsection 714.1(A)
Calcium Chloride	Subsection 714.2
Rapid-Setting Patching Materials	Approved list
Fine Aggregate for Epoxy Concrete	Gradation specified by epoxy manufacturer

557.3 CONSTRUCTION

A. *Mix Design.* Prepare a mix design as specified in Subsection 713.1(C) and submit for testing and approval [14] days before starting patching operations.

B. *Equipment.* Meet the following:

1. *Concrete Removal Equipment.* Furnish concrete removal equipment that will remove concrete in the repair area to the depth required without damaging sound concrete below the bottom of the patch.

2. *Forms for Patches Next to Shoulders.* Furnish forms that are straight, free of defects, and made of wood or metal.

3. *Proportioning and Mixing Equipment.* Use proportioning and mixing equipment that meets Subsection 501.3(B). Use mobile mixing equipment that meets AASHTO M 241M/M 241.

C. *Preparing Partial-Depth Patch Area.* Construct partial-depth patches at specified locations or as directed by the Engineer. Make a vertical saw cut around the perimeter of the patch area to a minimum depth of 2 in. (50 mm).

Use pneumatic tools to remove concrete within the patch area to a minimum depth of 2 in. (50 mm) until sound and clean concrete is exposed. If the depth of the repair exceeds 4 in. (100 mm), remove the entire area to full depth and replace as specified in Section 558. Limit the maximum size of pneumatic hammers to 30 lb (13.6 kg).

Cut shoulders next to the patch longitudinally to the depth of the patch and to a minimum width of 12 in. (300 mm). Extend the cut 12 in. (300 mm) beyond both transverse limits of the patch to ease form placement. Patch shoulders with the same type of material as in the existing shoulder.

Sandblast exposed concrete faces to remove loose particles, oil, dust, traces of asphalt concrete, and other contaminates before patching. Remove sandblasting residue before placing the bonding agent.

D. *Placing Patch Material.* Place and consolidate the patch mixture to eliminate voids at the interface of the patch and existing concrete. If a partial-depth repair area joins a working joint, use an insert, or other bond-breaking medium, to maintain working joints or cracks. Form the new joint to the same width as the existing joint or crack.

Repair the pavement using one of the following methods, as specified in the contract.

1. *Accelerated Strength Portland Cement Concrete Patch Mixtures.* Use accelerated strength portland cement concrete patch mixtures where early opening [4 to 6 h] to traffic is required. Use an epoxy bonding agent when placing accelerated portland cement concrete patches. Apply a thin coating of the epoxy bonding agent and scrub it into the surface with a stiff-bristled brush. Delay placing the concrete until the epoxy is tacky.

   Place accelerated portland cement concrete patches only when the air or pavement temperature is 40°F (5°C) and rising. Finish patches to the cross section of the existing pavement. Provide a surface texture to the patch with a stiff-bristled brush or match the texture of the existing pavement. Cure the patch as specified in Subsection 501.3(M).

2. *Normal Set Portland Cement Concrete Patch Mixture.* Use normal set portland cement concrete patch mixture where the patch is protected from traffic for a minimum of 24 h. Use a bonding grout composed of one part portland cement to one part sand by volume with sufficient water to produce a mortar of thick, creamy consistency. Place the patch grout within 90 minutes of adding water.

   Scrub the bonding grout evenly over the concrete surfaces to be patched. Remove excess grout from concrete surface pockets. Place the concrete patch mixture before the bonding grout dries. Remove dried or hardened grout by sandblasting and replace it at no cost to the Agency. Place and consolidate the patch mixture to eliminate voids at the faces between the patch and adjacent concrete. Finish patches to the cross section of the existing pavement.

   Texture the patch with a stiff-bristled brush to meet the texture of the existing pavement. Cure the patch as specified in Subsection 501.3(M).

3. *Rapid-Set Patch Materials.* Install the patch material to meet the manufacturer's recommendations. Prepare the repair area surface as specified in Subsection 557.3(C), except where modified by the manufacturer's recommendations. Follow manufacturer's recommended method for bonding, placing, and curing. Open the patched areas to traffic according to the manufacturer's recommendations.

4. *Epoxy Resin Patching Mortars or Epoxy Concrete.* Submit epoxy mortar and epoxy concrete mix designs to the Agency laboratory for verification and approval [14] days before use. Provide designs compatible with the concrete pavement at the patch sites.

   Before blending, precondition the epoxy resin and the catalyst to produce a homogenous liquid between 75°F (24°C) and 90°F (32°C). Mix the epoxy components according to the manufacturer's mixing recommendations before adding aggregates to the patch mixture. Blend in a mixer that produces a homogenous mass. Mix only that quantity of material that will be used within 1 of mixing.

Prime the entire surface of the repair areas, including overlapping of the surface of the area next to the patch, with neat blended epoxy immediately before placing the epoxy mixture. Place the epoxy mixture and tamp it to eliminate voids. Screed the surface to produce the required finish. Keep traffic off of the repair area for at least 3 h after screeding.

557.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. *Class A Patch.* Class A patches consist of a patch with no surface dimension less than 0.2 ft (60 mm) and a depth no greater than 2 in. (50 mm). The Engineer will measure Class A patches in ft^2 (m^2). The Engineer will record Class A patches less than 5 ft^2 (0.5 m^2) in area as 5 ft^2 (0.5 m^2).

B. *Class B Patch.* Class B patches consist of a patch for a joint or crack spall having a width of 0.2 ft (60 mm) or less and a depth no greater than 2 in. (50 mm). The Engineer will measure Class B patches in ft (m). The Engineer will record Class B patches less than 2 ft (0.6 m) in length as 2 ft (0.6 m).

C. *Extra Depth.* The Engineer will measure the average depth of patches meeting the surface measurement dimension requirements for Class A or B. The Engineer will measure average depth more than 2 in. (50 mm) as extra depth to the nearest 1 in. (25 mm).

557.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Class A patch	ft^2 (m^2)
(B) Class B patch	ft (m)
(C) Extra Depth Patch (Class A)	ft^2 (m^2)
(D) Extra Depth Patch (Class B)	ft (m)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 558
FULL-DEPTH PATCHING

558.1 DESCRIPTION

Construct full-depth patches of portland cement concrete pavement.

558.2 MATERIALS

Provide materials as specified in:

Portland Cement	Subsection 701.2
Aggregate for Untreated Base Course	Subsection 703.3
Reinforcing Steel	Subsection 711.1
Chemical Admixtures	Subsection 713.3(B)
Fly Ash	Subsection 713.3(C)(1)
Calcium Chloride	Subsection 714.2
Epoxy Resin Adhesives	AASHTO M 235M/M 235

558.3 CONSTRUCTION

A. *Mix Design.* Prepare a mix design as specified in Subsection 713.1(C) and submit for testing and approval [14] days before starting patching operations.

B. *Proportioning and Mixing Equipment.* Use proportioning and mixing equipment that meets Subsection 501.3(B). Use mobile mixing equipment that meets AASHTO M 241M/M 241.

C. *Preparing Repair Areas.* Repair in accordance with specified full-depth patching requirements for continuously reinforced, mesh-reinforced, plain-doweled, and plain- jointed sections, as applicable:

1. *Mesh-Reinforced, Plain-Doweled, and Plain-Jointed Pavement.*

a. *Removing Existing Pavement.* Vertically saw the slab full depth with a diamond blade to the limits of the patch.

The Contractor may use carbide-tipped wheel saws to within 3 in. (75 mm) of the transverse limits of each patch. Remove the remaining strips by sawing the slab full depth.

The minimum patch size depends on the type of load transfer to be used. If mechanical load transfer methods such as $1^{1}/_{4}$-in. (32-mm) dowel bars or tiebars are not used, the minimum patch size is 10 ft (3 m) in length and 12 ft (3.6 m) in width. If mechanical load transfer methods are used, the minimum patch size is 6.5 ft (2 m) in length and 12 ft (3.6 m) in width. If the limits of a patch are within 6.5 ft (2 m) of a joint, extend the area to be patched to include the joint.

The Contractor may remove shoulders next to the patch to accommodate formwork by sawing the shoulder full depth longitudinally and transversely. Repair shoulders with the same type of material as in the existing shoulder. Make longitudinal cuts no more than 12 in. (300 mm) from the edge of the pavement. Make the transverse cuts only far enough beyond the limits of the patch to accommodate the formwork.

Remove the concrete using methods that do not damage the subgrade or surrounding pavement.

After removing the old concrete, install dowel bars and tiebars. Use quicksetting, non-shrink mortar or epoxy to grout the bars into the existing slabs. Remove material disturbed below the level of slab removal. Dry the patch area and compact the subgrade as specified in Section 204. Compact subbase as specified in Section 304. Do not place new subbase material in the patch area. Fill the disturbed areas with concrete when the patch is placed.

b. *Underpinned Patches.* After removing the old concrete from the patch area, excavate the existing subbase material to a depth of 6 in. ± 1 in.

(150 mm ± 25 mm). Excavate unsuitable material found in the subgrade or subbase, as directed. Extend the excavation under the existing slab, on each side of the patch, a minimum of 6 in. (150 mm).

Backfill the excavated area with material meeting Section 203. Compact in layers less than 4 in. (100 mm) to the elevation of the existing subgrade or subbase.

Excavate the subbase so that a uniform cross section is maintained beneath the existing slabs. Drain and compact the subgrade as specified in Section 204.

2. *Continuously Reinforced Pavement.*

a. *Removing Existing Pavement.* Remove existing pavement by sawing two full- depth cuts outside the area to be patched and then sawing two partial-depth cuts outside the full-depth cuts. Saw the partial-depth cuts 8 in. (200 mm) outside the full-depth cuts if the replacement steel is to be welded. If the replacement steel is to be tied, saw the partial-depth cuts according to the limits specified in Subsection 558.3(C)(2)(c). Make the partial-depth cuts $1^1/_2$ to 2 in. (38 to 50 mm) deep without cutting the steel reinforcement. Make longitudinal cuts full depth. Cut shoulders as specified in Subsection 558.3(C)(1)(a).

The Contractor may break the concrete between the full-depth saw cuts down to the reinforcing steel with [17.5-lb (8-kg)] chipping hammers. Remove the debris without disturbing the base. Remove the remaining concrete between the partial-depth saw cuts by hand methods. Avoid bending or damaging the reinforcing steel.

b. *Preparing the Subbase.* After removing the old concrete from the patch area, drain, dry, and mechanically compact the existing loose subbase to the compaction level of the existing subbase. Do not place new subbase material in the patch area. Fill the disturbed areas with concrete when the patch is placed.

c. *Steel Replacement.* If more than 10 percent of the reinforcing steel is visibly corroded and damaged, extend the limits of the patch until visibly sound reinforcing steel is exposed to the required lap length. The required lap lengths for various sizes of tied reinforcing bars are as follows:

No. 4	12 in. (300 mm)
No. 5	18 in. (450 mm)
No. 6	22 in. (550 mm)

Provide a minimum clearance of 3 in. (75 mm) between the ends of new reinforcing steel and the existing pavement slab face to allow for expansion. Match the size, number, and spacing of the reinforcing steel to the existing pavement.

The Contractor may weld the new reinforcing steel if the welds are at least 4 in. (100 mm) long and $^1/_4$ in. (6 mm) wide. Stack the bars at the welded point on top of each other. Use electrodes that meet AWS A5.1/A5.1M E70 xx. Ensure there is no arc strike outside the permanent weld area. Prohibit tack welds. Lap and tie the new reinforcing steel at the center of the patch and meet the specified lap requirements. Place reinforcing steel to obtain a minimum concrete cover of $2^1/_2$ in. (64 mm). If the existing cover of the new reinforcing steel is less than $2^1/_2$ in. (64 mm), splice the new steel underneath the existing reinforcing steel. Support all reinforcing steel using chairs or similar devices. All welding must meet AWS D1.4/D1.4M.

D. *Placing Concrete.* Place concrete as outlined below:

1. *Placing Forms.* Use forms meeting Subsection 501.3(B)(5) to provide straight and neat lines at the shoulder for full depth patches.

2. *Cleaning Concrete Faces.* Sandblast exposed concrete faces where new concrete is to be bonded until they are clean, and allow to thoroughly dry.

3. *Concrete.* Furnish concrete as specified in Subsection 713.1(C). Where grouting is not required, keep all surfaces in contact with new concrete moist.

   a. *Placing Concrete.* Place concrete immediately after grouting to prevent drying of the grout.

   b. *Finishing and Texturing.* Vibrate, finish, and texture the concrete to meet Subsection 501.3.

   c. *Curing and Protection.* Meet Subsection 501.3(M). Protect concrete patches from rain for a minimum of 12 after placement when normal set concrete is used, and 3 when rapid set concrete is used.

E. *Opening to Traffic.* Use compressive strength test results to determine the schedule for opening the pavement to traffic.

Prohibit traffic on normal set concrete patches for at least 72 or on rapid set concrete patches for at least 4 h. Require longer waiting periods when ambient temperature is below 55°F (13°C).

558.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure full-depth patching by the yd^2 (m^2) of concrete removed. The Engineer will record each patch less than 2 yd^2 (1.5 m^2) in area as 2 yd^2 (1.5 m^2).

558.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Full depth patch	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified, including removing and disposing of the old pavement; placing new reinforcing steel; furnishing, placing, finishing, jointing, and curing the concrete; and repairing of the shoulder.

If the Engineer changes a partial-depth repair patch to a full-depth patch at an area prepared for partial-depth repair, the Agency will pay one-half the contract unit price for partial-depth patch in addition to the contract unit price for full-depth patch.

SECTION 559
DIAMOND GROOVING CONCRETE PAVEMENT

559.1 DESCRIPTION

Groove the existing pavement surface longitudinally or transversely.

559.2 MATERIALS

Reserved.

559.3 CONSTRUCTION

A. *Grooving*. Begin and end transverse or longitudinally grooved areas normal to the pavement centerline.

Begin longitudinal grooving 6 in. (150 mm) from the outside edge of pavement or reflective marker and run in a continuous pattern across the lane surface to within 6 in. (150 mm) of all longitudinal joints.

Begin transverse grooving 12 in. (300 mm) from the outside edge and run in a continuous pattern to 12 in. (300 mm) from the opposite edge.

For both types of grooving, cut grooves in a pattern $^1/_8$ in. (3 mm) wide by $^3/_{16}$ in. (5 mm) deep with a center-to-center spacing of $^3/_4$ in. (20 mm).

If a single grooving blade becomes ineffective at cutting the required groove, continue work for the remainder of the work shift without recutting the omitted groove. If two or more grooving blades become ineffective at cutting grooves, stop grooving operations and replace the defective blades.

Ensure that the actual grooved area covers at least 90 percent of any selected 3 ft by 100 ft (1 m by 30 m) longitudinal pavement area grooved.

Grooving is not required in areas where pavement reinforcement is exposed.

Remove slurry or residue that results from the grooving operation. Prevent slurry flow across shoulders, lanes occupied by public traffic, or into gutters or other drainage facilities.

Conduct a final sweeping with power equipment before opening the pavement to traffic.

B. *Equipment.* Furnish a self-propelled grooving machine with diamond blades mounted on a multiblade arbor and a minimum cutting head width of 3 ft (1 m). The grooving machine control device must align the grooves, detect variations in the pavement surface, and automatically adjust the cutting head height to maintain the specified depth. Furnish a full complement of grooving blades and spacers capable of cutting grooves to the specified width, depth, and spacing.

C. *Groove Tolerances.* Meet the tolerances specified below:

Spacing	$\pm^1/_8$ in. (3 mm)
Depth	$\pm^1/_{16}$ in. (1.5 mm)
Width	$\pm^1/_{64}$ in. (0.4 mm)

The width of grooves on curves and superelevations may slightly exceed the above tolerances.

Cut transverse grooves no closer than 3 in. (75 mm) or more than 9 in. (225 mm) from a transverse joint.

559.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will determine the quantity of pavement grooving by multiplying the width and length of the grooved area. The Engineer will not make deductions for grooving omitted at edges, joints, manholes, or other devices.

559.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Pavement grooving	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 560
DIAMOND GRINDING CONCRETE PAVEMENT

560.1 DESCRIPTION

Grind and texture existing portland cement concrete pavement longitudinally using a diamond grinder.

The Agency will provide a surface profilogram and a listing of surface types, showing aggregates incorporated in the pavement.

560.2 MATERIALS

Reserved.

560.3 CONSTRUCTION

A. *Diamond Grinding.* Uniformly grind and texture the entire pavement surface area until the surface on both sides of the transverse joints and all cracks are in the same plane and meet the required smoothness. Exclude shoulders.

Begin and end grinding from locations normal to the pavement centerline.

Provide the surface of the ground pavement with a corduroy-type texture consisting of parallel grooves between $^3/_{32}$ in. (2.25 mm) and $^5/_{32}$ in. (3.75 mm) wide, with a distance between the grooves of $^1/_{16}$ in. (1.5 mm) to $^1/_8$ in. (3 mm) and a difference between the peaks of the ridges and the bottom of the grooves of ____ in. (mm).

Remove slurry or residue resulting from the grinding operations as specified in Subsection 559.3(A). Conduct a final sweeping with power equipment before opening the pavement to traffic.

B. *Equipment*. Furnish a self-propelled grinding machine with diamond blades mounted on a multiblade arbor and a minimum cutting head width of 3 ft (1 m). Use equipment that does not damage the underlying surface of the pavement. Repair or replace equipment that causes raveling, aggregate fractures, spalls, or joint damage.

C. *Tolerances*. After the Contractor completes grinding and texturing, the Engineer will test the pavement surface for smoothness to ensure it meets the surface tolerance for new pavement specified in Subsection 401.3(L)(1). Grind the adjacent shoulders or pavement to provide the required cross slope for drainage.

Provide a uniform pavement cross slope without depressions or misalignment of slope greater than _____ in. (mm) in _____ ft (m) when tested by stringline or straightedge placed perpendicular to the centerline.

Straightedge requirements do not apply across longitudinal joints or outside the ground areas. A _-ft (m) test area used to measure tolerance must have a grinding coverage of 95 percent.

560.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will determine the quantity of pavement grinding by multiplying the width by the length of the ground area.

560.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Pavement grinding	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 561
MILLING PAVEMENT

561.1 DESCRIPTION

Strip pavement by a cold milling process before resurfacing.

561.2 MATERIALS

Reserved.

561.3 CONSTRUCTION

A. *Milling Setup.* Mill the surface in a longitudinal direction. For the initial pass, use as a reference the curb, longitudinal edge of pavement, or a string attached to the pavement surface. Furnish a milling machine with a steering guide or reference that allows the operator to follow the guidance reference within 2 in. (50 mm). When milling next to previously milled pavement, use the edge of the milled trench as the longitudinal reference for succeeding passes.

Provide a milled surface with a uniform texture free of excessive gouges, ridges, and grooves.

Provide an end transition on a 4:1 (1:4) slope to the existing pavement surface at each end of the milling work each day. End the milling passes as close to each other as practical. Do not leave longitudinal joints more than 2 in. (50 mm) deep exposed during nonworking hours.

Conduct milling operations so that no water runoff collects along milled joints or unmilled areas.

B. *Milling Equipment.* Use self-propelled milling equipment capable of removing the pavement surface necessary to provide profile, cross slope, and surface texture uniformly across the full width of the milling machine. Use a machine with an automatic grade and cross-slope control system that is fully proportional and capable of field calibration. Reference the grade and cross-slope control system from a towed averaging ski or direct matching shoe. The machine must control dust created by the cutting action. Recover and stockpile or dispose of milled material at a rate equivalent to the pavement removal rate.

C. *Exposed Concrete Surface Tolerance.* Provide a final milled surface that does not vary by more than $^1/_8$ in. (3 mm) when tested using a 10-ft (3-m) straightedge. Limit the difference in surface elevation between adjacent passes to $^1/_8$ in. (3 mm).

Provide a milled-surface cross slope that meets the specified cross slope within $^1/_4$ in. in 10 ft (6 mm in 3 m). Provide longitudinal transitions from one cross slope to another cross section having a different cross slope or depth of cut at the rate of $^1/_{10}$ percent of slope per 25 ft (7.5 m) of travel or $^1/_8$ in. (3 mm) of depth per 25 ft (7.5 m) of travel.

Conduct a final sweeping with power equipment before opening the pavement to traffic.

561.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure pavement milling by the yd^2 (m^2) of surface area acceptably milled to the specified depth. The measurement will include adjacent shoulders.

561.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Pavement milling	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified, including cleaning the milled surface and hauling and stockpiling reclaimed material.

SECTION 562
PORTLAND CEMENT CONCRETE BONDED OVERLAYS

562.1 DESCRIPTION

Construct a portland cement concrete bonded overlay on an existing portland cement concrete pavement. Include cleaning and preparing the existing surface, applying a bonded overlay, partial- and full-depth patching, repairing curb, and disposing of removed materials.

562.2 MATERIALS

Provide materials as specified in:

Portland Cement, Type I or Type II	Subsection 701.2
Reinforcing Steel	Subsection 711.1
Concrete	Subsection 713.1(A)
Curing Materials	Subsection 713.2
Grout	Subsection 713.5(B)
Water	Subsection 714.1(A)

When a separate mix design is required for partial- or full-depth patches ahead of the bonded overlay, the contract will specify the quantities for each mix.

562.3 CONSTRUCTION

A. *Bonded Overlay Equipment.*

1. *Preparing the Surface.* Use milling, sandblasting, shotblasting, or high-pressure waterblasting equipment to prepare the surface. Ensure that the equipment removes all rust, oil,

rubber, and concrete laitance and contaminants from the existing pavement surface, and controls dust.

a. *Milling/Scarifying*. Provide a machine that uniformly scarifies and removes the existing surface to the specified depths and cross section. Obtain Agency approval to use other types of removal devices.

b. *Sandblasting*. Ensure equipment has dust-control devices.

c. *Shotblasting*. Provide equipment with a self-contained cleaning system and dust collector. Ensure the equipment can discharge reused pellets and contaminants into a separator that automatically recycles the cleaned abrasive and discharges dust and surface contaminants into a dust collector.

d. *High-Pressure Waterblasting*. Use equipment that operates at a pressure in excess of 6,000 psi (41.4 MPa).

e. *High-Pressure Water with Abrasive Blasting*. Provide blasters capable of blasting with water and sand or other abrasives. Operate blaster with the nozzle held 6 to 18 in. (150 to 450 mm) from the surface.

2. *Proportioning and Mixing Equipment*. Meet Subsection 501.3(B) and as follows. Provide enough equipment mixing capacity to place the bonded overlay mix without interruption.

3. *Placing and Finishing Equipment*. Meet Subsection 501.3 and as follows. Furnish equipment with an elevation control system that operates from a ski or set stringline, unless a pad line constructed to controlled elevation is used. Manually place and finish intersection radii, structures, or other small areas inaccessible to mechanical equipment.

   Ensure equipment provides for mechanical vibration.

4. *Grout-Mixing Equipment*. The Contractor may mix grout in central mix plants, ready- mix trucks, concrete mobiles, or in small paddle mixers on the project site.

5. *Vibration*. Provide the number of vibrators and a vibration frequency as specified in Subsection 501.3(B)(3). Use hand-held vibrators for all handwork.

B. *Preparing the Surface and Patching Pavement*.

1. *Removing Asphalt and Milling Portland Cement Concrete Surface*. Remove asphalt concrete overlay and scarify a minimum of $^{1}/_{4}$ in. (6 mm) of existing underlying concrete surface by surface milling. Scarify to remove asphalt, laitance, loose concrete, and foreign materials from the concrete pavement.

2. *Scarification/Milling—Partial-Depth Removal, 1 in. (25 mm)*. Scarify the existing concrete pavement to a nominal depth of 1 in. (25 mm) after removing asphalt overlay. Determine areas requiring partial-depth scarification by sounding with hammers, dragging with chains, or other acceptable methods. Perform partial-depth scarification on minimum widths of 24 in. (600 mm) and minimum lengths of 12 in. (300 mm).

3. *Scarification/Milling—Partial-Depth Removal, 2 in. (50 mm).* Scarify the existing concrete pavement to a nominal depth of 2 in. (50 mm) after removing the asphalt overlay. Determine areas requiring partial-depth scarification by sounding with hammers, dragging with chains, or other acceptable methods. Provide 2-in. (50-mm) scarification at random cracks where partial-depth removal and placement of reinforcing steel is required to stop the movement of the crack.

4. *Full-Depth Removal and Replacement.* Remove or stabilize the slab as specified in Section 558. The contract will show, or the Engineer will direct, the areas to be removed. Match full-depth patch profile to existing pavement and leave the patch surface slightly rough. Cure the surface with wet burlap and clean the surface before overlaying.

5. *Reinforcing Steel Presence.* Remove reinforcing steel encountered during surface scarification, partial-depth removal, full-depth removal, or curb removal to the limits of excavation.

6. *Material Removed.* Dispose of material removed as specified in Subsection 201.3.

7. *Preparing the Surface—Sandblasting/Shotblasting/Waterblasting.* Before grouting and placing bonded overlays, prepare the surface by sandblasting, shotblasting, and high-pressure waterblasting. Remove surface dirt, oil, other foreign material, laitance, or loose concrete from the scarified and patch surfaces just before placing the grout and bonded overlay. Clean surface by airblasting to remove loose particles. Prevent contamination of the scarified surface with compressor oil. Ensure the existing concrete surface prepared for bonded overlays is dry before placing grout and new concrete. Allow additional drying time of the slab when using the waterblasting procedure.

C. *Placing and Finishing Concrete.*

1. *General.* Placing and finishing operations include partial- and full-depth patches, curb replacement, and concrete-bonded overlay. Provide items needed to grout, place, finish, texture, cure, joint, and seal the concrete-bonded overlay.

   Before placing bonded overlays, hold a pre-pour conference with the Agency to review equipment, proposed placement operation procedures, personnel, and previous experience to ensure coordination of all operations. Include the following in the proposed placement operations plan:

   a. Assurance that concrete can be continuously and uniformly produced and placed.

   b. Method for re-profiling the existing pavement with scarification equipment. Discuss equipment or operation adjustments to be made to obtain the minimum depth specified if problems occur in obtaining the specified depth caused by crown or surface irregularities.

   c. The method for locating existing joints so accurate joint saw cuts can be made in the new concrete.

2. *Grout.* Brush or spray a thin coating of grout onto the dry prepared surface immediately ahead of concrete-bonded overlay placement. Provide a thorough, even coating without allowing excess grout collection in pockets.

   Limit the area of applied grout to ensure it is covered with new concrete before the grout dries. Apply additional grout if a whitish appearance indicates the grout surface is drying. In areas where the grout becomes thoroughly dried, remove grout by sandblasting or shot-blasting, and reclean the affected area.

3. *Reinforcing Steel.* Place reinforcing steel at random cracks that have been scarified to a depth of 2 in. (50 mm) after grouting operations and before placing concrete. Support and hold reinforcing steel in place to ensure a minimum depth of cover of 2 in. (50 mm). Use No. 4 or No. 5 reinforcing steel bars on 30-in. (750-mm) to 48-in. (1.2-m) centers.

4. *Surface Texture.* After achieving a tight, uniform overlay surface, texture the surface with burlap or by artificial turf drag, brooming, transverse tining, or a combination of these methods.

5. *Cure.* Apply curing compound as specified in Subsection 501.3(M) at the rate of 1 gal/15yd^2 (4 L/14 m^2).

6. *Joints.* Insert or form transverse joints in the plastic concrete overlay immediately. Mark and saw overlay concrete joints directly over existing joints. Precut expansion joints in the plastic concrete. Make two saw cuts over the expansion joints in the new overlay and remove the concrete between saw cuts.

   Saw transverse and expansion joints full depth for overlays less than 3 in. (75 mm).

   Saw longitudinal joints one-half the depth of the overlay.

D. *Testing and Opening to Traffic.*

1. *Slump.* Use concrete with a maximum slump, as determined by AASHTO T 119M/T 119, of 2 $^1/_2$ in. (64 mm).

2. *Percent Entrained Air.* Use concrete with an entrained air content of 6$^1/_2$ percent, ±1$^1/_2$ percent, as determined by AASHTO T 152.

3. *Bond Strength.* Test the bond strength at the interface between the old and new concrete using Test Method No. Iowa 406B, September 1984, as developed by the Office of Materials, Iowa Agency of Transportation. The minimum shear strength is 200 psi (1.38 MPa).

4. *Compressive Strength—Opening to Traffic.* Do not open the overlay to traffic or construction equipment until the concrete bonded overlay attains a minimum compressive strength of 3,500 psi (24 MPa) and all joints have been cleaned and filled with joint material. Test concrete compression cylinders according to AASHTO T 22.

5. *Defective Concrete*. Remove and replace concrete not meeting the requirements of this Section or exhibiting excessive cracking, delamination, and distress at no cost to the Agency.

6. *Pavement Rideability*. The Engineer will test the pavement surface for smoothness as specified in Subsection 401.3(L)(2).

562.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

1. *Bonded Overlay, Furnish Only*. The Engineer will measure the quantity of bonded overlay concrete, including patching, miscellaneous concrete per type of mix proportions, and admixture, by the yd^3 (m^3). The measurement will include quantities used for partial- depth patches, full-depth patches, replacing curb, and adjusting manholes and structures.

2. *Bonded Overlay, Placement Only*. The Engineer will compute the area of bonded overlay in yd^2 (m^2) based on the longitudinal surface measurement and nominal plan width. The Engineer will measure irregular and patched areas separately in yd^2 (m^2).

3. *Asphalt Removal and Portland Cement Concrete Surface Milling*. The Engineer will measure the quantity of pavement surface scarified in yd^2 (m^2).

4. *Partial-Depth Removals, 1 in. (25 mm) and 2 in. (50 mm)*. The Engineer will compute the areas of partial-depth removals in yd2 (m2) from measurements of the locations by depth class.

5. *Full-Depth Removal*. The Engineer will compute the areas of full-depth removal in yd^2 (m_2) from surface measurements. The measurement will include areas around manholes and structures adjusted or raised to meet new grade lines. Consider removal and replacement of unsuitable subgrade as incidental to the work.

6. *Curb Removal*. The Engineer will measure the length of curb removal in ft (m) along the line and slope of the curb removed.

7. *Preparing Surface (Sandblasting/Shotblasting/Waterblasting)*. The Engineer will compute the quantity of pavement surface prepared from surface measurement in yd^2 (m^2). Consider dust control as incidental to the work.

8. *Reinforcing Steel*. The Engineer will measure the quantity of reinforcing steel placed by bar length placed and will convert to lb (kg) based on bar size.

562.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Bonded overlay, furnish only	yd^3 (m^3)
(B) Bonded overlay, placement only	yd^2 (m^2)
(C) Removing asphalt and milling portland cement concrete surface	yd^2 (m^2)
(D) Partial-depth removal, 1 in. (25 mm)	yd^2 (m^2)
(E) Partial-depth removal, 2 in. (50 mm)	yd^2 (m^2)
(F) Full-depth removal	yd^2 (m^2)
(G) Curb removal	ft (m)
(H) Preparing surface (sandblasting/shotblasting/waterblasting)	yd^2 (m^2)
(I) Reinforcing steel	lb (kg)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified, including disposing of removed materials.

SECTION 563
PORTLAND CEMENT CONCRETE UNBONDED OVERLAYS

563.1 DESCRIPTION

Place portland cement concrete unbonded overlays, including pavement patching of existing surface, applying a bond breaker, repairing curb, and disposing of removed material.

563.2 MATERIALS

Provide materials as specified in:

Portland Cement	Subsection 701.2
Asphalt Cements	Subsection 702.1(A)
Cover Coat Material Aggregates	Subsection 703.9
Reinforcing Steel Mesh and Prestressing Strand	Subsection 711.3
Curing Materials	Subsection 713.2
Water	Subsection 714.1(A)

A. *Cement.* Use Type I and Type II cement only.

B. *Concrete.* Meet Subsection 713.1(A) and as follows. The contract will specify quantities for each mix where a separate mix is required for partial- or full-depth patches ahead of resurfacing.

C. *Reinforcing Steel.* Use deformed epoxy-coated bars.

1. *Bar Specifications.*

Table 563.2-1. Bar Specifications

Steel Type	Grade	AASHTO	Reinforcement	
			Longitudinal	Transverse
Billet	40	M 31M/M 31	x	x
Billet	60	M 31M/M 31	x	x
Rail	50	M 322M/M 322		x
Rail	60	M 322M/M 322	x	x
Axle	40	M 322M/M 322	x	x
Axle	60	M 322M/M 322	x	x

Use AASHTO M 31M/M 31, Grade 40 bars for transverse bars welded to supports, bars that cross the longitudinal joint, and bars that are to be bent and later straightened.

2. *Reinforcing Steel.* Meet the following requirements for continuous reinforced concrete pavement resurfacing:

a. *Length of Reinforcing Bars.* Use longitudinal bars not less than 30 ft (9.1 m) long except where shorter bars are required for starting or ending a staggered lap pattern.

b. *Size and Spacing of Reinforcing Bars.* Install the longitudinal bars not less than 4 in. (100 mm) and not more than 9 in. (225 mm) center-to-center.

D. *Load Transfer Devices.* Use sawed load transfer devices free of burrs.

E. *Fibrous Concrete.* The contract will specify fibers.

F. *Bituminous Materials.*

1. *Asphalt Concrete.* Place a uniform layer to a minimum depth of 1 in. (25 mm).

2. *Slurry Seal.* Place to a minimum depth of $^1/_8$ in. (3 mm).

G. *Lean Concrete.* Level the roadway using a lean concrete mixture with $^3/_8$-in. (10-mm) top size aggregate. Minimum thickness is 1 in. (25 mm). Apply a wax base curing compound at a rate of 1 gal/15 yd^2 (4 L/14 m^2).

H. *Polyethylene Sheeting.* Place sheeting of 6 mil (0.15 mm) thickness over the area to be paved.

I. *Roofing Felt.* Place roofing felt with a mass per unit area of 15 lb/3 yd^2 (6.8 kg/2.5 m^2) over the area to be paved.

563.3 CONSTRUCTION

A. *Equipment:*

1. *Milling/Scarifying Equipment.* Meet Subsection 562.3(A)(1)(a).

2. *Proportioning and Mixing Equipment.* Meet Subsection 562.3(A)(2).

3. *Placing and Finishing Equipment.* Meet Subsection 562.3(A)(3).

4. *Vibration.* Meet Subsection 562.3(A)(5).

5. *Interlayer Treatment.* Use equipment that will place the bond breaker medium to the specified quantities.

B. *Preparing the Surface and Pavement Patching.*

1. *Removing Asphalt.* Meet Subsection 562.3(B)(1).

2. *Patching Pavement.* Fill deep spalls with asphalt concrete or concrete before placing the interlayer treatment.

3. *Full-Depth Removal and Patching.* Remove pavement full depth or stabilize as specified in Section 558. Construct full-depth patches before placing the overlay.

4. *Disposing of Material Removed.* Dispose of material removed as specified in Subsection 201.3.

C. *Placing and Finishing Concrete.*

1. *Concrete Overlay.* The concrete overlay must meet Subsection 501.3. Before placing unbonded overlays, hold a pre-pour conference as specified in Subsection 562.3(C)(1).

2. *Reinforcing Steel.*

   a. *Load Transfer Devices.* Meet Subsection 501.3(J)(2)(b).

   b. *Fiber-Reinforced Concrete Pavement.* Add the specified fiber reinforcement to the concrete mixture.

   c. *Tiebars.* Meet Subsection 501.3(J)(1)(b).

3. *Surface Texture.* Meet Subsection 562.3(C)(4).

4. *Cure.* Apply curing compound meeting Subsection 501.3(M) at the rate of 1 gal/15 yd^2 (4 L/14 m^2).

5. *Joints.* Saw transverse joints in the new concrete overlay.

   Clean and seal joints as specified in Subsection 501.3(J) before opening the pavement to traffic.

   Joints are not required in a lean concrete course.

D. *Testing and Opening to Traffic.*

1. *Slump.* Use concrete having a maximum slump, as determined by AASHTO T 119M/T 119, of 3 in. (75 mm) for concrete placed by vibration or 4 in. (100 mm) for hand-placed concrete.

2. *Percent Entrained Air.* Meet Subsection 562.3(D)(2).

3. *Compressive Strength.* Open pavements to traffic as specified in Subsection 562.3(D)(4).

4. *Pavement Rideability.* The Engineer will test pavement surfaces for smoothness as specified in Subsection 401.3(L)(2).

563.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. *Concrete Overlay, Furnish Only.* The Engineer will measure the quantity of overlay concrete, including patching and miscellaneous concrete per type of mix proportions and admixture specified, by the yd3 (m3). The measurement will include quantities used for overlay for partial-depth patches, full-depth patches, curb replacement, manhole adjustment, and structure adjustment.

B. *Concrete Overlay, Placement Only.* The Engineer will compute the area in yd^2 (m^2) from longitudinal surface measurement and nominal width. The Engineer will measure irregular and patched areas separately in yd^2 (m^2).

C. *Removing Asphalt and Milling Portland Cement Concrete Surface.* The Engineer will measure quantity of pavement surface scarified in yd^2 (m^2).

D. *Partial-Depth Removals, 1 in. (25 mm) and 2 in. (50 mm).* The Engineer will compute the areas in yd^2 (m^2) from measurements of the locations by depth class.

E. *Full-Depth Removal.* The Engineer will compute areas of full-depth removals in yd^2 (m^2) from surface measurements. The measurement will include full-depth removal areas around manholes and structures adjusted or raised to meet new grade lines. Consider removal and replacement of unsuitable subgrade as incidental to the work.

F. *Curb Removal.* The Engineer will measure the length of curb removal in ft (m) along the line and slope of the curb to be removed.

G. *Reinforcing Steel.* The Engineer will measure quantities as follows:

1. *Plain Resurfacing.* The Engineer will compute the quantity of reinforcing steel placed over random cracks by measuring the size and length placed and converting to lb (kg) using the standard No. 4 bar. The Engineer will include dowels at joints in the measure.

2. *Mesh-Reinforced Resurfacing*. The Engineer will include steel reinforcing or dowels in the measure.

3. *Continuously Reinforced Resurfacing*. The Engineer will measure reinforcing bars by area in yd^2 (m^2) of concrete resurfacing specified or required to be reinforced, with no allowances made for necessary laps and splices.

H. *Interlayer Treatment*. The Engineer will measure quantities as follows:

1. *Slurry Seal*. The Engineer will compute the area of slurry seal in yd^2 (m^2) from surface measurements.

2. *Asphalt*. The Engineer will measure asphalt by the ton (Mg).

3. *Lean Concrete, Furnish Only*. The Engineer will measure the quantity of lean concrete furnished by the yd^3 (m^3).

4. *Lean Concrete, Placement Only*. The Engineer will compute the area of lean concrete placed in yd^2 (m^2) from longitudinal surface measurements and nominal plan width. The Engineer will measure irregular areas separately in yd^2 (m^2).

5. *Polyethylene Sheeting*. The Engineer will compute quantities in yd^2 (m^2) from surface measurements.

6. *Roofing Felt*. The Engineer will compute quantities in yd^2 (m^2) from surface measurements.

563.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Concrete overlay, furnish only	yd^3 (m^3)
(B) Concrete overlay, placement only	yd^2 (m^2)
(C) Removing asphalt and milling portland cement concrete surface	yd^2 (m^2)
(D) Partial-depth patch	yd^2 (m^2)
(E) Full-depth removal	yd^2 (m^2)
(F) Curb removal	ft (m)
(G) Plain resurfacing reinforcing steel	lb (kg)
(H) Continuously reinforced resurfacing steel	yd^2 (m^2)
(I) Slurry seal	yd^2 (m^2)
(J) Asphalt concrete	ton (Mg)
(K) Lean concrete, furnish only	yd^3 (m^3)
(L) Lean concrete, placement only	yd^2 (m^2)
(M) Polyethylene sheeting	yd^2 (m^2)
(N) Roofing felt	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified, including disposing of removed materials.

SECTION 564
PORTLAND CEMENT CONCRETE DIRECT PARTIALLY BONDED OVERLAYS

564.1 DESCRIPTION

Furnish and place portland cement concrete direct partially bonded overlays including preparing the existing surface, patching pavement, repairing curb, and disposing of removed material.

564.2 MATERIALS

Provide materials as specified in:

Portland Cement	Subsection 701.2
Asphalt Cements	Subsection 702.1(A)
Reinforcing Steel and Mesh	Section 711
Curing Materials	Subsection 713.2
Water	Subsection 714.1(A)

A. *Concrete.* Meet Subsection 563.2(B).

B. *Reinforcing Steel.* Meet Subsection 563.2(C).

C. *Load Transfer Devices.* Meet Subsection 563.2(D).

D. *Fibrous Concrete.* The contract will specify fibers.

E. *Bituminous Materials.* Meet Subsection 563.2(F).

564.3 CONSTRUCTION

A. *Equipment.* Meet the following:

1. *Proportioning and Mixing Equipment.* Subsection 562.3(A)(2).
2. *Placing and Finishing Equipment.* Subsection 562.3(A)(3).
3. *Vibration.* Subsection 562.3(A)(5).

B. *Preparing the Surface and Patching Pavement.*

1. *Preparing Surface.* Sweep the surface clean of dirt, dust, and foreign material after completing repairs to the existing pavement and before placing the overlay. Trim extruding joint sealing material from rigid pavements.

2. *Patching Pavement.* Fill deep spalls with asphalt or concrete before placing the overlay.

3. *Full-Depth Removal and Replacement.* Remove the pavement slab full-depth or stabilize as specified in Section 558. The contract will show, or the Engineer will direct, the areas to be removed. Remove and replace unsuitable subgrade encountered with acceptable suitable earth fill material or granular materials. Compact the subgrade replacement material to the level of the existing subgrade material. Payment for the subgrade removal is incidental to full-depth removal.

   Replace full-depth patches as directed before placing the overlay.

4. *Material Removed.* Dispose as specified in Subsection 201.3.

C. *Placing and Finishing Concrete.*

1. Place, finish, texture, cure, joint, and seal the concrete overlay as specified in Subsection 501.3.

2. Before placement operations, hold a pre-pour conference as specified in Subsection 562.3(C)(1).

3. *Reinforcing Steel.*

   a. *Load Transfer Devices.* Meet Subsection 501.3(J)(2)(b).

   b. *Fiber-Reinforced Concrete Pavement.* Add the specified fiber reinforcement to the concrete mixture.

   c. *Tiebars.* Meet Subsection 501.3(J)(1)(b).

4. *Surface Texture.* Meet Subsection 562.3(C)(4).

5. *Cure.* Apply curing compound as specified in Subsection 501.3(M), at the rate of 1 gal/15 yd^2 (4 L/14 m^2).

6. *Joints.* Saw transverse joints in the new concrete overlay. Mark and saw the joints within 1 in. (25 mm) of existing joints.

   Clean and seal all joints as specified in Subsection 501.3(J) before opening the pavement to traffic.

D. *Testing and Opening to Traffic.* Meet Subsection 562.3(D).

564.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. *Concrete Overlay, Furnish Only.* The Engineer will measure the quantity of overlay concrete, including patching and miscellaneous concrete per type of mix proportions and admixtures, by the yd^3 (m^3). The measurement will include quantities used for partial- depth patches, full-depth patches, replacing, and adjusting manholes and structures.

B. *Concrete Overlay, Placement Only.* The Engineer will compute the area of concrete overlay in yd^2 (m^2) from longitudinal surface measurement and nominal width. The Engineer will measure irregular areas separately in yd^2 (m^2).

C. *Full-Depth Removal.* The Engineer will compute the areas of full-depth removal in yd^2 (m^2) from surface measurements, including full-depth removal areas around manholes and structures adjusted or raised to meet new grade lines.

D. *Curb Removal.* The Engineer will measure the length of curb removal by the ft (m) as measured along the line and slope of the curb to be removed.

E. *Reinforcing Steel.* The Engineer will measure reinforcing steel as outlined below:

1. *Plain Resurfacing.* The Engineer will compute the quantity of reinforcing steel placed over random cracks by measuring size and length placed and converting to lb (kg) using the standard No. 4 bar. The measurement will include dowels at joints.

2. *Mesh-Reinforced Resurfacing.* The measurement will include steel reinforcing or dowels in plain resurfacing.

3. *Continuously Reinforced Resurfacing.* The Engineer will measure quantities by area in yd^2 (m^2) of concrete resurfacing, with no allowance for necessary laps and splices.

F. *Mesh and Dowels.* The Engineer will not measure mesh or dowels for payment, as these items will be included in the cost of placing concrete.

564.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Concrete overlay, furnish only	yd^3 (m^3)
(B) Concrete overlay, placement only	yd^2 (m^2)
(C) Full-depth removal	yd^2 (m^2)
(D) Curb removal	ft (m)
(E) Plain resurfacing reinforcing steel	lb (kg)
(F) Continuously reinforced resurfacing steel	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified, including disposing of removed materials.

SECTION 565
RECYCLING PORTLAND CEMENT CONCRETE PAVEMENT (PCCP)

565.1 DESCRIPTION

Furnish and place portland cement concrete, using recycled portland cement concrete that has been crushed and sized for aggregate.

565.2 MATERIALS

Provide materials as specified in Subsection 501.2.

The Agency will evaluate aggregate derived from crushing the existing pavement to determine its suitability for use in the portland cement concrete.

565.3 CONSTRUCTION

A. *Placing Pavement.* Place recycled concrete pavement using the stationary side-form or by slip-form methods as specified in Subsection 501.3(G)(1). The Contractor may form and finish irregularly shaped areas using hand methods.

B. *Removing Old Pavement.*

1. Fracture the existing portland cement concrete into pieces that can be transported to the mixing site.
2. Remove asphalt patches, overlays, and sealing materials before fracturing the portland cement concrete. Dispose of the asphalt materials as specified in Subsection 201.3 or stockpile and salvage them.
3. Minimize contamination of the salvaged concrete with underlying subbase material or soil.

C. *Crushing and Stockpiling.*

1. Crush to a maximum size of $1^{1}/_{2}$ in. (38 mm).
2. Separate the crushed material over a $^{3}/_{8}$-in. (9.5-mm) screen and store in separate stockpiles to prevent contamination.
3. Use stockpiling methods that meet Subsection 501.3(B)(1). Ensure the maximum material passing the No. 200 (75-µm) sieve in the total product does not exceed 5 percent by weight.
4. Take ownership of salvaged reinforcing steel and remove from the project.

D. *Mix Proportions.* Meet Subsection 713.1(A) and the following:

1. Make trial mixes and test specimens using the crushed concrete as aggregate to evaluate the mixture. Crushed concrete for trial mixes may be laboratory-produced before preparing the mix design. Provide enough crushed pavement material to make all of the necessary trial mixes and test specimens.

2. Add enough virgin aggregate to the trial mixes to produce acceptable workability.

E. *Water and Consistency.* Use enough mixing water to produce acceptable workability and uniform consistency as specified below:

1. Determine slump according to AASHTO T 119M/T 119. Minimum allowable slump is $^1/_2$ in. (12 mm). Maximum allowable slump is 3 in. (75 mm) for stationary side-form pavement; 2 in. (50 mm) for slip-form pavement; and 4 in. (100 mm) for hand-finished pavement.

2. Determine the design water-cement ratio in the laboratory using the materials to be used on the project.

3. If concrete having the required consistency cannot be produced without exceeding the maximum allowable water–cement ratio, increase the cement content as directed by the Engineer without exceeding the maximum water–cement ratio.

F. *Percent Entrained Air.* Provide an entrained air content in the concrete, determined by AASHTO T 152, of $6^1/_2$ percent ± $1^1/_2$ percent.

G. *Durability.* The minimum freeze–thaw durability factor of recycled concrete is 80 when evaluated using AASHTO T 161, Procedure B, modified to provide a 90-day moist cure period. Other tests that would provide equivalent durability information may be used. Do not use the L.A. Abrasion test.

H. *Proportioning and Mixing Equipment.* Meet Subsection 501.3(B).

I. *Finishing.* Meet Subsection 501.3(K).

J. *Curing and Protection of Pavement.* Meet Subsection 501.3(M).

K. *Pavement Joints.* Locate, space, and install contraction, expansion, and longitudinal joints as specified in Subsection 501.3(J).

L. *Filling Joints.* Saw transverse joints in the new concrete overlay early enough to prevent cracking of the overlay.

Clean and seal joints as specified in Subsection 501.3(J) before opening the pavement to traffic.

M. *Pavement Rideability.* Meet Subsection 401.3(L)(2).

565.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. *Breaking, Removing, and Hauling.* When the contract provides for removing and hauling of old pavement to a designated area for crushing, the Engineer will compute the area of pavement removed in yd^2 (m^2) by measuring the width from edge to edge, or back of curb, if any, and the longitudinal distance of the pavement surface. Disposal of reinforcing steel is incidental to removing the old pavement.

B. *Crushing and Stockpiling.* The Engineer will measure the quantity of crushed and stockpiled concrete pavement material by the ton (Mg).

C. *Coarse and Fine Aggregate.* The Engineer will measure the quantity of virgin coarse and fine aggregate by the ton (Mg).

D. *Portland Cement Concrete Pavement.* The Engineer will compute the area of completed pavement in yd^2 (m^2) from longitudinal surface measurement and plan width. The Engineer will measure irregular and patched areas separately in yd^2 (m^2).

565.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Breaking, removing, and hauling	yd^2 (m^2)
(B) Crushing and stockpiling	ton (Mg)
(C) Coarse aggregate	ton (Mg)
(D) Fine aggregate	ton (Mg)
(E) Portland cement concrete pavement	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 566
PORTLAND CEMENT CONCRETE SHOULDERS

566.1 DESCRIPTION

Construct concrete shoulders.

566.2 MATERIALS

Provide materials as specified in Subsection 551.2.

566.3 CONSTRUCTION

A. *Concrete Mixture Proportioning.* Proportion concrete mixture based on a predetermined cement content or a minimum strength as provided in Subsection 713.1(A).

B. *Equipment.* Meet Subsection 501.3(B). Furnish equipment sufficiently ahead of the start of construction for examination and approval.

C. *Installation of Tiebars.* Use deformed tiebars or tie bolts to hold the concrete shoulders to the existing concrete pavement. Drill holes in the existing concrete at locations and to the depth shown for the approved type of tiebar. Install expansion-type tie bolts according to the manufacturer's instructions. Grout tiebars with an approved nonshrink grout or epoxy.

D. *Mixing and Placing Concrete.* Meet Subsection 501.3.

E. *Shoulder Surface Finish.*

1. *Rumble Strips.* Use hand tools or mechanical floats or rollers to form the corrugations.

2. *Pavement Texture.* Provide a final finish on the surface as specified in Subsection 501.3(K)(7).

F. *Transverse Contraction Joints.* Construct joint planes of weakness by forming or cutting grooves in the surface. Match transverse locations with the mainline transverse joints. Meet Subsection 501.3(J) for sawing time and joint dimensions.

G. *Longitudinal Construction Joints.* Construct a joint next to the mainline pavement. Saw or groove the joint with edging or jointing tools.

H. *Surface Testing.* Ensure the maximum surface irregularity between rumble strips does not exceed $^{1}/_{4}$ in. (6 mm) when measured with a 10-ft (3-m) straightedge.

I. *Joint Sealing.* Meet Subsection 501.3(J).

J. *Curing and Protection of Shoulder.* Meet Subsection 501.3(M).

K. *Opening to Traffic.* Ensure the concrete has a minimum compressive strength of 2,500 psi (17.2 MPa) before opening the shoulder to traffic.

566.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure the area of completed shoulder in yd^2 (m^2) from the longitudinal surface measurement and plan width.

566.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Portland cement concrete shoulder	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 567
CRACKING AND SEATING

567.1 DESCRIPTION

Crack existing portland cement concrete pavement and roll the broken concrete until surface material is well-seated before placing an asphalt pavement overlay.

567.2 MATERIALS

Reserved.

567.3 CONSTRUCTION

A. *Cracking and Seating Equipment.* Use a device to crack the concrete pavement that exerts a minimum of 12,000 ft-lb (16,300 J) of energy with a spade or guillotine-type cracker mounted on a vehicle with controlled forward and transverse movement. Crack the pavement full depth, while maintaining aggregate interlock between the pieces. Do not use any device that causes undue displacement of the concrete or damages drainage facilities, utilities, or other property, or destabilizes the base or subgrade.

Provide a screen to protect vehicles in the adjacent lane from flying chips during the cracking process.

Seat the cracked concrete with a vibratory roller.

Furnish vibratory rollers with separate controls for energy and propulsion. Furnish vibratory rollers with a variable amplitude and frequency system capable of producing a frequency of 2,000 vibrations per minute and meeting the following requirements:

Diameter of drum	4 ft (1.22 m)
Length of drum	6.5 ft (2. m)
Unit static force on drum	125 lb/in. (56.7 kg/25 mm) of width
Total applied force on drum	325 lb/in. (147.4 kg/ 25 mm) of width

Ensure rollers are capable of starting, stopping, and reversing direction smoothly without loosening or distorting the surface being rolled.

Equip rollers with devices for moistening the rollers or tires. Do not use petroleum or tar products for this purpose.

B. *Preparing the Area.* Remove existing asphalt patching or overlay before cracking the pavement.

C. *Test Section.* The Engineer will designate test sections to be used before full production cracking operations begin. Crack the test sections using varying energy and striking patterns until a pattern is established that cracks the pavement to the extent required. Use the pattern established to crack the remaining pavement as long as the crack pattern meets the specified size requirements. If the production pattern stops producing cracks to the extent required, use another test section to identify a new successful pattern. Furnish and apply water to dampen the pavement surface after cracking so the extent of breakage can be seen.

D. *Cracking Operations.* Perform cracking one lane at a time to produce pieces approximately 1.2 to 1.8 ft^2 (0.11 to 0.17 m^2) in area. Orient the greatest dimension of the pieces transverse to the pavement centerline. Prohibit cracking within $2^1/_2$ ft (0.75 m) of any transverse joint or other location.

Produce cracks that are continuous without extensive spalling along the crack. Extensive spalling is spalling more than 1 in. (25 mm) deep. Do not shatter the pavement or base during cracking operations.

Protect and prevent damage to underground utilities, drainage facilities, bridge approach slabs, and decks. Repair all such damage at no cost to the Agency.

Apply water randomly once each day to the surface to verify the specified extent of breakage. Adjust the energy or striking pattern based on these check sections.

E. *Seating Operations.* After cracking, roll the concrete to seat firmly and lay the cracked pieces to an even surface.

Continue rolling until the surface material is well-seated and uniformly compacted.

Remove soft spots or rocking pieces detected and undercut unsuitable material as directed. Backfill these areas with crushed aggregate base to the bottom of adjacent portland cement concrete pavement and cover the crushed aggregate base with hot mix asphalt concrete. Perform rolling only under dry pavement conditions.

F. *Sweeping*. Sweep and clean the surface of loose and spalled material after the pavement has been cracked and seated.

G. *Maintenance*. Maintain the pavement according to the traffic control plan if the pavement is opened to traffic after the cracking and seating operation and before placing the first asphalt concrete course. Maintain the pavement for traffic according to the Traffic Control Plan. Perform asphalt concrete pavement construction within two weeks of completing the cracking and seating operations.

567.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure cracking and seating concrete pavement by the yd^2 (m^2), using the width of the existing portland cement concrete pavement and the centerline length of each roadway and ramp.

567.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Cracking and seating concrete pavement	yd^2 (m^2)

Payment for cracking and seating concrete pavement includes:

A. Breaking existing portland cement concrete pavement;

B. Providing a screen to protect traffic;

C. Providing water to dampen the pavement;

D. Seating broken pavement for sweeping and maintaining; and

E. Furnishing all other necessary labor, equipment, tools, and incidentals to complete the work.

AASHTO

DIVISION 600
MISCELLANEOUS CONSTRUCTION

SECTION 601
CONCRETE FOR INCIDENTAL CONSTRUCTION

601.1 DESCRIPTION

Furnish and place portland cement concrete for incidental construction.

601.2 MATERIALS

Provide materials as specified in:

Portland Cement	Subsection 701.2
Fine Aggregate	Subsection 703.1(A)
Coarse Aggregate	Subsection 703.1(B)
Lightweight Aggregate	Subsection 703.1(C)
Concrete	Subsection 713.1(B)
Curing Materials	Subsection 713.2
Air-Entraining Admixture	Subsection 713.3(A)
Chemical Admixtures	Subsection 713.3(B)
Fly Ash	Subsection 713.3(C)(1)
Water	Subsection 714.1(A)

601.3 CONSTRUCTION

A. *Mix Design*. Meet Subsection 713.1(B).

B. *Batching and Mixing*. Meet Subsection 501.3(B).

C. *Testing*. Meet Subsection 808.3(C).

D. *Forms*.

1. *Construction*. Construct mortar-tight forms that can withstand concrete pressure, vibration, and other loads. Ensure forms will produce smooth, even concrete surfaces. Fillet and chamfer forms and provide a bevel or draft at projections as specified.

2. *Forms*. Use one of the following for all exposed concrete surfaces:

   a. Exterior plywood with the face grain running perpendicular to the supports.

   b. Lumber dressed on at least one side and two edges.

   c. Metal.

   d. Slip-forms. Discontinue using slip-forms if the product does not meet specification tolerances.

3. *Ties or Anchorages*. Use ties or anchorages that may be removed to at least 1 in. (25 mm) from the face without damaging the concrete. Fill cavities with cement mortar. Leave surfaces sound, smooth, and evenly colored.

4. *Cleanouts*. Provide a means for removing extraneous material from bottoms of forms before placing the concrete.

5. *Surface Treatment*. Treat forms with an approved release agent before placing reinforcing steel. Moisten wood forms with water immediately before placing concrete. Do not use material that discolors or damages the concrete.

6. *Metal Forms*. Use metal forms that retain their shape. Countersink bolt and rivet heads. Hold forms in place with connecting devices that can be removed without damaging the concrete. Use only metal forms that provide a smooth surface and align properly. Keep metal forms free of rust, grease, and other foreign matter.

7. *Form Removal*. Remove forms without damaging the concrete.

   If concrete operations are not controlled by beam or cylinder tests, maintain forms for the following periods, exclusive of times when temperatures drop below 40°F (5°C):

Nonload supporting	[12 to 24] h
Load supporting	Meet Subsection 803.3(D)

E. *Placing Concrete*. Meet Subsection 808.3(E).

F. *Finishing Concrete Surfaces*. Meet Subsection 808.3(H).

G. *Curing Concrete*. Meet Subsection 808.3(I).

601.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The measurement will include the volume occupied by reinforcing steel, anchors, conduits, weep holes, piling, or chamfers and other pipes less than 18 in. (450 mm) in diameter.

601.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Structural concrete, Class _____	yd^3 (m^3)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 602
RESERVED

SECTION 603
CULVERTS AND STORM DRAINS

603.1 DESCRIPTION

Provide or construct stormwater conduits.

603.2 MATERIALS

Joint Fillers	Subsection 707.1
Joint Mortar	Subsection 707.2
Flexible Watertight Gaskets	Subsection 707.3
Nonreinforced Concrete Pipe	Subsection 708.1
Reinforced Concrete Pipe	Subsection 708.2
Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe	Subsection 708.6
Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe	Subsection 708.7
Polyethylene (PE) Corrugated Drainage Pipe or Tubing	Subsection 708.9

Polyvinyl Chloride (PVC) Sewer Pipe and Fittings	Subsection 708.10
Polyethylene (PE) Corrugated Drain Tile	Subsection 708.11
Corrugated Polypropylene (PP) Pipe	Subsection 708.12
Acrylonitrile-Butadiene-Styrene (ABS) Sewer Pipe and Fittings	Subsection 708.13
Polypropylene (PP) Corrugated Drainage Pipe or Tubing	Subsection 708.14
Ductile Iron Culvert Pipe	Subsection 709.1
Metallic-Coated Corrugated Steel Pipe for Sewers and Drains	Subsection 709.2
Bituminous-Coated Corrugated Steel Pipe and Pipe Arches	Subsection 709.3
Corrugated Aluminum Culvert Pipe	Subsection 709.6
Bituminous-Coated Corrugated Aluminum Culvert Pipe	Subsection 709.8
Steel Structural Plate for Pipe, Pipe Arches, and Arches	Subsection 709.10
Full Bituminous-Coated Steel Structural Plate Pipe, Pipe Arches, and Arches	Subsection 709.11
Aluminum Structural Plate for Pipe, Pipe Arches, and Arches	Subsection 709.12
Full Bituminous-Coated Aluminum Structural Plate for Pipe, Pipe Arches, and Arches	Subsection 709.13
Polymer-Precoated Corrugated Steel Pipe for Sewers and Drains	Subsection 709.14
Nestable Corrugated Steel Pipe	Subsection 709.15
Slotted Corrugated Steel Pipe	Subsection 709.16
Concrete	Subsection 713.1(B)

603.3 CONSTRUCTION

A. *Excavating.* Excavate trenches as specified in Section 206.

B. *Bedding.* Bed conduit using Agency standards, manufacturer's recommendations, or as follows:

1. *Class A Bedding.* Install a continuous Class D concrete cradle.

2. *Class B Bedding.* Bed to a depth of not less than 30 percent of the vertical outside diameter of conduit plus 4 in. (100 mm). Use sand or selected sandy soil passing a $^3/_8$-in. (9.5-mm) sieve, with not more than 10 percent passing a No. 200 (75-µm) sieve. Reshape the trench bottom to accommodate pipe bells.

3. *Class C Bedding.* Compact and shape bedding to fit the conduit to 10 percent of its total height. Reshape the trench bottom to accommodate pipe bells.

a. For structural plate pipe, ensure the length of bedding arc does not exceed the width of the bottom plate.

b. Shape bedding blankets of silty loam, loam, or concrete sand to fit the pipe bottom. Meet the following thickness requirements:

   i. 1 in. (25 mm) for $^{1}/_{2}$-in. (13-mm) corrugations,

   ii. 2 in. (50 mm) for 1-in. (25-mm) corrugations, and

   iii. 3 in. (75 mm) for 2-in. or $2^{1}/_{2}$-in. (50-mm or 63-mm) corrugations.

C. *Laying Conduit.* Place conduit from the downstream end. Place bell or groove ends of rigid conduits and outside circumferential laps of flexible conduits facing upstream. Position flexible conduit with longitudinal laps or seams at the sides. Do not place conduit until the specified outlet is provided.

Lay paved or partially lined conduit so the longitudinal centerline of the pavement segment follows the flow line. Orient the vertical plane so that it varies no more than 5 degrees from the design orientation.

D. *Joining Conduit.* Join conduit sections so that the inner surfaces are flush and even.

Secure or seal the conduit joints.

Clean all foreign material from the conduit.

Remove and replace or relay misaligned, improperly settled, or damaged pipe.

E. *Backfill.* Backfill the trench with selected material as specified in Section 206.

Backfill and compact on both sides of the conduit equally. Protect the conduit with a 3-ft (1-m) cover of fill before allowing heavy equipment crossings.

F. *Boring or Jacking.* Bore or jack conduit without damaging the roadway grade or surface. Install pipe concurrent with boring operations unless a jacking sleeve is used.

603.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure conduit with sloped or skewed ends along the invert.

B. The Engineer will measure end sections by the number of units installed.

C. The Engineer may include branch connections and elbows in the length measurement for conduit or may measure these items separately by the number of installed units.

Note: Agencies should select one of two alternates:

Alternate No. 1. The Engineer will not measure excavation for conduits, including planned excavation below flow-line grade for induced trench, bedding, and backfill.

Alternate No. 2. The Engineer will measure, and the Agency will pay for, excavation for conduits, including excavation below the flow line grade and for induced trench, bedding, and backfill, under Section 206.

603.5 POST INSTALLATION INSPECTION

If required, perform an inspection in each phase of construction of a conduit no sooner than 30 days and no later than 90 days after the completion of the finished grade when not below pavement and after the completion of the rough subgrade when any portion of the conduit is below pavement. The Engineer may permit inspection beyond the 90-day limit. The degree of inspection and percentage of installations will be identified by the Agency.

Perform the inspection with a technician certified by a National Association of Sewer Service Companies (NASSCO) Pipeline Assessment Certification Program (PACP). Prepare a report using agency format, or the PACP Color-Coded Code Charts within seven days of the inspection.

Furnish a video recording of all conduit and drainage structure inspections. On the recording, identify the date and time of the inspection, a description of the conduit or drainage structure being inspected, the location, and the viewing direction. Record the entire run of conduit being inspected. Provide a source of light that allows all areas of concern to be readily observed on the video recording. Furnish the video recording in a digital, reproducible format on one of the following media types: DVD, CD, or other media type approved by the agency.

603.6 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

	Pay Item	Pay Unit
(A)	_____(1) Corrugated _____(3) pipe (or pipe arch)	ft (m)
(B)	_____(1) Corrugated _____(3) end sections	each
(C)	_____(1) Nestable corrugated steel pipe	ft (m)
(D)	_____(1) Slotted corrugated steel pipe	ft (m)
(E)	_____(2) Bituminous coated corrugated _____(3) pipe (or pipe arch)	ft (m)
(F)	_____(2) Bituminous coated corrugated _____(3) end sections	each
(G)	_____(5) Ductile iron pipe, Class _____(6)	ft (m)
(H)	_____(1) Structural _____(4) plate (pipe), (pipe arch), or (arch)	ft (m)

	Pay Item	Pay Unit
(I)	_____[1] Full bituminous coated structural _____[3] plate (pipe), (pipe arch), or (arch)	ft (m)
(J)	_____[4] Reinforced concrete pipe, Class _____[6]	ft (m)
(K)	_____[6] Bored or jacked pipe	ft (m)
(L)	_____[4] Reinforced concrete end section	each
(M)	_____[4] Nonreinforced concrete pipe, Class _____[6]	ft (m)
(N)	_____[4] Reinforced concrete arch pipe, Class _____[6]	ft (m)
(O)	_____[4] Reinforced concrete elliptical pipe, Class_____[6]	ft (m)
(P)	_____[4] Plastic and polyethylene corrugated drainage pipe or tubing	ft (m)
(Q)	_____[6] Elbow	each
(R)	_____[6] Branch connection	each
(S)	_____[1] Precoated, galvanized steel culverts and underdrains _____[7]	ft (m)

Note: Superscript numbers shown in parentheses apply to the following information code to be added as applicable.

(1) Insert size and thickness.

(2) Insert size, thickness, and fiber bonding if applicable.

(3) Insert either "steel" or "aluminum alloy."

(4) Insert size.

(5) Insert class.

(6) Insert size, type, class, etc., as necessary to identify.

(7) Insert type and thickness of coating.

Payment for all inspections is included with the contract unit price of the corresponding pay item.

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified, including any cutting and patching of pavement or restoration of vegetative surfaces associated with the conduit installation process.

SECTION 604
MANHOLES, INLETS, AND CATCH BASINS

604.1 DESCRIPTION

Construct manholes, inlets, and catch basins.

604.2 MATERIALS

Provide materials as specified in:

Clay or Shale Brick	Subsection 706.1
Concrete Brick	Subsection 706.2
Concrete Masonry Blocks	Subsection 706.3
Joint Fillers	Subsection 707.1
Joint Mortar	Subsection 707.2
Flexible Watertight Gaskets	Subsection 707.3
Corrugated Metal Units	Section 709
Reinforcing Steel	Subsection 711.1
Concrete	Subsection 713.1(B)
Precast Concrete Units	Subsection 714.6
Frames, Grates and Covers, and Ladder Rungs	Subsection 714.7

604.3 CONSTRUCTION

Use Class B structural concrete, as specified in Subsection 713.1(B). Cure wet, exposed concrete surfaces and masonry for at least 48 h.

Ensure joints made for precast manhole sections form a flexible, watertight seal.

Set metal frames in a full bed of mortar.

Install pipe sections flush inside the structure wall. Fit masonry neatly and tightly around the pipe.

Build on stable foundations. Excavate and backfill as specified in Subsection 206.3.

When grade adjustment of existing structures is required, remove and reconstruct existing walls as specified. Clean and reset frames when specified. If existing casting and supporting walls are in good condition, adjust the manhole casting cover to the correct grade with an approved device.

Keep silt, debris, and foreign matter away from each structure until work is accepted. Replace castings where specified.

Install minimum $^{3}/_{8}$-in. (10-mm) thick preformed expansion joint to separate catch basins and inlets that abut existing concrete. Adjust castings to grade prior to placing surface course material.

604.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure quantities according to the following types:

   1. *Type 1.* Structures connected to pipe with maximum diameter of 42 in. (1 m).

   2. *Type 2.* Structures connected to pipe with minimum diameter of 48 in. (1.2 m).

B. The Engineer will measure each manhole deeper than 6 ft (2 m) for added payment. Added manhole depth will exclude the upper 6 ft (2 m). The Engineer will measure additional manhole depth according to the following classes:

   1. *Class 1.* Each manhole ≤10 ft (3 m) deep.

   2. *Class 2.* Each manhole >10 ft (3 m) and ≤20 ft (7 m) deep.

   3. *Class 3.* Each manhole >20 ft (7 m) and ≤30 ft (10 m) deep.

   4. *Class 4.* Each manhole >30 ft (10 m) deep.

604.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
Manhole, type _____	each
Inlets	each
Catch basins	each
Manhole, type _____ additional depth, Class _____	ft (m)
Castings, type _____	each

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 605
UNDERDRAINS

605.1 DESCRIPTION

Construct underdrains and blind drains.

605.2 MATERIALS

Provide materials as specified in:

Permeable Material	Subsection 703.17(A)
Coarse Aggregate for Underdrain Course	Subsection 703.17(B)
Filter Fabric Material	Subsection 705.1
Perforated Concrete Pipe	Subsection 708.3
Concrete Drain Tile	Subsection 708.4
Porous Concrete Pipe	Subsection 708.5
Perforated Polyvinyl Chloride (PVC) Pipe and Fittings for Underdrain	Subsection 708.10
Polyethylene (PE) Corrugated Drainage Pipe and Tubing	Subsection 708.11
Polypropylene (PP) Pipe and Fittings	Subsection 708.12
Acrylonitrile-Butadiene-Styrene (ABS) Sewer Pipe and Fittings	Subsection 708.13
Metallic-Coated Corrugated Steel Pipe for Underdrains	Subsection 709.4
Bituminous-Coated Corrugated Steel Pipe for Underdrains	Subsection 709.5
Corrugated Aluminum Pipe for Underdrains	Subsection 709.7
Bituminous-Coated Corrugated Aluminum Pipe for Underdrains	Subsection 709.9
Precoated, galvanized Steel Underdrains	Subsection 709.14

605.3 CONSTRUCTION

A. *Installing Pipe.* Excavate trench as specified in Subsection 206.3. Line the trench with a filter fabric as specified in Section 620. Place and compact a minimum 3-in. (75-mm) layer of bedding material, meeting Subsection 703.17(B), in the trench bottom and firmly embed the pipe.

Place perforated pipe with perforations down. The last 10 ft (3 m) at the outlet end may be nonperforated pipe. Provide watertight joints using coupling fittings or bands.

Lay nonperforated pipe with the bell end upgrade with open joints wrapped or unwrapped, as specified. Plug upgrade ends of subdrainage pipe installations.

Following approval of installed pipe, place backfill material, meeting

Subsection 703.17(A), to a height of 12 in. (300 mm) above the pipe. Place the remaining granular backfill and compact to required height.

Mark each outlet end of the subdrainage system.

B. *Blind Drains.* Excavate trenches for blind drains as specified in Subsection 206.3. Fill the trench with backfill material to the specified depth.

605.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

Note: Agencies should select one of two alternates:

Alternate No. 1. The Engineer will not measure excavation and backfill for payment.

Alternate No. 2. The Engineer will measure, and the Agency will pay for, excavation as specified in Section 206. The Engineer will measure aggregates by the ton (Mg) or yd^3 (m^3).

605.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) ____-in. (mm) Perforated corrugated steel pipe for underdrains, Class ____	ft (m)
(B) ____ -in. (mm) Corrugated steel pipe for underdrains, Class ____	ft (m)
(C) ____ -in. (mm) Perforated bituminous coated corrugated steel pipe for underdrains, Class ____	ft (m)
(D) ____ -in. (mm) Bituminous coated corrugated steel pipe for underdrains, Class ____	ft (m)
(E) ____ -in. (mm) Perforated concrete pipe for underdrains, Class ____	ft (m)
(F) ____ -in. (mm) Concrete drain tile for underdrains, Class ____	ft (m)
(G) ____ -in. (mm) Porous concrete pipe for underdrains	ft (m)
(H) ____ -in. (mm) Perforated corrugated aluminum alloy pipe for underdrains, Type ____	ft (m)
(I) ____ -in. (mm) Corrugated aluminum pipe for underdrains, Type	ft (m)
(J) ____ -in. (mm) Perforated bituminous coated corrugated aluminum alloy pipe for underdrains, Type ____	ft (m)
(K) ____ -in. (mm) Bituminous coated corrugated aluminum alloy pipe for underdrains, Type ____	ft (m)
(L) ____ -in. (mm) Perforated polyvinyl chloride (PVC) pipe and fittings, Class ____	ft (m)
(M) ____ -in. (mm) Polyethylene (PE) corrugated drainage pipe and tubing	ft (m)
(N) ____ -in. (mm) Acrylonitrile butadiene styrene (ABS) sewer pipe and fittings	ft (m)
(O) ____ -in. (mm) Precoated, galvanized steel underdrains, Type ____	
(P) ____ -in. (mm) Blind drain	ft (m)
(Q) Aggregate for drainage	ton (Mg), yd^3 (m^3)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 606
GUARDRAIL

606.1 DESCRIPTION

Construct guardrails.

606.2 MATERIALS

Provide materials as specified in:

Wire Rope or Wire Cable	Subsection 711.2
Metal Beam Rail	Subsection 712.4
Timber Rail	Subsection 712.5
Guardrail Posts	Subsection 712.7
Guardrail Hardware	Subsection 712.8
Steel Box Beam Rail, Posts, and Hardware	Subsection 712.9
Paint	Section 813

606.3 CONSTRUCTION

Assemble and erect guardrails at specified locations to meet standards of *A Guide to Standardized Highway Barrier Hardware*.

A. *Posts.* Set posts plumb in excavated holes or drive them, if permitted. Drive without damaging posts. Backfill holes and compact with layers of specified material. Replace existing pavement where damaged.

B. *Rail Elements.* Construct rail elements to specified line and grade with laps in the direction of traffic flow. Tighten all bolts, except adjustment bolts. Limit bolt extension beyond the nuts to $^1/_2$ in. (10 mm).

   Apply rust-inhibiting primer to damaged areas. Paint inaccessible surfaces before construction. Brush or pressure-spray railing components.

   Apply two coats of paint to galvanized surfaces abraded to expose the base metal and to threaded portions of all fittings and fasteners and cut ends of bolts. Use high-zinc dust content paint that meets Federal Specification MIL-P-21035, or two coats of zinc-dust, zinc-oxide paint that meets Federal Specification MIL-P-24441/20.

C. *Reset Guardrail*. Remove, store, and reset existing guardrail. Repaint as specified in Subsection 606.3(B).

606.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure guardrail from center of end posts. The Engineer will measure guardrail connected to masonry or steel structures to the face of the structure. The Engineer will measure double-faced rail attached to the same post as a unit.

B. The Engineer will measure end anchorages, terminal sections, and end sections as units specified and installed.

606.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Guardrail type	ft (m)
Type G1—Cable guardrail	
Type G2—W-beam guardrail (weak post)	
Type G3—Box-beam guardrail	
Type G4—W-beam guardrail	
Type G5—Thrie-beam guardrail	
Type MB2—W-beam median barrier (weak post)	
Type MB3—Box-beam barrier (steel)	
Type MB4—W-beam median barrier	
(B) Reset guardrail, Type	ft (m)
(C) End anchorage, Type	each
(D) Terminal section, Type	each
(E) Median barrier wye assembly	each

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 607
FENCES

607.1 DESCRIPTION

Construct fence and gates.

607.2 MATERIALS

Provide materials as specified in:

Concrete	Section 601, Subsection 713.1(B)
Barbed Wire	Subsection 712.1
Woven Wire	Subsection 712.2
Fence Posts	Subsection 712.6
Gates	Subsection 712.11

607.3 CONSTRUCTION

Clear and grub fence alignment as specified in Subsection 201.3.

Adjust post spacing at fence breaks or at intersections with existing fences to meet the specified closure.

When the contract requires embedment of posts, braces, or anchors in concrete, install temporary guys or braces to secure posts in position until concrete sets. Wait 7 days after placing concrete before installing materials on posts or placing strain on guys and braces.

Embed posts a minimum of [30 in. (750 mm)] in the ground. Set tops of posts to required grade and alignment.

Firmly attach fencing to the posts, and brace, stretch taut, and install to required elevations.

Furnish and install a ground according to Section 9 of the National Electric Safety Code at each crossing of an electric transmission, distribution, or secondary line.

Position fence to follow the ground contour, with the bottom of the fence fabric between 1 in. and 6 in. (25 mm and 150 mm) above the ground. Grade to provide a neat appearance. Use longer posts with added wire strands in areas where abrupt changes in ground profile make it impractical to maintain specified ground clearance. Allow vertical clearance between barbed wire strands as specified for the type of fence installed. Repair posts after cutting or drilling.

Remove, store, and reset existing fence, when specified. Reset to meet provisions for setting new fence. Replace damaged materials including staples and fasteners.

607.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure fence and resetting fence along the top of the fence from outside-to-outside of end posts for each continuous run.

B. The Engineer will measure all missing or unsuitable fence material replaced when resetting fence in units of the size and type specified.

C. The Engineer will measure gates as complete units of the size and type specified.

607.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) ____ -in. (mm) Fence, Type ____	ft (m)
(B) Resetting fence, Type _____	ft (m)
(C) ____ -in. (mm) Gate, Type ____	each
(D) Replacement parts, Type ____	each

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 608
SIDEWALKS

608.1 DESCRIPTION

Construct asphalt or concrete sidewalks.

608.2 MATERIALS

Provide materials as specified in:

Asphalt	Section 702
Concrete, Class B	Section 601, Subsection 713.1(B)
Bed Course Material	Subsection 703.12
Joint Fillers	Subsection 707.1
Reinforcing Steel	Subsection 711.1

608.3 CONSTRUCTION

A. *Concrete Sidewalks.*

1. *Excavating.* Excavate to the depth and width necessary to install and brace forms. Shape the foundation and compact to meet contract specifications. Replace soft and yielding material with approved material.

2. *Forms.* Use full-depth forms that are strong enough to resist the concrete pressure. Maintain horizontal and vertical alignment. Use clean forms and coat with an approved form-release agent. Place reinforcing steel as specified in Section 809.

3. *Placing Concrete.* Moisten the foundation prior to placing concrete. Proportion, mix, and place as specified in Section 601 or 808, as specified. Place uniformly in one course.

4. *Finishing.* Float and apply a light broomed finish. Edge all outside slab and all joint edges to a $^1/_4$-in. (6-mm) radius.

5. *Joints.* Fill expansion joints with the specified preformed expansion joint filler.

   Section the sidewalk using false joints at [5-ft (1.5-m)] intervals, approximately [$^1/_8$ in. (3 mm)] wide, and at least [1 in. (25 mm)] deep using a jointing tool, sawing, or other approved means. Match curb or pavement joints.

   Form full-depth construction joints around all appurtenances, such as manholes and utility poles. Use a minimum $^1/_2$ in. (13 mm) thick preformed expansion joint filler.

   Install full-depth preformed expansion joint filler between concrete sidewalks and structures.

6. *Curing.* Cure concrete as specified in Subsection 808.3(I) for 72 h. Do not allow pedestrian and vehicle traffic on the concrete for [7] days unless the surface is protected by planks, plywood, or a minimum [1-in. (25-mm)] sand layer. Do not place protection directly on the concrete for a minimum [12] after application of the cure.

B. *Asphalt Sidewalks.*

1. *Excavating.* Meet Subsection 608.3(A)(1).

2. *Forms.* Meet Subsection 608.3(A)(2).

3. *Bed Course.* Place and compact bed course material in layers up to 4 in. (100 mm) deep.

4. *Placing Asphalt.* Place on the compacted bed course to the required depth. Compact with a roller. Use hand tamping in inaccessible areas.

608.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure, and the Agency will pay for, reinforcing steel under Section 809.

608.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
Concrete sidewalk	yd^2 (m^2)
Asphaltic sidewalk	ton (Mg), yd^3 (m^3)
Bed course material	ton (Mg), yd^3 (m^3)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified. The Agency will consider excavation, backfilling, disposal of surplus materials, preformed expansion joint material, and other miscellaneous items as incidental to the cost of the work.

SECTION 609
CURB, CURB AND GUTTER, PAVED DITCHES, AND PAVED FLUMES

609.1 DESCRIPTION

Construct or reset curb, gutter, or combination curb and gutter, paved ditch, and paved flume.

609.2 MATERIALS

Provide materials as specified in:

Tack Coat	Section 404
Concrete	Section 601, Subsection 713.1(B)
Asphalt	Section 702
Bed Course Material	Subsection 703.12(A)
Masonry Mortar Aggregate	Subsection 703.13
Joint Filler	Subsection 707.1
Joint Mortar	Subsection 707.2
Reinforcing Steel	Subsection 711.1
Stone Curbing	Subsection 714.4
Precast Concrete Curbing	Subsection 714.5

609.3 CONSTRUCTION

A. *Stone Curbing.*

1. *Excavating.* Excavate to the required depth and compact base material. Replace soft, unacceptable material with approved material and compact.

2. *Installing.* Set the front top arris line to the required line and grade. Fill and tamp all spaces under the curb with the same material as the bed course.

3. *Joints.* Lay stone curbing with closed joints and fill with mortar, as specified.

   Align curb joints with portland cement concrete pavement expansion joints. Match the joint widths and fill with the specified expansion joint filler.

4. *Backfilling.* Fill remaining excavated areas with approved material in maximum 6-in. (150-mm) loose lifts. Compact to the density of the surrounding material.

B. *Cast-in-Place Concrete Curbing or Curb and Gutter.*

1. *Excavating.* Meet Subsection 609.3(A)(1).

2. *Forms.* Use full-depth forms that are strong enough to resist the concrete pressure. Maintain horizontal and vertical alignment. Use clean forms and coat with an approved form-release agent. Use metal divider plates.

3. *Mixing and Placing.* Proportion, mix, and place concrete as specified in Subsections 713.1(B), 501.3(B) and 808.3(E), respectively. Strike off concrete to the specified cross section. Finish to match adjacent concrete finish or as specified.

4. *Contraction Joints.* Construct [$^1/_8$ in. (3 mm)] wide by [$1^1/_2$ in. (40 mm)] deep joints in maximum [10-ft (3-m)] sections, or match existing adjacent concrete pavement joints, whichever is less.

5. *Expansion Joints.* Form expansion joints at the specified intervals using a [$^3/_4$ in. (19 mm)] thick preformed expansion joint filler. Place additional expansion joints to match expansion joints in adjacent concrete pavement.

6. *Curing.* Cure concrete as specified in Subsection 808.3(I) for 72 h. Leave forms in place for 24 h, or until concrete sets, so that forms can be removed without damaging the concrete. Do not allow pedestrian and vehicle traffic on the concrete for [7] days unless the surface is protected by planks, plywood, or similar protection. Do not place protection directly on the concrete for a minimum [12] after application of the cure.

7. *Backfilling.* Backfill and compact in maximum 6-in. (150-mm) loose lifts with approved material to the specified elevations.

8. *Curb Machine.* Construct curbs and gutters with a curb-forming machine meeting Subsections 609.3(E)(3)(a) and 609.3(E)(3)(b).

C. *Precast Concrete Curbing.* Install as specified in Subsection 609.3(A).

D. *White Concrete Curbing.* Install as specified in Subsection 609.3(A).

Make the surface of the curbing from a mortar mix of 1 part white portland cement to $1^3/_4$ parts washed mortar sand. Apply a mortar mix of approximately 1 in. (25 mm), or construct the entire curb with white portland cement.

Use approved light-colored mortar sand. Place the surface mortar within 20 minutes of placing the base concrete.

Score or deform the surface and finish as specified.

Add color pigments as specified.

E. *Asphalt Curbing.*

1. *Excavating.* Meet Subsection 609.3(A)(1).

2. *Preparing the Surface.* Clean fresh laid bituminous surfaces before placing curbing.

   Clean all other existing surfaces with compressed air and dry the surface. Apply a tack coat to the surface at a rate of 0.5 to 0.15 gal/yd^2 (0.2 to 0.7 L/m^2).

3. *Placing.* Construct asphalt curbing with a self-propelled, automatic curb machine or use a paver with curbing attachments that meet the following:

   a. Machine weight compacts without having to ride above the paving surface.

   b. Machine forms curbs of consistent texture, shape, and density.

      The Contractor may construct short sections of curbing or curbing with short radii by other approved methods that produce curbing of equal quality to machine-produced curbing.

4. *Painting and Sealing.* Seal or paint only on clean dry curbing that has cooled to the ambient air temperature.

F. *Resetting Curb.*

1. *Salvaging Curbing.* Remove, store, and clean curb to be reset. Replace lost, damaged, or destroyed salvaged curb at no cost to the Agency.

2. *Excavating.* Meet Subsection 609.3(A)(1).

3. *Reset Curb.* Meet Subsections 609.3(A)(2) and 609.3(A)(3).

4. *Backfilling.* Meet Subsection 609.3(A)(4).

5. *Cutting and Fitting.* Cut and fit curbing where specified.

G. *Paved Ditches and Paved Flumes.* Construct subgrade for paved ditches and paved flumes to the line and grade specified. Remove and replace soft sections and unsuitable material with approved material. Compact and shape subgrade to a smooth, even surface. Moisten the subgrade before placing portland cement concrete.

Provide transverse joints at [20-ft (6-m)] intervals using removable $^1/_8$-in. (3-mm) thick templates, scoring or sawing to a minimum depth of $^3/_4$-in. (20-mm), or using approved "leave-in" type inserts. Form expansion joints at 100-ft (30-m) intervals using [$^3/_4$-in. (19-mm)] thick preformed expansion joint filler.

609.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure new and reset curbing along the front face at the finished grade elevation.

B. The Engineer will measure combination curb and gutter along the face of the curb.

C. The measurement will include the length for drainage structures installed in the curbing section or for driveway openings where the gutter is carried across the drive.

609.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Curb, Type _____	ft (m)
Type 1—Stone curbing constructed of quarried natural stone	
Type 2—Cast-in-place concrete curbing	
Type 3—Precast concrete curbing	
Type 4—Doweled concrete curbing	
Type 5—Reflecting concrete curbing	
Type 6—Asphaltic curbing	
Type 7—Extruded concrete curbing	
(B) Gutter, Type ____	ft (m)
(C) Curb and gutter, Type ____	ft (m)
(D) Reset curb, Type ____	ft (m)
(E) Bed course material	ton (Mg), yd^3 (m^3)
(F) Paved ditch	yd^2 (m^2)
(G) Paved flume	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 610
TURF ESTABLISHMENT

610.1 DESCRIPTION

Establish turf in designated areas.

610.2 MATERIALS

Provide materials as specified in:

Emulsified Asphalt	Subsection 702.1(C)
Agricultural Limestone	Subsection 715.2
Fertilizer	Subsection 715.3
Seed	Subsection 715.8
Mulch	Subsection 715.13

610.3 CONSTRUCTION

Provide turf establishment at the completion of a unit, a portion of the project, or as specified.

A. *Preparing the Soil.* Cultivate areas to be seeded to the specified depth to provide a firm, friable seedbed. Clear areas to be seeded of plant growth, stones [2 in. (50 mm)] in diameter or larger, and other debris. Apply limestone, if specified, uniformly before or during soil preparation and till into the soil. Meet finish grades.

B. *Seeding Seasons.* Seed between dates established by Agency. Obtain written permission from the Engineer to seed at other dates.

   Do not seed if the weather is windy or the ground is excessively wet, frozen, or otherwise untillable.

C. *Application Methods.* Place seed, fertilizer, limestone, and mulch by one of the following methods:

   1. *Hydraulic Method.* Mix seed and fertilizer or seed, fertilizer, and mulch with the specified quantity of water to form a slurry. Add wood cellulose mulch after the other slurry ingredients have been completely mixed. Thoroughly blend the mix, and apply evenly under pressure at specified rates within 8 of mixing. Retreat areas not adequately covered.

Inoculate legume seed with approved cultures according to the manufacturer's instructions. Apply inoculum at the manufacturer's recommended rate.

Do not compact hydraulically applied seed, fertilizer, and mulch.

2. *Dry Method.* Apply dry seed and fertilizer with mechanical seeders, seed drills, landscape seeders, cultipackers, fertilizer spreaders, or other mechanical seeding equipment.

   Spread dry fertilizer and ground limestone separately at specified rates, and till to the required depth. Compact seeded areas within [8] of seeding.

   The Contractor may use hand-operated seeding devices to apply seed, fertilizer, and ground limestone in a dry form on areas inaccessible to mechanical seeders.

D. *Applying Mulch.* When specified, spread straw, hay, or other mulch evenly over seeded areas at the rate of [800 lb/acre (900 kg/ha)] or as otherwise recommended by the manufacturer. Anchor mulch with mulch tillers, asphalt emulsion, twine, netting, or other approved tie-down or adhesive material. Use Type SS-1, or approved equal, emulsion. Prevent asphalt adhesive material from marking or defacing structures, pavements, utilities, and plant growth.

   Protect newly graded slopes with hay or straw at times other than the normal seeding season.

E. *Grub Proofing.* Use specified materials and application rates to grub-proof designated areas.

F. *Care during Construction.* Repair all damage to seeded areas until final acceptance.

610.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure turf establishment to the nearest [0.1 acre (0.1 ha)] of ground surface covered by seed, fertilizer, mulch, or limestone, as specified.

B. The Engineer will measure, and the Agency will pay for, topsoil under Section 208.

610.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Turf establishment	
(1) Hydraulic Method (without mulch)	acre (ha)
(2) Hydraulic Method (with mulch)	acre (ha)
(3) Dry Method (without mulch)	acre (ha)
(4) Dry Method (with mulch)	acre (ha)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 611
FURNISH AND PLANT TREES, SHRUBS, VINES, AND GROUND COVERS

611.1 DESCRIPTION

Furnish, deliver, and plant or transplant trees, shrubs, vines, and ground cover plants of the type, size, or age specified.

611.2 MATERIALS

Provide materials as specified in:

Concrete Masonry Blocks	Subsection 706.3
Water	Subsection 714.1(B)
Topsoil	Subsection 715.1
Agricultural Limestone	Subsection 715.2
Fertilizer	Subsection 715.3
Mulch	Subsection 715.13
Plant Materials	Subsection 715.14
Miscellaneous Landscape Materials	Subsection 715.16

611.3 CONSTRUCTION

A. *Planting Seasons.* Plant during the following seasons:

1. Deciduous material _____ (Agency to indicate preferred dates)

2. Evergreen material _____ (Agency to indicate preferred dates)

   Do not plant in frozen ground or when the Engineer determines that the soil is unsuitable.

B. *Plant Materials.* Provide plant materials meeting Subsection 715.14.

C. *Layout.* Stake plant material locations and bed outlines to meet field conditions and as specified.

D. *Excavating Plant Pits and Beds.* Remove sod, weeds, roots, and other material unsuitable for backfill and dispose of as specified in Subsection 201.3. Excavate plant pits to the width necessary for proper backfilling.

E. *Preparing Backfill Soil.* Use a prepared backfill soil of topsoil, loam, or selected soil, peat moss, or peat humus. The mixture volume is four parts topsoil, loam, or selected soil to one part peat moss or peat humus.

F. *Setting Plants.* Set plants plumb and at the same or slightly lower level than the depth at which they were grown.

1. *Bare Root Stock.* Place prepared backfill soil in the plant pit to the required minimum depth. Arrange bare-rooted plants in the center of the pit and spread the roots out in a natural position. Cut broken or damaged roots back to sound root growth.

   Work backfill soil around and over the roots, and settle by firming and tamping. Thoroughly water the backfill around the plants. Form water basins at least [4 in. (100 mm)] deep around individual plants to the same diameter as the plant pit.

2. *Balled and Burlapped Stock.* Place balled and burlapped plants in a stable, upright position. Handle and move plants by the ball. Remove and replace plants with broken or loose root balls. Fill backfill soil around the plant ball to half the depth of the ball. Tamp and thoroughly water. Cut and remove the burlap from the upper ball half, or loosen and fold back. Place the remainder of the backfill. Form water basins at least [4 in. (100 mm)] deep around individual plants to the same diameter as the plant pit.

3. *Container-Grown Stock.* Reject container-grown stock that is pot-bound, for which the top system is greater than the container size, or has roots growing out of the container. Ensure that stock has a fibrous, cohesive root system. Remove plants from the container immediately before planting. Take care to prevent root damage. Carefully place stock in the prepared pit so that plants are stable and rest upright. Fill with backfill soil around the stock to half the depth of the ball. Tamp, thoroughly water, and place the remainder of the backfill.

G. *Fertilizing.* Apply the specified fertilizer evenly at the specified rate for each plant variety. Work fertilizer into the prepared backfill material. Cultivate into the top 2 in. (50 mm) of the plant pit area within 5 days after planting. Apply fertilizer before mulching plant pits.

H. *Watering.* Maintain a saturated soil around each plant during the plant establishment period.

I. *Guying and Staking.* Guy and stake each tree immediately after planting.

J. *Wrapping.* Wrap deciduous trees with trunk diameters of _____ in. (mm) or larger (Agency to indicate size) with burlap or other approved material. Wrap from the base of the tree to the first branches. Tie wrappings at the top and bottom and at 2-ft (0.5-m) intervals. Apply wrapping within _____ of inspection and approval (Agency to specify time).

K. *Anti-Desiccant Spray.* Use an anti-desiccant spray instead of wrapping when specified. Apply spray within _____ or _____ days after planting (Agency to specify time in working or calendar days).

L. *Pruning.* Prune to remove damaged or broken limbs.

M. *Mulching*. Furnish mulch meeting Subsection 715.13. Place mulch to the specified depth over pit or saucer areas of each tree and shrub and over the entire planting bed area. Add _____ lb (kg) of nitrogen to plants mulched with wood chips or sawdust (Agency to specify amount) beyond the normal dressing of commercial fertilizer. Place mulch within _____ h after planting _____ (Agency to specify time).

N. *Restoring and Cleanup*. Restore all existing grass areas damaged or scarred during construction at no cost to the Agency.

O. *Plant Establishment Care and Replacement Period*. During the establishment period (as defined by the Agency), water, cultivate, prune, repair, adjust guys and stakes, and perform other work necessary to keep the plant healthy and growing. Remove and replace unhealthy plants promptly. Attend a joint semi-final inspection _____ days (Agency to establish) before the end of the establishment period to decide the acceptability of the material. During the following planting season, replace unacceptable plants as originally specified. Attend a final inspection of plant material within _____ days (Agency to establish) after replacement planting.

611.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure, and the Agency will pay for, any topsoil required other than prepared backfill soil according to Section 208.

611.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item		Pay Unit
(A) ________________________	_______________	each
(Plant name)	(Size)	

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified, including any water used to saturate surrounding soil.

SECTION 612
MOBILIZATION

612.1 DESCRIPTION

Perform preparatory work and operations necessary to move personnel, equipment, supplies, and incidentals to the project site. Include other work performed or cost incurred before the project starts.

612.2 MATERIALS

Not applicable.

612.3 CONSTRUCTION

Not applicable.

612.4 MEASUREMENT

Not applicable.

612.5 PAYMENT

The Agency will pay for mobilization at the contract unit price as follows:

Pay Item	Pay Unit
(A) Mobilization	Lump Sum

The Agency will make payment according to the following schedule. Each partial payment will be 25 percent of the lump sum price for Mobilization or 2.5 percent of the contract price, whichever is less.

A. The Agency will make the first payment with the first estimate.

B. The Agency will make the second payment after the Contractor finishes 5 percent of the contract.

C. The Agency will make the third payment after the Contractor finishes 10 percent of the contract.

D. The Agency will make the fourth payment after the Contractor finishes 20 percent of the contract.

E. Once work is substantially completed, the Agency will pay any amount bid for Mobilization exceeding 10 percent of the Contract price.

SECTION 613
PORTABLE TRAFFIC BARRIER

613.1 DESCRIPTION

Furnish, install, move, and remove portable traffic barriers.

613.2 MATERIALS

Provide materials as specified in:

Concrete	Section 601, Subsection 713.1(B)
Precast Concrete Units	Subsection 714.6
Reinforcing Steel	Section 809
Steel Structures	Section 811

Furnish barrier sections when shown on the plans. Barrier sections must meet the crash testing requirements of NCHRP 350 or MASH TL-3 or TL-4 specifications as per test matrix for Longitudinal Barriers. The Engineer may approve the use of the product if:

- Barrier sections substantially meet typical cross-section dimension requirements,
- There is no evidence of structural damage such as major spalls or cracks,
- The general condition of both the barrier sections and their connectors is acceptable,
- The barrier is new, or
- The barrier is being reused and the Contractor submits written certification that the re-used barrier sections and materials substantially conform to the requirements of this Item.

Department-furnished barrier sections will be at a stockpile location or an existing traffic barrier installation shown on the plans.

613.3 CONSTRUCTION

Construct precast units to the tolerances shown on the plans and as specified in Subsection 714.6. The Contractor may remove the precast units from the forms and casting bed after 12 if the units reach a compressive strength of at least 1,400 psi (9.65 MPa).

After use, stockpile barrier sections and connection hardware that are to be retained by the Department at the location shown on the plans or as otherwise directed. Obtain assembly and installation information for the portable steel traffic barrier from the manufacturer, and provide the Engineer with an installation and repair manual specific to the portable steel traffic barrier.

Repair or replace all traffic barrier or connecting hardware damaged by the Contractor's operations at the Contractor's expense.

Repair or replace any pavement damaged in the process of installing, moving, or removing barrier sections at the Contractor's expense.

613.4 MEASUREMENT

The Engineer will measure concrete barrier along the centerline.

613.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
Portable Concrete Barrier	ft (m)

This price is full compensation for:

- Furnishing and installing barrier sections and connection hardware;
- Delivering and installing Department-furnished barrier sections and connection hardware from a designated source;
- Moving barrier section installations on the project from one location to another (including disassembly and reassembly costs), moving barrier sections from an installation on the project to a temporary storage area (including disassembly costs), and moving barrier sections from a temporary storage area to an installation site on the project (including assembly costs);
- Removing barrier sections and connection hardware from the Project and delivering to the Department stockpile area shown on the plans or as directed; and
- Removing barrier and connection hardware to be retained by the Contractor from the Project.

SECTION 614
CONCRETE BARRIER

614.1 DESCRIPTION

Construct concrete barriers.

614.2 MATERIALS

Provide materials as specified in:

Concrete	Section 601, Subsection 713.1(B)
Precast Concrete Units	Subsection 714.6
Reinforcing Steel	Section 809

614.3 CONSTRUCTION

Provide precast, cast-in-place, or slip-form barriers meeting contract requirements.

Excavate to the required depth and compact the barrier foundation to the specified density, line, and grade. Replace soft and unsuitable material and compact with an approved material.

After placing the barrier, backfill remaining excavated areas and compact to specified density with approved material in layers up to [6 in. (150 mm)].

Construct cast-in-place barrier with forms that meet Subsection 601.3(D) or use a slip-form machine. Construct precast units as specified in Subsection 714.6. The Contractor may remove the precast units from the forms and casting bed after 12 if the units reach a compressive strength of at least 1,400 psi (9.65 MPa).

Apply a Class 2 rubbed finish as specified in Subsection 808.3(J)(2) to exposed cast-in-place or precast barrier faces. Apply a Class 1 ordinary finish as specified in Subsection 808.3(J)(1) to exposed slip-form barrier faces.

Ensure that the surfaces of barriers vary no more than $^1/_4$ in. in 10 ft (6 mm in 3 m), as measured from a straightedge in a longitudinal direction. Meet a tolerance of $^1/_4$ in. (6 mm) in vertical and horizontal alignment between adjoining units measured from a 10-ft (3-m) straightedge in a longitudinal direction across the joint.

Cast linkage for connecting precast barriers with the concrete section.

614.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure concrete barrier along the centerline.

614.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Concrete barrier	ft (m)
Type MB5—Concrete Barrier (New Jersey)	

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 615
EROSION CHECKS

615.1 DESCRIPTION

Furnish, transport, and construct rock and wire checks, grouted rock checks, and concrete checks in roadway ditches to prevent erosion.

615.2 MATERIALS

Provide materials as specified in:

Cement	Section 701; AASHTO M 85, Type I or Type II low-alkali cement
Fine Aggregate for Grout	Subsection 703.1(A)
Aggregate for Rock and Wire Checks	Subsection 703.15
Aggregate for Grouted Rock Checks	Subsection 703.15(C)
Filter Fabric	Subsection 705.1
Wire Mesh	Subsection 712.10
Concrete, Class A	Subsection 713.1(B)
Curing Compound	Subsection 713.2(C)
Water	Subsection 714.1(A)

615.3 CONSTRUCTION

A. *Filter Fabric.* Cover specified area with filter fabric material as specified in Section 620.

B. *Rock and Wire Checks.* Excavate the trench to specified dimensions. Lay wire mesh in the trench and place rocks in close contact uniformly on the fabric. Stretch wire mesh over the rocks. Form a tight, close-fitting mat by lacing the top and bottom layers of wire mesh together with industry-standard galvanized steel tie wires. Backfill and tamp open spaces between the trench wall and the mat with material excavated from the trench.

Dispose of surplus material outside the roadway ditch limits as specified in Subsection 201.3.

C. *Grouted Rock Checks.* Use grout consisting of one part portland cement and three parts fine aggregate by volume. Mix cement and fine aggregate with water to a consistency that can be hand troweled.

Excavate trench to the specified dimensions. Cover the bottom with a minimum [2 in. (50 mm)] of grout. Clean, wet, and hand place rocks. Embed and thoroughly bind the rocks in grout. Smooth the finished grouted rock check surface to the specified line and grade.

Place grout only when the atmospheric temperature is above 35°F (2°C). Remove and replace frozen grout. Cure grout as specified in Subsection 808.3(I). After grout sets, backfill spaces between the trench wall and the grouted rock check with excavated material and compact. Dispose of surplus excavated trench material as specified in Subsection 201.3.

D. *Concrete Checks.* Excavate the trench to specified dimensions. Fill with concrete, shape, and consolidate. Uniformly finish the concrete check surface. Place concrete only when the ambient temperature is above 35°F (2°C). Remove and replace frozen concrete. Cure concrete as specified in Subsection 808.3(I).

615.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

615.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Erosion checks	yd^3 (m^3)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 616
RESERVED

SECTION 617
REFERENCE MARKERS

617.1 DESCRIPTION

Furnish and place project, right-of-way, access control, and survey markers.

617.2 MATERIAL

Provide materials as specified in:

Concrete, Class B	Subsection 713.1(B)
Reinforcing Steel	Section 809
Reference Markers	Agency supplied

617.3 CONSTRUCTION

A. *General*. Use precast or cast-in-place reinforced concrete post reference markers, as specified by Agency. Locate and place posts at the staked reference points. Set posts as shown in the contract.

B. *Protecting*. Protect reference markers. Replace moved or damaged markers at no cost to the Agency.

C. *Field Marking*. Confirm field staking prior to installation.

617.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

617.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Project markers	each
(B) Right-of-way markers	each
(C) Survey markers	each
(D) Access control markers	each

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 618
TRAFFIC CONTROL

618.1 DESCRIPTION

Furnish, install, and maintain traffic signs, barricades, lights, signals, cones, concrete barriers, pavement marking, and other traffic control devices including flagging and pilot car operations.

618.2 MATERIALS

Meet the *Manual on Uniform Traffic Control Devices (for Highways and Streets)* (MUTCD) and other contract requirements.

618.3 CONSTRUCTION

Place traffic control devices at their specified location before starting construction. Maintain traffic devices during mobile operations.

In cases of serious or willful disregard for safety of the traveling public or construction workers, the Engineer may place traffic control devices in proper condition and deduct the cost from Contractor payment. The Engineer will suspend work if it determines that safe traffic control provisions are not being provided or maintained.

Designate a traffic control supervisor to monitor traffic control operations at all times. Ensure that the supervisor is available to respond to calls at any time. Provide the name of the traffic control supervisor at the preconstruction conference and to local police.

Remove pavement traffic markings without altering or damaging the pavement surface or texture. Remove all residue that might interfere with drainage, cause pollution, or create a traffic hazard.

Preserve the color and texture of the adjoining pavement. Do not cover markings with paint or asphalt.

Apply pavement markings and traffic control devices according to the MUTCD and the approved traffic control plan. Remove old markings and place new markings prior to shifting or adjusting traffic patterns. Ensure there are no conflicting pavement markings.

618.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

618.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Construction traffic sign, panel size _____	each, ft (m)
Panel Size A: 0.1 to 9. ft^2 (0.1 to 1. m^2)	
Panel Size B: 9.1 to 16. ft^2 (1. to 2. m^2)	
Panel Size C: 16.1 ft^2 (2. m^2) and over	
(B) Barricade type _______	each, ft^2 (m^2)
(C) Drum	each
(D) Cone	each
(E) Vertical panel	each
(F) Warning light, Type _____	each, unit day

Pay Item	Pay Unit
(G) Flashing arrow panel	each, unit day
(H) Temporary pavement markings	ft (m)
(I) Pavement marking removal	ft (m)
(J) Temporary raised pavement marker	ft (m)
(K) Flagger	hour
(L) Pilot car	hour
(M) Concrete barrier (temporary)	ft (m)
(N) Delineator	each
(O) Traffic signal (temporary)	each or unit day
(P) Crash cushion (temporary)	each or unit day
(Q) Variable message sign	each or unit day

The Agency will use one of two alternates to replace traffic control devices:

Alternate No. 1. The Agency will pay for replacement of devices damaged beyond repair while in service, by no fault of the Contractor, under Subsections 618.4 and 618.5. The Agency will not pay for stolen or misused traffic control devices or for those that become unusable due to normal wear.

Alternative No. 2. The Agency will consider replacement of traffic control devices as incidental to other items of work.

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 619
EROSION CONTROL MATS AND BALES

619.1 DESCRIPTION

Furnish and install erosion mats, sod, or bales to prevent erosion.

619.2 MATERIALS

Provide materials as specified in:

Emulsified Asphalt	Subsection 702.1(C)
Water	Subsection 714.1(B)

Fertilizer	Subsection 715.3
Seed	Subsection 715.8
Temporary Rolled Erosion Control Products	Subsection 715.11
Turf Reinforcement Mats	Subsection 715.12
Erosion and Sediment Control Materials	Subsection 715.15
Jute Mesh	Subsection 715.15(B)
Woven Paper or Sisal Mesh Netting	Subsection 715.15(C)
Synthetic Erosion Control Mats	Subsection 715.15(D)
Wood Fiber Blanket	Subsection 715.15(E)
Fiberglass Roving	Subsection 715.15(F)
Staples	Subsection 715.15(G)
Bracing and Anchoring Stakes	Subsection 715.16(A)
Straw or Hay Bales	Agency specified
Wooden or Metal Stakes	Agency specified
Grass Sod	Agency specified

619.3 CONSTRUCTION

Place erosion mat on designated areas immediately after seeding or sodding. Before placing the mat, remove all stones and clods more than [1½ in. (40 mm)] in diameter, and roots, sticks and other material that would keep the mat from lying directly on the soil. Install mat as specified in the contract. Moisten the seedbed to a minimum 2-in. (50-mm) depth without causing washing or erosion.

A. *Temporary Erosion Control Mats.* Provide erosion control mat, made from jute, wood, or other natural fibers, or from photodegradable synthetics, as specified. Place matting in the direction of flow. Spread mat evenly and smoothly on the soil. Do not stretch the mat. Place wood fiber blanket with the netting on top. Bury the upgrade end of each strip a minimum of [6 in. (150 mm)] in a vertical slot cut in the soil. Press the soil firmly against the embedded fabric or blanket. When placing jute fabric over sod, bury at least [6 in. (150 mm)] of the upgrade end under the downgrade sod at junction slots. Drive vertical staples to anchor the mat. Space staples at 3-ft (1-m) centers along mat edges and alternately space at 3-ft (1-m) centers through the center. Space staples at 10-in. (250-mm) centers at ends or junction slots.

B. *Fiberglass Roving.* Spread fiberglass roving evenly to form a random mat of continuous glass fibers at the rate of [0.20 to 0.30 lb/yd^2 (0.10 to 0.15 kg/m^2)]. Anchor fiberglass roving by applying emulsified asphalt evenly over the glass fibers at [0.25 to 0.35 gal/yd^2 (1. to 1.5 L/m^2)]. Bury upgrade ends 1 ft (300 mm) to prevent undermining.

Expand and apply roving with a pneumatic sprayer at the rate of 40 ft^3/min (0.2 m^3/s) of air at 80 to 100 psi (0.55 to 0.70 MPa). Apply asphalt with a distributor with suitable hoses and spray attachments.

C. *Bales.* Place bales end-to-end across designated areas immediately after shaping ditches and slopes. Position bales at right angles to the direction of the flow, embed, and anchor securely. Excavate sumps upstream from dikes.

Remove erosion bales after slopes and ditches have been stabilized and turf has been established to the extent that future erosion is unlikely. Use bales as mulch or dispose of as specified in Subsection 201.3. Reshape the ditch, fill sumps and trenches, dispose of excess eroded material, and add topsoil, fertilizer, and seed.

D. *Sod.* Deliver sod to the work site in acceptable condition. Place within 36 of harvest. Before harvest, trim top growth to approximately 2 in. (50 mm). Machine cut sod in even strips a minimum of $^3/_4$ in. (20 mm) deep and roll with top growth to the inside. Shape and fertilize the area to receive the sod. Place sod from downstream end of the waterways. Drive two U-shaped staples flush with the sod at the upstream end of each strip. Thoroughly water the sod for 3 weeks after placement.

619.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will use slope measurements for surface area.

B. The Engineer will not measure mat entrenched in the soil at ends or junction slots.

619.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Erosion mat	ft^2 (m^2)
(B) Bales	each
(C) Sod	ft^2 (m^2)
(D) Seed	lb (kg)
(E) Fertilizer	lb (kg)
(F) Water	gal (L)
(G) Asphalt	gal (L)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 620
FILTER FABRIC

620.1 DESCRIPTION

Furnish and install a drainage fabric for pavement edge drains, interceptor drains, well drains, and recharge basins.

620.2 MATERIALS

Provide materials as specified in:

Filter Fabric	Subsection 705.1 for the class specified

620.3 CONSTRUCTION

A. *Protecting and Storing Geotextiles.* Meet Subsection 316.3(A). Limit weather exposure to a maximum of 14 days between lay down and cover.

B. *Preparing the Surface.* Meet Subsection 316.3(B).

C. *Placing Geotextiles.* Meet Subsection 316.3(C).

D. *Constructing Seams.* Construct seams by sewing or overlapping, or as recommended by fabric manufacturer. Overlap longitudinal seams in trenches a minimum length equal to the trench width. Make all other overlaps a minimum 18 in. (450 mm). Overlap in the direction of flow. If sewn, ensure that the seam strength is at least 70 percent of the required tensile strength of the unaged fabric.

E. *Backfilling Trench.* After placing the backfill material in trench installations, fold fabric over the top of the filter material to overlap at least 12 in. (300 mm) or the width of the trench, whichever is less.

F. *Repairing Damaged Fabric.* Remove and replace or repair damaged fabric at no cost to the Agency. Repair damaged fabric using a patch that extends 3 ft (1 m) beyond the damage.

620.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will not measure overlapped and wasted material for payment.

B. The Engineer will measure, and the Agency will pay for, excavation, backfill, bedding, and cover material as separate items under Sections 206 and 822.

620.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Filter fabric	yd^2 (m^2), ft (m)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

AASHTO

DIVISION 700
MATERIAL REQUIREMENTS

These Specifications do not include all material requirements to construct items covered under Divisions 200 through 800. In most cases, a simple reference is provided. For additional, detailed requirements, refer to the current AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing or to applicable ASTM specifications. The joint AASHTO-AGC-ARTBA publication, A Guide to Standardized Highway Drainage Products, provides additional requirements for drainage items. Individual agencies should add specifications for locally used materials and should augment requirements for materials as necessary.

Where more than one option exists within a cited Subsection, the Agency will identify the one to use.

SECTION 701
HYDRAULIC CEMENT

701.1 GENERAL

Provide product from only one mill for any brand and type of hydraulic cement used, although exceptions may be made to reduce excessive air entrainment when using air-entraining cement.

Protect the cement from dampness during storage. Do not use partially set cement or cement that contains caked lumps or cement salvaged from discarded or used bags.

701.2 PORTLAND CEMENT

Meet AASHTO M 85.

701.3 BLENDED HYDRAULIC CEMENT

Meet AASHTO M 240.

701.4 MASONRY CEMENT

Meet ASTM C91/C91M.

SECTION 702
ASPHALT

702.1 BITUMINOUS MATERIALS

A. *Asphalt Cements or Binders*. Meet AASHTO M 20 (Discontinued in 2009) penetration-graded asphalt, AASHTO M 320 for performance-graded asphalt, or AASHTO M 226 for viscosity-graded asphalt.

B. *Cutback Asphalt*. Meet AASHTO M 81 for rapid curing (RC) types and M 82 for medium curing (MC) types.

C. *Emulsified Asphalt*. Meet AASHTO M 140 or M 208.

D. *Temperature Application Range*. Apply asphalt of the type specified within the following temperature ranges:

Table 702.1-1a. Temperature Application Range (°F)

Type and Grade of Material	Spray (°F)	Mix (°F)
RC 70	80–150	80–150
RC 250	100–175	80–150
RC 800	160–225	135–185
RC 3000	200–275	175–225
MC 30	50–120	50–120
MC 70	80–150	80–150
MC 250	100–200	100–200
MC 800	185–260	160–210
MC 3000	225–275	200–250
All emulsions	50–160	50–160
Asphalt cement (all grades)	400 maximum	As required to achieve a kinematic viscosity of 150–300 centistokes

Table 702.1-1b. Temperature Application Range (°C)

Type and Grade of Material	Spray (°C)	Mix (°C)
RC 70	27–66	27–66
RC 250	38–79	27–66
RC 800	71–107	57–85
RC 3000	93–135	79–107
MC 30	10–49	10–49
MC 70	27–66	27–66
MC 250	38–93	38–93
MC 800	85–127	71–99
MC 3000	107–135	93–121
All emulsions	10–71	10–71
Asphalt cement (all grades)	204 maximum	As required to achieve a kinematic viscosity of 150–300 centistokes

702.2 HOT MIX ASPHALT

A. *Mixture Composition.* Develop a job mix formula for each mixture according to AASHTO R 35 or Agency procedure _____. Meet the specified aggregate gradation requirements.

Ensure the job mix formula and related tolerances are within the master range. Submit the following information:

1. All information required in the report section of AASHTO R 35 or Agency procedure ______.
2. Temperature range for mixing.
3. Temperature range for compacting.
4. Laboratory test data, samples and sources of the components, and asphalt binder viscosity–temperature relationships.

Submit a written job mix formula for review and approval at least [21] calendar days before production, or when sources change.

Ensure project mixtures meet the following tolerances:

Table 702.2-1. Project Mixture Tolerances

Property	Requirement
Maximum Aggregate Size	±[0]%
Passing No. 4 (4.75-mm) and larger sieve	±[7]%
Passing No. 8 (2.36-mm) to No. 100 (0.15-mm) sieve	±[4]%
Passing No. 200 (0.75-mm) sieve	±[2] %
Asphalt	±[0.4]%
Mixture temperature	±[20°F (10°C)]

Table 702.2-2. Mixture Tolerances for Open-Graded Friction Course

Property	Requirement
Maximum Aggregate Size	±[0]%
Passing No. 4 [4.75-mm] sieve[a]	±[8]%
Passing No. 8 [2.36-mm] to No. 100 [0.15-mm] sieve	±[6]%
Passing No. 200 [0.75-mm] sieve	±[2]%
Asphalt	±[0.5]%
Mixture temperature	±[20 °F (10 °C)]

[a] Excludes contract-specified maximum size.

Unless otherwise noted on the plans, the Engineer will accept bituminous mixtures containing up to [30] percent reclaimed asphalt concrete pavement, provided that the mixture meets all the requirements of these specifications. Crush, screen, or otherwise size reclaimed asphalt concrete pavement such that at least [95] percent passes the [2-in. (50-mm)] sieve.

Unless otherwise noted on the plans, the Engineer will accept bituminous mixtures containing up to [5] percent recycled asphalt shingles, provided that the mixture meets all the requirements of the AASHTO PP 78.

B. *Sampling*. The Engineer will perform sampling according to the following standards:

1. *Aggregate*. AASHTO R 90 (formerly T 2).

2. *Asphalt Binder*. AASHTO R 66 and T 315.

3. *Hot Mix Asphalt (HMA)*. AASHTO R 97 (formerly T 168).

4. *Warm Mix Asphalt (WMA)*. AASHTO T 315.

C. *Aggregate*. Construct stockpiles to prevent segregation. Store aggregate from different sources or of different gradations in separate stockpiles.

D. *Additives.* Use anti-stripping or silicone additives, as specified. Comply with mix design ratios. Confirm the addition rate through field tests performed during production. Follow the manufacturer's recommendations for incorporating additives into the mix.

E. *Reclaimed Asphalt Pavement (RAP).* AASHTO M 323.

F. *Recycled Asphalt Shingles (RAS).* AASHTO MP 23 and PP 78. Grind particles such that 100 percent passes the $^{3}/_{8}$-in. (9.5-mm) sieve. Deleterious materials kept to 1 percent of mass and Non-Metallic materials kept to 0.5 percent.

702.3 WARM MIX ASPHALT

A. *Mixture Composition.* Develop a job mix formula for each mixture according to AASHTO R 35 and its Appendix X2, "Special Mixture Design Considerations and Practices for Warm Mix Asphalt (WMA)" or Agency procedure _____. Meet the specified aggregate gradation requirements.

B. *Asphalt.* The same grade of binder should be used with WMA and HMA. For WMA processes with very low production temperatures, it may be necessary to increase the high temperature performance grade of the binder to meet rutting resistance requirements.

C. *Additives.* WMA process selection should be made by the producer in consultation with the specifying agency and technical assistance personnel from WMA process suppliers. Use NTPEP or agency-approved WMA additives. Follow manufacturer's recommendations for incorporating WMA additives into the mix.

SECTION 703
AGGREGATES

703.1 CONCRETE AGGREGATES

A. *Fine Aggregate.* Meet AASHTO M 6.

B. *Coarse Aggregate.* Meet AASHTO M 80. Provide coarse aggregate in two separate sizes, meeting the gradation requirements of AASHTO M 43 for either the No. 67 and No. 4 sizes or the No. 57 and No. 3 sizes. When the nominal top size of coarse aggregate is 1 in. (25 mm) or less, separation into two separate sizes is not necessary.

C. *Lightweight Aggregate.* Meet AASHTO M 195.

D. *Recycled Concrete Aggregate.* Meet ASTM C33.

703.2 ROAD-MIX ASPHALT SURFACE COURSE AGGREGATES

Blend coarse aggregate meeting ASTM D692/D692M with fine aggregate meeting AASHTO M 29 to produce the specified gradation.

Use aggregates of crushed stone, crushed slag, crushed gravel, or natural gravel.

703.3 TREATED OR UNTREATED BASE COURSE AGGREGATES

Meet AASHTO M 147. Provide aggregates of crushed stone, crushed slag, crushed gravel, or natural gravel. The Agency may specify use of glass cullet meeting AASHTO M 318 or crushed reclaimed concrete aggregate meeting AASHTO M 319.

703.4 AGGREGATES FOR ASPHALT BASE COURSE AND ASPHALT CONCRETE

A. *Coarse Aggregate.* Meet ASTM D692/D692M and AASHTO M 323. Provide aggregate of crushed stone, crushed slag, crushed gravel, or natural gravel.

B. *Fine Aggregate.* Meet AASHTO M 29 and AASHTO M 323. Provide aggregate of natural sand, manufactured sand, stone screenings, slag screenings, or a combination of these materials.

C. *Recycled Materials.*

1. *Reclaimed portland cement concrete (RPCC)* includes reuse as aggregate or subbase. The Agency may specify reuse of reclaimed concrete aggregate meeting AASHTO M 319.

2. *Reclaimed asphalt pavement (RAP).* RAP is salvaged, milled, pulverized, broken, or crushed asphalt pavement. Crush or break RAP so that 100 percent of the particles pass the 2-in. (50-mm) sieve.

3. *Recycled asphalt shingles (RAS).* RAS is defined as processed asphalt shingle material from manufacturing of asphalt roofing shingles or from re-roofing residential structures. Process the RAS by ambient grinding or granulating such that 100 percent of the particles pass the $^{3}/_{8}$-in. (9.5-mm) sieve. Perform a sieve analysis on processed RAS material before extraction (or ignition) of the asphalt.

703.5 AGGREGATE FOR OPEN GRADED BITUMINOUS BASE (OGBB)

A. *Aggregate Physical Properties.* Meet the requirements specified in Table 703.5-1.

Table 703.5-1. Aggregate Physical Properties for OGBB

Test	Requirement
LA Abrasion, % wear, maximum	40
Mechanically fractured faces (of material retained on No. 4 (4.75-mm) sieve), % minimum	75% with 2 or more
Aggregate Durability Index, minimum	40
Flat or elongated pieces on combined and retained on No. 4 (4.75-mm) sieve, % maximum	15
Natural Sand and Gravel, % maximum	0
Clay Balls and Friable Particles, % maximum	0
Soft Particles, % maximum	5
Sticks or Roots, % maximum	0

B. *Gradation Requirements.* Meet the requirements specified in Table 703.5-2.

Table 703.5-2. Gradation Requirements for OGBB

Sieve Size	Percent Passing
1.5 in. (37.5 mm)	100
1.0 in. (25. mm)	95–100
$^{1}/_{2}$ in. (12.5 mm)	25–60
No. 4 (4.75 mm)	0–10
No. 10 (2.0 mm)	0–5
No. 200 (75 μm)	0–3

703.6 AGGREGATE FOR OPEN GRADED PORTLAND CEMENT CONCRETE BASE (OGPCCB)

A. *Aggregate Physical Properties.* Meet the requirements specified in Table 703.6-1.

Table 703.6-1. Aggregate Physical Properties for OGPCCB

Test	Requirement
LA Abrasion, % wear, maximum	40
Mechanically fractured faces (of material retained on No. 4 (4.75-mm) sieve), % minimum	70% with 2 or more
Aggregate Durability Index, minimum	40
Flat or elongated pieces on combined and retained on No. 4 (4.75-mm) sieve, % maximum	15
Natural Sand and Gravel, % maximum	0
Clay Balls and Friable Particles, % maximum	0
Soft Particles, % maximum	5
Sticks or Roots, % maximum	0

B. *Gradation Requirements.* Meet the requirements specified in Table 703.6-2.

Table 703.6-2. Gradation Requirements for OGPCCB

Sieve Size	Percent Passing
1.5 in. (37.5 mm)	100
1.0 in. (25. mm)	95–100
$^{1}/_{2}$ in. (12.5 mm)	25–60
No. 4 (4.75 mm)	0–10
No. 8 (2.36 mm)	0–5
No. 200 (75 μm)	0–2

703.7 AGGREGATE GRADATION FOR ASPHALT PAVEMENT

Size, grade, proportion, and combine aggregate fractions to produce composite blends that meet the design requirements of AASHTO M 323 or as otherwise specified by the Agency.

703.8 AGGREGATE GRADATION FOR COLD PLANT MIX ASPHALT PAVEMENT

A. *Aggregate for Pavement.* Size, grade, proportion, and combine the several aggregate fractions so that resulting composite blends meet the design requirements specified by the Agency.

B. *Aggregate for Top Dressing.* Use top dressing material containing dry sand, stone screenings, or slag screenings graded so that at least 95 percent passes the No. 4 (4.75-mm) sieve and not more than 40 percent passes the No. 50 (300-µm) sieve.

703.9 COVER COAT MATERIAL AGGREGATE

Provide aggregates meeting ASTM D1139/D1139M of crushed stone, crushed slag, crushed gravel, or natural gravel. Use only one type of aggregate unless alternate types are approved.

Ensure that the aggregate has a retained asphalt film above 95 percent, when tested according to AASHTO T 182 (Discontinued in 2007). The Contractor may use aggregates not meeting this requirement for asphalt surface treatments and seal coats if an acceptable chemical additive or wetting agent is used to produce a water-resistant film. (The Agency may supply specifications.)

703.10 BLOTTER SAND

Meet AASHTO M 43, Size 10.

Ensure aggregate is free of organic or other harmful material.

703.11 MINERAL FILLER

Meet AASHTO M 17.

703.12 BED COURSE MATERIAL

A. *Sidewalks and Curbing.* Use material containing cinders, sand, slag, gravel, crushed stone, or other approved material graded so that all particles pass a $^1/_2$-in. (12.5-mm) sieve.

B. *Protecting Slopes.* Cover slopes with porous, free-draining material consisting of sand, cinders, gravel, slag, crushed stone, or other approved free-draining material. Use uniformly graded and sized material so that 100 percent passes a $1^1/_2$-in. (37.5-mm) sieve.

703.13 MASONRY MORTAR AGGREGATE

Meet AASHTO M 45.

703.14 LIMESTONE DUST

Meet AASHTO M 17.

Ensure limestone dust is free of flat platelet grains or rhombohedral grains.

703.15 AGGREGATE FOR RIPRAP

Provide hard, durable, crushed, quarried, natural stone aggregate, or reclaimed portland cement concrete (RPCC) as aggregate for riprap. Evaluate hardness, durability, and quality according to ASTM D4992. Use stone with an apparent specific gravity of at least 2.4, or use broken concrete with absorption less than 5 percent. Provide stone that contains no weak laminations and cleavages and that will not disintegrate when exposed to water or weathering. Ensure that the aggregate meets the following additional requirements:

A. *Class 1 Riprap.*

1. *Primary Stone.* Provide stone that is at least 3 in. (75 mm) thick, with a minimum weight (mass) of 50 lb (23 kg). Ensure that at least 60 percent of the stone has a weight (mass) of more than 80 lb (35 kg).

2. *Choke Stone.* Provide fragments or spalls sized to wedge between the primary stones.

B. *Class 2 Riprap.* Use smaller stones graded to ensure even distribution throughout the riprap; at least 60 percent must have a weight (mass) of more than 80 lb (35 kg).

C. *Grouted Riprap.* Meet requirements for Class 1 or Class 2 riprap.

D. *Wire-Enclosed Riprap.* Use round or angular aggregate, with at least 95 percent retained on a 2-in. (50-mm) sieve.

E. *Sacked-Concrete Riprap.* Use aggregate consisting of clean pit run, sandy or gravel material free of roots, organic matter, or other detrimental matter. Meet the following gradation requirements:

Table 703.15-1. Gradation Requirements Sacked-Concrete Riprap

Sieve	Percent Passing
2 in. (50 mm)	80–100
No. 200 (75 μm)	0–4

703.16 FILTER AGGREGATE FOR RIPRAP

Provide aggregates of hard, durable particles or fragments of crushed stone or natural gravel. Evaluate hardness, durability, and quality according to ASTM D4992. Screen or crush materials to meet the following gradation requirements:

Table 703.16-1. Gradation Requirements for Riprap

Sieve	Percent Passing
3 in. (75 mm)	100
No. 4 (4.75 mm)	20–50
No. 200 (75 μm)	0–10

703.17 DRAINAGE AGGREGATE

A. *Permeable Material.* Use hard, durable, clean sand, gravel, crushed stone, or crushed slag to backfill trenches, construct underdrains, or for other subdrainage purposes. Evaluate hardness, durability, and quality according to ASTM D4992. Ensure that permeable material contains no organic material, clay balls, or other detrimental matter.

B. *Coarse Aggregate for Underdrain Course.* Provide aggregate meeting AASHTO M 80 and the gradation requirements of AASHTO M 43 for size No. 89.

(The Agency may specify alternative gradation.)

C. *Fine Aggregate for Underdrain.* Provide aggregate meeting AASHTO M 6.

(The Agency may specify alternative gradation.)

703.18 AGGREGATE FOR PROTECTION AND FILTRATION

A. *Stone Blanket Protection.* Provide aggregate meeting AASHTO M 80 and the gradation requirements of AASHTO M 43 for size No. 357.

B. *Filter Blanket.* Provide aggregate meeting AASHTO M 80 and the gradation requirements of AASHTO M 43 for size No. 467.

SECTION 704
RESERVED

SECTION 705
FABRICS

705.1 FILTER FABRIC FOR SUBSURFACE DRAINAGE

Meet AASHTO M 288, Class 2, for subsurface drainage.

705.2 FABRIC REINFORCEMENT FOR ASPHALT PAVEMENT

Meet AASHTO M 288 for paving fabrics.

705.3 SEPARATOR FABRIC

Meet AASHTO M 288 for separation.

705.4 SILT FENCE

Meet AASHTO M 288 for temporary silt fence.

SECTION 706
MASONRY UNITS

706.1 CLAY OR SHALE BRICK

Meet one of the following specifications and grade requirements:

A. *Sewer Brick.* ASTM C32.

B. *Building Brick.* ASTM C62.

706.2 CONCRETE BRICK

Meet ASTM C55 for the grade specified.

706.3 CONCRETE MASONRY BLOCKS

Use rectangular or segmented concrete masonry blocks and, when specified, shape ends to interlock at vertical joints. Use solid blocks meeting requirements of ASTM C129, C139, or C90, and hollow blocks meeting ASTM C90. Comply with the dimensions specified.

706.4 STONE MASONRY

A. *Rubble Stone.* Provide unweathered stone without worn, rounded, or weathered faces.

B. *Ashlar Stone.* Provide stone that is reasonably fine grained and uniform in color and free of defects. Ensure that the stone is of demonstrated satisfactory quality and of such character that it can be brought to plane or curved lines and surfaces.

SECTION 707
JOINT MATERIALS

707.1 JOINT FILLERS AND SEALANTS

Before incorporating sealant materials and separating and blocking medium into the work, test and obtain approval for all materials used, or use Agency-certified materials. The Agency will inspect, test, and approve all seals and lubricant materials for joint repair before they are used in the work. Furnish a certificate of compliance as specified in Subsection 106.4 for materials used.

Where installation procedures include manufacturer's recommendations, submit the catalog data and recommendations before beginning joint resealing.

A. *Poured Joint Sealants.*

1. *Joint Seals for Pavements.* Meet ASTM D3406, ASTM D6690, or ASTM D1776/D1776M.

2. *Joint Seals for Bridge Deck.* Meet *AASHTO LRFD Bridge Design Specifications*.

B. *Preformed Elastomeric Joint Sealants.*

1. *Joint Seals for Concrete Pavement.* Meet ASTM D2628. Provide lubricants meeting ASTM D2835 to install preformed compression seals in concrete pavement.

2. *Joint Seals for Bridges.* Meet AASHTO M 297.

C. *Silicone Sealants.* Use sealant material that meets ASTM D5893/D5893M.

D. *Preformed Joint Fillers.* Meet AASHTO M 33, M 153, or M 213, as specified. Furnish filler for each joint in a single piece for the full depth and width required. Punch the filler to accommodate dowels. When authorized to use more than one piece for a joint, accurately staple or otherwise securely fasten the abutting ends to shape.

E. *Polystyrene Board Fillers.* Meet ASTM C203. Furnish board fillers of expanded polystyrene with a minimum flexural strength of 36 psi (0.25 MPa) and a compressive yield strength of between 14.5 to 43.5 psi (0.1 to 0.3 MPa) at 5 percent compression.

707.2 JOINT MORTAR

Use joint mortar of one part portland cement and two parts sand and water mixed to the required consistency. Use mortar within 30 minutes of mixing.

707.3 FLEXIBLE WATERTIGHT GASKETS

A. *Joints for Circular Concrete Sewer and Culvert Pipe*. Meet ASTM C990.

B. *Joints for Concrete Pipe and Manholes Using Rubber Gaskets*. Meet ASTM C443 (ASTM C443M).

707.4 WATERSTOPS

A. *Polyvinyl Chloride (PVC) Waterstops*. Provide PVC waterstops that meet the requirements specified in Table 707.4-1.

Table 707.4-1. PVC Waterstops

Property	Test Method	Requirement
Specific gravity	ASTM D792	1.35 max
Durometer hardness	ASTM D2240	75 ± 5
Tensile strength	ASTM D412	1,800 psi (12.5 MPa)
Elongation	ASTM D412	350%
Cold brittleness	ASTM D746	–35°F (–37°C)

B. *Rubber Waterstops*. Provide synthetic rubber waterstops that meet the requirements specified in Table 707.4-2.

Table 707.4-2. Rubber Waterstops

Property	Requirement	
Composition	Neoprene (not less than 70 percent by volume), reinforcing carbon black, zinc oxide, polymerization agents, and softeners	
Durometer hardness	ASTM D2240	50 to 60
Tensile strength	ASTM D412	2,750 psi (19 MPa)
Elongation at break	ASTM D412	600%
Tensile strength (aged)	65% of original, after 7 days in air at 160°F ± 2°F (70°C ± 1°C), or after 4 days in oxygen at 160°F ± 2°F (70°C ± 1°C), and 300 psi (2.1 MPa) pressure	

C. *Copper Waterstops*. Meet ASTM B152/B152M.

SECTION 708
CONCRETE AND PLASTIC PIPE

708.1 NONREINFORCED CONCRETE PIPE

Meet AASHTO M 86 M/M 86 for specified diameters and strength classes.

708.2 REINFORCED CONCRETE PIPE

Meet AASHTO M 170 (AASHTO M 170M) or M 242M/M 242 for specified diameters and strength classes or D-loads.

Unless otherwise specified, pipe wall design and use of elliptical reinforcement in circular pipe are optional.

Use precast reinforced concrete end sections that meet the specified requirements.

708.3 PERFORATED CONCRETE PIPE

Meet AASHTO M 175M/M 175 for specified diameters and strength classes.

708.4 CONCRETE DRAIN TILE

Meet AASHTO M 178M/M 178 for specified material, diameters, and quality classes.

708.5 POROUS CONCRETE PIPE

Meet AASHTO M 176M/M 176 for specified diameters.

708.6 REINFORCED CONCRETE ARCH CULVERT, STORM DRAIN, AND SEWER PIPE

Meet AASHTO M 206M/M 206 for the class specified.

708.7 REINFORCED CONCRETE ELLIPTICAL CULVERT, STORM DRAIN, AND SEWER PIPE

Meet AASHTO M 207M/M 207 for the class specified.

708.8 PRECAST REINFORCED CONCRETE BOX SECTION

Meet AASHTO M 259 (M 259M) or M 273 (M 273M) for specified dimensions and loading conditions.

708.9 POLYETHYLENE (PE) CORRUGATED DRAINAGE PIPE OR TUBING

Meet AASHTO M 252 or M 294 as applicable for specified type or size. For perforated pipe, ensure perforation size and spacing meet AASHTO M 252 or M 294.

708.10 POLYVINYL CHLORIDE (PVC) SEWER PIPE AND FITTINGS

Meet ASTM D 3034, AASHTO M 278, or AASHTO M 304 for specified type or class. For perforated pipe, ensure perforation size and spacing meet AASHTO M 278 or M 304.

708.11 POLYETHYLENE (PE) CORRUGATED DRAIN TILE

Meet AASHTO M 252 for specified diameters. For perforated pipe, ensure perforation size and spacing meet AASHTO M 252.

708.12 CORRUGATED POLYPROPYLENE (PP) PIPE

Meet AASHTO M 330.

708.13 ACRYLONITRILE-BUTADIENE-STYRENE (ABS) SEWER PIPE AND FITTINGS

Meet ASTM D2680. For perforated pipe, ensure perforation size and spacing meet AASHTO M 278 requirements.

708.14 POLYPROPYLENE (PP) CORRUGATED DRAINAGE PIPE OR TUBING.

Meet AASHTO M 330 for specified type or size. For perforated pipe, ensure perforation size and spacing meet AASHTO M 330.

SECTION 709
METAL PIPE

709.1 DUCTILE IRON CULVERT PIPE

Meet ASTM A716 for specified diameters.

709.2 METALLIC-COATED CORRUGATED STEEL PIPE FOR SEWERS AND DRAINS

Use pipe and coupling bands meeting AASHTO M 36 for the specified dimensions.

Ensure that special sections such as elbows and prefabricated flared end sections meet AASHTO M 36.

709.3 BITUMINOUS-COATED CORRUGATED STEEL PIPE AND PIPE ARCHES

Use pipe and coupling bands meeting AASHTO M 36 and AASHTO M 190 requirements for specified dimensions and bituminous coating type. Fully coat coupling bands with bituminous materials.

Ensure that special sections such as elbows and prefabricated flared end sections meet AASHTO M 36 and M 190 requirements.

When fiber-bonded bituminous coating is specified, ensure that the pipe used meets AASHTO M 36 for pipe made of zinc and aramid fiber coated sheet, and that the bituminous coating meets AASHTO M 190 for the type specified.

709.4 METALLIC-COATED CORRUGATED STEEL PIPE FOR UNDERDRAINS

Meet AASHTO M 36 for the specified diameters and perforation class.

709.5 BITUMINOUS-COATED CORRUGATED STEEL PIPE FOR UNDERDRAINS

Meet AASHTO M 36 for the specified diameters and perforation class.

Coat pipe with bituminous material meeting AASHTO M 190 for specified type and coating. Fully coat coupling bands. Meet specified minimum diameter perforations after coating.

709.6 CORRUGATED ALUMINUM CULVERT PIPE

Meet AASHTO M 196 for specified dimensions.

709.7 CORRUGATED ALUMINUM PIPE FOR UNDERDRAINS

Meet AASHTO M 196 for specified diameters and perforation class.

709.8 BITUMINOUS-COATED CORRUGATED ALUMINUM CULVERT PIPE

Meet AASHTO M 196. Coat pipe with bituminous material meeting AASHTO M 190. Provide coating and invert paving of the type specified.

709.9 BITUMINOUS-COATED CORRUGATED ALUMINUM PIPE FOR UNDERDRAINS

Meet AASHTO M 196. Coat pipe with bituminous material meeting AASHTO M 190. Meet specified minimum diameter perforations after coating.

709.10 STEEL STRUCTURAL PLATE FOR PIPE, PIPE ARCHES, AND ARCHES

Meet AASHTO M 167M/M 167 for these conduits and for the bolts and nuts for connecting plates.

709.11 FULL BITUMINOUS-COATED STEEL STRUCTURAL PLATE PIPE, PIPE ARCHES, AND ARCHES

Meet AASHTO M 167M/M 167 for these conduits and for the bolts and nuts for connecting plates. Coat conduit with bituminous material meeting AASHTO M 190 or M 243.

709.12 ALUMINUM STRUCTURAL PLATE FOR PIPE, PIPE ARCHES, AND ARCHES

Meet AASHTO M 219 for these conduits and for the bolts and nuts for connecting plates.

709.13 FULL BITUMINOUS-COATED ALUMINUM STRUCTURAL PLATE FOR PIPE, PIPE ARCHES, AND ARCHES

Meet AASHTO M 219 for conduits. Coat conduits with bituminous material meeting AASHTO M 190 or M 243.

709.14 POLYMER-PRECOATED CORRUGATED STEEL PIPE FOR SEWERS AND DRAINS

Meet AASHTO M 245.

709.15 NESTABLE CORRUGATED STEEL PIPE

Meet Military Specification MIL-P-236.

709.16 SLOTTED CORRUGATED STEEL PIPE

Use slotted pipe with either angle-slots or grate-slots, as specified.

For angle slot drains, meet the chemical and physical requirements of ASTM A36/A36M. Meet Subsection 714.7 for grate-slot drain assemblies. galvanize slot angles and grate-slot assemblies according to AASHTO M 111M/M 111.

Furnish commercial-quality flashing galvanized with a G165 coating designation according to ASTM A653/A653M. Meet ASTM A307 for bolts and nuts. Meet ASTM A501 for structural tubing spacers. galvanize bolts, nuts, and spacers according to AASHTO M 111M/M 111.

SECTION 710
STRUCTURAL STEEL

710.1 STRUCTURAL STEEL

A. *General.* Furnish the grade or grades of steel as specified in the plans.

Ensure that the steel used in the main load-carrying member components that are subject to tensile stress meets the applicable AASHTO M 270M/M 270 Charpy V-Notch Impact Test requirements.

Galvanize ferrous metal products, excluding fasteners and hardware items, according to AASHTO M 111M/M 111. galvanize fasteners and hardware according to AASHTO M 232M/M 232, except as noted in *AASHTO LRFD Bridge Design Specifications*, Article 6.4.3.

B. *Carbon Steel.* Meet AASHTO M 270M/M 270, Grade 36 (Grade 250).

C. *High-Strength, Low-Alloy Structural Steel.* Meet AASHTO M 270M/M 270, Grades 50 or 50W (Grades 345 or 345W).

D. *High-Strength, Low-Alloy, Quenched-and-Tempered Steel Plate.* Meet AASHTO M 270M/M 270, Grade 70W (485W).

E. *High-Yield-Strength, Quenched-and-Tempered Alloy Steel Plate.* Meet AASHTO M 270M/M 270, Grades 100 or 100W (690 or 690W).

For quenched-and-tempered alloy steel structural shapes and seamless mechanical tubing, meet AASHTO M 270M/M 270, Grades 100 or 100W (690 or 690W) steel, except that the specified maximum tensile strength may be 140,000 psi (965 MPa) for structural shapes and 145,000 psi (1000 MPa) for seamless mechanical tubing.

F. *Steel for Eyebars.* Meet AASHTO M 270M/M 270, Grades 36, 50, or 50W (250, 345, or 345W).

G. *Structural Tubing.* Meet ASTM A500/A500M, Grade B.

710.2 HIGH-STRENGTH FASTENERS

A. *Materials.* For structural steel joints, provide high-strength bolts that meet ASTM F3125/F3125M. Ensure that the hardness of bolts does not exceed 33 HRC. For unpainted weathering grades of steel, use Type 3 bolts.

Ensure that the supplier provides the lot number on the shipping package and a certification identifying the date and location of all testing. Include rotational capacity tests and bolt and nut coating thickness, when applicable.

Provide results of the following tests:

1. Proof load tests of bolts performed according to ASTM F606/F606M, Method 1.
2. Wedge tension tests of full-size bolts performed according to ASTM F606/F606M.
3. Proof load tests of nuts as required by ASTM A563.
4. Ensure galvanized bolts are wedge-tested after galvanizing. Perform proof load tests for nuts used with galvanized bolts after galvanizing, overtapping, and lubricating.

   For bolts, provide nuts meeting ASTM A563,

   Grades C, C3, D, DH, or DH3 (Property Classes 8S, 8S3, 10S, or 10S3).

   For bolts, provide nuts meeting ASTM A563), Grades DH or DH3 (Property Classes 10S or 10S3).

   Lubricate galvanized nuts with a lubricant containing a visible dye. Ensure black bolts are oily to the touch when delivered and installed.

   Furnish washers of hardened steel meeting ASTM F436/F436M.

B. *Identifying Marks.*

1. Ensure [ASTM A325 (A325M)] fasteners have the following markings, as applicable.
   a. *Bolts and Nuts.* Mark bolt heads to identify the grade [by the symbol "A325" ("A325M")], the manufacturer, and the type (if Type 3). Mark nuts to identify the property class, the manufacturer, and the type (if Type 3).
   b. *Direct Tension Indicators.* Mark direct tension indicators to identify the manufacturer and the type ["325" (8.8)].
   c. *Washers.* Mark washers to identify the manufacturer and the type (if Type 3).
2. Ensure [ASTM A490 (A490M)] fasteners have the following markings, as applicable.
   a. *Bolts and Nuts.* Mark bolt heads to identify the grade [by the symbol "A490" ("A490M")], the manufacturer, and the type (if Type 3). Mark nuts to identify the property class, the manufacturer, and the type (if Type 3).
   b. *Direct Tension Indicators.* Mark direct tension indicators to identify the manufacturer and the type ["490" (10.9)].
   c. *Washers.* Mark washers to identify the manufacturer and the type (if Type 3).

C. *Dimensions.* Ensure bolt and nut dimensions meet the Heavy Hexagon Structural Bolts and Heavy Semi Finished Hexagon Nuts (Metric Heavy Hexagon Structural Bolts and Metric Heavy Semi Finished Hexagon Nuts) requirements in ANSI B18.2.1 (B18.2.3.7M) and B18.2.2 (B18.2.4.6M), respectively.

D. *Galvanizing.*

1. Do not galvanize bolts.

2. For Type 1 fasteners, hot dip galvanize according to AASHTO M 232M/M 232, Class C, or mechanically galvanize according to ASTM B695.

3. Tension test bolts after galvanizing.

4. Use the same process to galvanize the washers, nuts, and bolts of any assembly.

5. Overtap nuts the minimum amount required for the fastener assembly. Lubricate galvanized nuts with a lubricant containing a visible dye.

E. *Alternate Fasteners.* Obtain approval to use other fasteners or fastener assemblies. Ensure that alternate fasteners meet the materials, manufacturing, and chemical composition requirements and the mechanical property requirements of the same specification in full-size tests, and have body diameter and bearing areas under the head and nut, or their equivalent, not less than those provided by a bolt and nut of the same nominal dimensions prescribed.

Approved alternate fasteners may differ in other dimensions from those of the specified bolts and nuts.

Obtain approval to use high-strength steel lock-pin and collar fasteners, as an alternate for the specified high-strength bolts, by documenting the following information:

1. The shank and head meet the requirements of ASME B18.2.6 for bolts and ANSI B18.2.2 for nuts.

2. Each fastener provides a solid shank body of sufficient diameter to provide tensile and shear strength equivalent to or greater than that of the bolt specified.

3. A cold-forged head on one end that is of adequate type and dimensions.

4. A shank length suitable to fasten the material, locking grooves, breakneck groove, and pull grooves (all annular grooves) on the opposite end.

5. A steel locking collar of proper size for shank diameter used, that, by means of suitable installation tools, is cold swaged into the locking grooves, forming head for the grooved end of the fastener after the pull groove section has been removed.

6. The steel locking collar is a standard product of an established manufacturer of lock-pin and collar fasteners.

F. *Load Indicator Devices.* The Contractor may use load-indicating devices meeting ASTM F959/F959M with the specified bolts, nuts, and washers. If approved, the Contractor may use alternative design direct tension indicating devices provided they meet the above requirements or approved manufacturer specifications.

710.3 WELDED SHEAR CONNECTORS

A. *Materials.* Furnish stud shear connectors meeting the requirements of AASHTO M 169, cold-drawn bars, UNS Designations G 10150, G 10180, or G 10200, either semi- or fully kilned. When flux retaining caps are used, ensure that steel used for the caps is a low-carbon grade suitable for welding and that meets ASTM A109/A109M requirements.

Meet Table 710.3-1 requirements with bar stock used to produce finished studs. Determine yield by the 0.2 percent offset method.

Table 710.3-1. Tensile Properties of Stud Shear Connectors

Property	Requirement
Tensile strength, minimum	60,000 psi (415 MPa)
Yield strength, minimum	50,000 psi (345 MPa)
Elongation, minimum	20% in 2 in. (50 mm)
Reduction of area, minimum	50%

B. *Test Methods.* Determine tensile properties according to the applicable sections of AASHTO T 244. Perform tensile tests on finished studs welded to test plates using the test fixture in Figure 7.2 of ANSI/AASHTO/AWS D1.5. Repeat the test if fracture occurs outside the middle half of the gauge length.

C. *Finish.* Furnish finished studs of uniform quality and condition, free from injurious laps, fins, seams, cracks, twists, bends, or other defects. Produce a finish by cold drawing, cold rolling, or machining.

D. *Certification.* Furnish the manufacturer's certification that the delivered studs meet material requirements. Furnish certified copies of in-plant quality control test reports, as requested.

E. *Quality Assurance.* The Engineer may select, at the Contractor's expense, studs of each type and size to verify compliance with the specified requirements.

710.4 STEEL FORGINGS AND STEEL SHAFTING

A. *Steel Forgings.* Meet AASHTO M 102M/M 102, Classes C, D, F, or G.

B. *Cold-Finished Carbon Steel Shafting.* Meet AASHTO M 169, Grades UNS Designations G 10160 to G 10300, inclusive.

710.5 CASTINGS

A. *Steel Castings.*

1. *Steel Castings.* Meet AASHTO M 103M/M 103, Grade 70–36 (485–250).

2. *Chromium Alloy Steel Castings.* Meet AASHTO M 163M/M 163, Grade CA 15M.

B. *Iron Castings.*

1. *Gray Iron Castings.* Meet AASHTO M 105, Class 30.

2. *Ductile Iron Castings.* Meet ASTM A536, Grade 60-40-18 (414-276-18). Furnish specified test coupons, and test specimens from integral casting parts, such as risers, for castings with a mass exceeding 1,000 lb (450 kg).

3. *Malleable Iron Castings.* Meet ASTM A47/A47M, Grade 35018 (24118).

Clean scale and sand from all castings before delivery.

710.6 BEARING DEVICES

Meet Section 818.

710.7 PAINTING

Meet Section 813.

SECTION 711
REINFORCING STEEL AND WIRE ROPE

711.1 REINFORCING STEEL

A. *Billet-Steel Bars for Concrete Reinforcement.* Meet AASHTO M 31 M/M 31 and ASTM A706/A706M.

B. *Rail-Steel Bars for Concrete Reinforcement.* Meet AASHTO M 322 M/M 322 and ASTM A996/A996M.

C. *Axle-Steel Bars for Concrete Reinforcement.* Meet AASHTO M 322 M/M 322 and ASTM A996/A996M.

Furnish deformed bars for concrete structures meeting the tensile properties for the grade specified.

Furnish tie bars that meet AASHTO M 31 M/M 31 or M 322M/M 322. Do not use rail steel for tie bars to be bent and restraightened during construction.

Furnish plain, round dowel bars meeting AASHTO M 31 M/M 31 or M 322 M/M 322, for mechanical properties only, or AASHTO M 227 M/M 227. Ensure dowels are free from burs or other distortions that might limit slippage in the concrete. Meet AASHTO M 254 for pre-applied protective and bond-breaking coatings.

Use metal of an approved design for dowel bar sleeves.

Provide epoxy-coated reinforcing steel to meet ASTM A775/A775M.

711.2 WIRE ROPE OR WIRE CABLE

Meet AASHTO M 30 for type specified.

A. *Fabricated Steel Bar or Rod Mats for Concrete Reinforcement.* Meet AASHTO M 54M/M 54.

B. *Welded Steel Wire Fabric for Concrete Reinforcement.* Meet AASHTO M 336M/M 336.

711.3 PRESTRESSING STRAND OR WIRE

A. *Prestressing Strand for Concrete Reinforcement.* Meet AASHTO M 203M/M 203.

B. *Prestressing Wire for Concrete Reinforcement.* Meet AASHTO M 204M/M 204.

SECTION 712
FENCE AND GUARDRAIL

712.1 BARBED WIRE

Meet AASHTO M 280 for specified coating class and style.

712.2 WOVEN WIRE

Meet AASHTO M 279 for specified coating class and style.

712.3 CHAIN-LINK FENCE

Meet AASHTO M 181 for chain-link fabric, fittings, and hardware for the specified metal, coating, wire sizes, and mesh.

712.4 METAL BEAM RAIL

Meet AASHTO M 180 for the specified class and type of corrugated-sheet steel beam rail elements. Ensure galvanized or painted rub rails meet the chemical and physical properties of ASTM A36/A36M. Meet the chemical and physical properties of ASTM A588/A588M for corrosion-resistant rail. galvanize according to AASHTO M 111M/M 111.

712.5 TIMBER RAIL

Cut timber rail, meeting AASHTO M 168, from the specified grade of dry, well-seasoned, and dressed timber stock of the species specified. Use timber preservatives meeting AASHTO M 133.

712.6 FENCE POSTS

A. *Wood*. Furnish straight, sound, seasoned, and peeled wood posts with ends cut square. Trim knots flush with the surface. Treat posts as specified. Peeling requirements do not apply to red cedar posts or bracing.

   Use dimension timber and lumber, of the specified species and grade, for fences or gates. Ensure members are sound, straight, and free from knots, splits, and shakes. Dress and finish all sides.

B. *Concrete*. Furnish concrete and reinforcing steel for concrete posts as specified.

C. *Steel*. Furnish rolled steel posts meeting AASHTO M 281 and galvanize according to AASHTO M 111M/M 111. Furnish tubular steel posts meeting AASHTO M 181. Use standard commercial grade fittings, hardware, and appurtenances according to current standard practice if not otherwise specified.

712.7 GUARDRAIL POSTS

Meet the joint AASHTO-AGC-ARTBA publication, A Guide to Standardized Highway Barrier Rail Hardware.

712.8 GUARDRAIL HARDWARE

Meet the joint AASHTO-AGC-ARTBA publication, A Guide to Standardized Highway Barrier Rail Hardware.

712.9 STEEL BOX BEAM RAIL

Meet ASTM A500/A500M or A501/A501M. galvanize after fabrication according to AASHTO M 111M/M 111.

Meet ASTM A500/A500M or A501/A501M dimensional and mechanical requirements for corrosion-resistant steel rail elements. Ensure elements have an atmospheric corrosion resistance approximately twice that of carbon structural steel with copper. Provide posts meeting Subsection 712.7 and hardware meeting Subsection 712.8.

712.10 WIRE AND STAKES FOR WIRE-ENCLOSED RIPRAP

A. *Woven Wire.* Use 2 in. by 4 in. (50 mm by 100 mm) V-mesh fabric, with two-strand twisted, [12.5] gauge wires, meeting AASHTO M 279, Class 1 or better.

B. *Lacing and Tie Wire.* Use galvanized, [12.5]-gauge smooth steel wire. In lieu of lacing, use 9-gauge galvanized hog rings at 4-in. (100-mm) spacings.

C. *Steel Stakes.* Provide steel stakes 5 ft (1.5 m) or greater in length of 3-in. (75-mm) outer diameter standard pipe, or 4-in. by 4-in. by $^3/_8$-in. (100-mm by 100-mm by 10-mm) angles.

712.11 GATES

Meet Federal Specification RR-F-191, Fencing, Wire and Post, Metal (and Gates, Chain-Link Fence, and Accessories).

SECTION 713
CONCRETE

713.1 CONCRETE

A. *Concrete Mix Design and Trial Batches for Pavements.* Proportion portland cement concrete using one of the options below. Meet the Agency-approved mix design proportions and restrictions, or submit a mix design proposal for approval.

1. *Mix Based on Minimum Strength.* Use an approved mix design to define the proportions of materials necessary to produce a workable concrete that meets the properties specified in Table 713.1-1.

2. *Contractor-Proposed Mix.* Design using Table 713.1-1, and obtain approval for each mix design used in project production. Submit each job mix formula at least 30 days before concrete production. Include laboratory test data and samples of all materials to be used in the mix, and identify the proposed source or manufacturer of the materials.

Table 713.1-1. Properties of Mixes

Property	Value	AASHTO Test Method
Compressive strength (min)	3,500 psi (25. MPa)	T 22
Flexural strength (min)	550 psi (3.8 MPa)	T 97
Flexural strength (min)	650 psi (4.5 MPa)	T 177
Slump	$^3/_8$ to 3 in. (10 to 75 mm)	T 119M/T 119
Slump Flow (SCC)	22 to 26 in. (550 to 650 mm)	T 347
Surface Resistivity	Agency Specified	T 358
Cement content		
without air (min)	564 lb/yd^3 (335 kg/m^3)	
with air (min)	598 lb/yd^3 (355 kg/m^3)	
Fly ash		
Class C	30% maximum cement replacement	
Class F	25% maximum cement replacement	
GGBFS	50% maximum cement replacement	
Water/cement (w/c) ratio	(includes all cementitious material)	
without air (max)	0.53	
with air (max)	0.49	
w/c ratio for SCC	0.32 to 0.45	
Entrained air	5% to 8%	T 152, T 196M/T 196

Conduct trial batch testing of the proposed mix, and submit test results showing compliance with specified minimum strength, durability, air content, aggregate gradation, and workability requirements. Use laboratory tests to determine the cement content required with individual aggregate combinations. Establish exact proportions by testing trial mixes, and adjust to produce concrete that meets plasticity and workability requirements. Show aggregate proportions in terms of saturated surface dry condition. Adjust batch weights periodically during production to account for aggregate moisture content.

Mold and cure test specimens using AASHTO T 23. Specify the cement content in lb/yd^3 (kg/m^3), the maximum water/cement (w/c) ratio, the design w/c ratio, and the mix consistency.

3. *Mix Based on Predetermined Cement Content.* Ensure each yd^3 (m^3) of concrete used on the project contains the mix design amount of cement, ±2 percent. Use values from Table 713.1-1 for w/c ratios, slump, and air content.

   Submit samples of the concrete mix components for testing and approval at least 30 days before production and identify sources of all components. Use trial batch mixes to determine proportions, including admixtures, and ensure that they produce concrete meeting the specified plasticity and workability requirements.

4. *Mix Design Changes.* Provide a new mix design, based on trial mixes, for approval when there is any change in the source or character of materials used during production of concrete for the project. Provide the approved mix design proportions prior to concrete production and adjust as necessary under the following conditions:

   a. If the cement content of the concrete varies by more than 2 percent from the designated value, adjust proportions to maintain a cement content within the tolerance designated in Subsection 713.1(A)(3).

   b. If the concrete does not meet design consistency, change the approved mix design without adjusting the designated cement content, except as provided in Subsections 713.1(A)(4)(c) and 713.1(A)(4)(d) below.

   c. If concrete with the required consistency cannot be produced within the allowable w/c material ratio, increase the cement content but not the maximum w/c material ratio.

   d. For air-entrained concrete, change proportions or mixing procedures as necessary to maintain air content within specific limits.

B. *Concrete Mix Design for Structures.* Furnish a mix design for each class of concrete to be used. For normal weight concrete, use the absolute volume method per ACI Publication 211.1. For lightweight concrete, select mix proportions based on trial mixes with the cement factor rather than water/cement ratio being determined by the specified strength per ACI Publication 211.2.

   Base the mix design on an average concrete strength so that no more than 10 percent of strength tests will be expected to fall below the specified strength. Modify mix design through the course of work as necessary to comply with strength and consistency requirements.

   Verify mix design by laboratory trial batches. Ensure that the strength of at least 5 test cylinders from the trial batch meets or exceeds 815 psi (5.6 MPa) above the specified strength.

   Proportion concrete according to the classes in Table 713.1-2.

   (The classes and values defined in Table 713.1-2 are representative only. The Agency will modify values based on experience and desired properties of the concrete.)

Table 713.1-2a. Concrete Classes for Structures (U.S. Customary Units)

Class of Concrete	Minimum cement content (lb/yd^3)	Maximum w/c ratio (lb/lb)	Air content range (percent)	Size of coarse aggregate per AASHTO M 43 Size Number	Specified 28-day compressive strength (psi)
A	611	0.49[a]	—	No. 57	4,000
A(AE)	611	0.45	$6 \pm 1^1/_2$	No. 57	4,000
B	517	0.58	—	No. 3 and No. 57[b]	2,400
B(AE)	517	0.55	6 ± 1	No. 3 and No. 57[b]	2,400
C	659	0.49	—	No. 7	4,000
C(AE)	659	0.45	$6 \pm 1^1/_2$	No. 7	4,000
D	472[c]	0.64	—	No. 67 and No. 4	—
P	564	0.49[a]	[d]	No. 57 or No. 67	[d]
S	659	0.58	—	No. 57	—

[a] Use w/c ratio of 0.45 for concrete exposed to saltwater or deicing chemicals.

[b] Furnish coarse aggregate for Class B and Class B(AE) in two separate sizes as shown.

[c] Up to 25 percent of cement may be replaced with fly ash.

[d] Specified elsewhere.

Table 713.1-2b. Concrete Classes for Structures (SI Units)

Class of Concrete	Minimum cement content (kg/m^3)	Maximum w/c ratio (kg/kg)	Air content range (percent)	Size of coarse aggregate per AASHTO M 43 Size Number	Specified 28-day compressive strength (MPa)
A	363	0.49a	—	No. 57	27.6
A(AE)	363	0.45	$6 \pm 1^1/_2$	No. 57	27.6
B	307	0.58	—	No. 3 and No. 57[b]	16.6
B(AE)	307	0.55	6 ± 1	No. 3 and No. 57[b]	16.6
C	391	0.49	—	No. 7	27.6
C(AE)	391	0.45	$6 \pm 1^1/_2$	No. 7	27.6
D	280[c]	0.64	—	No. 67 and No. 4	—
P	335	0.49[a]		No. 57 or No. 67	[d]
S	391	0.58	—	No. 57	—

[a] Use w/c ratio of 0.45 for concrete exposed to saltwater or deicing chemicals.

[b] Furnish coarse aggregate for Class B and Class B(AE) in two separate sizes as shown.

[c] Up to 25 percent of cement may be replaced with fly ash.

[d] Specified elsewhere.

When the concrete will be exposed to deicing salts, limit fly ash content to 25 percent by mass of the total cementitious material.

Limit natural pozzolans in blended cements to 25 percent of the total cementitious material when the concrete is exposed to deicing chemicals (per ACI 318) and its loss on ignition to 5 percent. When steel is embedded in the concrete, use mix water with chloride ion concentration less than 1,000 ppm or sulfate as SO_4 in excess of 1,300 ppm.

Limit total of fly ash or other pozzolans and silica fume to 35 percent by mass of the total cementitious material.

Use only Type A (water reducing), Type B (retarding), Type D (water reducing and retarding), Type F (water reducing, high range), or Type G (water reducing, high range, and retarding) admixtures. Limit chloride ion content in admixtures to less than 1 percent in reinforced concrete, and less than 0.1 percent in prestressed concrete by weight (mass) of admixture.

Use a grout or mortar of cement, fine aggregate, and water to fill voids less than $^3/_4$ in. (20 mm), and modify sand gradation so that all material passes the No. 8 (2.36 mm) sieve.

Use either a nonshrink admixture or an expansive hydraulic cement conforming to ASTM C845/C845M for nonshrink mortar and grout.

In the calculations, include mixing water, water in admixtures, and water in aggregate in excess of saturated surface dry condition. Proportion water additionally to obtain the consistencies specified in Table 713.1-3.

Table 713.1-3a. Concrete Consistencies (U.S. Customary Units)

Type of Work	Nominal Slump (in.)	Maximum Slump (in.)
Formed Elements:		
Sections > 12 in.	1 to 3	5
Sections ≤ 12 in.	1 to 4	5
Cast-in-place piles and drilled shafts not vibrated	5 to 8	9
Concrete placed under water	5 to 8	9
Filling for riprap	3 to 7	8

Table 713.1-3b. Concrete Consistencies (SI Units)

Type of Work	Nominal Slump (mm)	Maximum Slump (mm)
Formed Elements:		
Sections > 300 mm	25 to 75	125
Sections ≤ 300 mm	25 to 100	125
Cast-in-place piles and drilled shafts not vibrated	125 to 200	225
Concrete placed under water	125 to 200	225
Filling for riprap	75 to 175	200

Measure slump before adding high-range water reducers. When using high-range water reducers, limit cement content to a maximum of 800 lb/yd^3 (475 kg/m^3).

C. *Concrete Mix Design for Patches*. Provide one of the following concrete designs for partial-depth and full-depth patches, as specified in the contract.

1. *Accelerated Strength Portland Cement Concrete Patch Mixtures*. Use Type I or Type III portland cement to provide concrete with a minimum strength of 3,000 psi (20.7 MPa) in 24 h.

   Ensure plastic concrete has an air content of [$6^1/_2$ percent ± $^1/_2$ percent]. The slump must be 1 to 3 in. (25 to 75 mm) at the time of concrete placement unless a nonretarding, high-range, water-reducing system is used.

2. *Normal Set Portland Cement Concrete Patch Mixture*. Meet applicable requirements of Subsection 713.1(A).

3. *Rapid Setting Patching Materials*. Rapid setting patching materials must reach a minimum compressive strength of 3,000 psi (20.7 MPa) in 24 h.

4. *Epoxy Resin Patching Mortars*. Use only Agency-approved materials. Prepare epoxy resin patching mortars according to the manufacturer's recommendations.

713.2 CURING MATERIALS

A. *Burlap Cloth made from Jute or Kenaf*. Meet AASHTO M 182.

B. *Sheet Materials for Curing Concrete*. Meet ASTM C171.

C. *Liquid Membrane-Forming Compounds for Curing Concrete*. Meet ASTM C309.

713.3 ADMIXTURES

A. *Air-Entraining Admixtures*. Meet AASHTO M 154M/M 154.

B. *Chemical Admixtures.* Meet AASHTO M 194 M/M 194 for water-reducing, set-retarding, and set-accelerating admixtures.

C. *Mineral Admixtures:*

1. *Fly Ash and Raw or Calcined Natural Pozzolans.* Meet AASHTO M 295.
2. *Ground Granulated Blast Furnace Slag.* Meet AASHTO M 302.
3. *Silica Fume.* Meet AASHTO M 307.
4. *High-Reactivity Pozzolans.* Meet AASHTO M 321.

713.4 SELF-CONSOLIDATING CONCRETE (SCC)

Self-Consolidating Concrete (SCC) is highly flowable, nonsegregating concrete that can spread into place, fill formwork, and encapsulate reinforcement without any mechanical consolidation.

A. *Slump Flow of SCC.* Determine slump flow of self-consolidating concrete (SCC), both in the laboratory and in the field, following AASHTO T 347.

B. *Fabrication of SCC Test Specimens.* Fabricate test specimens according to AASHTO T 23.

C. *Segregation of SCC.* Determine static segregation (stability) of SCC following ASTM C1610/C1610M, and resistance to static segregation following ASTM C1712.

D. *Passing Ability of SCC.* Determine the passing ability of SCC by J-ring following AASHTO T 345.

E. *Visual Stability of SCC.* Determine visual stability index of self-consolidating concrete (SCC), both in the laboratory and in the field, following AASHTO T 351.

F. *Filling Capacity of SCC.* Determine filling capacity of self-consolidating concrete (SCC) using the Caisson test, following AASHTO T 349.

G. *Formwork Pressure during Placement of SCC.* Determine the formwork pressure during field placement of SCC, measuring by pressure transducers attached to formwork, following AASHTO T 352.

713.5 MORTAR AND GROUT

A. *Grout for Pavement Jacking, Subsealing, and Stabilization.* Furnish a grout with 7-day compressive strength greater than 600 psi (4.15 MPa) as determined according to AASHTO T 106M/T 106, and an initial set time of less than 2 h, as determined according to AASHTO T 154.

At least 14 days before starting work, submit for approval a list of grout materials and additives to be used.

Include:

1. Mill certifications for the portland cement;

2. Physical and chemical analysis for pozzolans;

3. Grain structure analysis for limestone dust; and

4. Grout testing results by the Agency-approved independent laboratory showing 1-day, 3-day, and 7-day compressive strengths, flow cone times, shrinkage and expansion observed, and time of initial set.

B. *Grout for Bonded Overlays.* Provide a grout for bonding new concrete to existing or previously placed concrete consisting of equal parts by weight of portland cement and concrete sand. Mix cement and sand with enough water to form a slurry that can be applied with a stiff brush or broom to the old concrete in a thin, even coating that does not run or puddle in low spots. Agitate the grout before and during use. Place grout within 90 minutes after mixing. Dispose of grout not placed within the 90-minute limit in an appropriate location. Obtain Agency approval before substituting an equivalent grout of portland cement and water to be applied by pressure spray.

Use the following mix designs for grout:

Table 713.5-1. Grout Mix with Sand

Component	Content
Cement	1,376 lb/yd^3 (816 kg/m^3)
Sand	1,370 lb/yd^3 (813 kg/m^3)
Water	811 lb/yd^3 (481 kg/m^3)

Table 713.5-2. Grout Mix without Sand

Component	Content
Cement	1,725 lb/yd^3 (782 kg/m^3)
Water	853 lb/yd^3 (387 kg/m^3)

Ensure a maximum water–cement ratio of 0.62.

C. *Pneumatically Applied Mortar.* To construct and repair concrete structures and encase steel members, use a mix design that will provide a cement to aggregate ratio, based on dry loose volumes, of not less than 1:3.5. To line ditches and channels and to pave slopes, use a mix design that will provide a cement to aggregate ratio of not less than 1:5.

The Contractor may substitute up to 30 percent coarse aggregate meeting AASHTO M 43 for No. 8 or No. 89 size aggregate for fine aggregate.

Do not use recovered rebound as fine aggregate. The Contractor may use recovered material that is clean and free of foreign material, in quantities of no more than 20 percent of the total fine aggregate.

Adjust the water content to be as low as practical and to ensure that the mix is sufficiently wet to adhere properly. Apply material sufficiently dry so that it will not sag or fall from vertical or inclined surfaces or separate in horizontal work.

D. *Masonry Applications.*

1. *Mortar.* Proportion mortar by volume as follows:

    - 1 part portland cement
    - 0.25 to 0.5 part hydrated lime
    - 2.25 to 3 parts sand

    or

    - 1 part portland cement
    - 1 part masonry cement
    - 2.25 to 3 parts sand

    Mix by hand or machine with enough water to provide a workable mix. Use within 1.5 and before initial set. Ensure a 28-day compressive strength of 1,900 psi (13 MPa).

2. *Grout.* Meet ASTM C476.

SECTION 714
MISCELLANEOUS REQUIREMENTS

714.1 WATER

A. *Mixing and Curing Applications.* Use water meeting the requirements of AASHTO M 157, Section 4.1.4 for mixing and curing. Potable-quality water requires no testing.

B. *Landscaping Applications.* Use irrigation-quality water free of elements harmful to plant growth for irrigating trees, plants, and seeded areas.

714.2 CALCIUM CHLORIDE

Meet AASHTO M 144.

714.3 LIME

A. *Hydrated Lime for Soil Stabilization.* Meet AASHTO M 216.

B. *Quicklime for Soil Stabilization*. Meet AASHTO M 216.

C. *Lime for Asphalt Mixtures*. Meet AASHTO M 303.

D. *Lime for Masonry Purposes*. Meet ASTM C207.

E. *Lime for Structural Purposes*. Meet ASTM C5.

714.4 STONE CURBING

A. *Stone Curb*. Provide stone from approved sources, using only one type of stone in each application.

Ensure no drill holes mar exposed faces. Cut joints of circular or curved stone curb on radial lines. Furnish stone segments at least [4 ft (1200 mm)] in length.

Ensure finished surfaces meet the following:

1. *Top*. Provide a true plane with surface variations less than [$^{1}/_{4}$ in. (6 mm)]. Pitch front and back arris lines straight and true.

2. *Front*. Provide a true plane with variations less than [1 in. (25 mm)].

3. *Butted Ends (top and front face)*. Finish ends square with the planes of the top, back, and face. Provide a true plane with a maximum gap of [$^{1}/_{4}$ in. (13 mm)]. Ensure the remainder of the end breaks back no more than [4 in. (100 mm)] from the plane of the joint.

4. *Back*. Limit surface batter to 3:1.

B. *Slope Stone Curb*. Provide stone segments at least [2 ft (600 mm)] in length and meeting the requirements for stone curb specified in Subsection 714.4(A), except as follows:

1. *Exposed Surfaces*. Top surface maximum variation of [$^{1}/_{2}$ in. (13 mm)]; [1 in. (25 mm)] on other exposed faces.

2. *Unexposed Surfaces*. Unexposed surfaces maximum variation of [3 in. (75 mm)] from a true plane within a length of [2 ft (600 mm)].

3. *Butted Ends*. Maximum gap of [$^{3}/_{4}$ in. (20 mm)] on exposed faces between adjacent segments of curb.

714.5 PRECAST CONCRETE CURBING

Construct curbing of precast concrete units as specified. Use reinforcing steel meeting Subsection 711.1.

714.6 PRECAST CONCRETE UNITS

Cast units in steel forms. Use structural concrete that attains a 28-day compressive strength of 3,000 psi (20.7 MPa), as determined according to AASHTO T 22. Ensure air-entrained concrete has an air content of [6] percent ± [$1^1/_2$] percent. Cure precast units according to AASHTO M 170 (AASHTO M 170M). Ensure water absorption of individual cores does not exceed 8 percent, as determined according to ASTM C642. Provide additional reinforcing steel, as necessary, to handle precast units.

Cast cylinders from each concrete batch or truck mixer load of concrete to provide at least two cylinders each for compression tests at 7, 14, and 28 days. If the specified strength requirements are met at 7 or 14 days, certify units for use 14 days from the casting date.

Reject units with cracked, honeycombed, or patched areas more than [30 in.^{2} (20,000 mm^2].

Provide precast reinforced concrete manhole riser sections and appurtenances meeting AASHTO M 199M/M 199.

714.7 FRAMES, GRATES AND COVERS, LADDER RUNGS

A. *Drainage, Sewer, Utility, and Related Castings.* Meet AASHTO M 306.

1. *Gray Iron Castings.* Meet Subsection 710.5(B)(1); strength class optional.
2. *Ductile Iron Castings.* Meet Subsection 710.5(B)(2).
3. *Aluminum-Alloy Sand Castings.* Meet Subsection 716.5(B).

B. *Carbon Steel Castings.* Meet Subsection 710.5(A)(1); strength class optional.

C. *Structural Steel.* Meet ASTM A 283/A 283M, Grade D or better.

D. *Galvanizing.* Meet AASHTO M 111M/M 111M.

E. *Malleable Iron Castings.* Meet Subsection 710.5(B)(3), Grade optional.

SECTION 715
ROADSIDE IMPROVEMENT MATERIALS

715.1 TOPSOIL

Provide topsoil containing loose, friable material free of subsoil admixtures, refuse, stumps, rocks, roots, brush, weeds, or other material that impedes plant growth. Ensure minimum and maximum pH values of _____ (by Agency). Ensure organic content of topsoil ranges between _____ and _____ percent as determined by test method _____ (by Agency; test topsoil according to the standards of the Association of Official Agricultural Chemists).

Provide topsoil meeting the following gradation analysis:

Table 715.1-1. Topsoil Gradation Requirements

Sieve Size	Percent Passing
1 in. (25 mm)	100
1/4 in. (6.3 mm)	97–100
No. 10 (2 mm)	80–100

Table 715.1-2. Topsoil Particle Size Distribution

Particle Size	Minimum (percent)	Maximum (percent)
Sand: No. 200 to No. 10 (75-µm to 2-mm) sieve	20	75
Silt: 0.2 mm to No. 200 (75-µm) sieve	10	60
Clay: 0.2 mm or less	5	30

Remove stones and other objects 2 in. (50 mm) in diameter and larger.

715.2 AGRICULTURAL LIMESTONE

Provide a calcic or dolomitic ground limestone containing at least _____ percent (by Agency) of total (calcium and magnesium) carbonates. Meet standards of the Association of Official Agricultural Chemists.

Ensure a minimum 40 percent passing a No. 100 (150-µm) sieve and a minimum 95 percent passing a No. 8 (2.36-mm) sieve.

Note to Agency: Use other agricultural liming materials as specified; i.e., agricultural hydrated, agricultural pulverized, agricultural superfine, agricultural granulated slag. Indicate acceptable materials, sieve analysis, and application rates.

715.3 FERTILIZER

Provide a commercial-grade fertilizer meeting the standards of the Association of Official Agricultural Chemists and the specified nutrient content. Furnish an affidavit certifying the nutrient content.

715.4 FIBER ROLLS AND SOCKS

A. *Excelsior fiber rolls.* Furnish fiber rolls of curled excelsior fiber rolled into a cylindrical shape and encased in a tubular netting.

B. *Straw fiber rolls.* Furnish straw fiber rolls that are manufactured from certified weed free straw and wrapped in a tubular mesh.

C. *Coir rolls.* Furnish coir fiber rolls that are 100 percent coconut fiber.

D. *Compost socks*. Furnish tubular mesh filled with mature compost according to Subsection 715.4(E).

E. *Tubular mesh for fiber rolls*. Provide tubular mesh with openings no larger than $^3/_8$ in. (10 mm). Mesh material is not required to be biodegradable, but must be removed at the end of the project if it is not biodegradable. Provide tubular mesh of the diameter stated in the plans. Fill according to manufacturer's recommendations.

F. *Other fiber material*. Use of recycled material that meet the requirements of the application may be considered. Submit to the Contracting Officer (CO) for approval.

715.5 FLOATING TURBIDITY CURTAINS

Furnish curtains made of tightly woven nylon, plastic, or other non-deteriorating material conforming to Table 713.1-3 and the following:

Fabric overlap when more than one width of fabric is required	6 in. (150 mm)
Supporting flotation buoyancy	29 lb/ft (1.4 kPa) min.
Ballast chain (galvanized)	$^5/_{16}$ in. (8 mm)
Dual galvanized wire rope load lines with a heavy vinyl coating	$^5/_{16}$ in. (8 mm) diameter

715.6 GRAVEL BAGS.

Furnish woven fabric bags with a minimum water flow rating of 145 gallons per minute per foot (1.8 cubic meters per minute per meter) as tested by ASTM D4491/D4491M. Fill the bags with clean coarse aggregate.

715.7 PREFABRICATED FILTER INSERT

Size inlet filter inserts to fit the catch basin or drop inlet and provide a high-flow bypass. Follow manufacturer's recommendations.

715.8 SEED

Meet the following seed formula(s):

(Agency to provide the types of seed or seed mixtures, including percentage of purity, germination, and weed seed content.)

Deliver in labeled and sealed containers to the job. Seed and labels are subject to the Association of Official Seed Analysts testing provisions.

Inoculate legume seed with approved cultures according to the manufacturer's instructions.

715.9 SEDIMENT FILTER BAGS

Furnish rot- and mildew-resistant bags composed of a non-woven geotextile fabric conforming to Table 715.9-1 and the following:

A. Minimum footprint 150 ft^2 (14 m^2),

B. Sewn-in sleeve to fit minimum 4-in. (100-mm) pump discharge hose, and

C. Secure discharge hose with a hose clamp.

Table 715.9-1. Topsoil Gradation Requirements

Property	Test Method (ASTM)	Units	Specifications
Mass	D3776/D3776M	oz/yd (g/m)	10.0 (310)
Minimum grab tensile strength	D4632/D4632M	lb (N)	250 (1100)
Tensile elongation at break	D4632/D4632M	%	50
Minimum puncture strength	D4833/D4833M	lb (N)	115 (510)
Minimum trapezoid tear strength	D4533/D4533M	lb (N)	100 (445)
Minimum sewn seam strength	D4632/D4632M	lb (N)	200 (900)
Mullen burst	D3786/D3786M	lb/in.^{2} (kPa)	350 (2400)
Ultraviolet resistance	D4355/D4355M	%	70
Permittivity	D4491/D4491M	sec–1	1.2
Water flow rate	D4491/D4491M	gal/minute/ft (m^3/minute/m)	145 (1.8)

715.10 TACKIFIERS

Furnish a commercially available product containing no solvents or other diluting agents toxic to plant life that is without growth- or germination-inhibiting factors, nonflammable, nontoxic to aquatic organisms, and functional for at least 180 days.

A. *General purpose tackifier.* Furnish one of the following:

1. *Plant based tackifier.* Furnish a natural high molecular weight polysaccharide, a high-viscosity hydrocolloid that is miscible in water, and labeled as one of the following:

   a. *Guar gum.* A product derived from the ground endosperm of the guar plant, Cyamopsis tetragonolobus, treated with dispersing agents for easy mixing and dilutable at the rate of 1 to 5 lb per 100 gal (1.2 to 6 kg per 1000 L) of water.

   b. *Psyllium.* A product manufactured from the finely ground mucilloid coating of Plantago ovata or Plantago ispaghula seeds; able to dry and form a firm, but rewettable membrane.

   c. *Starch.* A product manufactured from a nonionic, water-soluble, granular material derived from corn, potato, or other plant-based source.

2. *Polymeric emulsion blend tackifier.* Furnish a prepackaged liquid or dry powder, anionic formulation with a residual monomer content not exceeding 0.5 percent by mass and labeled with one of the following as the primary active ingredient:

   a. Acrylic copolymers and polymers;

   b. Polymers of methacrylates and acrylates;

   c. Copolymers of sodium acrylates and acrylamides;

   d. Polyacrylamide and copolymer of acrylamide; or

   e. Hydrocolloid polymers.

B. *Polymer stabilized fiber matrix tackifier.* Furnish the following:

1. A liquid formulation with polyacrylamide as the primary active ingredient with the following requirements:

   a. Linear, anionic copolymer of acrylamide and sodium acrylate; and

   b. Anionic with a residual monomer content that is at most 0.5 percent by mass.

2. Formulated and labeled as one of the following:

   a. *Water-in-oil emulsion.* A product containing at least 2.6 lb/gal (3.1 kg/10 L) pure polyacrylamide that is at least 30 percent active; or

   b. *Liquid dispersed polyacrylamide.* A product containing at least 4.4 lb/gal (5.3 kg/10 L) pure polyacrylamide that is at least 35 percent active.

715.11 TEMPORARY ROLLED EROSION-CONTROL PRODUCTS

Furnish temporary rolled erosion-control products conforming to Table 715.11-1 and the following (see the Erosion Control Technology Council website (ECTC.org) for commercially available products that may conform to these specifications):

A. *Type 1.A, ultra-short-term mulch-control netting.* Furnish a mulch control netting consisting of rapidly degrading photodegradable synthetic mesh or woven biodegradable natural fiber netting.

B. *Type 1.B, ultra-short-term net-less erosion-control blanket.* Furnish an erosion control blanket composed of processed rapidly degrading natural or polymer fibers mechanically interlocked or chemically adhered together to form a continuous matrix.

C. *Type 1.C, ultra-short-term single-net erosion-control blanket and open-weave textile*. Furnish one of the following materials:

1. An erosion-control blanket composed of processed degradable natural or polymer fibers mechanically-bound together by a single rapidly degrading, synthetic or natural-fiber netting to form a continuous matrix; or

2. An open-weave textile composed of processed rapidly degrading natural or polymer yarns or twines woven into a continuous matrix.

D. *Type 1.D, ultra-short-term double-net erosion-control blankets*. Furnish an erosion-control blanket composed of processed natural or polymer fibers mechanically-bound between two rapidly degrading, synthetic, or natural-fiber nettings to form a continuous matrix.

E. *Type 2.A, short-term mulch-control netting*. Furnish a mulch-control netting consisting of photodegradable synthetic mesh or woven biodegradable natural fiber.

F. *Type 2.B, short-term net-less erosion-control blanket*. Furnish an erosion-control blanket composed of processed degradable natural or polymer fibers mechanically-interlocked or chemically-adhered together to form a continuous matrix.

G. *Type 2.C, short-term single-net erosion-control blanket or open-weave textile*. Furnish one of the following materials:

1. An erosion-control blanket composed of processed degradable natural or polymer fibers mechanically-bound together by a single degradable synthetic or natural-fiber netting to form a continuous matrix; or

2. An open-weave textile composed of processed degradable natural or polymer yarns or twines woven into a continuous matrix.

H. *Type 2.D, short-term double-net erosion-control blankets*. Furnish an erosion control blanket composed of processed natural or polymer fibers mechanically bound between two natural-fiber or synthetic nettings to form a continuous matrix.

I. *Type 3.A, extended term mulch control netting*. Furnish a mulch-control netting consisting of a slow-degrading synthetic mesh or woven natural fiber.

J. *Type 3.B, extended term erosion control blanket or open weave textile*. Furnish one of the following materials:

1. An erosion-control blanket composed of processed slow-degrading natural or polymer fibers mechanically-bound together between two slow-degrading synthetic or natural-fiber nettings to form a continuous matrix; or

2. An open-weave textile composed of processed slow-degrading natural or polymer yarns or twines woven into a continuous matrix.

K. *Type 4, long-term erosion control blanket or open weave textile*. Furnish one of the following materials:

1. An erosion-control blanket composed of processed slow-degrading natural or polymer fibers mechanically-bound together between two slow-degrading synthetic or natural-fiber nettings to form a continuous matrix; or

2. An open-weave textile composed of processed slow-degrading natural or polymer yarns or twines woven into a continuous matrix.

Table 715.11-1. Temporary Rolled Erosion-Control Products

Property	Test Method	Rolled Erosion-Control Product Type										
		1.A[(a)]	1.B	1.C	1.D	2.A[(a)]	2.B	2.C	2.D	3.A[(1)]	3.B	4
Typical functional longevity[(b)] (months)	N/A	3	3	3	3	12	12	12	12	24	24	36
Minimum tensile strength	ASTM D6818	5 lb/ft (0.73 kN/m)	5 lb/ft (0.73 kN/m)	50 lb/ft (0.73 kN/m)	75 lb/ft (0.73 kN/m)	5 lb/ft (0.73 kN/m)	5 lb/ft (0.73 kN/m)	50 lb/ft (0.73 kN/m)	75 lb/ft (1.9 kN/m)	25 lb/ft (0.36 kN/m)	100 lb/ft (1.45 kN/m)	125 lb/ft (1.82 kN/m)
Maximum "C" factor at maximum gradient for slope applications[(c)]	ASTM D6459 or other qualified independent test[(f)]	0.10 at 1V:5H	0.10 at 1V:4H	0.15 at 1V:3H	0.20 at 1V:2H	0.10 at 1V:5H	0.10 at 1V:4H	0.15 at 1V:3H	0.20 at 1V:2H	0.10 at 1V:5H	0.25 at 1V:1½H	0.25 at 1V:1H
Minimum shear stress for channel applications[(d)(e)]	ASTM D7207 or other qualified independent test[(f)]	0.25 lb/ft² (12 Pa)	0.50 lb/ft² (24 Pa)	1.50 lb/ft² (72 Pa)	1.75 lb/ft² (84 Pa)	0.25 lb/ft² (12 Pa)	0.50 lb/ft² (24 Pa)	1.50 lb/ft² (72 Pa)	1.75 lb/ft² (84 Pa)	0.25 lb/ft² (12 Pa)	2.00 lb/ft² (96 Pa)	2.25 lb/ft² (108 Pa)

(a) Obtain max "C" factor and allowable shear stress for mulch-control nettings with the netting used in conjunction with pre-applied mulch material.

(b) Functional longevities are for guidance only. Actual functional longevities may vary based on site and climatic conditions.

(c) "C" factor calculated as ratio of soil loss from rolled erosion-control product protected slope (tested at specified or greater gradient, v:h) to ratio of soil loss from unprotected (control) plot in large-scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions and failure criteria using Erosion Control Technology Council (ECTC), Test Method No. 2.

(d) Minimum shear stress the rolled erosion-control product (un-vegetated) can sustain without physical damage or excess erosion (> ½-in. (> 12.7-millimeter) soil loss) during a 30-minute flow event in large-scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions and failure criteria using ECTC, Test Method No. 3.

(e) The permissible shear stress levels established for each performance category are based on historical experience with products characterized by Manning's roughness coefficients in the range of 0.1 to 0.5.

(f) Other large-scale test methods determined acceptable by the CO.

715.12 TURF REINFORCEMENT MATS

Furnish a rolled erosion control product composed of non-degradable synthetic fibers, filament, nets, wire mesh, and other elements processed into a permanent, three-dimensional matrix conforming to Table 715.12-1. See the Erosion Control Technology Council website (ECTC.org) for commercially available products that may conform to these specifications.

Table 715.12-1. Turf Reinforcement Mats

Properties[(a)]	Test Method	Rolled Erosion-Control Product Type		
		5.A	5.B	5.C
Minimum tensile strength[(b)(c)]	ASTM D4595	125 lb/ft (1.82 kN/m)	150 lb/ft (2.19 kN/m)	175 lb/ft (2.55 kN/m)
UV stability (minimum % tensile retention)	ASTM D4355/ D4355M (500-hour exposure)	80	80	80
Minimum thickness[(b)]	ASTM D6525/ D6525M	1/4 in. (6.35 mm)	1/4 in. (6.35 mm)	1/4 in. (6.35 mm)
Maximum gradient for slope applications	—	2V:1H	2V:1H	2V:1H
Minimum shear stress for channel applications[(d)]	ASTM D6460 or other qualified independent test[(e)]	6.0 lb/ft^2 (288 Pa)	8.0 lb/ft^2 (384 Pa)	10.0 lb/ft^2 (480 Pa)

(a) For turf reinforcement mats containing degradable components, obtain property values on the non-degradable portion of the matting alone.

(b) Minimum average roll values, machine direction only.

(c) Field conditions with high-loading and high-survivability requirements may warrant the use of turf reinforcement mats with tensile strengths of 3,000 pounds per foot (44 kN/m) or greater.

(d) Minimum shear stress the turf reinforcement mat (fully vegetated) can sustain without physical damage or excess erosion (>½-in. (>12.7-mm) soil loss) during a 30-minute flow event in large-scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions and failure criteria using Erosion Control Technology Council, Test Method No. 3.

(e) Other large-scale test methods determined acceptable by the CO.

715.13 MULCH

A. *Straw.* Furnish certified weed-free straw from oats, wheat, rye, rice, or other grain crops that is without mold or other objectionable material. Furnish straw in an air-dry condition suitable for placing with mulch blower equipment.

B. *Wood fiber.* Furnish processed wood fiber from wood chips conforming to the following:

1. Colored with a green dye noninjurious to plant growth;
2. Readily dispersible in water;
3. Nontoxic to seed or other plant material;
4. Free of growth- or germination-inhibiting substances;
5. Free of weed seed;
6. Air dried to a moisture content of 12 ± 3 percent;
7. Packaged in new labeled containers with the manufacturer's name; and
8. Packaged in a condition appropriate for mixing in a homogeneous slurry suitable for application with power spray equipment.

C. *Grass straw cellulose fiber.* Furnish processed grass straw fiber conforming to the following:

1. Colored with a green dye noninjurious to plant growth;
2. Readily dispersible in water;
3. Nontoxic to seed or other plant material;
4. Free of growth- or germination-inhibiting substances;
5. Free of weed seed;
6. Air dried to a moisture content of 10 ± 0.2 percent;
7. Air dried to a uniform mass of ±5 percent;
8. Packaged in new containers labeled with the manufacturer's name and air-dry mass; and
9. Packaged in a condition appropriate for mixing in a homogeneous slurry suitable for application with power spray equipment.

D. *Peat moss.* Furnish a granulated sphagnum peat moss conforming to the following:

Sticks, stones, and mineral matter	0 percent
Partially decomposed stems and leaves of sphagnum	75 percent min.
Color	Brown
Textured from porous fibrous to spongy fibrous	
pH	3.5 to 7.5
Air-dried	

E. *Mature compost.* Furnish partially decomposed organic material, (such as leaves, grass, shrubs, and yard trimmings) cured for 4 to 8 weeks. Maturity is indicated by temperature stability and soil-like odor. Furnish friable, dark brown, weed-free, and pathogen-free mature compost conforming to the following:

Carbon/nitrogen ratio	25/1 to 35/1
Carbon/phosphorus ratio	120/1 to 240/1
pH	6.0 to 7.8
Water content	40 percent max.
Particle size	
(a) Seeding and sodding	½ in. (12 mm) max.
(b) Erosion control	1 in. (25 mm) max.
Organic material	50 percent min.
Synthetic, plastic, metal, or glass material	2 percent max.

F. *Straw for hydroseeding.* Furnish clean agricultural straw milled to 1 in. (25 mm) or less in length. Dry the fibers to 10 percent moisture for compaction. Bale in heat-sealed plastic bags.

G. *Bonded fiber matrix hydromulch.* Furnish a mixture of fibers and bonding agent which, when hydraulically applied and dried, produce a matrix conforming to the following:

1. Does not dissolve or disperse when wetted;
2. Holds at least 10 oz (1000 g) of water per ounce (100 grams) of dry matrix;
3. Has no germination or growth inhibiting factors;
4. Forms no water insensitive crust;
5. Contains material that is 100 percent biodegradable; and
6. Is colored with a green dye noninjurious to plant growth.

H. *Recycled pulp fiber.* Furnish cellulose fiber mulch products manufactured from natural material diverted from the waste-stream of manufacturing processes or produced from recycled material. These include newsprint, chipboard, corrugated cardboard, wood chips, and similar material. Process the material to eliminate substances that inhibit seed germination and plant growth. Add a colored dye that is non-injurious to plant growth and fades rapidly with exposure to light. Supply fiber that readily blends with water, grass seed, fertilizer, and other additives to for a slurry suitable for application with power spray equipment. Furnish a homogeneous mixture conforming to the following:

Synthetic, plastic, metal, or glass material	0 percent
Weed seed	0 percent
Moisture content	15 percent max.

Ash content	7 percent max.
Organic matter	90 percent min.
Boron	250 ppm max.
Water-holding capacity	800 to 1200 percent by mass
pH	4.0 to 8.5

I. *Wood chips.* Provide wood chips from local sources including clearing. Maximum size of chips is 4 by 2 by $^1/_2$ in. (100 by 50 by 13 mm).

715.14 PLANT MATERIALS

A. *Quality of Plant Materials.* Meet the current edition of American Standard for Nursery Stock (ASNS), ANSI, Z60.1 of the American Nursery and Landscape Association (ANLA) and as follows:

1. Use healthy, nursery-grown stock that has been transplanted or root-trimmed two or more times.

2. Ensure branch systems show normal development with no disfiguring knots, broken terminal growth, or other blemishes.

3. Provide trees with reasonably straight stems and branches that reflect natural growth patterns.

4. Provide plant materials meeting state and Federal laws controlling inspection for plant diseases and insect infestations.

B. *Plant Names.* Use plants with scientific and common plant names conforming to Hortus Third, by the staff of the L. H. Bailey Hortorium, Cornell University.

Deliver named and tagged plants of the size specified. Obtain approval to substitute species.

C. *Grading Standards.* Grade plants according to the ASNS, current edition.

D. *Nursery Inspection and Plant Quarantine.* Supply healthy plants free from disease and insect pests. Ship plants according to nursery inspection and plant quarantine regulations of the states of origin and destination. Ensure the certificate of inspection accompanies each package, box, bale, or carload shipped or otherwise delivered.

E. *Balled and Burlapped Plants.* Dig balled and burlapped plants carefully to conserve as many fibrous roots as possible. Ensure that soil forms a firm ball and is the original, undisturbed soil in which the plant was grown. Ensure ball size conforms to ASNS.

F. *Delivery and Inspection.* Make plants and related certifications available for inspection in the nursery or collecting source [14] days prior to delivery.

Do not consider approval to move nursery material as final acceptance.

G. *Protection and Temporary Storage.* Keep plants moist and protected when in transit, in temporary storage, and on the project site.

Protect plants delivered, but not scheduled for immediate planting, as follows:

1. For bare root materials, open the bundles, separate plants, and lean in trenches.
2. For balled and burlapped material, cover with sawdust, woodchips, or other suitable material to keep moist.

715.15 EROSION AND SEDIMENT CONTROL MATERIALS

Furnish material in lengths of a minimum _____ ft (m) (by Agency).

A. *Burlap.* Use standard weave burlap with a mass of [3.5 to 5.0 oz/yd^2 (120 to 170 g/m^2)].

B. *Jute Mesh.* Use jute mesh of a uniform, plain weave with warp and weft yarns of approximately the same size. The physical requirements are:

1. Width: 46 to 48 in. ± 1 in. (1,150 to 1,200 mm ± 25 mm), 78 warp ends per 48-in. (1,200 mm) of width, 45 weft ends per yd (m) of length.
2. Range of cloth weight: 1.22 to 1.80 lb/yd (0.6 to 0.9 kg/m) with a 5 percent minimum tolerance at standard atmospheric conditions.

C. *Woven Paper or Sisal Mesh Netting.* Weave paper or sisal mesh netting from twisted yarns available in rolls 46 to 48 in. (1,150 to 1,220 mm) wide. Mesh may vary from closed to open weave and range from $^1/_8$-in. to $^1/_4$-in. (3 mm to 6 mm) openings. Ensure shrinkage after wetting is no more than 20 percent of the surface area.

D. *Synthetic Erosion Control Mats.* Use 10-ft (3-m) wide black polypropylene extruded plastic net with rectangular mesh openings approximately 1 in. by 2 in. (25 mm by 50 mm) or $^3/_4$ in. by $^7/_8$ in. (19 mm by 21 mm). Ensure a material mass of approximately 2.6 lb/1,000 ft^2 (13 g/m^2). Use 10-in. (255-mm) U-pins, 11-gauge wire or heavier, with 2-in. (50-mm) throats to secure the netting.

E. *Wood Fiber Blanket.* Furnish blankets with uniform interlocking wood excelsior fibers with net backing on one side. Ensure fibers are curled, barbed, and evenly distributed to provide consistent thickness. Ensure a weight (mass) of 78 lb/80 yd^2 (530 g/m^2) ± 10 percent, under average atmospheric conditions with a backing mesh size no greater than 1$^1/_2$ in. by 3 in. (38 mm by 75 mm). Weave backing from twisted paper, cotton cord, a biodegradable plastic, or other approved material. Ensure blanket is nontoxic to plants.

Furnish in rolled strips 48 in. ± 1 in. (1,200 mm ± 25 mm) in width.

F. *Fiberglass Roving Material.* Form fiber glass roving material from continuous fibers drawn from molten glass, coated with a chrome-complex sizing compound, collected into strands. Lightly bind together into roving without the use of clay, starch, or other deleterious substances.

Wind the roving into a cylindrical package approximately 1 ft (0.3 m) high so it can be fed continuously from the center of the package through an ejector driven by compressed air and expanded into a mat of glass fibers on the soil surface. Use material without solvents or other agents toxic to plant or animal life.

Meet the requirements specified in Table 715.15-1.

Table 715.15-1. Fiberglass Roving Requirements

Property	Limits
Strand/rove	56 to 64
Fibers/strand	184 to 234
Fibers diameter, in. (mm) (Trade Designation G)	0.35 to 0.4 in. (0.9 to 0.10)
yd/lb (m/kg) of rove	210 to 230 (420 to 460)
Organic content, percent maximum	0.75

G. *Staples.* Anchor erosion mat with U-shaped staples, 11-gauge or larger diameter steel wire. For firm soils, use staples 1 to 2 in. (25 to 50 mm) wide and at least 6 in. (150 mm) long. For loose soils, use staples at least 12 in. (300 mm) long. Use staples at least 8 in. (200 mm) long if placing jute fabric over sod.

715.16 MISCELLANEOUS LANDSCAPE MATERIALS

A. *Bracing and Anchoring Stakes.* Brace or support trees with wooden stakes meeting the American Lumber Standards.

B. *Hose.* Use rubber or fabric garden or stream hose with _____ gauge (Agency to specify) wire to brace and guy trees.

C. *Guy Wire.* Use new, soft annealed galvanized steel, _____ gauge (Agency to specify).

D. *Wrapping Material.* Use crinkled waterproof paper with a mass of at least 0.4 lb/ft^2 (200 g/m^2). Wrap with two sheets of paper cemented together with asphalt. Use masking tape when specified. Use burlap in 6-in. (150-mm) wide rolls, when specified.

E. *Twine:*

1. For trees 3 in. (75 mm) or smaller in diameter, use two-ply twine.
2. For trees greater than 3 in. (75 mm) in diameter, use three-ply twine.

F. *Antidesiccant.* Use a permeable emulsion permitting transpiration, when specified.

SECTION 716
ALUMINUM FOR STRUCTURES

716.1 ALUMINUM MATERIALS

A. *General*. Furnish aluminum as specified in the plans. Ensure that the supplier provides a lot number on the shipping package and a certification.

Fabricate structural aluminum in accordance with the *AASHTO LRFD Bridge Construction Specifications* and the AWS D1.2/D1.2M Structural Welding Code—Aluminum.

B. *Aluminum Plate*. Meet ASTM B209 (B209M).

C. *Aluminum Extrusions*. Meet ASTM B221 (B221M), B308/B308M, or B429/B429M.

716.2 FASTENERS

A. *High-Strength Bolts and Bolting Materials*. Provide high-strength bolts meeting ASTM F3125 (F3125M), Type 1.

Provide nuts meeting ASTM A563 (A563M).

Provide washers of hardened steel meeting ASTM A563 or A563M. Provide results of the following tests:

1. Proof load tests of bolts performed according to ASTM F606/F606M, Method 1.
2. Wedge tension tests of full-size bolts performed according to ASTM F606/F606M.
3. Proof load tests of nuts as required by ASTM A563 or A563M.

B. *Stainless Steel Bolts and Nuts*. Provide bolts meeting ASTM F593, alloy groups 1, 2, or 3, and nuts meeting ASTM F594.

C. *Aluminum Rivets*. Meet ASTM B316/B316M.

D. *Dimensions*. Ensure bolt and nut dimensions meet the Heavy Hexagon Structural Bolts and Heavy Semi Finished Hexagon Nuts (Metric Heavy Hexagon Structural Bolts and Metric Heavy Semi Finished Hexagon Nuts) requirements in ANSI B18.2.1 (B18.2.3.7M) and B18.2.2 (B18.2.4.6M), respectively.

E. *Galvanizing*. Ensure high-strength steel fasteners are either hot dip galvanized according to AASHTO M 232M/M 232, Class C, or mechanically galvanized according to ASTM B695. Use the same process to galvanize washers, nuts, and bolts of any assembly.

F. *Aluminum, Stainless Steel, and Steel Lock-Pin and Collar Fasteners*. Meet Military Specification MIL-P-23469.

716.3 WELDED SHEAR CONNECTORS

Structural Welding Code—Aluminum. Meet ANSI/AASHTO/AWS D1.2

716.4 ALUMINUM FORGINGS

Meet ASTM B247 (B247M).

716.5 CASTINGS

A. *Aluminum Castings*. Meet ASTM B26/B26M.

B. *Aluminum-Alloy Permanent Mold Castings*. Meet ASTM B108/B108M.

SECTION 717
TIMBER

717.1 SAWED TIMBER

Manufacture sawed timber products, meeting AASHTO M 168, of the species specified.

717.2 STRUCTURAL GLUED, LAMINATED TIMBER

Manufacture structural glued laminated timber, of the sizes and shapes indicated on the plans, according to ANSI/AITC A190.1.

As employed in ANSI/AITC A190.1, structural glued laminated timber is an engineered, stress-rated product of a timber-laminating plant. The product consists of suitably selected and prepared wood laminations securely bonded together with wet use adhesives. Ensure that the grain of all laminations is approximately parallel longitudinally and that the maximum net thickness for the separate laminations is 2 in. (50 mm). Laminations may consist of pieces end joined to form any length, pieces placed or glued edge-to-edge to make wider pieces, or pieces bent to a curved form during gluing.

After end trimming each completed member, apply an approved end sealer on glued laminated structural members that will not be treated with preservatives.

717.3 TIMBER TREATMENT

A. *Timber Preservatives*. Treat timber with a preservative suitable to the conditions of exposure, pentachlorophenol with a Type C solvent, or with a waterborne preservative of either Type CCA or ACZA. Use preservatives meeting AASHTO M 133.

Meet the following pressure treatment requirements, as applicable:

1. General. AWPA Standard U1.
2. Guardrail and Fence Posts. AWPA Standard U1.
3. Structural Timbers. AWPA Standard U1.
4. Piles. AWPA Standard U1.

B. *Branding and Job Site Inspection.* Identify each piece of treated timber with a legible brand, mark, or tag to identify the treater and the specification requirements to which the treatment conforms. The Engineer will allow treated wood products bearing the quality mark of the American Wood Preservers Bureau (AWPB). The Engineer may reinspect treated timber at the job site to determine retention of preservatives and may extract and analyze the preservative to determine its quality.

C. *Inspection at Treatment Plant.* Ensure inspections are performed at the plant according to AASHTO M 133. The treater or an independent commercial inspection agency approved by the AWPB and the Engineer may perform these inspections. The Contractor may engage the inspection agency either directly or through the supplier.

D. *Certificate of Compliance.* Ensure that a manufacturer's certificate of compliance and inspection reports accompany each shipment. Identify the preservative used, the specification required, and the test results. Ensure documents are signed by the treater or the qualified independent inspection agency.

717.4 TIMBER CONNECTORS AND HARDWARE

A. *Connectors.* Meet AASHTO LRFD Bridge *Design Specifications*.

B. *Rods, Plates, Eyebars, and Shapes.* Meet AASHTO M 270M/M 270, Grade 36 (250).

C. *Cast Steel or Gray Iron Castings.* Meet Subsection 710.5.

717.5 PAINTING

Paint timber as specified in Section 813.

717.6 CERTIFICATES OF COMPLIANCE

Furnish the following certificates of compliance, as applicable, to the Engineer, upon delivery of the materials to the job site:

A. Certification by an agency certified by the American Lumber Standards Committee that the timber or lumber conforms to the grade, species, and any other specified requirements.

B. Certification by a qualified inspection and testing agency that the glued-laminated timber complies with the grade, species, and other requirements outlined in ANSI/AITC A190.1.

C. If the wood is to be treated with a preservative, certification of compliance, as specified in Subsection 717.3(D).

SECTION 718
GROUND ANCHORS AND RELATED MATERIALS

718.1 ANCHORAGE DEVICES

A. *Stressing Anchorages.* Provide a combination of either a steel bearing plate with wedge plate and wedges, or a steel bearing plate with a threaded anchor nut. The steel bearing and wedge plate may also be combined into a single element. Ensure anchorage devices are capable of developing 95 percent of the specified minimum ultimate tensile strength (SMTS) of the prestressing steel tendon. Ensure anchorage devices meet the static strength requirements of the PTI *Post-Tensioning Manual*.

B. *Bearing Plate.*

1. *Steel.* Meet AASHTO M 270M/M270, Grade 36 (250).

2. *Ductile Iron.* Meet ASTM A536.

C. *Trumpet.* Fabricate trumpets either from a steel pipe or tube. Meet the requirements of ASTM A53/A53M for pipe or ASTM A500/A500M for tubing. The minimum wall thickness of steel trumpets is $^{1}/_{8}$ in. (3 mm) for diameters up to 4 in. (100 mm) and $^{3}/_{16}$ in. (5 mm) for larger diameters.

D. *Anchorage Covers.* Provide anchorage covers fabricated from steel or plastic with a minimum thickness of $^{1}/_{8}$ in. (3 mm). Ensure the joint between the cover and the bearing plate is watertight.

E. *Wedges.* Design wedges to preclude premature failure of the prestressing steel due to notch or pinching effects under static and dynamic strength requirements of the PTI *Post-Tensioning Manual*. Do not reuse wedges.

Design wedges for epoxy-coated strand to be capable of biting through the epoxy coating and into the strand. Do not remove the epoxy coating from the strand to allow the use of standard wedges. Design anchor nuts and other threadable hardware for epoxy-coated bars to thread over the epoxy coated bar and still meet the requirements for carrying capacity.

718.2 BONDBREAKER

Provide bondbreaker fabricated from a smooth plastic tube or pipe having the following properties:

A. Resistant to chemical attack from aggressive environments, grout, or corrosion inhibiting compound;

B. Resistant to aging by ultra-violet light;

C. Fabricated from material that is not detrimental to the tendon;

D. Capable of withstanding abrasion, impact, and bending during handling and installation;

E. Enables the tendon to elongate during testing and stressing; and

F. Allows the tendon to remain unbonded after lock-off.

718.3 ANCHOR GROUT

A. *Mixture.* Use grout of a pumpable neat mixture of cement and water that is stable (bleeds less than 2 percent), fluid, and provides a minimum 28-day compressive strength of at least 3,000 psi (21 MPa), as determined according to ASTM C109/C109M at time of stressing. Use Type I, II, III, or V Portland cement meeting AASHTO M 85. Provide water for mixing grout that is potable, clean, and free of injurious quantities of substances known to be harmful to portland cement or prestressing steel.

B. *Admixtures.* With the Engineer's approval, the Contractor may use admixtures that control bleed, improve flowability, reduce water content, and retard set in the grout. If using admixtures, ensure that they are compatible with the prestressing steels and mixed according to the manufacturer's recommendations. The Contractor may add expansive admixtures to the grout used for filling sealed encapsulations, trumpets, and anchorage covers. Do not use accelerators.

C. *Grout Tubes.* Use grout tubes with an adequate inside diameter to enable the grout to be pumped to the bottom of the drill hole. Ensure grout tubes are strong enough to withstand a minimum grouting pressure of 150 psi (1 MPa).

718.4 CENTRALIZERS

Fabricate centralizers from plastic, steel, or material that is not detrimental to the prestressing steel. Do not use wood. Ensure that the centralizer will be able to support the tendon in the drill hole and will position the tendon so a minimum of $^1/_2$ in. (12 mm) of grout cover is provided.

Ensure that the centralizers will allow grout to flow freely around the tendon and up the drill hole.

Centralizers are not required on pressure-injected anchors installed in coarse-grained soils when the grouting pressure exceeds 150 psi (1 MPa), nor on hollow stem-augered anchors when they are grouted through the auger with grout having a slump of 9 in. (225 mm) or less.

718.5 CORROSION-INHIBITING COMPOUND

For placement in the free length or the trumpet area, provide an organic compound (i.e., grease or wax) with appropriate polar moisture displacing, corrosion-inhibiting additives, and self-healing properties. Ensure that the compound remains viscous and is chemically stable and nonreactive with the prestressing steel, the sheathing material, and the anchor grout. The Contractor may use corrosion inhibiting compounds meeting the PTI "Specification for Unbonded Single Strand Tendons."

718.6 HEAT SHRINKABLE SLEEVES

Fabricate heat shrinkable sleeves from a radiation crosslinked polyolefin tube, with a nominal wall thickness of 0.24 in. (0.6 mm), internally coated with an adhesive sealant, having a nominal thickness of 0.2 in. (0.5 mm).

718.7 PRESTRESSING STEEL

A. *Tendons.* Provide ground anchor tendons fabricated from single or multiple elements of one of the following prestressing steels:

1. Steel bars meeting AASHTO M 275M/M 275.
2. Seven-wire, low-relaxation strands meeting AASHTO M 203M/M 203.
3. "Compact" seven-wire, low-relaxation strands meeting ASTM A779/A779M.
4. Epoxy coated strand meeting ASTM A882/A882M.
5. Epoxy coated reinforcing steel bars meeting ASTM A775/A775M.

B. *Centralizers and Spacers.* Provide centralizers at maximum intervals of 10 ft (3 m), with the deepest centralizer located 1 ft (0.3 m) from the end of the anchor and the upper centralizer for the bond zone located no more than 5 ft (1.5 m) from the top of the tendon bond length. Use spacers to separate the steel strands of strand tendons. Provide spacers at maximum intervals of 10 ft (3 m). The Contractor may combine spacers with centralizers.

C. *Prestressing Steel Couplers.* Provide prestressing steel bar couplers that are capable of developing 100 percent of the minimum specified ultimate tensile strength of the prestressing steel bar. Ensure steel strands used for a soil or rock anchor are continuous with no splices, unless approved by the Engineer.

718.8 SHEATH

Use a sheath as part of the corrosion protection system for the unbonded length portion of the tendon. Fabricate the sheath from one of the materials specified in Table 718.8-1.

Table 718.8-1. Sheath Materials

Material	Reference	Minimum Wall Thickness, in. (mm)
Polyethylene Tube	ASTM D1248, Type II, III or IV	$^{1}/_{16}$ in. (1.5 mm)
Hot-Melt Extruded Polypropylene Tube	ASTM D4101, cell classification B55542-11	$^{1}/_{16}$ in. (1.5 mm)
Hot-Melt Extruded Polyethylene Tube	ASTM D1248, Type III	$^{1}/_{16}$ in. (1.5 mm)
Steel Tubing	ASTM A500/A500M	$^{3}/_{16}$ in. (5 mm)
Steel Pipe	ASTM A53/A53M	$^{3}/_{16}$ in. (5 mm)
PVC Pipe or Tube	ASTM D1784, Class 13464-B	Schedule 40

718.9 SPACERS

Use spacers to separate elements of a multi-element tendon. Ensure spacers allow grout to flow freely around the tendon and up the drill hole. Fabricate spacers from plastic, steel, or material that is not detrimental to the prestressing steel. Do not use wood.

718.10 TENDON BOND LENGTH ENCAPSULATIONS

If the plans require the tendon bond length to be encapsulated to provide additional corrosion protection, fabricate the encapsulation from one of the materials specified in Table 718.10-1.

Table 718.10-1. Encapsulation for Tendons

Material	Reference	Minimum Wall Thickness in. (mm)
High Density Corrugated Polyethylene Tubing	AASHTO M 252	$^{1}/_{16}$ in. (1.5 mm), except for pregrouted tendons, which may have a minimum wall thickness of 0.4 in. (1 mm)
Deformed Steel Tubing or Pipes	A500/A500M	$^{3}/_{16}$ in. (5 mm)
Corrugated, Polyvinyl Chloride Tubes	ASTM D1784, Class 13464-B	$^{1}/_{16}$ in. (1.5 mm)
Fusion-Bonded Epoxy	ASTM A775/A775M	0.15 in. (0.38 mm)

AASHTO

DIVISION 800
STRUCTURES

SECTION 801
EXCAVATION AND BACKFILL FOR MAJOR STRUCTURES

801.1 DESCRIPTION

Remove or excavate material to construct foundations for bridges, retaining walls, and other major structures.

801.2 MATERIALS

Borrow (as specified by the Agency).

801.3 CONSTRUCTION

A. *Working Drawings.* Provide working drawings, with calculations for excavation procedures, embankment construction, and backfilling operations. Obtain approval of working drawings prior to performing the work. Show details of shoring, bracing, slope treatment, or other protective systems proposed for use.

B. *Excavating.* Remove existing structures within the area to be excavated as specified in Subsection 802.3. Where practicable, construct substructures in open excavation. Shore, brace, or use cofferdams to protect the excavation, where necessary. The Contractor may omit backforms when footings can be placed in the dry without the use of cofferdams.

   Excavate only within the limits of caissons, cribs, cofferdams, steel piling, or sheeting. Do not excavate in the natural stream bed adjacent to the structure. Remove loose material from foundation rock, and clean and cut to a firm surface. Cut the surface either level, stepped, or roughened, as specified. Remove and replace loose material resulting from blasting, or fractured rock caused by overbreak below bearing level, with concrete or grout.

   Excavate foundation to 3 ft (1 m) below the elevation shown on the drawings. Excavate more than 3 ft (1 m) below the elevation only when shown.

   Remove and dispose of buried natural or man-made objects found in the excavation.

C. *Backfilling.* Backfill spaces not occupied by abutments, piers, or other permanent work with embankment up to the surface of the surrounding ground. Compact backfill to at least [95] percent of the maximum density, as determined by AASHTO T 99 [Method C], and neatly grade its top surface. The Engineer will use AASHTO [T 191 or T 310] to assess in-place field density. Deposit fill placed around piers on both sides to approximately the same elevation at the same time. Place no rocks larger than 3 in. (75 mm) against the concrete surfaces. Place backfill in roadway embankments as specified in Subsection 203.3(F)(4).

Deposit fill at retaining walls, abutments, wingwalls, and bridge bents in embankment in well compacted, horizontal layers not to exceed 6 in. (150 mm) in thickness, and bring up uniformly on all sides of the structure or facility. Compact backfill within or beneath embankments, within the roadway in excavated areas, or in front of abutments and retaining walls or wingwalls to the same density as required for embankments.

D. *Drainage.* Make adequate provision for the thorough drainage of backfill. At each weep hole, place French drains, consisting of at least 2 ft^3 (0.6 m^3) of permeable material wrapped in filter fabric to prevent clogging and transmission of fines from the backfill.

801.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will establish the following limits to measure structure excavation:

1. Horizontal limits will be taken as vertical planes 20 in. (500 mm) outside of the neat lines of footings or structures without footings,
2. The top limits are the original ground or the top of the required grading cross section, whichever is lower, and
3. The lower limits are the bottom of the footing or base of structure.

B. When the contract does not specifically provide for measurement and payment of temporary support structures and embankment, consider this work as incidental to structure excavation.

801.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Structure excavation (Class)	yd^3 (m^3)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 802
REMOVAL OF EXISTING STRUCTURES

802.1 DESCRIPTION

Remove and dispose of existing major structures.

802.2 MATERIALS

None.

802.3 CONSTRUCTION

Excavate material to remove the existing structure. Cut and dismantle structure for partial removal, as shown. Protect work not to be removed. Remove existing structure and retain or dispose of materials as specified in Section 202. Backfill as specified in Section 203.

802.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. When the contract does not specifically provide for measurement and payment of temporary support structures and embankment, consider this work as incidental to structure excavation.

802.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Removal of existing structure	lump sum

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 803
TEMPORARY WORKS

803.1 DESCRIPTION

Construct and remove temporary facilities used in the execution of the work. These temporary works may include falsework, forms and form travelers, cofferdams, shoring, water control systems, and temporary bridges.

803.2 MATERIALS

Provide materials as specified in:

Timber	Section 717

803.3 CONSTRUCTION

A. *Working Drawings.* Provide working drawings with design calculations and supporting data in sufficient detail to allow a structural review of the proposed design of a temporary work. Include such data as the sequence and rate of concrete placement. Furnish copies of the working drawings [30] days in advance of the work for review, revision, and approval. Start construction only after the drawings have been approved.

Have a registered Professional Engineer design the temporary works according to *AASHTO LRFD Bridge Design Specifications* or the *AASHTO Guide Design Specifications for Bridge Temporary Works*, or the *AASHTO Construction Handbook for Bridge Temporary Works* or to other established and generally accepted design code or specification for such work.

Construct temporary works in conformance with the approved working drawings. Verify that the quality of the materials and work employed are consistent within the design. Remove and retain, or dispose of, temporary works upon completion of their use. Restore the area to its original or planned condition and dispose of debris.

Provide working drawings for falsework, signed and sealed by a registered Professional Engineer, when the height of falsework exceeds [16 ft (5 m)], or whenever traffic, other than workers involved in constructing the bridge, will travel under the falsework.

B. *Falsework and Forms.* Furnish rigid and strong falsework and forms to safely support the imposed loads and produce the lines and grades indicated. Impart the required surface texture and rustication with forms and provide uniformity of color of formed surfaces.

Limit loads of falsework onto other structures as specified in Subsection 808.3(M).

For roadways remaining open to traffic during construction, provide a horizontal clearance of [5 ft (1.5 m)] greater than the width of the approach traveled way. For Interstate routes and freeways, provide vertical clearance of [14.4 ft (4.4 m)]. Over other classes of roadways, provide vertical clearance of [14.1 ft (4.3 m)].

Construct falsework and set grades that allow for anticipated settlement and deflection, provide the vertical alignment and camber indicated for the permanent structure, allow for minor adjustments during the placement of concrete or structural steel, and allow for the gradual release of the falsework. Provide for accurate measurement of falsework settlement during the placing and curing of the concrete.

Support falsework or formwork for deck slabs on girder bridges directly on the girders. Brace and tie girders to resist forces that would cause rotation or torsion in the girders. Weld falsework support brackets or braces to structural steel members, or reinforcing steel only where specified or directed.

For concrete surfaces that will be exposed to view, provide formwork that will produce a smooth surface of uniform texture and color. Arrange panels lining such forms so that the joint lines form a symmetrical pattern conforming to the general lines of the structure. Use the same type of form lining material throughout each element of a structure. Use rigid forms to ensure the undulation of the concrete surface is less than [$^1/_8$ in. (3 mm)] when checked with a [60-in. (1500-mm)] straightedge or template. Fillet sharp corners with approximately [$^3/_4$-in. (20-mm)] chamfer strips.

Set and hold forms true to the dimensions, lines, and grades of the structure prior to and during the placement of concrete. Bevel or draft at projections, such as copings, to ensure easy removal. Clean forms, inspect for damage and, if necessary, repair prior to reuse. Discontinue use of forms that appear to be defective until defects are corrected. Treat forms with form oil or other approved release agent before placing the reinforcing steel. Do not use material that adheres to or discolors the concrete.

Construct metal ties or anchorages within the forms to ensure that they may be removed to a depth of at least [1 in. (25 mm)] from the face without injury to the concrete. Use ordinary wire ties only when the concrete will not be exposed to view and where the concrete will not come in contact with salts or sulfates. Use chisels or nippers to cut back wire ties at least [$^1/_4$ in. (6 mm)] from the face of the concrete after removing the forms. Use nippers for green concrete. Design fittings for metal ties to minimize the size of the cavities remaining after their removal. Fill the cavities with cement mortar and leave the surface sound, smooth, even, and uniform in color.

When epoxy-coated reinforcing steel is required, use embedded ties, anchorages, or spreaders of corrosion-resistant material or coated with a dielectric material.

Provide an access opening in the forms for cleaning out extraneous material immediately before placing the concrete in narrow walls and columns, where the bottom of the form is inaccessible.

Design and fabricate cardboard tubes, which are placed in forms to produce voids in concrete slabs. Fabricate the outside layers of the tubes to be fully waterproof. Protect such tubes from the weather, and store and install by methods that prevent distortion or damage prior to concrete placement. Prevent fresh concrete from entering the tubes during concrete placement. Cover the ends of tube forms with mortar tight and waterproof caps. Use a premolded rubber joint filler $^1/_4$ in. (6 mm) in thickness around the perimeter of the caps to allow expansion when wood or other expandable material is used for capping tubes. Provide a polyvinyl chloride (PVC) vent tube near each end of each tube. Construct these vents, provide positive venting of the voids, and trim the vent tubes to within [$^5/_8$ in. (15 mm)] of the bottom surface of the finished concrete after removing the exterior form. Anchor or tie tube forms to prevent displacement of the tubes during concrete placement.

C. *Placing Concrete.* Deposit concrete in the forms after all work connected with constructing the forms has been completed, all debris has been removed, all materials to be embedded in the concrete have been placed for the unit to be cast, and the forms and materials have been inspected.

D. *Removing Falsework and Forms.* When removing supports, avoid overstressing the concrete or damaging its surface, and allow the structure to uniformly and gradually take the stresses resulting from its own mass.

After placing concrete, maintain falsework or forms for the time periods specified in Table 803.3-1, exclusive of days when the temperature is below 40°F (5°C):

Table 803.3-1. Falsework and Forms

Falsework:	Time
Spans more than 13 ft (4 m)	14 days
Spans of 13 ft (4 m) or less	10 days
Bent caps not yet supporting girders	10 days
Forms:	**Time**
Not supporting the dead mass of the concrete	24 hours
For interior cells of box girders and railings	12 hours

Alternatively, if, after 7 days following concrete placement, the concrete attains the specified compressive strength, remove forms or falsework. Release falsework supporting any span of a continuous or rigid frame bridge only after the structural concrete in the entire span attains the specified compressive strength.

Release falsework before placing the railings, copings, or barriers for all types of bridges.

Release falsework for post-tensioned portions of structures after the prestressing steel has been tensioned.

Remove all forms and falsework except for the following:

1. Portions of driven falsework piles that are more than 12 in. (300 mm) below subgrade within roadbeds, or 24 in. (600 mm) below the original ground or finished grade outside of roadbeds, or 24 in. (600 mm) below the established limits of any navigation channel;

2. Footing forms if their removal would endanger the safety of cofferdams or other work;

3. Forms from enclosed cells where access is not provided;

4. Deck forms in the cells of box girder bridges that do not interfere with the future installation of utilities shown.

E. *Cofferdams.* Construct cofferdams to adequate depths to ensure stability and to adequate heights to seal off water. Safely design and construct cofferdams, and make as watertight as is necessary for the proper performance of the work that must be done inside them. Ensure interior dimensions of cofferdams provide sufficient clearance to construct forms and allow inspection of their exteriors, and to allow pumping from outside the forms. Right, reset, or enlarge cofferdams tilted or moved laterally during the process of sinking to provide the necessary clearance.

Control the ingress of water so that footing concrete can be placed in the dry. Determine if a seal is required, and, if required, determine the depth of the seal and the cure time required. After the seal has cured, pump out the cofferdam and place the balance of the concrete in the dry. When weighted cofferdams are employed and the weight is used to partially overcome the hydrostatic pressure acting against the bottom of the foundation seal, provide special anchorage such as dowels or keys to transfer the entire weight of the cofferdam into the foundation seal. Control the elevation of the water inside the cofferdam to prevent flow through the seal during the placing and curing of a foundation seal; if the cofferdam is to remain in place, vent or port at or below the low-water level.

Construct shoring to support loads imposed and to comply with applicable safety regulations.

Construct cofferdams to protect green concrete against damage from sudden fluctuations in water level and to prevent damage to the foundation by erosion. Place struts and braces in cofferdams or shoring systems for the permanent work. After completing the substructure, remove cofferdams and shoring with all sheeting and bracing without disturbing or otherwise damaging the finished work.

Submit working drawings for temporary water control systems, dikes, bypass channels, flumes and other surface water diversion works and cutoff walls and pumping systems, including wellpoint and deep-well systems used to prevent water from entering excavations or structures. Include details of the design and the equipment, operating procedures, and location of point or points of discharge. Meet applicable water pollution and erosion control requirements.

Pump from outside the foundation enclosure in a manner that precludes movement of water through the fresh concrete. Avoid pumping while placing concrete and for a period of 24 h thereafter, unless done from a suitable sump separated from the concrete work by a watertight cofferdam.

Dewater a sealed cofferdam after the seal has set sufficiently to withstand the hydrostatic pressure.

Regulate pumping from wellpoints or deep wells to avoid subsidence of adjacent property.

F. *Temporary Bridges.* Construct, maintain, and remove temporary bridges so as not to endanger the work or the public.

Design temporary bridges according to *AASHTO LRFD Bridge Design Specifications*. If design live loads are not specified elsewhere in the contract documents, 75 percent of the HL93 loading may be used. Submit for approval working drawings and design calculations prepared by a registered Professional Engineer, showing complete design and details, including the maximum loads to be carried. Design haul road bridges or other bridges over any right-of-way open to the public or over any railroad not for public use to meet *AASHTO LRFD Bridge Design Specifications*, when applicable, or to other appropriate standards.

803.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

803.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Falsework	incidental
(B) Falsework (Type)	lump sum
(C) Temporary structure	lump sum
(D) Cofferdams	lump sum
(E) Shoring systems	lump sum
(F) Water-control systems	lump sum

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 804
DRIVEN FOUNDATION PILES

804.1 DESCRIPTION

Furnish and drive foundation piles of the type and dimensions designated, including cutting off or building up foundation piles when required.

Use methods and procedures that will keep deformations of existing structures and utilities within the levels specified in the contract. If deformations exceed the specified amount, stop work immediately.

Monitor and control vibrations from construction activities. When specified, engage the services of a professional vibrations consultant to monitor and record vibration levels. Use vibration monitoring equipment capable of detecting velocities of [0.1 in./sec (0.25 mm/sec) or less]. If vibrations exceed the specified level, stop work immediately and take whatever measures necessary to reduce vibration levels below the specified tolerable level.

804.2 MATERIALS

Provide materials as specified in:

Steel Piles, Grade 36, 50, or 50W (Grade 250, 345, or 345W)	Subsection 710.1
Castings for Steel Piles Shoes	Subsection 710.5(A)(1)
Reinforcing Steel	Subsection 711.1
Portland Cement Concrete, Class A	Subsection 713.1(B)
Timber Piles	Subsection 717.1
Timber Preservative and Treatment	Subsection 717.3
Forms	Subsection 803.3(B)
Paint/Coatings	Section 813

804.3 CONSTRUCTION

A. *Pile Driving Equipment:*

1. *Pile Hammers.* Provide to the Engineer the technical specifications and operating instructions related to hammer equipment. The Contractor may drive piles with air, steam, diesel, or hydraulic hammers. If specifically allowed in the contract, the Contractor may use gravity hammers to drive timber piles only. Submit Wave Equation Analyses that demonstrate the proposed driving system together with the proposed drop heights are properly

dimensioned and meet the requirements of blow count range and the allowable stresses of Subsection 804.3(A)(2).

a. *Gravity Hammers*. When gravity hammers are allowed, ensure the weight (mass) of the ram is between 2,000 and 3,500 lb (900 and 1,600 kg) and the height of drop does not exceed 15 ft (4.5 m).

b. *Air and Steam Hammers*. Use a plant and equipment having sufficient capacity to maintain, under working conditions, the volume and pressure specified by the manufacturer. Equip the plant and equipment with accurate pressure gauges that are easily accessible to the Engineer. Use Wave Equation Analyses to show the proposed hammer system is properly dimensioned and with the proposed strokes that meet the requirements of blow count range and the allowable stresses of Subsection 804.3(A)(2).

c. *Diesel Hammers*. Equip open-end (single-acting) diesel hammers with a device such as rings on the ram to allow the Engineer to visually determine hammer stroke at all times during pile-driving operations. Also, Provide the Engineer with a chart from the hammer manufacturer equating stroke and blows per minute for the open-end diesel hammer that will be used. Also provide and maintain in working order for the Engineer's use an approved device to automatically determine and display ram stroke for open-end diesel hammers.

   Equip closed-end (double-acting) diesel hammers with a bounce chamber pressure gauge, mounted near ground level so as to be easily read by the Engineer. Also, provide the Engineer with a chart, calibrated to actual hammer performance within 90 days prior to initial use, equating bounce chamber pressure to either equivalent energy or stroke for the closed-end diesel hammer that will be used.

d. *Hydraulic Hammers*. Use a power plant having sufficient capacity to maintain, under working conditions, the volume and pressure specified by the manufacturer. Equip the power plant and equipment with accurate pressure gauges that are easily accessible to the Engineer.

e. *Non-Impact Hammers*. Do not use non-impact hammers, such as vibratory hammers, or driving aids such as jets, followers, and prebored holes, unless either specifically allowed in writing by the Engineer or stated in the contract documents. When non-impact hammers may be used to install production piles, first establish the pile toe elevation for the ultimate pile capacity by load testing or driving test piles with an impact hammer. Perform, at no cost to the Agency, such load tests or extra work required to drive test piles as determined by the Engineer as a condition of approval of the non-impact hammers or driving aids. Control installation of production piles with vibratory hammers according to the power consumption, rate of penetration, specified toe elevation, or other means acceptable to the Engineer that ensure the ultimate pile capacity equals or exceeds the ultimate capacity of the test pile. In addition, retap one of every ten piles driven with a vibratory hammer with an impact hammer of suitable energy to verify the ultimate pile capacity as specified in Subsection 804.3(E).

2. *Approval of Pile Driving Equipment.* Size pile driving equipment to ensure project piles can be driven with reasonable effort to the ordered lengths without damage. Submit to the Engineer the necessary pile driving equipment information at least 30 days prior to driving piles, using the form shown in Figure 804.3-1 or similar.

   a. *Wave Equation Analysis.* The Engineer will use the wave equation to determine the suitability of the Contractor's proposed pile driving system. Do not transport pile driving equipment to the project site without the Engineer's written approval.

      Approval criteria of pile driving systems will consist of both the required number of hammer blows per 1 in. (25 mm) and the pile stresses at the required ultimate pile capacity. The acceptable range of hammer blows, as indicated by the wave equation at the ultimate pile capacity, is between 3 and 15 blows per in. (25 mm).

      In addition, the Engineer will use the following criteria in evaluating wave equation results to determine the acceptability of the Contractor's proposed driving system.

      i. For steel piles, the maximum allowable compressive driving stress is 90 percent of the minimum yield strength of the pile material.

      ii. For prestressed concrete piles in normal environments, the maximum allowable tensile stress is 3 multiplied by the square root of the concrete compressive strength, f_c', plus the effective prestress value, f_{pe}, or $3\sqrt{f_c' + f_{pe}}$, with all units expressed in psi. (When units are expressed in MPa, the maximum allowable tensile stress is $0.25\sqrt{f_c' + f_{pe}}$).

      iii. The maximum allowable compressive stress for prestressed concrete piles is 85 percent of the compressive strength minus the effective prestress value, or 0.85 $f_c' - f_{pe}$. In severe corrosive environments, the maximum allowable tensile stress for prestressed concrete piles is f_{pe}.

      iv. For timber piles, the maximum allowable compressive driving stress is three times the allowable static design strength listed on the plans.

      The Engineer will notify the Contractor of the acceptance or rejection of the driving system within 14 calendar days of receiving the Contractor's Pile and Driving Equipment Data Form. If the Engineer's wave equation analyses show that the Contractor's proposed equipment or methods will result in either pile damage or an inability to drive the pile with a reasonable driving resistance to the desired ultimate capacity, modify or replace the proposed methods or equipment at no cost to the Agency until subsequent wave equation analyses indicate the piles can be reasonably driven to the desired ultimate capacity, without damage. The Engineer will notify the Contractor of the acceptance or rejection of the revised driving system within 7 calendar days of receipt of a revised Pile and Driving Equipment Data Form.

      Use the approved system to drive piles. Do not modify the driving system without the Engineer's written approval. The Engineer will only consider changes to the driving

Contract No.:____________________

Project:__________________________

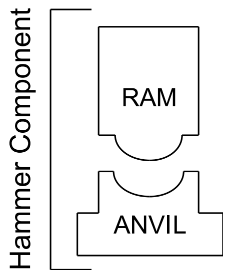
County:__________________________

Structure Name and/or No.:______________________________

Pile Driving Contractor or Subcontractor:____________________

____

(Piles driven by)



Hammer

Manufacturer:________________ Model No.:__________________

Hammer Type: Serial No.:____

Manufacturer's Maximum Rated Energy:______________________ (ft-lb)

Stroke at Maximum Rated Energy:_____________________________ (ft)

Range in Operating Energy: ___________ to __________________ (ft-lb)

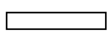
Range in Operating Stroke: ____________ to ____________________ (ft)

Ram Weight:_________________________ (lb)

Modifications:____

____

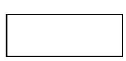
____



Striker Plate

Weight: ___________________ (lb) Diameter:_________________ (in.)

Thickness:__________________ (in.)



Hammer Cushion

Material #1

Name:_______________________

Hammer Area:___________ (in.^{2})

Cushion Thickness/Plate:___ (in.)

No. of Plates:________________

Material #2 (for Composite Cushion)

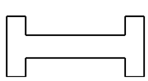
Name:______________________

Area: __________________ (in.^{2})

Thickness/Plate:__________ (in.)

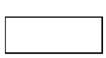
No. of Plates:_______________

Total Thickness of Hammer Cushion:_______________________________



Helmet (Drive Head)

Weight:__________________ (lb)



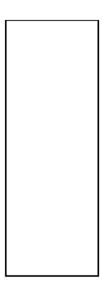
Pile Cushion

Material:____

Area:____________________ (in.^{2}) Thickness/Sheet:_________ (in.)

No. of Sheets:_______

Total Thickness of Pile Cushion:______________________________ (in.)



Pile

Pile Type: ____________________

Wall Thickness:____________ (in.) Taper:_______________________

Cross Sectional Area:_____ (in.^{2}) Weight/Meter:________________

Ordered Length: __________ (ft)

Design Load: _____________ (lb)

Ultimate Pile Capacity:____ (lb)

Description of Splice:____

____

Driving Shoe/Closure Plate Description:___________________________

____

Submitted By:________________ Date:___________________

Telephone No.: _______________ Fax No.:_________________

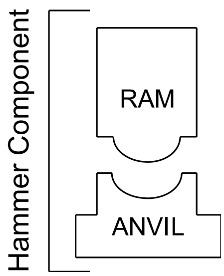
Figure 804.3-1a. Pile and Driving Equipment Data Form (U.S. Customary Units)

Contract No.:____________________ Structure Name and/or No.:__________________________

Project:_________________________ Pile Driving Contractor or Subcontractor:_________________

County:_________________________ ________________________________

(Piles driven by)



Hammer

Manufacturer:_________________ Model No.:_______________

Hammer Type: Serial No.:___________________________________

Manufacturer's Maximum Rated Energy:_________________ (Joules)

Stroke at Maximum Rated Energy:_____________________ (meters)

Range in Operating Energy: __________ to _____________ (Joules)

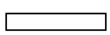
Range in Operating Stroke: __________ to _____________ (meters)

Ram Weight:______________ (kg)

Modifications:____

____

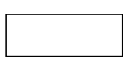
____



Striker Plate

Weight: ___________________ (N) Diameter:____________ (mm)

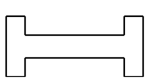
Thickness:_______________ (mm)



Hammer Cushion

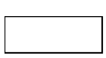
Material #1	Material #2 (for Composite Cushion)
Name:______________________	Name:___________________
Hammer Area:__________ (mm²)	Area: _______________ (mm²)
Cushion Thickness/Plate:__ (mm)	Thickness/Plate:______ (mm)
No. of Plates:________________	No. of Plates:_____________

Total Thickness of Hammer Cushion:___________________________



Helmet (Drive Head)

Weight:_________________ (kN)



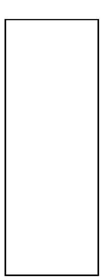
Pile Cushion

Material:____

Area:___________________ (mm²) Thickness/Sheet:______ (mm)

No. of Sheets:________________

Total Thickness of Pile Cushion:___________________________ (mm)



Pile

Pile Type: ____________________

Wall Thickness:___________ (mm) Taper:_____________________

Cross Sectional Area:_____ (mm²) Weight/Meter:_____________

Ordered Length: __________ (m)

Design Load: _____________ (kN)

Ultimate Pile Capacity:_____ (kN)

Description of Splice:_______________________________________

____

Driving Shoe/Closure Plate Description:_______________________

____

Submitted By:________________ Date:________________

Telephone No.: ______________ Fax No.:______________

Figure 804.3-1b. Pile and Driving Equipment Data Form (SI Units) system after the Contractor has submitted the necessary information for a revised wave equation analysis. The Engineer will notify the Contractor of the acceptance or rejection of the pile driving system changes within 7 calendar days of receiving the Contractor's request.

b. *Alternate Approval Method*. Final approval of the equipment and procedures are subject to satisfactory field performance, as in Table 804.3-1.

c. *Alternate Approval Based on Dynamic Load Testing*. When the project includes the performance of dynamic load testing (DLT) on initial production piles or test piles, the Engineer will use the results of the DLT in combination with Wave Equation analysis to determine the suitability of the driving equipment. Final approval of the equipment and procedures are subject to satisfactory field performance.

If the Engineer's DLT results and wave equation analyses show that the Contractor's proposed equipment or methods will result in either pile damage or an inability to drive the pile with a reasonable driving resistance to the desired ultimate capacity, modify or replace the proposed methods or equipment at no cost to the Agency until subsequent DLT and wave equation analyses indicate the piles can be reasonably driven to the desired ultimate capacity, without damage. The Engineer will notify the Contractor of the acceptance or rejection of the driving system within 3 calendar days after completion of Dynamic Load Tests.

Use the approved system to drive piles. Do not modify the driving system without the Engineer's written approval. The Engineer will only consider changes to the driving system after the Contractor has submitted the necessary information for a revised wave equation analysis. A hammer substituted, repaired on site, or removed from the site and returned is considered to have its performance altered (efficiency increased or decreased), which is considered a change in the driving system and is subject to a dynamic load test at no additional compensation. The Engineer will notify the Contractor of the acceptance or rejection of the pile driving system changes within 3 calendar days of after performing the DLT.

Table 804.3-1a. Alternate Approval Method Minimum Pile Hammer Requirements (U.S. Customary Units)

Ultimate Pile Capacity (kips)	Minimum Manufacturer's Rated Hammer Energy (foot-pounds)
180 and under	9,000
181 to 300	15,000
301 to 415	20,000
416 to 540	24,000
541 to 600	26,000
601 and over	Wave Equation Required

Table 804.3-1b. Alternate Approval Method Minimum Pile Hammer Requirements (SI Units)

Ultimate Pile Capacity (kN)	Minimum Manufacturer's Rated Hammer Energy (Joules)
800 and under	12,000
800 to 1,350	20,000
1,351 to 1,850	27,000
1,851 to 2,400	32,000
2,401 to 2,650	35,000
2,651 and over	Wave Equation Required

Use the approved system to drive piles. If the Engineer determines the Contractor's hammer is unable to transfer sufficient energy to the pile, remove the hammer from service until repaired to the satisfaction of the Engineer. Do not modify the driving system without the Engineer's written approval. The Engineer will only consider changes to the driving system after the Contractor has submitted a new Pile and Driving Equipment Data form. The Engineer will notify the Contractor of the acceptance or rejection of the proposed change in driving equipment within 7 calendar days of receiving the Contractor's request.

3. *Drive System Components and Accessories:*

   a. *Hammer Cushion.* Equip impact pile driving equipment, designed to be used with a hammer cushion, with a suitable thickness of hammer cushion material to prevent damage to the hammer or pile and to ensure uniform driving behavior. Furnish hammer cushions made of durable manufactured materials, provided in accordance with the hammer manufacturer's guidelines. Do not use wood, wire rope, or asbestos hammer cushions. Place a striker plate, as recommended by the hammer manufacturer, on the hammer cushion to ensure uniform compression of the cushion material. Remove the hammer cushion from the helmet and inspect in the presence of the Engineer when beginning pile driving at each structure or after each 100 h of pile driving, whichever is less. Replace hammer cushions compressed to less than 75 percent of the original thickness before resuming pile driving.

   b. *Helmet.* Piles driven with impact hammers require an adequate helmet or drive head to distribute the hammer blow to the pile head. Align the helmet axially with the hammer and the pile. Use leads to guide the helmet and prevent it from swinging freely. Fit the helmet around the pile head in a manner that prevents transfer of torsional forces during driving, while maintaining proper alignment of hammer and pile. Use a pile helmet that fits loosely over the pile head and is at least 1 in. larger than the pile dimensions.

      For steel and timber piling, cut the pile heads squarely, and provide a helmet, as recommended by the hammer manufacturer, to hold the axis of the pile in line with the axis of the hammer.

For precast concrete and prestressed concrete piles, ensure the pile head is perpendicular to the longitudinal axis of the pile to prevent eccentric impacts from the helmet.

For special types of piles, provide appropriate helmets, mandrels, or other devices according to the manufacturer's recommendations to prevent damage to the piles during driving operations.

c. *Pile Cushion.* Protect the heads of concrete piles with a pile cushion made of plywood, hardwood, or composite plywood and hardwood materials. Prior to driving, place on the pile head a minimum pile cushion thickness as determined by the Engineer based on Wave Equation Analysis, DLT, or both. Provide a new pile cushion for each pile. In addition, replace the pile cushion if, during the driving of any pile, the cushion is compressed more than one-half the original thickness or if the cushion begins to burn. Ensure the pile cushion dimensions match the cross-sectional area of the pile top.

d. *Leads.* Use leads to support piles in line and position while being driven. Construct pile driver leads to allow the hammer to move freely while maintaining the alignment with the pile to ensure concentric impact for each blow. The Contractor may either use fixed- or swinging-type leads. When using swinging-type leads, fit a pile gate at the bottom of the leads and, in the case of batter piles, fit a horizontal brace between the crane and the leads, as necessary. Ensure that the pile section being driven does not extend above the leads. Adequately embed the leads in the ground or constrain the pile in a structural frame such as a template to maintain alignment. Provide leads of sufficient length to make the use of a follower unnecessary, and design to allow proper alignment of batter piles.

e. *Followers.* Only use followers when approved in writing by the Engineer, or when specifically stated in the contract documents. In cases where a follower is allowed, drive the first pile in each bent, and every tenth pile driven thereafter, full length without a follower, to determine that adequate pile penetration is being attained to develop the ultimate pile capacity.

Hold and maintain the follower and pile in equal and proper alignment during driving. Use a follower of the material and dimensions that will allow the piles to be driven to the penetration depth determined necessary from the driving of the full-length piles. Verify the final position and alignment of the first two piles installed with followers in each substructure unit according to the location tolerances specified in Subsection 804.3(F)(3) before installing additional piles.

f. *Jets.* Only perform jetting if approved in writing by the Engineer or when specifically stated in the contract documents. When jetting is not required in the contract documents, but approved after the Contractor's request, determine the number of jets and the volume and pressure of water at the jet nozzles necessary to freely erode the material adjacent to the pile without affecting the lateral stability of the final in-place pile. Assume responsibility for damage to the site caused by unapproved or improper jetting operations. When jetting is specifically required in the contract documents, provide a jetting plant having sufficient capacity to deliver at all times a pressure equivalent to at least 100 psi (700 kPa) at two $^3/_4$-in. (19-mm) jet nozzles. In either case, unless otherwise directed by the Engineer, remove jet pipes when the pile toe is a minimum of 5 ft (1.5 m) above the prescribed toe elevation, and drive the pile to the required ultimate pile capacity with an impact hammer. Also, control, perform any necessary treatment, and dispose of jet water in a manner satisfactory to the Engineer.

g. *Preboring.* When stated in the contract documents, prebore holes at pile locations to the depths shown on the plans. Prebore holes of a size smaller than the diameter or diagonal of the pile cross section that is sufficient to allow penetration of the pile to the specified depth. If subsurface obstructions, such as boulders or rock layers, are encountered, the Contractor may increase the hole diameter to the least dimension adequate for pile installation. Fill the void space remaining around the pile after completion of driving with sand or other approved material. Do not use spuds, i.e., a short and strong-driven member that is removed to make a hole for inserting a pile, in lieu of preboring.

B. *Driven Pile Capacity:*

1. *Wave Equation.* The Engineer will determine the ultimate pile capacity based on a wave equation analysis. In projects where DLT are included in initial production piles or test piles, the Engineer may use the DLT results to refine the wave equation analysis. Drive piles with the approved driving equipment to the ordered length or the length necessary to obtain the required ultimate pile capacity. Do not use jetting or other methods to facilitate pile penetration unless either specifically allowed in the contract documents or approved by the Engineer after a revised driving resistance is established from the wave equation analysis. Consider adequate pile penetration to be obtained when the specified wave equation resistance criteria is achieved within 5 ft (1.5 m) of the pile toe elevation, based on ordered length. Drive piles that do not achieve the specified resistance within these limits to penetrations established by the Engineer.

2. *Dynamic Formula.* Only use dynamic formula to determine ultimate pile capacity if either the contract documents specify that dynamic formula be used or the Engineer approves use of dynamic formula. In such cases, drive piles to a penetration depth necessary to obtain the ultimate pile capacity according to the following formula:

U.S. Customary Units:

$$R_u = 1.75\left[\sqrt{E}(\log(10N_b))\right] - 100$$

where:

R_u = ultimate pile capacity (kips)

E = manufacturer's rated hammer energy at the field observed ram stroke (foot-pounds)

log $(10N_b)$ = logarithm to the base 10 of the quantity 10 multiplied by N_b, the number of hammer blows per inch at final pile penetration

SI Units:

$$R_u = 7\left[\sqrt{E}\,(\log(10N_b))\right] - 550$$

where:

R_u = ultimate pile capacity (kN)

E = manufacturer's rated hammer energy at the field observed ram stroke (Joules)

log ($10N_b$) = logarithm to the base 10 of the quantity 10 multiplied by N_b, the number of hammer blows per 25 mm at final pile penetration

C. *Compression Load Tests:*

1. *Static Load Tests.* Perform compression load tests according to ASTM D1143/D1143M using the quick load test method, except take the test to plunging failure or to the capacity of the loading system. Ensure testing equipment and measuring systems meet ASTM D1143/D1143M, except ensure that the loading system is capable of applying 150 percent of the ultimate pile capacity unless a different testing load is specified in the Plans, and use a load cell and spherical bearing plate. Submit to the Engineer for approval detailed plans prepared by a licensed professional engineer of the proposed loading apparatus. Construct the apparatus to allow the various increments of the load to be placed gradually, without causing vibration to the test pile. When the approved method requires the use of tension (reaction) piles, install tension piles, when feasible, of the same type and diameter as the production piles and in the location of permanent piles, except do not use timber or tapered piles installed in permanent locations as tension piles.

   The design load is 50 percent of the failure load. The failure load of a pile tested under axial compressive load is that load which produces a settlement at failure of the pile head equal to the following:

   U.S. Customary Units:

   For piles 24 in. or less in diameter or width,

$$S_F = S + (0.15 + 0.008D)$$

   For piles greater than 24 in. in diameter or width,

$$S_F = S + \frac{D}{30}$$

   where:

   S_F = settlement at failure (in.)

   S = elastic deformation of total pile length (in.)

   D = pile diameter or width (in.)

SI Units:

For piles 610 mm or less in diameter or width,

$$S_F = S + \left(4 + 0.008D\right)$$

For piles greater than 610 mm in diameter or width,

$$S_F = S + \frac{D}{30}$$

where:

S_F = settlement at failure (mm)

S = elastic deformation of total pile length (mm)

D = pile diameter or width (mm)

Determine the top elevation of the test pile immediately after driving and again just before load testing to check for heave. Redrive or jack any pile that heaves more than $^1/_4$ in. (6 mm) to the original elevation prior to testing. Unless otherwise specified in the contract, wait at least three days between driving any anchor piles or the load test pile and starting the load test.

2. *Dynamic Load Tests.* The Engineer will take dynamic measurements according to the procedures in ASTM D 4945 during the driving of piles designated as dynamic load test piles.

Before placing the pile in the leads, allow the Engineer to take wave speed measurements and to predrill the required instrument attachment holes at each designated pile. Predriving wave speed measurements is not required for steel piles. When wavespeed measurements are to be made, ensure piling is in a horizontal position and not in contact with other piling. The Engineer will furnish the equipment, materials, and labor necessary to drill holes in the piles for instrument mounting. The Engineer will attach instruments near the head of the pile with bolts placed in masonry anchors for the concrete piles, or through drilled holes for steel piles, or with wood screws for timber piles.

Provide the Engineer reasonable means of access to the pile for attaching instruments after the pile is placed in the leads. Provide a platform with minimum size of 4 ft by 4 ft, or 16 ft^2, (1.2 m by 1.2 m, or 1.4 m^2) designed to be raised to the top of the pile while the pile is located in the leads. Assume that the Engineer will need approximately 1 h per pile to install the dynamic test equipment.

Provide electric power for the Engineer's dynamic test equipment. Provide a power supply at the outlet of 10 amp, 115 volt, 55–60 cycle, AC only. Equip field generators used as the power source with functioning meters for monitoring voltage and frequency levels.

Provide a shelter, with a minimum floor size of 8 ft by 8 ft (2.5 m by 2.5 m) and minimum roof height of 6 $^1/_2$ ft (2 m), to protect the dynamic test equipment from the elements.

Maintain the inside temperature of the shelter above 45°F (7°C). Locate the shelter within 50 ft (15 m) of the test location.

With the dynamic testing equipment attached, drive the pile to the design penetration depth or to a depth determined by the Engineer. The Engineer will use the ultimate pile capacity estimates at the time of driving and/or retapping from dynamic test methods to determine the required pile penetration depth for the ultimate pile capacity. The Engineer will monitor stresses in the piles during driving with the dynamic test equipment to ensure that the values determined do not exceed the values in Subsection 804.3(A)(2). If necessary, reduce the driving energy transmitted to the pile by using additional cushions or reducing the energy output of the hammer in order to maintain stresses below the values in Subsection 804.3(A)(2). If non-axial driving is indicated by dynamic test equipment measurements, immediately realign the driving system.

Wait up to 24 h (or a longer duration specified in the contract documents) and retap the dynamic load test pile with the dynamic testing instruments attached. Assume that the Engineer will require approximately $^1/_2$ h to reattach the instruments. Do not use a cold hammer for the redrive. Warm the hammer before beginning redrive operations by applying at least 20 blows to another pile. Redrive to a maximum penetration of 6 in. (150 mm), or to a maximum total number of hammer blows of 50, whichever occurs first. After retapping, the Engineer will either provide the cutoff elevation or specify additional pile penetration and testing.

3. *General.* On completion of the load testing, for any test or anchor piling that is not a part of the finished structure, remove or cut off at least 12 in. (300 mm) below either the bottom of footing or the finished ground elevation, if not located within the footing area.

D. *Test Piles (Indicator Piles).* Drive test piles when shown on the plans at the locations and to the penetration depths specified by the Engineer. Drive test piles with impact hammers unless specifically stated otherwise in the plans. In general, the specified length of test piles will be greater than the estimated length of production piles in order to allow for variation in soil conditions. Drive test piles using equipment identical to that proposed for use on the production piling. Excavate the ground at each test pile to the elevation of the bottom of the footing before driving the pile.

Drive test piles to a driving resistance established by the Engineer at the estimated pile toe elevation. Do not redrive test piles that fail to attain the specified driving resistance at a depth of 1 ft (300 mm) above the estimated pile toe elevation shown on the plans, until such piles "set up" for 12 to 24 h, or as directed by the Engineer. Do not use a cold hammer for the redrive. Warm the hammer before driving begins by applying at least 20 blows to another pile. If the specified driving resistance is not attained on redriving, the Engineer may direct the Contractor to drive a portion or all of the remaining test pile length and repeat the "set up" redrive procedure. For test piles driven to plan grade and not having the driving resistance required, splice and drive until the required capacity is obtained.

The Engineer will prepare a record of the driving of the test pile, reporting the number of hammer blows per foot (300 mm) for the entire driven length, the as-driven length of the test pile, cutoff elevation, penetration in ground, and any other pertinent information. Provide the information listed in Figure 804.3-1 to the Engineer for inclusion in the record. If a redrive is necessary, the Engineer will record the number of hammer blows per 1 in. (25 mm) of pile movement for the first 1 ft (300 mm) of redrive. Do not order piling for use in the permanent structure until the Engineer has reviewed test pile data and has authorized the pile order lengths. The Engineer will provide the pile order list within 7 calendar days after completion of all test pile driving specified in the contract documents.

E. *Ultimate Pile Capacity.* Drive piles to the penetration depth shown on the plans or to a greater depth if necessary to obtain the ultimate pile capacity. The Engineer will determine the ultimate pile capacity using one of the methods specified in Subsection 804.3(B).

Do not use jetting or other methods to facilitate pile penetration unless specifically allowed in the contract plans or the Engineer provides written approval. The Engineer will base the ultimate pile capacity of jetted piles on the driving resistances recorded during impact driving after the jet pipes have been removed. For jetted piles that fail to attain the ultimate pile capacity at the ordered length, splice at no cost to the Agency, and drive with an impact hammer until the ultimate pile capacity is achieved, as indicated by the appropriate criteria specified in Subsection 804.3(B).

The Engineer will only consider the ultimate pile capacity of piles driven with followers to be acceptable when the follower driven piles attain the same pile toe elevation as the full-length piles driven without followers, installed as specified in Subsection 804.3(B), which attained the required ultimate pile capacity.

The Engineer will base the ultimate pile capacity of piles driven with vibratory hammers on the driving resistance recorded during impact driving after the vibratory equipment has been removed from the first pile in each group of ten piles. Splice vibrated piles that fail to attain the ultimate pile capacity at the ordered length, at no cost to the Agency, and drive with an impact hammer until the ultimate pile capacity is achieved, as indicated by the appropriate criteria in Subsection 804.3(B). When the ultimate pile capacity is attained, install the remaining nine piles to similar depths with the same vibratory hammer power consumption and rate of penetration as the first pile.

F. *Preparation and Driving:*

1. *General.* Ensure the heads of all piles are in a true plane and perpendicular to the longitudinal axis of the pile before attaching the helmet. Protect the heads of concrete piles with a pile cushion as specified in Subsection 804.3(A)(3)(c).

   During pile driving, change the pile cushion as specified in Subsection 804.3(A)(3)(c) before excessive compression or damage takes place. The Engineer's prior approval of a pile hammer will not relieve the Contractor of responsibility for piles damaged because of misalignment of the leads, failure of cushion materials, failure of splices, malfunctioning of the pile hammer, or other improper construction methods. When the Engineer determines that such damage impairs the strength of the pile, replace the pile at no cost to the Agency.

2. *Preboring.* The Contractor may only use augering, wet-rotary drilling, or other methods of preboring when approved by the Engineer or when these methods are used in the same manner as was used for any indicator piles or load test piles. When such procedures are allowed, perform them in a manner that will not impair the capacity of the piles already in place or the safety of existing adjacent structures.

   Except for end bearing piles, discontinue preboring at least 5 ft (1.5 m) above the pile toe elevation, as determined from the ordered length, and drive the pile with an impact hammer to a driving resistance specified by the Engineer. Where piles are to be end-bearing on rock or hardpan, the Contractor may prebore to the surface of the rock or hardpan, and then retap the piles with an impact hammer to ensure proper seating.

   If the Engineer determines that preboring has disturbed the capacities of previously installed piles, restore those piles that have been disturbed to conditions meeting the requirements of this specification by redriving or by other methods acceptable to the Engineer. Perform redriving or other remedial measures after completing the preboring operations in the area. Perform any necessary remedial measures at no cost to the Agency, unless the preboring method was specifically included in the contract documents and properly executed by the Contractor.

3. *Location and Alignment Tolerance.* Ensure that the pile head at cutoff elevation is within 2 in. (50 mm) of plan locations for bent caps supported by piles, and within 6 in. (150 mm) of plan locations for piles capped below final grade. Ensure that the as-driven centroid of load of any pile group at cutoff elevation is within 5 percent of the plan location of the designed centroid of load. Construct the pile cap so that all piles are located at least 4 in. (100 mm) away from any edge of the cap. If it is necessary to increase the size of the cap to meet this edge distance requirement, perform the modification at no cost to the Agency.

   Install piles so that the axial alignment of the pile is within 2 percent of the specified alignment. For piles that cannot be inspected internally after installation, the Engineer will conduct an alignment check before the installation of the last 5 ft (1.5 m) of pile, or after installation is completed provided the exposed portion of the pile is not less than 5 ft (1.5 m) in length. The Engineer may require that driving be stopped in order to check the pile alignment. Do not pull laterally on piles to correct misalignment, or splice a properly aligned section on a misaligned section.

   If the location or alignment tolerances specified in the preceding paragraphs are exceeded, the Engineer will evaluate the extent of overloading. If, in the judgment of the Engineer, corrective measures are necessary, design and construct suitable measures at no cost to the Agency.

4. *Heaved Piles.* The Engineer will take level readings to measure pile heave at the start of the pile driving operations and will continue to take such readings until the Engineer determines that such checking is no longer required. The Engineer will take level readings immediately after the pile has been driven and again after piles within a radius of 15 ft

(4.5 m) have been driven. If pile heave is observed, the Engineer will take accurate level readings referenced to a fixed datum on all piles immediately after installation and periodically thereafter as adjacent piles are driven to determine the pile heave range. Redrive piles that have heaved more than $^{1}/_{4}$ in. (6 mm) to the required resistance or penetration, at no cost to the Agency. Do not place concrete in pile casings until pile driving has progressed beyond a radius of 15 ft (4.5 m) from the pile to be concreted. If pile heave is detected for pipe or shell piles that have been filled with concrete, redrive the piles to original position after the concrete has obtained sufficient strength using a proper hammer-pile cushion system, satisfactory to the Engineer.

5. *Installation Sequence.* Place individual piles in pile groups either starting from the center of the group and proceeding outwards in both directions, or starting at the outside row and proceeding progressively across the group.

G. *Unsatisfactory Piles.* Drive piles in a manner that will not subject piles to excessive or undue abuse, producing crushing and spalling of concrete, injurious splitting, splintering, brooming of the wood, or deformation of the steel. Do not force misaligned piles into proper position. Correct piles damaged during driving by reason of internal defects or by improper driving, or driven out of their proper location or below the designated cutoff elevation, at no cost to the Agency, using methods approved by the Engineer.

The Engineer will consider piles bent during installation to be unsatisfactory unless the ultimate capacity is proven by load tests performed at the Contractor's expense. If such tests indicate inadequate capacity, take corrective measures as determined by the Engineer, such as using bent piles at reduced capacity, installing additional piles, strengthening the bent piles, or replacing bent piles.

The Engineer will consider a concrete pile to be defective if a visible crack, or cracks, appears around the entire periphery of the pile, or if any defect is observed which, as determined by the Engineer, affects the strength or life of the pile or if damage is detected through dynamic load testing or pile integrity testing.

H. *Splices.* Use full-length piles where practical. Do not splice timber piles. Where splices are unavoidable for steel or concrete piles, obtain the Engineer's approval of the number, locations, and details of the splices. Ensure splices for cast-in-place piles are watertight. Splice concrete piles using the cement dowel method as detailed on the plans unless the Engineer approves alternate splices. The Engineer may approve mechanical splices for concrete or steel piles if the splice can transfer the full pile strength in compression, tension and bending. Submit shop drawings of any proposed mechanical splice to the Engineer for approval.

I. *Pile Shoes.* Provide and install pile shoes of the type and dimensions shown on the contract plans. For timber piles, fasten metal shoes securely to the pile. Provide timber pile toes that are carefully shaped to ensure a uniform bearing on the pile shoe. Fabricate steel pile shoes from cast steel meeting ASTM A27/A27M.

J. *Cutoff Lengths.* Trim the pile head of permanent piles and pile casings at the elevation shown on the plans or as ordered by the Engineer. Dispose of the cutoff lengths.

804.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. *Timber, Steel, and Precast Concrete Piles Furnished.* The Engineer will measure the quantity of piles furnished by the total length of piles in ft (m). The Engineer will exclude lengths of piles, including test piles, furnished to replace piles that were previously accepted by the Engineer but were subsequently damaged prior to completion of the contract. When extensions of piles are necessary, the extension length authorized in writing by the Engineer will be included in the quantity of piling furnished.

B. *Timber, Steel, and Precast Concrete Piles Driven.* The Engineer will measure piles driven by the ft (m) of piling in place measured below the cutoff elevation. Consider preboring, jetting, or other methods used to facilitate pile driving as incidental to the work.

C. *Cast-in-Place Pipe or Shell Concrete Piles.* The Engineer will measure the quantity of cast-in-place pipe or shell concrete piles by the length in ft (m) of steel pipe or shell piles driven, cast, and left in place. The Engineer will measure actual quantities from the toe of the steel pipe or shell pile to the bottom of the cap or bottom of the footing, as the case may be.

   Consider as incidental to the work reinforcing steel, excavation, drilling, cleaning of drilled holes, drilling fluids, sealing materials, concrete, and casing, and preboring, jetting, or other methods used to facilitate pile-driving procedures.

D. *Pile Shoes.* The Engineer will measure quantities of shoes actually installed on piles.

E. *Load Tests.* The Engineer will base the quantity of load tests on the number of load tests completed and accepted, excluding load tests made at the option of the Contractor.

   Include in the unit price bid for each load test, reaction and test piling that are not a part of the permanent structure. The Engineer will account for reaction and test piling, which are a part of the permanent structure, under the appropriate pay item.

F. *Splices.* The Engineer will only measure those splices made as required to drive the piles in excess of the ordered length provided by the Engineer.

G. *Furnishing Equipment for Driving Piles.* Include in the lump sum price bid for furnishing pile driving equipment the cost of furnishing all labor, materials, and equipment necessary for transporting, erecting, maintaining, replacing any ordered equipment, dismantling, and removing of the entire pile driving equipment. Include the cost of all labor, including the manipulation of the pile driving equipment and materials in connection with driving piles, in the unit price bid per linear meter for the piles to be driven.

   The Contractor may expect payment for this bid item as follows: the Agency will pay 75 percent of the amount bid after the Contractor has mobilized all necessary equipment and has started driving satisfactory piles. The Agency will pay the remaining 25 percent upon the completion of the pile driving work.

804.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) ____ Piles, furnished	m (ft)
(B) ____ Piles, driven	m (ft)
(C) ____ Piles, driven and cast-in-place	m (ft)
(D) ____ Test piles, furnished	m (ft)
(E) ____ Test piles, driven	m (ft)
(F) ____ Test piles, driven and cast-in-place	m (ft)
(G) Pile load test (static)	each
(H) Pile load test (dynamic)	each
(I) Splices	each
(J) Pile Shoes	each
(K) Furnishing Equipment for Pile Driving	lump sum

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 805
DRILLED PILES AND SHAFTS

805.1 DESCRIPTION

Construct drilled shafts of reinforced or unreinforced concrete with or without concrete bell footings.

805.2 MATERIALS

Provide materials as specified in:

Steel Casings	Sections 710 and 811
Reinforcing Steel	Section 711
Portland Cement Concrete, Class A	Subsection 713.1(B)

805.3 CONSTRUCTION

A. *Submittals:*

1. *Contractor Qualifications.* At the time of bid, submit the following information to demonstrate the qualifications of the Contractor (i.e., the drilled shaft specialty contractor):

   a. A list containing at least [3] projects completed in the last [3] years on which the Contractor installed drilled shafts of a diameter and length similar to those shown on the plans;

   b. The names and contact information of Agency's representatives who can verify the Contractor's participation on the listed projects; and

   c. A signed statement that the Contractor has inspected both the project site and all subsurface information made available by the Agency, including soil or rock samples referenced in the contract documents.

2. *Drilled Shaft Installation Plan.* No later than [30] calendar days prior to constructing drilled shafts, submit an installation plan to the Engineer for review. The Engineer will evaluate the drilled shaft installation plan for conformance with the plans, specifications, and special provisions. Within [14] days of receipt of the installation plan, the Engineer will notify the Contractor of any additional information required and any changes necessary to meet the contract requirements. Procedural approvals given by the Engineer are subject to trial in the field and do not relieve the Contractor of the responsibility to satisfactorily complete the work as detailed in the plans and specifications.

   Include the following information in the installation plan:

   a. Name and experience record of the drilled shaft superintendent who will be in charge of drilled shaft operations for the project.

   b. List of proposed equipment to be used, including cranes, drills, augers, bailing buckets, final cleaning equipment, desanding equipment, slurry pumps, core sampling equipment, tremies or concrete pumps, and casings.

   c. Details of the overall construction operation sequence and the sequence of shaft construction in bents or groups.

   d. Details of shaft excavation methods.

   e. When the use of slurry is anticipated, details of the mix design and its suitability for the subsurface conditions at the construction site, mixing and storage methods, maintenance methods, and disposal procedures.

   f. Details of methods to clean the shaft excavation.

   g. Details of reinforcement placement, including support and centralization methods.

h. Details of concrete placement, including proposed operations procedures for free fall, tremie, or pumping methods.

i. Details of casing installation and removal methods.

j. Time required to place concrete.

k. Procedures relating to hydrostatic effects that will be used to ensure the stability of the excavation is not compromised.

l. Details of any required load tests, including equipment and procedures, and recent calibration for any jacks or load cells.

m. Details of any required integrity test (cross sonic logging, Gamma-Gamma, or thermal integrity profile), test equipment, procedures and proposed Specialty Engineer to perform, log, analyze and report the test results.

n. Details of environmental control procedures used to prevent loss slurry or concrete into waterways or other protected areas.

o. Other information shown in the plans or requested by the Engineer.

B. *Trial Shaft Installation.* If required, construct an unreinforced concrete trial shaft using the methods, techniques, and equipment proposed for the project. Position the trial shaft away from production shafts in the location shown on the plans or as directed by the Engineer. Drill the trial shaft to the maximum depth of any production shaft shown in the plans. When shown on the plans, ream bells at specified trial shaft holes to establish the feasibility of belling in a specific soil stratum.

If the Contractor fails to achieve satisfactory results, the Engineer will require alterations in the equipment, construction methods, or both. Construct additional trial holes required to demonstrate the adequacy of altered methods or construction equipment at no cost to the Agency. Once the Engineer grants approval to construct production shafts, make no changes to the method or equipment used to construct the satisfactory trial shafts without the written approval of the Engineer.

Unless shown otherwise in the contract documents, fill the trial shaft holes with unreinforced concrete in the same manner that production shafts will be constructed. Cut off the concreted trial shafts 2 ft (0.6 m) below finished grade and leave in place. Restore areas disturbed as a result of the trial shafts as nearly as practical to their original condition.

C. *Protecting Existing Structures.* Use methods and procedures that will prevent caving of the shaft excavation and that will keep deformations of existing structures and utilities within the levels specified in the contract. If deformations exceed the specified amount, stop work immediately. Backfill the excavated hole if directed by the Engineer.

Monitor and control vibrations from construction activities. When specified, engage the services of a professional vibrations consultant to monitor and record vibration levels. Use vibration monitoring equipment capable of detecting velocities of [0.1 in./sec (0.25 mm/sec) or less]. If vibrations exceed the specified level, stop work immediately and take whatever measures necessary to reduce vibration levels below the specified tolerable level.

D. *Construction Sequence.* Complete excavation to the footing elevation before beginning shaft construction unless otherwise specified or approved by the Engineer. Repair disturbance to the footing areas caused by shaft installation at no cost to the Agency.

If drilled shafts are to be installed in conjunction with embankment placement, construct the drilled shaft after placing fill unless otherwise specified or approved by the Engineer.

Do not cap drilled shafts constructed prior to completing fill until the fill has been placed as near to grade as possible, leaving only the necessary work room for construction caps.

E. *General Construction Methods.* Perform excavations for shafts and bell footings, if shown on the plans, to the plan dimensions and elevations. Use the dry method, wet method, temporary casing method, or permanent casing method to produce sound, durable concrete foundation shafts free of defects. Select the method best suited to accomplish the work given the site conditions.

1. *Dry Construction Method.* The dry construction method consists of drilling the shaft excavation, removing accumulated seepage water and loose material from the excavation, placing the reinforcing cage, and placing the shaft concrete in a relatively dry excavation.

   Use the dry construction method only at sites where the groundwater table and site conditions are suitable to allow construction of the shaft in a relatively dry excavation, and where the sides and bottom of the shaft may be visually inspected by the Engineer prior to the placement of concrete.

   The Engineer will only approve use of the dry construction method when the trial shaft excavation demonstrates the following:

   a. less than 12 in. (300 mm) of water accumulates above the base over a [1]-h period when no pumping is allowed;

   b. the sides and bottom of the hole remain stable without detrimental caving, sloughing or swelling over a [4]-h period immediately following the excavation; and

   c. any loose material and water can be satisfactorily removed prior to inspection and prior to placing concrete.

   If the above criteria are not met, use the wet construction method or the casing construction method.

2. *Wet Construction Method.* The wet construction method consists of using water or slurry to maintain stability of the borehole perimeter while advancing the excavation to final depth, placing the reinforcing cage, and concreting the shaft. Where drilled shafts are to be located in open water areas, extend exterior casings from above the water elevation into the ground to protect the shaft concrete from water action during placement and curing of concrete. Install the exterior casing in a manner that will produce a positive seal at the

bottom of the casing so that no piping of water or other materials occur into or from the shaft excavation.

Use the wet construction method at sites where a dry excavation cannot be maintained for placement of the shaft concrete.

3. *Temporary Casing Construction Method.* Use this construction method at sites where the dry or wet construction methods are inadequate to prevent hole caving or excessive deformation of the hole. In this method, the casing may either be placed in a predrilled hole or advanced through the ground by twisting, driving, or vibration before being cleaned out.

4. *Permanent Casing Construction Method.* Use the permanent casing method only at the locations shown on the plans or where authorized by the Engineer.

   This method consists of placing a casing to the prescribed depth before beginning excavation, cutting off the casing and reinforcing steel at the prescribed elevation, and placing shaft concrete within the portion of the casing left in place.

F. *Excavation and Drilling Equipment.* Provide excavation and drilling equipment having adequate power, torque, and down thrust to excavate a hole of the maximum diameter and to a depth of 20 percent beyond the maximum depth shown on the plans.

Use excavation and overreaming tools of adequate design, size, and strength to perform the work shown in the plans. When the material encountered cannot be drilled using conventional earth augers with soil or rock teeth, drill buckets, grooving tools, overreaming tools, or a combination of these methods, provide special drilling equipment, such as rock core barrels, rock tools, air tools, blasting materials, and other equipment as necessary to construct the shaft excavation to the depth required. Obtain the Engineer's approval prior to performing blasting. If blasting is approved, follow the procedures specified in Subsection 805.3(H).

G. *Excavation Procedures and Conditions:*

1. *Excavating Shafts.* Excavate shafts at the locations and to the top and estimated bottom of shaft elevations, shaft geometry, and dimensions shown on the plans. Extend drilled shaft tip elevations if the Engineer determines that the material encountered is unsuitable or differs from that anticipated in the design of the drilled shaft.

2. *Drilling Log.* During the shaft excavation, maintain a drilling log containing information such as the description and approximate elevation of each soil or rock material encountered, seepage or groundwater, and remarks, including a description of the tools and drill rigs used and any modifications necessitated by changing ground conditions.

3. *Excavating Bells.* When shown in the plans, excavate bells to form the height and bearing area of the size and shape shown. Use mechanical methods to excavate the bell. Provide any drilled shaft concrete over the theoretical amount required to fill the excavation for the bells and shafts dimensioned on the plans at no cost to the Agency.

4. *Overreaming.* Perform sidewall overreaming if the Engineer determines that the sidewall of the hole has either softened due to excavation methods, swelled due to delays in concreting, or degraded because of slurry cake buildup. Depending on the condition of the sidewall, overream the shaft diameter by increasing the diameter of the drilled shaft between 1 and 6 in. (25 and 75 mm). The Engineer will direct the extent of sidewall overreaming. The Contractor may accomplish overreaming with a grooving tool, overreaming bucket, or other approved equipment. Bear costs associated with both sidewall overreaming and additional shaft concrete placement.

5. *Disposing of Excavated Materials.* Dispose of excavated materials removed from the shaft excavation as specified in Subsection 203.3(A).

6. *Removing Obstructions.* Remove surface and subsurface obstructions encountered at drilled shaft locations as specified in Section 202 and as follows. Use special procedures, tools, or both if the hole cannot be advanced using conventional augers, drilling buckets, underreaming tools, or some combination thereof. Such special procedures and tools may include chisels, boulder breakers, core barrels, air tools, hand excavation, temporary casing, and increasing the hole diameter. Do not perform blasting without the written approval of the Engineer.

7. *Lost Tools.* Do not consider drilling tools lost in the excavation as obstructions. Promptly remove lost tools at no cost to the Agency. Costs due to lost tool removal include costs associated with the repair of hole degradation resulting from the removal operation or the excessive time the hole remains open.

8. *Inspecting Cofferdams.* On projects with cofferdams, provide a qualified diver to inspect the cofferdam conditions when a seal is required for construction. Prior to placing the concrete seal, direct the diver to inspect the cofferdam interior periphery, including each sheeting indentation and around each drilled shaft to ensure no layers of mud or undesirable material remain above the planned bottom elevation of seal.

9. *Safety Measures.* Do not allow workers to enter the shaft excavation unless both a suitable casing has been installed and the water level has been lowered and stabilized below the level to be occupied, and adequate safety equipment and procedures have been provided to workers entering the excavation.

10. *Soil Sampling.* Take soil samples or rock cores where shown on the plans or as directed by the Engineer to determine the character of the material directly below the completed shaft excavation. Extract soil samples with a split spoon sampler or undisturbed sample tube. Cut rock cores with an approved double or triple tube core barrel to a minimum of 10 ft (3 m) below the bottom of the drilled shaft excavation either before excavating or at the time the shaft excavation is approximately complete. The Engineer may require the Contractor to extend the depth of coring up to a total depth of 20 ft (6 m).

    Measure, visually identify, and describe in a field log rock core and standard penetration test samples. Place samples in suitable containers, identified by the shaft location, elevation, and project number, and deliver to the Engineer along with the field log. If the samples are acquired when the excavation has reached the planned elevation of the shaft base, deliver the field log and samples immediately to the Engineer upon completion, and the Engineer will inspect the material and render a decision as to the suitability of the bearing stratum without delay. If the samples are acquired prior to excavation, deliver the samples and field log to the Engineer within 24 h after completing the exploration. The Engineer will then inspect the samples or cores and determine the final depth of required excavation based on the Engineer's evaluation of the material's suitability. Submit two copies of the final typed log to the Engineer at the time the shaft excavation is completed and accepted by the Engineer.

H. *Excavating Shafts in Rock by Blasting.* Only perform blasting with the approval of the Engineer.

1. *Blasting Plan.* Submit a blasting plan to the Engineer for review and approval at least two weeks before starting drilling and blasting operations or at any time the Contractor proposes changes to the drilling and blasting method. Include in the blasting plan the full details of the drilling and blasting patterns and the proposed controls for controlled perimeter and production blasting. At a minimum, include the following information in the blasting plan:

    a. Plan and section views of the proposed shaft excavation showing the proposed drill pattern in the rock, burden from perimeter hole to adjacent production holes, production blast hole configuration with dimensions, and blast hole diameter lift height.

    b. Loading diagram showing the types and amounts of explosives, primers, initiators, and other blasting components proposed for excavations.

    c. Initiation sequence of blast holes, including delay times and delay systems.

    d. Manufacturer's data sheets for explosives, primers, and initiators to be used on the project.

    The Engineer's review of the blast plan does not relieve the Contractor of the responsibility for the accuracy and adequacy of the plan when implemented in the field.

2. *Controlled Perimeter Blasting.* When using controlled perimeter blasting, perform the following activities:

    a. Prior to starting full-scale blasting operations, demonstrate the adequacy of the proposed plan by drilling, blasting, and excavating a short test shaft approximately 4 ft (1.2 m) in depth. If the test shaft using the proposed blast plan does not produce the intended results to the satisfaction of Engineer, make modifications to the plan until the intended results are obtained.

    b. Space the perimeter holes along the periphery of the shaft at 18 in. (450 mm) center-to-center. Depending on the actual results obtained in the test shaft, increase or decrease the spacing as required to obtain the intended results.

c. Ensure the burden distance from the perimeter holes to the adjacent production holes is at least 18 in. (450 mm). If the perimeter hole spacing is modified from the initial 18 in. (450 mm), ensure the ratio between the perimeter hole spacing and burden distance to the adjacent production holes is at least 1:1.

d. Ensure the diameter of the perimeter blast holes is at least $1^1/_4$ in. (32 mm) and at most 3 in. (75 mm).

e. Ensure the height of each excavation lift within the shaft does not exceed one-half the diameter of the shaft and under no circumstances exceeds 4 ft (1.2 m) in height.

f. Control the drilling of the perimeter holes by using proper equipment and techniques to ensure that the deviation of each perimeter hole from the neat line of the shaft does not exceed 3 in. (75 mm).

g. Use a delay sequence for the production holes that is from the center of the shaft outward towards the perimeter.

h. Detonate the perimeter holes last, after all other blasting has been completed in each excavation lift. The Contractor may detonate these perimeter holes on a delay basis during the production blasting or as a separate shot after the production blasting.

i. Before placing explosive charges in the drill holes, ensure that each drill hole is free of obstructions for its entire length. Take the necessary precautions to ensure that the placing of charges will not cause caving of materials from the walls of the drill holes.

j. Ensure that the maximum diameter of explosives used in the perimeter holes is no greater than one-half the diameter of the perimeter hole. For perimeter blasting, use small diameter, continuous column explosives especially manufactured for this type of controlled blasting. Do not use bulk ANFO (ammonium nitrate fuel oil) or factional portions of standard explosive cartridges affixed to detonating cord (string load) in the perimeter blast holes.

I. *Casings.* Furnish steel, smooth, clean, and watertight casings of ample strength to withstand both handling and driving stresses and the pressure of both concrete and the surrounding earth materials. Ensure that the outside diameter of the casing is not less than the specified diameter of the shaft, and that the outside diameter of any excavation made below the casing is not less than the specified diameter of the shaft. The Agency will not provide extra compensation for concrete required to fill an oversized casing or oversized excavation. Remove casings, except permanent casings, from shaft excavations. Leave in place any length of permanent casing installed below the shaft cutoff elevation.

When the shaft extends aboveground or through a body of water, the Contractor may form the portion exposed aboveground or through a body of water with removable casing, unless permanent casing is specified. Strip removable casing from the shaft in a manner that will not damage the concrete. Remove casings once the concrete has attained sufficient strength, provided curing of the concrete continues for a 72-h period, the shaft concrete is not exposed to salt water or moving water for seven days, and the concrete reaches a compressive strength of at least 2,500 psi (17.2 MPa), as determined from tests performed on concrete cylinders.

1. *Temporary Casing.* Consider subsurface casing to be temporary unless specifically shown as permanent casing in the contract documents. Remove temporary casing before completing the concreting of the drilled shaft. Installation of casing may require telescoping, predrilling with slurry, overreaming to beyond the outside diameter of the casing, or a combination of these methods.

   If electing to remove a casing and substitute a longer or larger diameter casing through caving soils, either stabilize the excavation with slurry or backfill before installing the new casing. The Engineer may approve other methods to control the stability of the excavation and protect the integrity of the foundation material.

   Before withdrawing the casing, ensure that the level of fresh concrete in the casing is a minimum of 5 ft (1.5 m) above either the hydrostatic water level in the formation or the level of drilling fluid in the annular space behind the casing, whichever is higher. While withdrawing the casing, take care to maintain an adequate level of concrete within the casing to ensure that fluid trapped behind the casing is displaced upward and discharged at the ground surface without contaminating or displacing the shaft concrete.

   The Engineer will consider temporary casings that have become bound or fouled during shaft construction and that cannot be practically removed as defective work. Improve such defective shafts to the satisfaction of the Engineer. Such improvement may consist of removing the shaft concrete and extending the shaft deeper to compensate for loss of frictional capacity in the cased zone, providing straddle shafts to compensate for capacity loss, or providing a replacement shaft. Perform corrective measures, including redesign of footings caused by defective shafts, to the satisfaction of the Engineer and at no cost to the Agency. The Agency will not pay for casing that remains in place.

2. *Permanent Casing.* Install permanent casing only when required by the contract documents. Provide a continuous casing between the top and bottom elevations prescribed in the plans. After completing installation, cut off the permanent casing at the prescribed elevation and install the necessary reinforcing steel and concrete in the casing.

J. *Slurry.* When using slurry in the drilling process, use mineral or polymer slurries unless other drilling fluids are approved in writing by the Engineer.

During construction, maintain the level of slurry at a height sufficient to prevent caving of the hole. If a sudden significant loss of slurry to the hole occurs, stop construction of that foundation until either a method to stop slurry loss or an alternate construction procedure has been approved by the Engineer.

Prevent the slurry from "setting up" in the shaft by using methods such as agitation, circulation, adjusting the properties of the slurry, or a combination of these methods.

Ensure that a heavily contaminated slurry suspension, which could impair the free flow of concrete, has not accumulated in the bottom of the shaft.

When slurry samples are found to be unacceptable, take whatever action is necessary to bring the slurry within specification requirements.

Provide a qualified professional testing laboratory approved by the Engineer to perform tests using suitable equipment and procedures on the drilling fluid. Perform fluid tests to verify the density, viscosity, pH and sand content on the premixed slurry supplied to the shaft excavation and on the fluid and slurry prior to placing concrete. Furnish reports of the required tests signed and sealed by an authorized representative from the qualified laboratory to the Engineer on completion of each drilled shaft.

If, in the opinion of the Engineer, the slurry construction method fails, discontinue the method and propose an alternate method for approval by the Engineer.

Dispose of waste slurry offsite in suitable areas according to the applicable local, state, and federal laws.

1. *Mineral Slurry.* Use a mineral slurry having both a mineral grain size that will remain in suspension and sufficient viscosity and gel characteristics to transport excavated material to a suitable screening system. Ensure the percentage and specific gravity of the material used to make the mineral suspension is sufficient to maintain the stability of the excavation and to allow proper concrete placement.

    a. *Mixing and Storing.* Premix mineral slurry thoroughly with clean fresh water, allowing for adequate time, according to the manufacturer's recommendation, for hydration prior to introduction into the shaft excavation. Provide slurry tanks of adequate capacity for slurry circulation, storage, and treatment. The Contractor may use excavated slurry pits in lieu of slurry tanks with the written permission of the Engineer.

    b. *Desanding.* Provide desanding equipment as necessary to control slurry sand content to less than 4 percent by volume at any point in the borehole at the time the slurry is introduced, including situations in which temporary casings will be used. Perform Sand Content Tests in accordance with API RP 13B (R2016) [Identical to ISO 10414-1:2008] to verify the maximum sand content requirement is met. The Agency will not require desanding for sign post or lighting mast foundations unless shown in the plans or special provisions.

    c. *Control Tests.* Conduct control tests to ensure the mineral slurry meets the requirements specified in Table 805.3-1. Conduct a minimum of four sets of tests during the first 8 h of slurry use. When the results show consistent behavior, the Contractor may decrease the testing frequency to one set for every 4 h of slurry use. Perform tests when the slurry temperature is above 40°F (4.5°C).

Table 805.3-1. Requirements for Mineral Slurry (Sodium Bentonite or Attapulgite in Fresh Water)

Property	At Time of Slurry Introduction	In Hole at Time of Concreting	Test Method
Density[a]	64.3 to 69.1 lb/ft^3 (10.1 to 10.8 kN/m^3)	64.3 to 75. lb/ft^3 (10.1 to 11.8 kN/m^3)	Density Balance
Viscosity[b]	28 to 45 sec/quart	28 to 45 sec/quart	Marsh Funnel
pH	8 to 11	8 to 11	pH paper, pH meter

a Increase by 2 lb/ft^3 (0.31 kN/m^3) in salt water.

b Standard measurements are in seconds per quart, not seconds per liter. 1 sec/quart is equivalent to 1.6 sec/L, but 1 quart, not 1 liter, of slurry should be used in the test.

If desanding is required, ensure sand content does not exceed 4 percent by volume at any point in the borehole as determined by the American Petroleum Institute (API) sand content test when the slurry is introduced.

d. *Required Fluid Level.* During construction, maintain the level of mineral slurry in the excavation at a level not less than 4 ft (1.2 m) above the highest expected piezometric pressure head along the depth of the shaft.

2. *Polymer Slurry.* The Contractor may use a natural or synthetic polymeric slurry product approved for use by the Agency. Ensure slurry properties at the time of mixing and at the time of concreting meet the manufacturer's written recommendations. Ensure that the sand content at the base of the drilled shaft excavation does not exceed 1 percent when measured according to Method API RP 13B (R2016), Section 8, immediately prior to concreting.

a. *Blended-Mineral Polymer Slurry.* If using a blended mineral-polymer slurry, submit a detailed report specific to the project, prepared and signed by a qualified slurry consultant, describing the slurry materials, the mix proportions, mixing methods, and quality control methods.

b. *Slurry Management Plan.* Prepare and submit a slurry management plan detailing provisions for controlling the quality of the slurry, including tests to be performed, the frequency of those tests, the test methods, and the maximum or minimum property requirements that must be met to ensure that the slurry meets its intended functions given the subsurface conditions at the construction site and the construction methods that are to be used. Include in the plan a set of the slurry manufacturer's written recommendations and the following tests, as a minimum:

- Density test (API RP 13B (R2016), Section 4),
- Viscosity test (Marsh funnel and cup, API RP 13B (R2016), Section 6.2, or approved viscometer, Section 6.3),
- pH test (pH meter, pH paper, API RP 13B (R2016), Section 11), and
- Sand content test (API sand content kit, API RP 13B (R2016), Section 9).

c. *Required Fluid Level.* During construction, maintain the level of mineral-polymer blended slurry in the excavation at a level not less than 4 ft (1.2 m) above the highest expected piezometric pressure head along the depth of the shaft. Maintain the level of polymer slurry at a level not less than 6 ft (1.8 m) above the highest expected piezometric pressure head along the shaft.

3. *Water as a Drilling Fluid.* Prior to placing concrete in a shaft excavation, take slurry samples using an approved sampling tool designed to sample over a depth range of 12 in. or less. Extract slurry samples from the base of the shaft and at intervals not exceeding [10 ft (3 m)] up the slurry column in the shaft, to verify the shaft has the acceptable values for density, viscosity, pH and sand content specified in 805-03(J)(1) and 805-03(J)(2) if polymer slurries are used.

   When slurry samples are found to be unacceptable, take whatever action is necessary to bring the slurry within specification requirements. Do not pour concrete until the slurry in the hole is re-sampled and test results produce acceptable values.

   If approved by the Engineer, the Contractor may use water as the drilling fluid. Ensure water used as the drilling fluid meets all requirements specified in Table 805.3-1, except that the maximum density shall not exceed 70 lb/ft^3 (11 kN/m^3) and the minimum density values indicated in Table 805.3-1 do not apply.

K. *Inspecting Excavated Shafts.* Provide equipment for checking the dimensions and alignment of each shaft excavation. Determine the dimensions and alignment under the supervision of the Engineer. Measure final shaft depths with a suitable weighted tape or other approved methods after final cleaning.

Ensure that the following requirements are met, as applicable:

1. A minimum of 50 percent of the base of each shaft has less than $^1/_2$ in. (12 mm) of sediment.

2. The maximum depth of sediment or debris at any place on the base of the shaft does not exceed 1$^1/_2$ in. (38 mm).

3. For dry excavations, the maximum depth of water does not exceed 3 in. (75 mm) prior to the concrete pour.

4. For dry shafts, the sidewalls are visually free of cuttings that may have been smeared on the walls during the removal and insertion of drilling tools.

   The Engineer will determine shaft cleanliness by visual inspection for dry shafts or other methods deemed appropriate for wet shafts.

L. *Construction Tolerances.* Construct drilled shafts with the following tolerances:

1. Maintain the drilled shaft position within 3 in. (75 mm) of the plan position in the horizontal plane at the plan elevation for the top of the shaft.

2. Limit the variation of the vertical alignment of the shaft excavation from the plan alignment to no more than $^1/_4$ in./ft (20 mm/m) of depth. Limit the variation of the alignment of a battered shaft excavation to no more than $^1/_2$ in./ft (40 mm/m) of distance along the axis of the shaft from the prescribed batter.

3. Keep the top of the reinforcing steel cage within 6 in. (150 mm) above and 3 in. (75 mm) below plan position.

4. All casing diameters shown on plans refer to outside diameter (O.D.) dimensions. Ensure dimensions of casings meet American Pipe Institute tolerances applicable to regular steel pipe. When approved, the Contractor may provide a casing larger in diameter than that shown in the plans.

5. Excavate the bells to the bearing area and height shown on the plans. Ensure the actual diameter of the bells does not exceed three times the specified shaft diameter. The Contractor may vary other plan dimensions to accommodate equipment with the Engineer's approval.

6. Ensure the top elevation of the shaft is within plus 1 in. (25 mm) or minus 3 in. (75 mm) of the plan top of shaft elevation.

7. Use excavation equipment and methods to ensure the completed shaft excavation has a planar bottom. Ensure the cutting edges of excavation equipment are normal to the vertical axis of the equipment within a tolerance of $\pm^3/_8$ in./ft (30 mm/m) of diameter.

The Engineer will consider drilled shaft excavations and completed shafts not constructed within the required tolerances as unacceptable. Furnish materials and perform the work necessary, including engineering analysis and redesign, to correct out-of-tolerance drilled shaft excavations to the satisfaction of the Engineer, at no cost to the Agency and without an extension to the completion date of the project.

M. *Constructing and Placing Reinforcing Steel Cage.* Immediately after the Engineer inspects and approves the shaft excavation, but prior to placing concrete, assemble and place as a unit the reinforcing steel cage, consisting of longitudinal bars, ties, cage stiffener bars, spacers, and centralizers. Remove loose material from the bottom of the excavation before placing reinforcing steel cage. Remove internal stiffeners as the cage is placed in the borehole so as not to interfere with the placement of concrete.

Tie and support the reinforcing steel so that it remains within tolerance of its intended position, as specified in Subsection 805.3(L). Use concrete spacers or other approved noncorrosive spacing devices at intervals not exceeding 10 ft (3 m) along the shaft to ensure concentric spacing for the entire cage length. Use a minimum of one spacer per 30 in. of circumference of cage with a minimum of three at each level. Construct spacers of approved material equal in quality and durability to the concrete specified for the shaft. Construct spacers of adequate dimensions to ensure a minimum of 3-in. (75-mm) annular space between the outside of the reinforcing cage and the side of the excavated hole. Provide approved cylindrical concrete feet (bottom supports) to ensure that the bottom of the cage is maintained at the proper distance above the base.

N. Check the elevation of the top of the steel cage before and after placing concrete. The Engineer will consider drilled shafts to be defective if the upward displacement of the rebar cage exceeds 2 in. (50 mm) or if the downward displacement exceeds 6 in. (150 mm) per 20 ft (6 m) of shaft length. Correct defective shafts to the satisfaction of the Engineer at no cost to the Agency. Do not construct additional shafts until the rebar cage support is modified in a manner satisfactory to the Engineer.

O. *Placing Concrete.* Place concrete as soon as possible after placement of the reinforcing steel cage. Continuously place the concrete in the shaft from the bottom to the top elevation of the shaft. Continue to place concrete after the shaft excavation is filled until good quality concrete is evident at the top of the shaft. Place concrete either by free fall (for dry holes only) or through a tremie or concrete pump. Ensure concrete placed by free fall falls directly to the base without contacting either the rebar cage or hole sidewall. The Contractor may use drop chutes to direct concrete to the base during free fall placement. Inspect hole for debris after placement.

P. Limit the time spent placing concrete to the maximum allowable elapsed time for placing concrete as determined by the slump loss test. The elapsed time for placing drilled shaft concrete includes the concrete mixing and transit time, the concrete placement time, the time required to remove any temporary casing that causes the concrete to flow into the space previously occupied by the casing, and the time required to insert any required column steel, bolts, weldments, etc. The allowable elapsed time is defined as the maximum elapsed time within which the concrete will maintain a slump of at least 5 in. (125 mm). Only use admixtures, such as water reducers, plasticizers, and retarders, in the concrete mix if specified in the contract documents. Maintain a minimum slump of 5 in. (125 mm) throughout the elapsed time. Use materials to produce and maintain the required slump through the elapsed time. Prior to beginning drilled shaft construction, provide slump loss tests results by an approved testing laboratory that demonstrate to the Engineer that the concrete will maintain a 5 in. (125 mm) or greater slump for the anticipated elapsed time. Conduct slump loss tests using concrete and ambient temperatures appropriate for the site conditions.

1. *Tremies.* The Contractor may use tremies to place concrete in either wet or dry holes. Use tremies consisting of a tube of sufficient length, weight, and diameter to discharge concrete at the shaft base elevation. Ensure that the tremie contains no aluminum parts that will have contact with the concrete. Ensure that the inside diameter of the tremie is at least 6 times the maximum size of aggregate used in the concrete mix, but not less than 10 in. (250 mm). Keep the inside and outside surfaces of the tremie clean and smooth to allow both flow of concrete and unimpeded withdrawal during concreting. Ensure that the wall thickness of the tremie is adequate to prevent crimping or sharp bends that could restrict concrete placement.

   Ensure that the tremie used for wet excavation concrete placement is watertight and of enough weight that will not float and can reach the bottom of the excavation by its own weight. Do not begin underwater or under-slurry placement until the tremie is placed to the shaft base elevation. Keep the concrete separate from the water or slurry prior to its discharge. The Contractor may use valves, bottom plates, or plugs for this purpose if the concrete discharge can begin within one tremie diameter of the base of the drilled shaft. The Contractor may either remove plugs from the excavation or use plugs of a material, approved by the Engineer that will not cause a defect in the shaft if not removed. Construct the discharge end of the tremie to allow free radial flow of concrete during placement operations. Ensure that the tremie discharge end is immersed in at least 5 ft (1.5 m) of concrete at all times after starting the flow of concrete. Ensure the flow of concrete is continuous. Maintain the level of concrete in the tremie above the level of slurry or water in the borehole at all times to prevent water or slurry intrusion into the shaft concrete.

If, at any time during the concrete pour, the tremie line orifice is removed from the fluid concrete column and discharges concrete above the rising concrete level, consider the shaft defective. In such case, remove the reinforcing cage and concrete, complete any necessary sidewall removal directed by the Engineer, and repour the shaft. Perform this corrective work at no cost to the Agency.

2. *Pumped Concrete.* The Contractor may use concrete pumps and lines for concrete placement in either wet or dry excavations. Provide pump lines of a minimum 4-in. (100-mm) diameter. Construct lines with watertight joints. Do not place concrete until the pump line discharge orifice is at the shaft base elevation.

   For wet excavations, use a plug or similar device to separate the concrete from the fluid in the hole until pumping begins. The Contractor may either remove plugs from the excavation or use plugs of a material, approved by the Engineer that will not cause a defect in the shaft if not removed.

   Ensure the discharge orifice remains at least 5 ft (1.5 m) below the surface of the fluid concrete. When lifting the pump line during concreting, temporarily reduce the line pressure until the orifice has been repositioned at a higher level in the excavation.

   If, at any time during the concrete pour, the pump line orifice is removed from the fluid concrete column and discharges concrete above the rising concrete level, consider the shaft defective. In such case, remove the reinforcing cage and concrete, complete any necessary sidewall removal directed by the Engineer, and repour the shaft. Perform this corrective work at no cost to the Agency.

3. *Drop Chutes.* The Contractor may use drop chutes to direct placement of free-fall concrete in excavations where the maximum depth of water does not exceed 3 in. (75 mm). Do not perform free-fall placement in wet excavations. The Contractor may use drop chutes consisting of a smooth tube of either one-piece construction or sections that can be added and removed. Alternatively, the Contractor can use as a drop chute a hopper with a short tube to direct the flow of concrete. Concrete may be placed either through the hopper at the top of the tube or through side openings as the drop chute is retrieved during concrete placement. If concrete placement causes the shaft excavation to cave or slough, or if the concrete strikes the rebar cage or sidewall, reduce the height of free fall or reduce the rate of concrete flow into the excavation, or both.

If caving or sloughing of the borehole walls occurs during free-fall placement of concrete, consider the shaft defective. In such case, remove the reinforcing cage and concrete, complete any necessary sidewall removal directed by the Engineer, and repour the shaft. Perform this corrective work at no cost to the Agency. If concrete placement cannot be satisfactorily accomplished by free fall in the opinion of the Engineer, use either tremie or pumping techniques for the pour.

Q. *Nondestructive Evaluation*. When called for in the contract documents or when requested by the Engineer, evaluate the structural integrity of completed drilled shafts using nondestructive testing techniques, such as (a) downhole tests conducted in access tubes, including cross-hole acoustic tests and backscatter gamma ray (gamma-gamma) tests, (b) sonic echo tests, or (c) thermal integrity profiling (TIP). The Agency will specify the type of testing, if any, to be used and the specific shafts on which to perform the testing. Perform the required testing and submit reports of the testing to the Engineer in a timely manner. Conduct testing after the concrete has cured for at least 72 h. Perform CSL in accordance with ASTM D6760. When required, perform Gamma-Gamma Logging (GGL) testing in accordance with Caltrans CTM 233 test method. When TIP is specified, conduct this test between 24 h and 72 h after concrete placement, in accordance with ASTM D7949.

Employ a registered professional engineer, who has been qualified by the State, to perform, evaluate, and report the tests. Submit the test report on any given shift to the Engineer within 3 working days of performing the test on that shaft. Submit a signed and sealed report to the Engineer that includes the testing and analysis results. Meet the reports requirement specified in the ASTM and CTM methods indicated above. In addition, include in the report a professional opinion that states whether the drilled shaft is free from integrity defects and whether the Specialty Engineer submitting the report recommends the shaft for acceptance.

R. Within 3 working days of receiving the test report, the Engineer will evaluate and analyze the results and provide the Contractor with a response regarding the acceptability of the shaft that was tested.

The Contractor may continue to construct drilled shafts before receiving the Engineer's notice of acceptance of the tested shaft or shafts. If, however, the Engineer finds the tested shaft(s) to be unacceptable, repair the unacceptable shaft to the satisfaction of the Engineer and at no cost to the Agency. With regard to shafts constructed after the unacceptable shaft was constructed and tested, the Contractor may either prove their acceptability to the satisfaction of the Engineer, at no cost to the Agency, or will cease all drilled shaft construction until a new construction procedure has been proposed by the Contractor and accepted by the Engineer. In this latter case, repair those drilled shafts constructed after the unacceptable shaft to the satisfaction of the Engineer and at no cost to the Agency. Submit a written plan to the Engineer regarding the repair of defects and revisions to construction procedures. If the plans involve changes to the structural design of the shafts or shaft caps, or to the geometry of the shafts, engage a registered professional engineer to perform any necessary redesign at no cost to the Agency.

The Engineer may require testing of additional shafts. If the testing of the additional shaft(s) indicates defects in these shafts, bear the costs of testing and repairing the defective shafts. If the testing reveals no defects, the Agency will bear the costs of testing the non-defective shaft.

1. *Tests in Access Tubes.* Place access tubes for crosshole acoustic or gamma-gamma logging or Thermal Integrity Profiling (TIP) on each reinforcing cage designated in the contract documents in the position and at the frequency shown on the plans. Provide access tubes for crosshole acoustic logging of Schedule 40 steel pipe, with at least a $1^1/_2$-in. (38-mm) inside diameter, meeting ASTM A53/A53M, Grade A or B, Type E, F, or S. For gamma-gamma testing, provide access tubes of Schedule 40 polyvinyl chloride (PVC) pipe with an inside diameter of at least 2 in. (50 mm). For TIP tests provide steel access tubes as specified for CSL above, or use thermal wires when these are required in the plans. Install access tubes full length from the tip of shaft to a point high enough above top of shaft to allow testing, but not less than 30 in. above the top of the drilled shaft, ground surface or water surface, whichever is higher. Equally space tubes around circumference of drilled shaft. Securely tie access tubes to the inside of the reinforcing cage and align tubes to be parallel to the vertical axis of the center of the cage.

   Ensure that the access tubes are free from loose rust, scale, dirt, paint, oil and other foreign material. Couple tubes as required with threaded couplers, such that inside of tube remains flush. Seal the bottom and top of the tubes with threaded caps. The tubes, joints and bottom caps shall be watertight. Seal the top of the tubes with lubricated, threaded caps sufficient to prevent the intrusion of foreign materials. Stiffen the cage sufficiently to prevent damage or misalignment of access tubes during the lifting and installation of the cage.

   Insert simulated or mock probes in each access tube prior to concreting to ensure the serviceability of the tube. Fill access tubes with clean potable water and recap prior to concreting. Repair or replace any leaking, misaligned or unserviceable tubes as in a manner acceptable to the Engineer prior to concreting. Immediately after concreting, check the water levels in the access tubes and refill as necessary.

   Prior to beginning downhole logging or testing, ensure that the test probes can pass through every tube to the bottom. If a tube is obstructed, core a hole, at no cost to the Agency, within the drilled shaft near the obstructed tube to the depth of the obstructed tube that is large enough to accommodate the probe for the full length of the hole. Obtain the Engineer's approval of the coring equipment, coring procedure, and location of the core hole prior to beginning the coring process. Use a coring method that provides for complete core recovery and minimizes abrasion and erosion of the core. Place the core hole at a position in the shaft that will not damage the reinforcing steel in the shaft. Identify the core hole, and any voids or defects, on a log and submit to the Engineer. Preserve cores and make available for inspection by the Engineer. Treat the core hole as an access tube and begin downhole testing. If a defect is observed, pay for coring costs and repair the shaft at no cost to the Agency. If no defects are observed, the Agency will pay for coring costs.

After completing all tests involving access tubes, fill the access tubes and core holes with grout having strength properties equivalent to or better than those of the drilled shaft concrete.

2. *Sonic Echo Tests.* The Contractor may perform sonic echo (pulse-echo) tests instead of downhole tests involving access tubes at the discretion of the Engineer. Ensure equipment and procedures used for sonic echo tests have a resolution capable of detecting defects occupying no more than 30 percent of the cross-sectional area of the drilled shaft and that are no greater than 6 in. (150 mm) thick. Indicate this resolution in the test report submitted to the Engineer. It is not necessary to construct access tubes prior to constructing the drilled shaft. If a defect is observed in a sonic echo test, pay for all testing costs and repair the shaft at no cost to the Agency. If no defects are observed, the Agency will pay for coring costs.

S. *Drilled Shaft Load Tests.* When the contract documents include static load testing of shafts, complete all load tests before constructing any production drilled shafts. Allow 5 working days from the last load test for the Engineer to analyze the load test data and make final determinations of base elevations. Do not construct production shafts until the Engineer provides authorization to proceed. Perform load tests at the locations shown on the plans or as directed by the Engineer. Unless otherwise specified, apply to the load test shafts the maximum test load corresponding to failure, as defined as a deflection of the shaft head equal to 5 percent of the shaft diameter.

Do not begin static load testing until the concrete has attained a compressive strength of 3,400 psi (23.4 MPa) as determined from cylinder breaks. Load test drilled shafts in the order directed by the Engineer. Perform static load tests according to ASTM D1143/D1143M (compression test quick test method) and ASTM D3966/D3966M (lateral test) or as modified herein. Supply the equipment necessary to conduct the static test, including equipment to measure loads and deflections. Ensure the loading frame apparatus can safely accommodate the maximum load to be applied.

Notify the Engineer within 10 calendar days of contract award of the load testing schedule. If nondestructive testing is to be performed as specified in Subsection 805.3(Q), ensure the schedule allows at least 1 working day for the Engineer's analysis of the nondestructive testing results prior to load testing.

Provide load cells of adequate size to measure the maximum load applied during the drilled shaft load tests. Equip the load cell with an adequate readout device. Before beginning load testing, furnish a certificate of calibration for the load cell from an approved testing laboratory. Ensure the calibration was performed for the range of the proposed loading within the two months preceding the load tests. Ensure the certified accuracy of the load cell is within 1 percent of the true load.

After testing is complete, cut off the test shafts (and any reaction shafts) at an elevation 2 ft (0.6 m) below the finished ground surface. The portion of the shafts cut off and removed are the property of the Contractor.

805.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure drilled shafts by the length in ft (m) from the plan top of shaft elevation to the final bottom of shaft elevation. The Engineer will not separately measure excavation or blasting.

B. The Engineer will determine quantity of concrete for bells based on the volume of concrete outside the plan dimensions of the shaft.

C. The Engineer will measure trial shafts by the length in ft (m) from the existing ground surface elevation at the center of the trial shaft hole prior to drilling to the authorized bottom elevation of the hole.

D. The Engineer will measure permanent casing by the length in ft (m) of each size casing used, as measured along the casing from the top of the shaft elevation or the top of casing, whichever is lower, to the bottom of the casing.

E. The Engineer will measure exploration holes by the length in ft (m) from the bottom of the shaft to the bottom of the exploration hole.

F. The Engineer will measure load tests by the number of load tests completed according to the specified loading procedures and to the designated maximum load shown on the plans. Payment will include all costs related to the performance of the load test and for the reporting of procedures and results.

G. The Engineer will measure nondestructive evaluation tests on a lump sum basis per shaft tested. The lump sum payment will include costs for mobilization, testing, analysis, and reporting.

H. The Engineer will quantify the number of hours of work per obstruction, as designated by the Engineer, required to remove the obstruction and resume excavation.

805.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Drilled shaft, furnished (size ___)	ft (m)
(B) Bells	cy^3 (m^3)
(C) Trial shafts, furnished (size ___)	ft (m)
(D) Trials bells, furnished (size ___)	cy^3 (m^3)
(E) Permanent casing (size ___)	ft (m)
(F) Exploration holes	ft (m)
(G) Load test	each
(H) Nondestructive evaluation	lump sum per drilled shaft
(I) Obstructions	h

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 806 GROUND ANCHORS

806.1 DESCRIPTION

Design, furnish, install, test, and stress permanent cement-grouted ground anchors that will develop the load-carrying capacity indicated on the plans.

806.2 MATERIALS

Provide materials as specified in Section 718.

806.3 CONSTRUCTION

A. *Submittals:*

1. *Contractor Qualifications.* At the time of bid, submit the following information to demonstrate the qualifications of the Contractor:

    a. a list containing at least [5] projects completed in the last [5] years on which the Contractor designed and installed ground anchors;

    b. the names and contact information of Agency's representatives who can verify the Contractor's participation on the listed projects;

c. name and experience record, indicating a minimum of three years of experience, of the engineer proposed to design and oversee the construction of the anchor system; and

d. names and experience records, indicating a minimum of one year experience in installing permanent ground anchors with the Contractor's organization, of the onsite superintendent and drill operators.

Do not substitute any of the proposed individuals without the written approval of the Engineer. The Engineer will approve or reject the Contractor's qualifications and staff within 15 working days after receiving the submission. Do not start work on the anchored wall system or order materials until the Engineer approves the qualifications submittal. The Engineer may suspend the work if the Contractor substitutes unqualified personnel for the approved personnel during construction. If work is suspended due to the substitution of unqualified personnel, assume liability for additional costs resulting from the suspension of work.

2. *Design and Working Drawings.* Submit working drawings and calculations to the Engineer for review and approval at least 30 working days before the start of the ground anchor work. Include the following information in the submittal:

   a. A ground anchor schedule providing:

      i. Ground anchor number;

      ii. Ground anchor design load;

      iii. Type and size of tendon;

      iv. Minimum total anchor length;

      v. Minimum bond length;

      vi. Minimum tendon bond length; and

      vii. Minimum unbonded length.

   b. A drawing of the ground anchor tendon and the corrosion protection system including details for the following:

      i. Spacers and their location;

      ii. Centralizers and their location;

      iii. Unbonded length corrosion protection system;

      iv. Bond length corrosion protection system;

      v. Anchorage and trumpet; and

      vi. Anchorage corrosion protection system.

c. Certificates of Compliance for the following materials, if used, stating that the material or assemblies provided will comply fully with the requirements of the contract.

   i. Prestressing steel, strand or bar;

   ii. Portland cement;

   iii. Prestressing hardware;

   iv. Bearing plates; and

   v. Corrosion protection system.

The Engineer will approve or reject the Contractor's working drawings and design submission within 30 working days after receipt of the submission. Approval of the design submittal does not relieve the Contractor of its responsibility to successfully complete the work.

3. *Mill Test Reports.* Submit mill test reports for the prestressing steel and the bearing plate steel to the Engineer for review and approval. The Engineer may require samples of any ground anchor material intended for use on the project. The Engineer will approve or reject the prestressing steel and bearing plate steel within 5 working days after receipt of the test reports. Do not incorporate the prestressing steel and bearing plates in the work without the Engineer's approval.

4. *Calibration Data.* Submit calibration data for each test jack, load cell, primary pressure gauge, and reference pressure gauge to be used to the Engineer for review and approval. The Engineer will approve or reject the calibration data within 5 working days after receipt of the data. Do not begin testing until the Engineer has approved the jack, load cell, primary pressure gauge, and reference pressure gauge calibrations.

5. *Reports and As-Built Drawings.* Within 20 calendar days after completing the ground anchor work, submit a report to the Engineer containing the following information:

   a. Prestressing steel manufacturer's mill test reports for the tendons incorporated in the installation;

   b. Grouting records indicating the cement type, quantity injected, and the grout pressures;

   c. Ground anchor test results and graphs; and

   d. As-built drawings showing the location and orientation of each ground anchor, anchor capacity, tendon type, total anchor length, bond length, unbonded length, and tendon bond length as installed, and locations of all instruments installed by the Agency.

B. *Existing Conditions.* Prior to beginning work, obtain utility location plans from the Agency. Contact a utility location service to verify the location of underground utilities before starting the work.

Survey the condition of adjoining properties and record and photograph evidence of settlement or cracking of adjacent structures. Submit a survey report to the Engineer before beginning work.

C. *Construction Quality Assurance.* Perform Contractor Quality Control inspection and testing throughout all aspects of anchored wall construction. The Agency will retain a Construction Acceptance Inspector to monitor all aspects of anchored wall construction. The Acceptance Inspector will perform material conformance testing as required. Assist the Acceptance Inspector as necessary. Account for Acceptance activities in the construction schedule. Correct deficiencies and nonconformities identified by the Acceptance Inspector.

D. *Design Criteria:*

1. *Tendons.* Unless otherwise directed, select the type of tendon to be used according to the following criteria. Size the tendon to ensure the design load does not exceed 60 percent of the specified minimum tensile strength (SMTS) of the prestressing steel. Choose the lock-off load for the tendon based on anticipated time or activity dependent load changes, and so that the load does not exceed 70 percent of the SMTS of the prestressing steel. Size the prestressing steel so that the maximum test load does not exceed 80 percent of the SMTS of the prestressing steel.

2. *Bond Length.* Determine the bond length necessary to develop the design load indicated on the contract drawings or the approved working drawings. The minimum bond length is 15 ft (4.5 m) for strand tendons in rock and 10 ft (3 m) for bar tendons in rock. The minimum bond length is 15 ft (4.5 m) for strand and bar tendons in soil. The minimum tendon bond length is 10 ft (3 m).

3. *Free Stressing Length.* The minimum free stressing length (unbonded length) for rock and soil anchors is 10 ft (3 m) for bar tendons and 15 ft (4.5 m) for strand tendons. Ensure the free stressing length extends at least 5 ft (1.5 m) or 20 percent of the height of the wall, whichever is greater, behind the critical failure surface. Evaluate the critical failure surface using slope stability or similar procedures.

E. *Corrosion Protection.* The Agency will identify corrosion protection requirements on the contract drawings. Design and construct corrosion protection systems to meet these requirements and to provide reliable ground anchors for temporary and permanent structures.

1. *Anchorage Protection:*

a. Provide stressing anchorages that will be permanently exposed to the atmosphere with a grout-filled cover, except, for restressable anchorages, use a corrosion inhibiting compound. Stressing anchorages encased in concrete at least 2 in. (50 mm) thick do not require a cover.

b. Seal the trumpet to the bearing plate. Ensure the trumpet overlaps the unbonded length corrosion protection by at least 4 in. (100 mm). Provide a trumpet of adequate length to accommodate movements of the structure and the tendon during testing and stressing. On strand tendons, ensure the trumpet is long enough to enable the tendon to transition from the diameter of the tendon along the unbonded length to the diameter of the tendon at the wedge plate without damaging the encapsulation.

c. Completely fill the trumpet with grout, except use corrosion inhibiting compounds for restressable anchorages. The Contractor may place compounds at any time during construction. Provide a permanent seal between compound-filled trumpets and the unbonded length corrosion protection. Place grout after the ground anchor has been tested and stressed to the lock-off load. For trumpets filled with grout, the Contractor may provide a temporary seal between the trumpet and the unbonded length corrosion protection. Alternatively, the Contractor may tightly fit the trumpet over the unbonded length corrosion protection for a minimum of 4 in. (100 mm).

2. *Unbonded Length Protection:*

   a. Provide corrosion protection of the unbonded length using a combination of sheaths, sheath filled with a corrosion inhibiting compound or grout, or a heat shrinkable tube internally coated with a mastic compound, depending on the tendon class. Ensure the corrosion inhibiting compound completely coats the tendon elements, fills the void between them and the sheath, and fills the interstices between the wires of 7-wire strands. Ensure the compound remains within the sheath.

   b. Surround the unbonded length of the tendon with a corrosion protective sheath that is long enough to extend into the trumpet, but that does not come into contact with the stressing anchorage during testing. Trim off excessive protection length.

   c. For pregrouted encapsulations and all Class I tendons, provide a separate bondbreaker or common sheath for supplemental corrosion protection or to prevent the tendon from bonding to the grout surrounding the unbonded length.

3. *Unbonded Length/Bond Length Transition.* Design and fabricate a transition between the corrosion protection for the bonded and unbonded lengths to ensure continuous protection from corrosive attack.

4. *Tendon Bond Length Protection for Grout-Protected Tendons (Class II):*

   a. The Contractor may use cement grout to protect the tendon bond length in non-aggressive ground when the installation methods ensure that the grout will remain fully around the tendon. Overlap the sheathing of the unbonded length with grout by at least 1 in. (25 mm).

   b. Use centralizers or grouting techniques that ensure a minimum of $^{1}/_{2}$ in. (12 mm) of grout cover over the tendon bond length.

5. *Tendon Bond Length Protection for Encapsulated Tendons (Class I):*

   a. Use a grout-filled, corrugated plastic encapsulation or a grout-filled, deformed steel tube. The Contractor may either grout the prestressing steel inside the encapsulation prior to inserting the tendon into the drill hole or after the tendon has been placed.

b. Use centralizers or grouting techniques that ensure a minimum of $^{1}/_{2}$ in. (12 mm) of grout cover over the encapsulation.

6. *Epoxy (Class I).* The Contractor may use fusion-bonded epoxy to provide a layer of protection for the steel tendon in addition to the cement grout.

7. *Coupler Protection:*

   a. For encapsulated bar tendons (Class I), cover the coupler and any adjacent exposed bar sections with a corrosion-proof compound or wax-impregnated cloth tape. Cover the coupler area with a smooth plastic tube, meeting the requirements for sheaths specified in Subsection 718.8, and overlap the adjacent sheathed tendon by at least 1 in. (25 mm). Seal the two joints with a coated heat shrink sleeve of at least 6 in. (150 mm) in length, or an approved equal. Ensure the corrosion-proof compound completely fills the space inside the cover tube.

   b. Submit corrosion protection details for strand couplers, if specifically allowed by the contract documents, to the Engineer for approval.

F. *Storing and Handling Tendons:*

1. Handle and store tendons in a manner that will prevent damage or corrosion. The Engineer will reject tendons with damage to the prestressing steel, corrosion protection, and/or the epoxy coating as a result of abrasions, cuts, nicks, welds and weld splatter. Protect the prestressing steel if welding is to be performed in the vicinity. Do not ground welding leads to the prestressing steel. Protect prestressing steel from dirt, rust, and other deleterious substances. The Engineer will consider a light coating of rust on the steel as being acceptable; however, if heavy corrosion or pitting is noted, the Engineer will reject the affected tendons.

2. Prior to inserting a tendon in the drill hole, examine, along with the Construction Acceptance Inspector, the tendon for damage to the encapsulation and the sheathing. If, in the opinion of the Construction Acceptance Inspector, the encapsulation is damaged, repair the encapsulation according to the tendon supplier's recommendations. If, in the opinion of the Construction Acceptance Inspector, the smooth sheathing has been damaged, repair the sheathing with ultrahigh molecular weight polyethylene tape. Wind the tape in a spiral around the tendon to completely seal the damaged area. Ensure the pitch of the spiral provides a double thickness at all points.

3. Pad banding for fabricated tendons to avoid damage to the tendon corrosion protection. Upon delivery to the site, store and handle fabricated anchors, or the prestressing steel for fabrication of the tendons on site, and all hardware in a manner that avoids mechanical damage, corrosion, and contamination with dirt or deleterious substances.

4. Lift pre-grouted tendons in a manner that does not cause excessive bending, which can debond the prestressing steel from the surrounding grout.

5. Do not expose prestressing steel to temperatures exceeding 450°F (230°C).

G. *Fabricating Anchors:*

1. Fabricate anchors either in the shop or in the field using materials that comply with Subsection 718.1 and the approved working drawings and schedules.

2. The Contractor may cut the prestressing steel either with an abrasive saw or, with the approval of the prestressing steel supplier, an oxyacetylene torch.

3. Ensure that the entire tendon bond length, especially for strand, is free of dirt, manufacturer's lubricants, corrosion-inhibitive coatings, or other deleterious substances that may significantly affect the grout-to-tendon bond or the service life of the tendon.

4. Pregrout encapsulated tendons on an inclined, rigid frame or bed by injecting the grout from the low end of the tendon.

H. *Drilling:*

1. *Drilling Method.* Use a drilling method that will establish a stable hole of adequate dimensions, within the tolerances specified. Drilling methods may involve rotary, percussion, rotary/percussive or auger drilling, or percussive or vibratory driven casing.

2. *Holes for Anchors.* Drill holes for anchors at the locations and to the length, inclination, and diameter shown on the contract drawings or the approved working drawings. Use a drill bit or casing crown that is not more than $^1/_8$ in. (3 mm) smaller than the specified hole diameter. Locate the drill hole at the ground surface within 12 in. (300 mm) of the location shown on the contract drawings or the approved working drawings. Locate the drill hole so the longitudinal axis of the drill hole and the longitudinal axis of the tendon are parallel. Do not drill ground anchor holes in a location that would require the tendon to be bent in order to connect the bearing plate to the supported structure. At the point of entry, install the ground anchor within ±3 degrees of the inclination from horizontal shown on the contract drawings or the approved working drawings. At the point of entry, ensure that the horizontal angle made by the ground anchor and the structure is within ±3 degrees of a line drawn perpendicular to the plane of the structure unless otherwise shown on the contract drawings or approved working drawings. Ensure that the ground anchors do not extend beyond the right-of-way or easement limits shown on the contract drawings.

I. *Inserting Tendons:*

1. Place tendons according to the contract drawings and details and the recommendations of the tendon manufacturer or specialist anchor contractor. Insert the tendon into the drill hole to the desired depth without difficulty. If the tendon cannot be completely inserted, remove the tendon from the drill hole and clean or redrill the hole to allow insertion. Do not drive or force partially inserted tendons into the hole.

2. Inspect each anchor tendon during installation into the drill hole or casing. Repair damage to the corrosion protection system, or replace the tendon if not repairable. Reconnect loose spacers or centralizers to prevent shifting during insertion. Repair damaged fusion-bonded

epoxy coatings according to the manufacturer's recommendations. If the patch is not allowed to cure prior to inserting the tendon in the drill hole, protect the patched area using tape or other suitable means.

3. Control the rate of placement of the tendon into the hole to ensure that no damage occurs to the sheathing, coating, and grout tubes during installation of the tendon. Ensure anchor tendons are not subjected to sharp bends. The Contractor may fit the bottom end of the tendon with a cap or bullnose to aid its insertion into the hole, casing, or sheathing.

J. *Grouting:*

1. Use a neat cement grout or a sand-cement grout. Ensure grout contains no lumps or other indications of hydration. Mix admixtures, if used, according to the manufacturer's recommendations.

2. Use grouting equipment that produces a grout free of lumps and undispersed cement. Use a positive displacement grout pump equipped with a pressure gauge to monitor grout pressures. Ensure the pressure gauge is capable of measuring pressures of at least 150 psi (1 MPa) or twice the actual grout pressures to be used, whichever is greater. Size the grouting equipment so that the grout may be pumped in one continuous operation. Use a mixer capable of continuously agitating the grout.

3. Inject the grout from the lowest point of the drill hole. The Contractor may pump grout through grout tubes, casings, hollow-stem augers, or drill rods. Place the grout either before or after inserting the tendon. Record the quantity of grout placed and the grout pressures. Control the grout pressures and grout takes to prevent excessive heave or fracturing.

4. After installing the tendon, the Contractor may fill the drill hole in one continuous grouting operation, except that pressure grouting shall not be used in the free length zone. Ensure that the grout at the top of the drill hole does not contact the back of the structure or the bottom of the trumpet.

5. If the ground anchor is installed in a fine-grained soil using drill holes larger than 6 in. (150 mm) in diameter, place the grout above the top of the bond length after testing and stressing the ground anchor. The Engineer will allow the Contractor to grout the entire drill hole at the same time if the Contractor can demonstrate that the particular ground anchor system does not derive a significant portion of its load-carrying capacity from the soil above the bond length portion of the ground anchor.

6. If grout-protected tendons are used for ground anchors anchored in rock, use pressure-grouting techniques. Pressure grouting requires that the drill hole be sealed and that the grout be injected until a minimum 50 psi (0.35 MPa) grout pressure (measured at the top of the drill hole) can be maintained on the grout for at least 5 minutes.

7. The grout tube may remain in the hole on completion of grouting if the tube is filled with grout.

8. Do not load the tendon for a minimum of 3 days after grouting.

K. *Installing Anchors:*

1. Install the anchor bearing plate and the anchor head or nut perpendicular to the tendon, within ±3 degrees and centered on the bearing plate, without bending or kinking of the prestressing steel elements. Ensure the wedge holes and wedges are free of rust, grout, and dirt.

2. Clean and protect the stressing tail from damage until final testing and lock-off. After the anchor has been accepted by the Engineer, cut the stress tail to its final length according to the tendon manufacturer's recommendations.

3. Extend the corrosion protection surrounding the unbonded length of the tendon beyond the bottom seal of the trumpet or 4 in. (100 mm) into the trumpet if no trumpet seal is provided. If the protection does not extend beyond the seal or sufficiently far enough into the trumpet, extend the corrosion protection or lengthen the trumpet.

4. Ensure that the corrosion protection surrounding the unbonded length of the tendon does not contact the bearing plate or the anchor head during testing and stressing. If the protection is too long, trim the corrosion protection to prevent contact.

L. *Stressing, Load Testing, and Acceptance.* Test each ground anchor. Perform extended creep testing and performance testing at the beginning of the anchor installation, prior to installation of the remaining soil anchors, unless directed otherwise by the Engineer. Do not apply loads greater than 10 percent of the design load to the ground anchor prior to testing. Ensure that the maximum test load is at least 1.33 times the design load, but does not exceed 80 percent of the specified minimum ultimate tensile strength (SMTS) of the prestressing steel of the tendon. Apply the test load simultaneously to the entire tendon. Do not stress single elements of multi-element tendons.

1. *Testing Equipment.* Provide testing equipment consisting of the following:

    a. Use a dial gauge or vernier scale capable of measuring to the nearest 0.01 in. (0.25 mm) to measure the ground anchor movement. Provide a movement-measuring device having a minimum travel equal to the theoretical elastic elongation of the total anchor length at the maximum test load. Ensure that the device has adequate travel so the ground anchor movement can be measured without resetting the device at an interim point.

    b. Use a hydraulic jack and pump to apply the test load. Measure the applied load using a jack and a calibrated primary pressure gauge. Engage an independent firm to calibrate the jack and primary pressure gauge as a unit. Ensure that the calibration was performed no longer than 60 calendar days prior to date on which the calibration submittals are provided to the Engineer. Do not begin testing until the Engineer has approved the calibration. Use a primary pressure gauge that is graduated in increments of 100 psi (0.69 MPa) or less. Ensure that the ram travel is at least 6 in. (150 mm) and preferably not less than the theoretical elongation of the tendon at the maximum test load. If elongations greater than 6 in. (150 mm) are required, the Engineer may allow restroking.

c. Keep a calibrated reference pressure gauge at the site to periodically check the production (i.e., primary pressure) gauge. Calibrate the reference gauge with the test jack and primary pressure gauge. Store the reference pressure gauge indoors and do not subject to rough treatment.

d. Provide an electrical resistance load cell and readout to be used when performing an extended creep test.

e. Place the stressing equipment over the ground anchor tendon in a manner that will ensure that the jack, bearing plates, load cells, and stressing anchorage are axially aligned with the tendon and that the tendon is centered within the equipment.

2. *General Stressing Procedures:*

a. Determine the stressing equipment, the sequence of stressing, and the procedure to be used for each stressing operation during the planning stage of the project. Operate equipment in strict accordance with the manufacturer's instructions.

b. Use stressing equipment capable of stressing the whole tendon in one stroke to the specified test load and of stressing the tendon to the maximum specified test load within 75 percent of the rated capacity. Use a pump capable of applying each load increment in less than 60 seconds.

c. Ensure equipment allows stressing of the tendon in increments so that the load in the tendon can be raised or lowered according to the test specifications, and allows the anchor to be lift-off tested to confirm the lock-off load.

d. Ensure stressing equipment has been recently calibrated within an accuracy of ±2 percent prior to use. Have the calibration certificate and graph available on site at all times. Ensure that the calibration is traceable to the National Institute of Standards and Technology (NIST).

3. *Load Testing Setup:*

a. Place dial gauges to bear on the pulling head of the jack, with their stems coaxial with the tendon direction. Support the gauges on an independent, fixed frame, such as a tripod, that will not move as a result of stressing or other construction activities during the operation.

b. Prior to setting the dial gauges, place the Alignment Load (AL) accurately on the tendon. The magnitude of AL depends on the type and length of the tendon.

c. Avoid regripping of strands, which would cause overlapping wedge bites, or wedge bites on the tendon below the anchor head.

d. Do not stress and test multiple element tendons with single element jacks.

e. Do not begin stressing until the grout has reached adequate strength.

4. *Performance Tests:*

   a. Conduct performance tests on 5 percent of the ground anchors or a minimum of 3 ground anchors, whichever is greater. The Engineer will select the ground anchors to be performance tested. Test the remaining ground anchors according to the proof test procedures specified in Subsection 806.3(L)(5).

   b. Conduct the performance test by incrementally loading and unloading the ground anchor according to the schedule provided in Table 806.3-1. Raise the load from one increment to another immediately after recording the ground anchor movement. Measure and record the ground anchor movement to the nearest 0.01 in. (0.25 mm) with respect to an independent fixed reference point at the alignment load and at each increment of load. Monitor the load with the primary pressure gauge. Place the reference pressure gauge in series with the primary pressure gauge during each performance test. If the load determined by the reference pressure gauge and the load determined by the primary pressure gauge differ by more than 10 percent, recalibrate the jack, primary pressure gauge, and reference pressure gauge at no cost to the Agency. At load increments other than the maximum test load, hold the load just long enough to obtain the movement reading.

   c. Hold the maximum test load in a performance test for 10 minutes. Use a load cell to monitor small changes in load during constant load-hold periods.

   d. Adjust the jack as necessary to maintain a constant load. Start the load-hold period as soon as the maximum test load is applied. Measure and record the ground anchor movement, with respect to a fixed reference, at 1, 2, 3, 4, 5, 6, and 10 minutes. If the ground anchor movement between 1 minute and 10 minutes exceeds 0.4 in. (1 mm), hold the maximum test load for an additional 50 minutes. If the load hold is extended, record the ground anchor movement at 15, 20, 30, 40, 50, and 60 minutes.

5. *Proof Tests:*

   a. Perform proof tests on all ground anchors not subjected to a performance test or an extended creep test. Perform the proof test by incrementally loading the ground anchor according to the schedule provided in Table 806.3-2. Raise the load from one increment to another immediately after recording the ground anchor movement. Measure and record the ground anchor movement to the nearest 0.01 in. (0.25 mm) with respect to an independent fixed reference point at the alignment load and at each increment of load. Monitor the load with the primary pressure gauge. At load increments other than the maximum test load, hold the load just long enough to obtain the movement reading.

Table 806.3-1. Steps for the Performance Test

Step	Loading	Applied Load	Record and Plot Total Movement (δ_{ti})	Record and Plot Residual Movement (δ_{ri})	Calculate Elastic Movement (δ_{ei})
1	Apply alignment load (AL)				
2	Cycle 1	0.25DL	δ_{t1}		
		AL		δ_{r1}	$\delta_{t1} - \delta_{r1} = \delta_{e1}$
3	Cycle 2	0.25DL	δ_2		
		0.50DL	δ_{t2}		
		AL		δ_{r2}	$\delta_{t2} - \delta_{r2} = \delta_{e2}$
4	Cycle 3	0.25DL	δ_3		
		0.50DL	δ_3		
		0.75DL	δ_{t3}		
		AL		δ_{r3}	$\delta_{t3} - \delta_{r3} = \delta_{e3}$
5	Cycle 4	0.25DL	δ_4		
		0.50DL	δ_4		
		0.75DL	δ_4		
		1.0DL	δ_{t4}		
		AL		δ_{r4}	$\delta_{t4} - \delta_{r4} = \delta_{e4}$
6	Cycle 5	0.25DL	δ_5		
		0.50DL	δ_5		
		0.75DL	δ_5		
		1.0DL	δ_5		
		1.2DL	δ_{t5}		
		AL		δ_{r5}	$\delta_{t5} - \delta_{r5} = \delta_{e5}$
7	Cycle 6	0.25DL	δ_6		
		0.50DL	δ_6		
		0.75DL	δ_6		
		1.0DL	δ_6		
		1.2DL	δ_6		
		1.33DL	δ_{t6}, zero reading for creep test		
8	Hold load for 10 minutes while recording movement at specified times. If the total movement measured during the load hold exceeds the specified maximum value, then extend the load hold to a total of 60 minutes.				
9	Cycle 6 cont'd.	AL		δ_{r6}	Cycle 6: $\delta_{tn} - \delta_{r6} = \delta_{e6}$

Notes: AL = Alignment Load;
DL = Design Load;
δ_i = total movement at a load other than maximum for cycle;
i = number identifying a specific load cycle.

Table 806.3-2. Proof Test Schedule

Step	Load
1	AL
2	0.25DL
3	0.50DL
4	0.75DL
5	1.0DL
6	1.20DL
7	1.33DL
8	Reduce to lock-off load
9	AL (optional)
10	Adjust to lock-off load

Notes: AL = Alignment Load;
DL = Design Load.

b. Hold the maximum test load in a proof test for 10 minutes. Adjust the jack as necessary to maintain a constant load. Start the load-hold period as soon as the maximum test load is applied. Measure and record the ground anchor movement with respect to a fixed reference at 1, 2, 3, 4, 5, 6, and 10 minutes. If the ground anchor movement between 1 minute and 10 minutes exceeds 0.4 in. (1 mm), hold the maximum test load for an additional 50 minutes. If the load hold is extended, record the ground anchor movements at 15, 20, 30, 40, 50, and 60 minutes.

6. *Extended Creep Test:*

a. The Agency will determine if extended creep testing is required and, if required, will select a minimum of two ground anchors to be creep tested. Use stressing equipment capable of measuring and maintaining the hydraulic pressure within 50 psi (0.35 MPa).

b. Conduct the extended creep test by incrementally loading and unloading the ground anchor according to the performance test schedule provided in Subsection 806.3(L)(4). At the end of each loading cycle, maintain a constant load for the observation period indicated in the creep test schedule in Table 806.3-3. Read and record the ground anchor movement during each observation period at 1, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30, 45, 60, 75, 90, 100, 120, 150, 180, 210, 240, 270, and 300 minutes, as appropriate for the load increment. Start each load-hold period as soon as the test load is applied. In a creep test, use the primary pressure gauge and reference pressure gauge to measure the applied load, and use the load cell to monitor small changes in load during constant load-hold periods. Adjust the jack as necessary to maintain a constant load.

c. Plot the ground anchor movement and the residual movement measured in an extended creep test. In addition, plot the creep movement for each load hold as a function of the logarithm of time.

Table 806.3-3. Extended Creep Test Schedule

Load	Observation period (min.)
AL	
0.25DL	10
0.50DL	30
0.75DL	30
1.0DL	45
1.20DL	60
1.33DL	300

Notes: AL = Alignment Load;
DL = Design Load.

7. *Ground Anchor Acceptance Criteria:*

a. A performance-tested or proof-tested ground anchor with a 10-minute load hold is acceptable if the: (1) ground anchor resists the maximum test load with less than 0.4 in. (1 mm) of movement between 1 minute and 10 minutes; and (2) total elastic movement at the maximum test load exceeds 80 percent of the theoretical elastic elongation of the unbonded length.

b. A performance-tested or proof-tested ground anchor with a 60-minute load hold is acceptable if the: (1) ground anchor resists the maximum test load with a creep rate that does not exceed 0.8 in. (2 mm) in the last log cycle of time; and (2) total elastic movement at the maximum test load exceeds 80 percent of the theoretical elastic elongation of the unbonded length.

c. A ground anchor subjected to extended creep testing is acceptable if the: (1) ground anchor resists the maximum test load with a creep rate that does not exceed 0.8 in. (2 mm) in the last log cycle of time; and (2) total elastic movement at the maximum test load exceeds 80 percent of the theoretical elastic elongation of the unbonded length.

d. Ensure the initial lift-off reading is within ±5 percent of the designed lock-off load. If this criterion is not met, adjust the tendon load accordingly and repeat the initial lift-off reading.

8. *Procedures for Anchors Failing Acceptance Criteria:*

   a. Either reject and replace anchors that do not satisfy the minimum apparent free length criteria at no additional cost to the Agency, or lock off such anchors at not more than 50 percent of the maximum acceptable load attained. In this case, apply no further acceptance criteria.

   b. The Contractor may postgrout and subject to an enhanced creep criterion those regroutable anchors that satisfy the minimum apparent free length criteria but fail the extended creep test at the test load. This enhanced criterion requires a creep movement of not more than 0.4 in. (1 mm) between 1 and 60 minutes at test load. Lock off anchors that satisfy the enhanced creep criterion at the design lock-off load. For those anchors that cannot be postgrouted or for regroutable anchors that do not satisfy the enhanced creep criterion, the Contractor may either reject the anchors or lock off such anchors at 50 percent of the maximum acceptable test load attained. In this event, apply no further acceptance criteria. The maximum acceptable test load with respect to creep corresponds to that load for which acceptable creep movements are measured over the final log cycle of time.

   c. In the event that an anchor fails, modify the design, the construction procedures, or both at no additional cost to the Agency. These modifications may include installing additional anchors, modifying the installation methods, reducing the anchor design load by increasing the number of anchors, increasing the anchor length, or changing the anchor type. Submit a description of proposed modifications to the Engineer in writing. Do not implement proposed modifications until the Engineer provides written approval.

9. *Anchor Lock-Off:*

   a. After completing testing, load the tendon so that after seating losses (i.e., wedge seating), the specified lock-off load will have been applied to the anchor tendon.

   b. The Engineer will specify the magnitude of the lock-off load, which will not exceed 70 percent F_{pu}, the minimum tensile strength of the tendon.

   c. Seat the wedges at a minimum load of 50 percent F_{pu}. If the lock-off load is less than 50 percent F_{pu}, use shims under the wedge plate and the wedges seated at 50 percent F_{pu}. Then remove the shims to reduce the load in the tendon to the desired lock-off load. The Contractor may lock off bar tendons at any load less than 70 percent F_{pu}.

10. *Anchor Lift-Off Test.* After transferring the load to the anchorage, and prior to removing the jack, conduct a lift-off test to confirm the magnitude of the load in the anchor tendon. Determine this load by reapplying load to the tendon to lift off the wedge plate (or anchor nut) without unseating the wedges (or turning the anchor nut). This moment represents zero time for longtime monitoring.

806.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure ground anchors based on planned quantities. The Engineer will not revise the number of ground anchors if the Contractor chooses to use an alternative number of anchors.

806.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Ground anchor	each
(B) Performance test	each
(C) Extended creep test	each

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 807
EARTH RETAINING SYSTEMS

807.1 DESCRIPTION

Furnish and install earth retaining systems, including concrete and masonry gravity walls, reinforced concrete retaining walls, sheet pile and soldier pile walls (with and without ground anchors or other anchorage systems), crib and cellular walls, and mechanically stabilized earth walls.

807.2 MATERIALS

Permeable Material	Subsection 703.17(A)
Filter Fabric	Subsection 705.1, Section 620
Pipe and Perforated Pipe	Section 708
Structural Steel	Subsection 710.1
Reinforcing Steel	Subsection 711.1
Class A Concrete	Subsection 713.1(B)
Pneumatically Applied Mortar	Subsection 713.5(C), Section 824

Treated Timber Sheet Piles	Section 717
Soldier Piles	Sections 717, 808, 811, and 816
Concrete Sheet Piles	Section 804
Precast and Cast-in-Place Concrete Panels	Section 808
Concrete Wales	Section 808
Steel Wales	Section 811
Paint for Structural Steel	Section 813
Stone Masonry	Section 814
Reinforced Concrete Block	Section 815
Steel Sheet Piles, Grade 50 (345)	AASHTO M 202M/M 202
Tie-rods, Grade 36 (250)	AASHTO M 270M/M 270

807.3 CONSTRUCTION

A. *Structure Backfill Material and Crib and Cellular Walls.* Ensure structure backfill material is free from organic matter or other unsuitable substances. Determine gradation according to AASHTO T 27. Use structure backfill material for crib and cellular walls. For wall heights greater than 20 ft (6 m), use material meeting the gradation requirements specified in Table 807.3-1.

Table 807.3-1. Requirements for Structure Backfill and Crib and Cellular Walls

Structure Backfill Material		Crib and Cellular Walls	
Sieve Size	Percent Passing	Sieve Size	Percent Passing
3 in. (75 mm)	100	3 in. (75 mm)	100
No. 4 (4.75 mm)	35–100	No. 4 (4.75 mm)	25–70
No. 30 (600 μm)	20–100	No. 50 (300 μm)	5–20
No. 200 (75 μm)	0–15	No. 200 (75 μm)	0–5

B. *Backfill for Mechanically Stabilized Earth Walls.* Ensure structure backfill material is free from organic matter or other unsuitable substances. Determine gradation according to AASHTO T 27. Use structure backfill material meeting the requirements specified in Table 807.3-2.

Use material with a minimum angle of internal friction of 34 degrees, as tested according to AASHTO T 236. Perform AASHTO T 236 testing on the portion of the material finer than the No. 10 (2-mm) sieve and compacted to 95 percent of maximum density, using AASHTO T 99, Methods C or D (with oversized correction) at optimum moisture content. No testing is required for backfills where 80 percent of the material is sized greater than $^3/_4$ in. (20 mm).

Table 807.3-2. Backfill Requirements for MSE Walls

Sieve Size	Percent Passing
4 in. (100 mm)	100
No. 40 (425 μm)	0–60
No. 200 (75 μm)	0–15[a]

[a] Plasticity Index (PI), less than 6, as tested according to AASHTO T 90.

Use materials with a magnesium sulfate soundness loss less than 30 percent after four cycles and free of shale or other particles of low durability. If backfill is to be used with steel soil reinforcement, use backfill material meeting the electrochemical requirements specified in Table 807.3-3.

Table 807.3-3. Requirements for Backfill Used with Steel Reinforcement

Property	Value
pH	5 to 10
Resistivity (min)	30 ohms
Chloride content (max)	100 ppm
Sulphate content (max)	200 ppm

C. *Crib Members:*

1. *Timber.* Use timber headers, stretchers, caps, posts, and sills meeting Section 816. Treat wood with preservatives meeting Subsection 717.3(A).

2. *Steel.* Fabricate steel crib members consisting of base plates, columns, stretchers, and spacers from sheet steel meeting AASHTO M 218. Fabricate crib members so that members of the same nominal size and thickness are fully interchangeable. Do not drill, punch, or drift to correct defects in manufacture. Replace members that have improperly punched holes. Galvanize bolts, nuts, and miscellaneous hardware according to AASHTO M 232 M/M 232.

3. *Concrete.* Construct concrete monolithic cell members consisting of 4-sided cells of uniform height and various depths cast according to Section 808. The minimum concrete compressive strength of cast members is 4,000 psi (28 MPa). Finish the exposed cell face with a Class 1 finish as specified in Subsection 808.3(J)(1). For faces not exposed to view, provide a uniform surface finish free of open pockets of aggregate or surface distortions greater than $^{1}/_{4}$ in. (6 mm).

D. *Mechanically Stabilized Earth Wall Facing System.* Provide facing consisting of precast concrete panels, cast-in-place concrete, or welded wire fabric.

Manufacture concrete panels with a minimum concrete compressive strength of 4,000 psi (28 MPa). Finish the exposed face with a Class 1 finish. For the face not exposed to view, provide a uniform surface finish free of open pockets of aggregate or surface distortions in excess of $^1/_4$ in. (6 mm). Locate soil reinforcement connection hardware during concrete placement to avoid contact with the panel reinforcing steel. Shop-fabricate welded wire fabric reinforcement from cold drawn wire meeting AASHTO M 336M/M 336, with the finished fabric also meeting AASHTO M 336M/M 336.

E. *Soil Reinforcement.* Galvanize steel soil reinforcement and steel connection hardware according to AASHTO M 111M/M 111. Manufacture steel strip reinforcement by hot rolling according to ASTM A36/A36M, Grade 65 (Grade 450).

F. *Working Drawings.* Submit working drawings and design calculations, including:

1. Earthwork requirements, including specifications for material and compaction of backfill.
2. Details of revisions or additions to drainage systems or other facilities required to accommodate the system.
3. Existing ground elevations verified by the Contractor for each location involving construction wholly or partially in original ground.
4. Complete design calculations substantiating that proposed designs satisfy the design parameters in the contract documents.
5. Complete details of all elements required for the proper construction of the retaining wall system, including complete material specifications.

Do not begin work on earth retaining systems until working drawings have been approved.

G. *Excavation and Backfill.* Excavate and backfill earth retaining systems as specified in Section 801. Replace excavated material with structure backfill material as specified in Section 801. Compact the material to a density of not less than 95 percent of the maximum density, as determined according to AASHTO T 99, Methods C or D (with oversize correction).

H. *Drainage.* Provide outlet works at sags in the profile and at the low ends of the gutter.

1. *Weep Holes.* Place a minimum of 2 ft^3 (0.6 m^3) of permeable material encapsulated with filter fabric at each weep hole. Cover joints between retaining wall panels, which function as weep holes, with filter fabric. Dry and thoroughly clean the face panels that are to receive the filter fabric.
2. *Drainage Blankets.* Construct drainage blankets consisting of permeable material encapsulated in filter fabric, collector pipes, outlet pipes, and cleanout pipes. Place the filter fabric on a compacted subgrade that is free of loose or extraneous material and sharp objects that could damage the filter fabric. Stretch, align, and place the fabric in a wrinkle-free manner. Overlap adjacent borders of the fabric 12 to 18 in. (300 to 450 mm). Repair torn or punctured fabric by covering the damaged area with a piece of fabric large enough to cover the damaged area and meet the overlap requirement.

Place the permeable material in horizontal layers and thoroughly consolidate by the same methods specified for structure backfill. Prohibit ponding or jetting of permeable material or structure backfill material. Maintain a minimum cover of 6 in. (150 mm) of permeable material, structure backfill, or embankment material between the fabric and the equipment during spreading and compaction of the permeable material.

Place perforated collector pipe, when required, within the permeable material to the flow line elevations shown. Place outlet pipes at sags in the flow line and at the low end of the collector pipe. Construct rock slope protection, when required, at the end of outlet pipes, as specified in Section 822. Place cleanout pipes at the high ends of collector pipes.

3. *Geocomposite Drainage Systems.* Place and secure the geocomposite drainage material tightly against the excavated face, lagging, or back of wall. Protect the drainage material against physical damage and grout leakage when concrete is to be placed against geocomposite drainage material.

I. *Retaining Wall Construction:*

1. *Concrete and Masonry Gravity Walls and Reinforced Concrete Retaining Walls.* Support and brace cast-in-place concrete footings for precast walls until the footing concrete has been placed and has achieved sufficient strength to support the wall elements.

   Provide the exposed face of concrete walls with a Class 1 finish as specified in Subsection 808.3(J)(1).

2. *Sheet Pile and Soldier Pile Walls.* Construct continuous walls of timber, steel, or concrete sheet piles, and soldier pile walls with horizontal facing elements of timber, steel, or concrete.

   a. *Sheet Pile Walls.* Drift sharpen piles at their lower ends to wedge adjacent piles tightly together during driving. Drive sheet piles to the required penetration or bearing capacity as specified in Section 804. After driving, cut off the tops of sheet piles to a straight line at the elevation specified. Brace sheet pile walls by wales or other bracing system. Properly lap and join the timber waling strips at splices and corners. Use wales of one continuous length between corners, and bolt the wales near the tops of the piles.

      If concrete sheet piles are detailed to have a tongue-and-groove joint on the portion below ground and a double grooved joint on the exposed portion, clean the upper grooves of sand, mud, or debris, and fill with grout. Use grout composed of one part cement and two parts sand. Deposit grout through a pipe within a watertight plastic sheath that extends the full depth of the slot formed by the grooves. Completely fill the slot with grout.

   b. *Soldier Pile Walls.* Soldier piles consist of driven piles or piles constructed in a drilled shaft excavation.

      Furnish and install driven piles as specified in Section 804.

Construct the drilled shaft excavation and place concrete or lean concrete backfill as specified in Section 805.

Use commercially available portland cement concrete. Ensure that the concrete backfill around precast concrete, timber, or steel pile members in the drilled shaft excavation has a minimum cement content of 17.5 lb/ft^3 (280 kg/m^3). Lean concrete backfill is a concrete mix using commercial quality sand and a maximum portland cement content of 3.5 lb/ft^3 (56 kg/m^3).

Construct precast concrete lagging or facing panels and cast-in-place concrete facing to meet Section 808. Use concrete anchors, welded connections and bolted connections for securing facing elements to the soldier piles. Construct the facing, horizontally spanning between soldier piles.

Provide a Class 1 finish on exposed surfaces of concrete wall facing.

c. *Anchored Sheet Pile and Soldier Pile Walls.* Construct anchored walls by anchoring sheet pile and soldier pile walls with a tie rod and concrete anchor system or with ground anchors.

d. *Wales.* Use wales consisting of timber, steel, or concrete. Align the wales so that tie rods or ground anchors can be installed without bending.

e. *Concrete Anchor System.* Construct either a drilled shaft concrete anchor system or a reinforced concrete anchor system.

   Drive battered anchor piles to the proper batter. Provide the tension anchor piles with adequate means of anchorage to the concrete anchor block.

   Construct drilled shaft concrete anchors as specified in Section 805.

f. *Tie Rods and Ground Anchors.* Install tie rods and prevent damage to the corrosion protection or bending of the tie rod during the handling and backfilling operations.

   Construct ground anchors as specified in Section 806.

   Complete tie rod and ground anchor installation before excavating in front of the wall more than 3 ft (1 m) below a level of tie rods or ground anchors.

   Place lagging closely following excavation in front of the wall to minimize ground loss.

3. *Crib Walls and Cellular Walls.* Construct timber, concrete, or steel crib walls and concrete monolithic cell walls complete with backfill material within the cells formed by the members.

   Construct and finish the foundation or bed course material to the exact grade and cross slope to achieve the vertical or battered face alignment. Firmly and evenly embed timber mud sills in the foundation material. Place concrete for leveling pads or footings against the sides of the excavation in the foundation material.

Use crib members and concrete monolithic cell members as specified above. Place structure backfill material as specified in Section 801. Backfill simultaneously with the erection of the members forming the cells. Avoid disturbance of, or damage to, the members during placement and compaction of backfill material. Place backfill in uniform layers less than 12 in. (300 mm) in thickness. Compact backfill to a minimum density of 95 percent of the maximum density as determined according to AASHTO T 99, Method C.

4. *Mechanically Stabilized Earth Walls.* Construct mechanically stabilized earthwalls consisting of a facing system to which steel or polymeric soil reinforcement is connected. Provide facing of precast concrete panels, cast-in-place concrete, or welded wire fabric.

   When constructing cast-in-place concrete facing, embed soil reinforcement to extend beyond the temporary facing into the facing concrete.

   Form welded wire facing by bending the horizontal soil reinforcement 90 degrees upward to form the wire face. Connect the vertical portion of the welded fabric forming the face to the next upper level of soil reinforcement. Place a separate backing mat and hardware cloth immediately behind the vertical portion of soil reinforcement.

   Provide a precast reinforced or cast-in-place concrete leveling pad at each panel foundation level. Place panels or wire fabric and support to achieve the final position.

   Place and compact structure backfill material at the same time as placement of facing and soil reinforcement, without distortion, damage, or displacement of the facing or soil reinforcement. Backfill to an elevation approximately $1^1/_4$ in. (30 mm) above the facing connection level before placing the next level of soil reinforcement. Roughly level the backfill material before placing the soil reinforcement. Uniformly tension soil reinforcement to remove slack in the connection or material.

   Install joint filler, bearing pads, and joint-covering material concurrently with face panel placement.

   When using steel reinforcement, furnish and install instrumentation for monitoring corrosion.

807.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure the vertical height of each section on the outer face from the bottom of the lowermost face element to the top of the wall for systems without footings. The Engineer will exclude all barriers.

807.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Earth retaining systems	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 808
CONCRETE STRUCTURES

808.1 DESCRIPTION

Furnish, place, finish, and cure concrete bridges, culverts, and miscellaneous structures, including cofferdams, forms, and falsework.

808.2 MATERIALS

Provide materials as specified in:

Cement:	
Portland Cement, Type I, II, or III	Subsection 701.2
Blended Hydraulic Cement, Type IP or IS	Subsection 701.3
Low-Alkali Cement	AASHTO M 85
Aggregates:	
Fine Aggregate	Subsection 703.1(A)
Coarse Aggregate	Subsection 703.1(B)
Lightweight Aggregate	Subsection 703.1(C)
Joint Materials:	
Poured Joint Sealants	Subsection 707.1(A)
Preformed Elastomeric Joint Sealants	Subsection 707.1(B), Section 819
Preformed Joint Fillers	Subsection 707.1(D)
Polystyrene Board Fillers	Subsection 707.1(E)
Waterstops	Subsection 707.4
Metal Armor	Section 823
Epoxy Bonding Agent	AASHTO M 235M/M 235

Contraction Joint Material	Asphalt saturated felt paper
Curing Materials:	
Waterproof Sheet Materials	Subsection 713.2(B)
Liquid Membranes	Subsection 713.2(C)
Admixtures:	
Air-Entraining Admixtures	Subsection 713.3(A)
Chemical Admixtures	Subsection 713.3(B)
Mineral Admixtures	Subsection 713.3(C)
Water	Subsection 714.1(A)
Reinforcing Steel	Section 711
Prestressing Steel	Sections 711 and 810

808.3 CONSTRUCTION

A. *Concrete Mix Design and Trial Batches*. Meet Subsection 713.1(B).

B. *Mixing and Transporting Concrete*. Meet Subsection 501.3(B).

C. *Testing*. Test concrete according to the test methods specified in Table 808.3-1.

Table 808.3-1. Concrete Testing Requirements

Property	Test Method
Sampling fresh concrete	AASHTO R 60
Density (unit weight)	AASHTO T 121M/T 121
normal density	
low density	
Yield	AASHTO T 121M/T 121
Air content	AASHTO T 121M/T 121 or T 152
Sieve analysis of aggregates	AASHTO T 27
Slump	AASHTO T 119M/T 119
Specific gravity and absorption	
of fine aggregate	AASHTO T 84
of coarse aggregate	AASHTO T 85
Making and curing of test specimens	
in the laboratory	ASTM C192/C192M
in the field	AASHTO T 23
Compressive strength	AASHTO T 22

Remove concrete represented by strength tests that are less than 500 psi (3.45 MPa) below the specified strength. The Engineer will review results not conforming to required design strengths and determine acceptance or if removal and replacement are necessary.

When a precast concrete member is steam or radiant heat cured, cure test specimens for precast concrete under the same conditions as a precast concrete member. Use precast members only after they attain their 28-day strength at any time within the 28-day cure period. Reject precast members that do not reach their strength in 28 days.

D. *Weather and Environmental Conditions.* Protect concrete from damage caused by weather or environmental conditions. Repair or remove and replace any damaged concrete.

Maintain concrete mixture temperature at placement between 60°F (15°C) and 90°F (32°C).

1. *Hot and Dry Weather Requirements.* Hot weather is defined as one or a combination of the following conditions that tends to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration, or otherwise causing detrimental results: high ambient temperature, high concrete temperature, low relative humidity, and high wind speed. Keep new concrete shaded from the sun, shielded from the wind, and kept wet with water, or protected by other methods to retain the moisture in the concrete throughout the curing period. When placing concrete in hot weather, take appropriate measures to reduce the hazards of increased rate of cement hydration, flash set, loss of water due to evaporation, high concrete ingredient temperatures, and the increased difficulty of concrete placement and finishing.

   a. *Concrete Temperature.* Ensure the temperature of the concrete at the point of discharge does not exceed 95°F (35°C).

   b. *Cooling Materials.* If necessary, reduce the temperature of the concrete by cooling one or more ingredients. Cool aggregates by fogging or other suitable means that will not result in a high variation of moisture content within the stockpile. Use chipped or crushed ice in the mix as a portion of the mixing water on a pound for pound (kilogram for kilogram) basis, provided such measure is determined at the time of placement in the mix. If ice is used, melt before discharging the batch from the mixing unit. Cool water by refrigeration or other means that will provide a uniform mixing water temperature.

   c. *Placing Concrete.* Immediately before placing concrete, cool the forms, reinforcing steel and other surfaces that will be in contact with the concrete by water spray or other approved methods when the ambient temperature rises above 90°F (32°C). Ensure there is no standing water in the concrete forms as a result of the spraying procedures. Provide sufficient skilled men and adequate equipment to place the concrete without delays that may cause excessive slump loss and evaporation due to over-mixing or exposure before placement.

   d. *Finishing.* Use windscreens, water fogging, or other approved means of supplying moisture to prevent shrinkage cracking due to moisture loss. If windscreens are required, construct with canvas barriers of suitable height erected on the windward side of the concrete placement. Maintain finishing operations as close as practicable behind the placing operation so that curing may begin as soon as possible.

e. *Protecting Bridge Deck.* Protect bridge deck concrete from rapid evaporation during periods of low humidity, wind, or high temperatures by using fog sprayers in the air, wind breaks, or sun shades, reducing the temperature of the concrete mixture before placement, and scheduling placement during cooler times of the day or at night. Place concrete at temperatures of 80°F (27°C) or less for bridge decks located over salt water.

   Limit the evaporation rate of the exposed concrete surface to less than 0.15 $lb/ft^2/h$ (0.75 $kg/m^2/h$). Determine the bridge deck surface evaporation rate according to Figure 808.3-1.

   To maintain the deck surface evaporation rate below 0.15 $lb/ft^2/h$ (0.75 $kg/m^2/h$), take one or more of the following actions:

   i. Mist the surface of the concrete with a triple-head nozzle rated at 1 gal/min (4 L/min) or less immediately behind the finishing machine and until the curing cover is applied. Produce a fine fog mist with the nozzle to maintain a sheen of moisture on the concrete surface without ponding.

   ii. Construct windscreens or enclosures, consisting of canvas barriers of suitable height erected on the windward side of the concrete placement, to effectively reduce the wind velocity throughout the area of placement.

   iii. Reduce the temperature of the concrete.

2. *Rainy Weather Requirements.* Under conditions of threatening rain, only place concrete if protection is provided. During rainy weather, properly cover new concrete, as necessary to prevent damage. Provide sufficient material for covering at the site of the work for immediate use.

3. *Cold Weather Requirements.* Cold weather is defined as a period when the average daily ambient temperature is below 40°F (5°C) for more than 3 successive days. Note: The average daily temperature is the average of the highest and lowest temperature during the period from midnight to midnight. When temperatures above 50°F (10°C) occur during more than half of any 24-h duration, the period shall no longer be regarded as cold weather. Provide a cold weather Placement and Curing Plan when cold weather is reasonably expected. Include as part of the Placement and Curing Plan detailed procedures for the production, transporting, placing, protecting, curing, and temperature monitoring of concrete during cold weather.

   When the air temperature is below 35°F (2°C), maintain the concrete mixture at a temperature of 60°F (16°C) or above and free of ice and frost during placement. Maintain temperature above 60°F (16°C) by heating aggregate, water, or both. Limit aggregate and water temperature to a maximum of 150°F (65°C). Do not heat aggregate by direct gas or

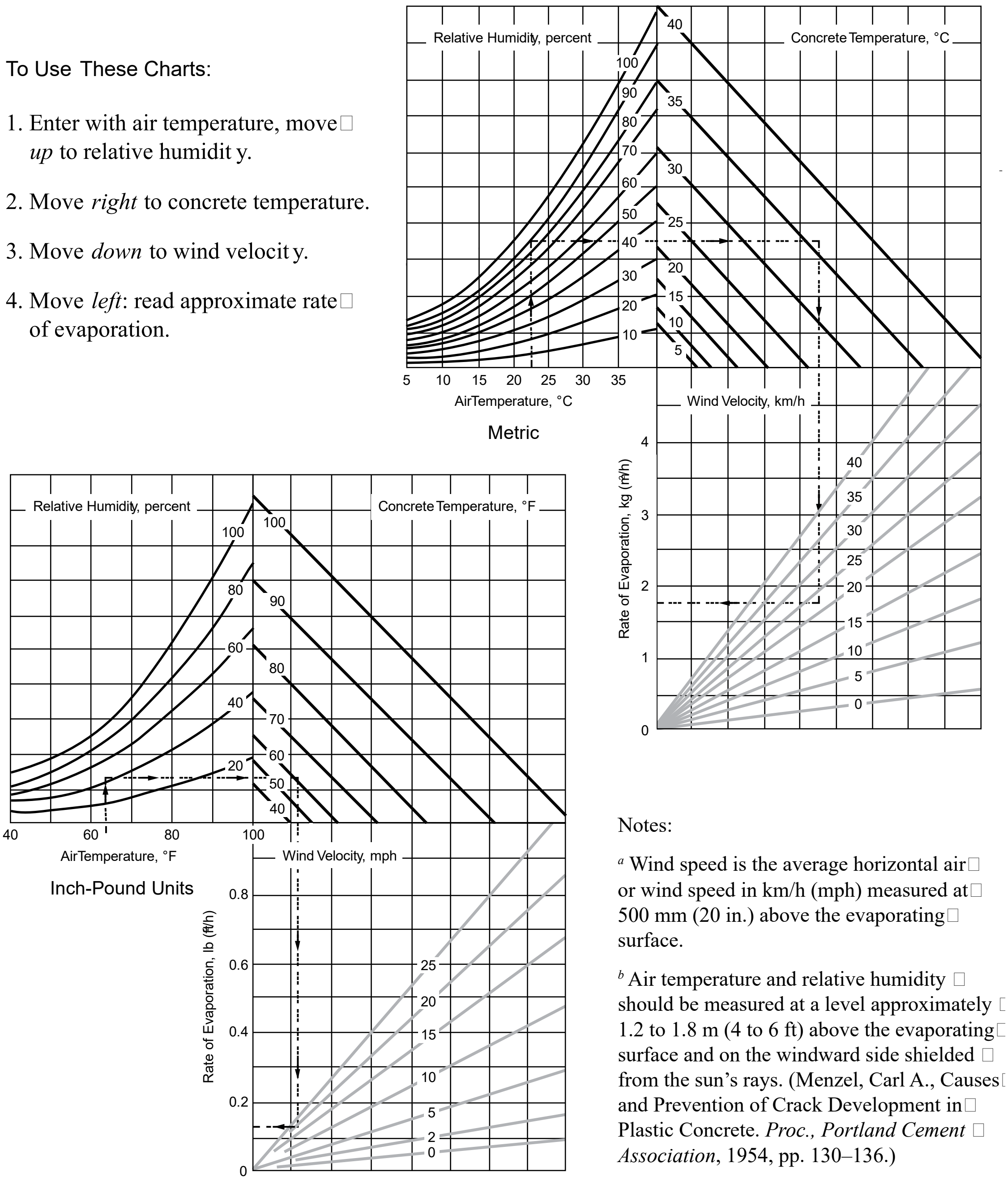


Figure 808.3-1. Evaporation Rate of Exposed Concrete Surface

oil flame or on sheet metal over fire. Add cement only after the combination of water and aggregate temperature is 100°F (38°C) or less.

Ensure material and equipment required for cold weather placement and curing protection is available at the project site before placing concrete. Remove snow, ice, and frost from the surfaces, including reinforcement and subgrade against which the concrete is to be placed. Place concrete only when the temperatures of all surfaces that will come into contact with the concrete are at least 35°F (2°C) and will be maintained at a temperature of 35°F (2°C) or above during placement.

Continuously maintain the concrete surface temperature at or above the required temperatures indicated in Table 808.3-2 for a curing period of at least 7 days. During the curing period, provide suitable measures to maintain the concrete surface temperature. Monitor surface temperature with continuously recording measuring devices that are accurate to within 2°F (1°C). Randomly place in an accessible location one temperature measuring device for every 1,500 ft^2 (140 m^2) of concrete surface area being cured.

Table 808.3-2a. Cold Weather Concrete Surface Temperature Requirements (U.S. Customary Units)

Property	Minimum Section Size Dimension			
	Under 1 ft	1–3 ft	Over 3 ft up to 6 ft	Over 6 ft
Minimum temperature of concrete during curing period	57°F	54°F	50°F	50°F
Maximum allowable temperature drop in any 24-h period during curing	50°F	40°F	29°F	20°F

Table 808.3-2b. Cold Weather Concrete Surface Temperature Requirements (SI Units)

Property	Minimum Section Size Dimension			
	Under 305 mm	305–915 mm	Over 915 mm up to 1.830 m	Over 1.830 m
Minimum temperature of concrete during curing period	14°C	12°C	10°C	10°C
Maximum allowable temperature drop in any 24-h period during curing	28°C	22°C	16°C	11°C

Do not count as a day contributing to the curing period any day during which the minimum concrete surface temperature requirement is not continuously maintained. Extend the minimum cure time as specified in Table 808.3-3 when pozzolan or slag is added to the mix or when otherwise necessary to develop satisfactory strength in the concrete. The Contractor may reduce the cure period for areas other than top slabs when test cylinders cured under the same conditions as the structure indicate that at least 70 percent of the specified strength has been achieved.

Table 808.3-3. Curing Times for Concrete Mixed with Pozzolans

Percentage of Cement Replaced by Weight with Pozzolans	Curing Period
10% or less	8 days
11%–15%	9 days
16%–20%	10 days

Heat the structure uniformly and in such a manner that no part of the concrete surface is heated to more than 90°F (32°C). Reduce heat gradually from the structure so that the temperature will not drop more than 20°F (11°C) in 8 h.

4. *Salt Water Environment Requirements.* For concrete exposed to salt or brackish water, use Class S cement for underwater applications and Class A for other work, as specified in Table 713.1-2. Mix concrete exposed to such conditions for a minimum of 2 minutes. Control water content and thoroughly consolidate concrete to ensure high impermeability, high density, and lack of rock pockets. Do not form construction joints between low-water level and the upper limit of wave action. Prohibit removal of forms between these levels or provide other acceptable protection to prevent newly placed concrete from direct contact with salt water for 30 days or more. For concrete exposed to sulfate soils or water, protect concrete from contact with the soil or water for 72 h or more.

E. *Placing Concrete.* Provide a placement plan. Place and consolidate the concrete mix in approved forms to make a dense homogeneous concrete. Place concrete within 90 minutes after adding cement to the mix. Moisten the forms with water before placing concrete. Place concrete continuously to prevent unplanned cold joints or damage to newly set concrete.

1. *Placement Sequence:*

   a. *Vertical Members.* Place concrete in vertical members of columns or walls and allow concrete to settle before placing integral horizontal members. Allow concrete to settle for at least 30 minutes. For members more than 15 ft (4.5 m) high, allow concrete to settle at least 12 h. Allow members to reach specified strength and have at least 7 days cure time before applying loading from horizontal members.

   b. *Box Culverts.* Place the footings and base slab of box culverts and allow to set before constructing the remainder of the culvert.

   c. *Superstructures.* Place concrete in the superstructure only after substructure forms are stripped to allow inspection of supporting concrete.

   For concrete placed in T-beams or deck girders whose depth is more than 4 ft (1.2 m), allow 5 days of curing time for the stem concrete before placing the top or deck slab. For box girders, place the bottom slab and stem in one or separate operations, but do not place top slab until the stem has 5 days of curing time.

d. *Arches.* Place the concrete in arch rings to load the centering uniformly and symmetrically. Place transverse arch sections so that each section is cast in one continuous operation. Bond each section together with suitable keys or dowels. Obtain approval for the sequence of placement and arrangement of sections.

e. *Precast Members.* Place concrete in the precast member in a sequence to obtain a well-consolidated concrete and to prevent settlement or shrinkage cracks.

2. *Placing Concrete.* Place concrete as near as possible to final position. Do not move the concrete laterally with vibrators. Limit lift thickness to 2 ft (0.6 m). Do not exceed the capacity of the vibrators to consolidate and merge the concrete with the previous lift. When dropping concrete more than 5 ft (1.5 m), use a tube with a hopper head or other approved device to prevent segregation of the mix and spattering of mortar. Use clean, watertight equipment and material, but avoid those made of aluminum. Equip chutes on steep slopes with baffles or reverses. Operate pumps to produce a continuous stream of concrete without air pockets or segregation. Discard all concrete material used to prime or clean the pump.

3. *Consolidating Concrete.* Consolidate all concrete, except underwater or other exempted placements, by mechanical vibration. Use internal vibration, except for thin sections, with forms designed for external vibration. Use properly sized vibrators capable of transmitting vibrations of not less than 5,500 vibrations per minute nor more than 13,500 vibrations per minute. Provide an adequate number of vibrators to accomplish the work, with one or more spare vibrators in case of breakdown. Use immersion-type vibrators featuring heads covered with rubber or other resilient non-metallic material to consolidate concrete reinforced with epoxy-coated reinforcement. Vibrate at point of deposit. Insert vibrators vertically and withdraw slowly to avoid segregation or grout pockets. Vibrate in a uniform pattern spaced less than 1.5 times the radius of visible effectiveness. Avoid vibration of hardened layers below the placement.

F. *Placing Concrete Underwater.* Obtain written approval before depositing concrete underwater, except when cofferdams are used to seal out water. Equalize hydrostatic pressure during placement and cure of cofferdams to prevent flow of water through cofferdams during this period. Use Class A concrete, as specified in Table 713.1-2, with the proportion of cement increased by 10 percent. Place concrete uniformly in its final position.

Use a tremie, concrete pump, or other approved device to place concrete in a compact mass in its final position. Use a tremie consisting of a watertight tube having a diameter of not less than 10 in. (250 mm) and fitted with a hopper at the top. Support the tremie to allow free movement of the discharge end over the entire top surface of the work and to allow rapid lowering as necessary to retard or stop the flow of concrete. Use concrete pumps with a device at the end of the discharge tube to prevent water from entering while the tube is first being filled with concrete. Keep the tremie tube full of concrete to the bottom of the hopper after placement has started. Withdraw the tremie, reseal the discharge end, and restart the placement if water enters the tube after placement is started. Use one tremie in each bay when cofferdam struts prevent lateral movement of tremies.

Proceed with dewatering only after test specimens cured under similar conditions show sufficient strength. Remove laitance or other unsatisfactory material by scraping, chipping, or other means that will not damage the surface of the concrete.

G. *Joints:*

1. *Construction Joints.* Extend planned reinforcing steel uninterrupted through joints. Place additional reinforcing steel dowels across unplanned joints.

   Construct shear keys at vertical joints and at horizontal joints, unless shown otherwise. Rough float the horizontal construction joints to consolidate the surface. Leave the joint in a roughened condition. Form depressions for shear keys covering approximately one third of the contact surface. Bevel the forms for keys so that removal will not damage the concrete. Clean construction joints of surface laitance, curing compound, and other foreign materials before placing fresh concrete against the surface of the joint. Use abrasive blast or other approved methods to clean horizontal construction joints to expose clean aggregate. Flush construction joints with water and allow to dry to a surface dry condition immediately before placing concrete.

   Bond new concrete to existing clean concrete structures. Drill and clean holes for reinforcing dowels $^1/_4$ in. (6 mm) larger than the nominal diameter of the dowels. Grout dowels in the holes when the concrete is saturated surface dry. Limit water content to no more than 1 gal/365 lb (1 L/43 kg) of cement. Do not retemper grout. Cure grout for at least 3 days. The Contractor may use epoxy instead of portland cement grout, with prior approval. Follow the manufacturer's recommendation.

   Form the face edges of all joints exposed to view with straight bulkheads or grade strips, and finish true to line and elevation.

2. *Expansion and Contraction Joints and Waterstops.* Construct expansion and contraction joints to include open joints, filled joints, joints sealed with sealants or waterstops, joints reinforced with steel armor plates or shapes, and joints with combinations of these features.

   Construct open joints by inserting and subsequently removing a wood strip, metal plate, or other approved material. Insert and remove the template without chipping or breaking the corners of the concrete. Finish open joints in decks and sidewalks with an edging tool, when not protected by metal armor. Remove mortar and other debris from open joints.

   Construct filled joints with preformed or premolded fillers unless polystyrene board is specified. Use a single piece of joint filler for each joint. Anchor joint filler material to one side of the joint by waterproof adhesive to prevent it from working out of the joint; take care not to interfere with the compression of the material.

   Construct sealed joints by first removing foreign material from the joint before installing pourable joint sealants. Cut down the filler material to the depth shown or approved, and clean the surface of the concrete that will be in contact with the sealant by light sandblasting. Place a polyethylene foam strip in the joint to retain the sealant and isolate it from the filler material. Follow the manufacturer's recommendations. Remove and replace the sealant material that fails to bond to the sides of the joint within 24 h after placement.

Use epoxy bonding agents to match cast joints.

Provide waterstops of metal, rubber, or plastic, as required, and of a type allowing joint movement without injury to the joint material. Splice, weld, or solder joints to be continuous and watertight. Prevent contamination of waterstop surfaces from oil, grease, dried mortar, or other foreign matter while the waterstop is being embedded in concrete. Ensure that all portions of the waterstop designed for embedment are tightly enclosed by dense concrete.

Form rubber waterstops with an integral cross section in suitable molds to produce a uniform section with a permissible variation in dimension of ±0.4 in. (±1 mm). Prohibit splices in straight strips. Cure the waterstop strips and special connection pieces to produce a dense, homogeneous cross section free from porosity. Ensure junctions in the special connection pieces are full molded. Use suitable clamps to securely hold the joints during the vulcanizing period. Provide a dense and homogeneous material at the splices throughout the cross section.

Install expansion joint armor assemblies so the top surface matches the plane of the adjacent finished concrete surface throughout the length of the assembly. Maintain assemblies in the correct position while placing the concrete. Install the expansion joint at the required opening. Avoid impairment of the clearance in any manner.

H. *Finishing Plastic Concrete.* Strike off surfaces of concrete that are not placed against forms to the planned elevation or slope, and finish the surface by floating with a wooden float to seal the surface. Tool construction and expansion joints with an edger. Leave joint filler exposed.

Finish bridge decks, approach slabs, and other concrete surfaces for use by traffic to a smooth, skid resistant surface. Provide adequate work bridges for proper performance of the work, including the application of fog sprays and curing compound, and for inspecting the work.

1. *Striking Off and Floating.* After the concrete is placed and consolidated, finish pavement surfaces using approved power-driven finishing machines. Conduct a dry run of the equipment before placing concrete. Use hand finish methods when approved for bridges less than 50 ft (15 m) in length or for irregular areas.

   Strike off surfaces with equipment supported by and traveling on rails or headers. Use equipment of sufficient strength and adjust to ensure the concrete surface will conform to the planned profile and cross section. Provide rails or headers on nonyielding supports spaced [2 ft (0.6 m)] on center and firmly secured for the scheduled length of concrete placement. Extend rails for finishing machines beyond both ends of the scheduled length of placement a distance that will allow the float of the finishing machine to fully clear the concrete to be placed. Adjust rails or headers for elevation. Allow for anticipated settlement, camber, and deflection of false work to obtain a finished surface true to the required grade and cross section. Install rails or headers of a type that no springing or deflection will occur under the mass of the finishing equipment. Locate the rails or headers so that finishing equipment may operate without interruption over the entire surface being finished. Adjust rails or headers as necessary to correct for unanticipated settlement or deflection that occurs during finishing operations. Remove the supports at least [2 in. (50 mm)] below the finished surface when rail supports are located within the area where concrete is being placed, and as soon as they are no longer needed. Fill the void with fresh concrete.

Maintain a slight excess of concrete in front of the cutting edge of the screed at all times. Carry this excess concrete to the end of the placement and remove from the slab.

After striking off the concrete, finish the surface with a float, roller, or other approved device to remove local irregularities and to leave sufficient mortar at the surface of the concrete for subsequent texturing. During finishing operations, remove excess water, laitance, or foreign materials brought to the surface by means of a squeegee or straightedge drawn from the center of the slab toward either edge. Finish the surface without adding water.

2. *Straightedging.* Check the surface with a 10-ft (3-m) metal straightedge placed parallel to the centerline of the bridge. Ensure that there are no deviations in excess of $^{1}/_{8}$ in. (3 mm) from the testing edge of the straightedge, or $^{3}/_{8}$ in. (10 mm) for deck surfaces that are overlaid with 1 in. (25 mm) or more of another material. Correct deviations in excess of these requirements before the concrete sets. Overlap the straightedge one-half the length of the preceding pass as the checking progresses.

3. *Texturing.* Produce a skid resistant texture on the surface by burlap or turf dragging, brooming, tining, or a combination of these methods. Finish to a smooth surface those areas that are to be covered with a waterproofing membrane deck seal.

   Provide a drag finish with a seamless strip of damp burlap over the full width of the surface. Use sufficient layers on the burlap drag and maintain sufficient length in contact with the concrete to slightly groove the surface, and to keep moving forward with a minimum bow of the lead edge. Keep the drag damp, clean, and free of particles of hardened concrete. The Contractor may substitute carpet or artificial turf for burlap when approved.

   Provide a broom finish with a stiff-bristle broom. Square the strokes across the slab, from edge to edge, with adjacent strokes slightly overlapped, to produce regular corrugations not more than $^{1}/_{8}$ in. (3 mm) in depth. Provide a finished surface free from porous spots, tears, irregularities, depressions, and small pockets or rough spots caused by disturbing particles of coarse aggregate embedded near the surface.

   Provide a transverse tined surface with a wire broom, comb, or finned float having a single row of tines or fins. Tine the surface with grooves from $^{1}/_{16}$ in. to $^{3}/_{16}$ in. (2 mm to 5 mm) wide and $^{1}/_{8}$ in. to $^{3}/_{16}$ in. (3 mm to 5 mm) deep, spaced $^{1}/_{2}$ in. to $^{3}/_{4}$ in. (12 mm to 20 mm) on centers. Discontinue tining 12 in. (300 mm) from the curb line on bridge decks. Provide a longitudinal broom finish in the area adjacent to the curbs.

Provide a grooved surface with a concrete saw designed specifically for grooving concrete surfaces. Groove the hardened surface with grooves from $^1/_{16}$ in. to $^3/_{16}$ in. (2 mm to 5 mm) wide and $^1/_8$ in. to $^3/_{16}$ in. (3 mm to 5 mm) deep, spaced $^1/_2$ in. to $^3/_4$ in. (12 mm to 20 mm) on centers. Discontinue grooves 12 in. (300 mm) from the curb line on bridge decks. Provide a longitudinal broom finish in the area adjacent to the curbs.

4. *Surface Testing and Correction.* Inspect finished deck roadway surfaces that will not be overlaid with a wearing surface. Mark variations in the surface that exceed $^1/_8$ in. (3 mm) from a 1-ft (3-m) straightedge. Correct marked irregularities with a concrete plane or grooving equipment to produce a textured surface equal in roughness to the surrounding unground concrete without shattering or otherwise damaging the remaining concrete.

5. *Surface Finishes:*

   a. *Pedestrian Walkway Surface Finish.* Strike off and float the surface with wooden or cork float. Broom the surface lightly in a transverse direction. Use an edging tool on edges and expansion joints. Lay out sidewalk surfaces in blocks with an approved grooving tool. Correct deviations of more than $^1/_8$ in. (3 mm) when checked with a 5-ft (1.5-m) straightedge.

   b. *Troweled and Brushed Finish.* Finish the surface with a steel trowel until a slick surface free of bleed water is produced. Brush the surface with a fine brush using parallel strokes.

   c. *Surface Under Bearings:*

      i. Finish the surface with a float finish where metallic masonry plates are to be placed directly on the concrete or on filler material less than $^1/_8$ in. (3 mm) thick. Grind the masonry plate contact area to provide full and even bearing.

      ii. Finish the concrete surface with a steel trowel when plates will be set on filler material between $^1/_8$ in. and $^1/_2$ in. (3 mm and 12 mm) thick. Provide a finished surface that varies by no more than $^1/_{16}$ in. (2 mm). Grind surfaces that fail to conform to the required flatness.

      iii. Finish with a wood float to a flat and even surface free of ridges those surfaces under elastomeric bearings and under metallic masonry plates that are supported on mortar or filler pads $^1/_2$ in. (12 mm) or greater in thickness.

I. *Curing Concrete.* Cure newly placed concrete using one or more of the methods specified below. Keep the surface of the concrete moist by a water fog spray applied without damaging the surface. Commence curing operations immediately after the free water has left the surface and finishing operations are completed.

Cure concrete for 7 uninterrupted days. Cure for 10 days when using pozzolans in excess of 10 percent by weight (mass) of the portland cement in the mix. The Contractor may reduce the cure period for areas other than top slabs when test cylinders cured under the same conditions as the structure indicate that at least 70 percent of the specified strength has been achieved.

In hot weather, apply water to concrete surfaces cured by the liquid membrane method or by the forms in place method, until the cooling effect is no longer needed.

1. *Curing Methods:*

    a. *Forms-in-Place Method.* Leave forms in place without loosening them for the cure.

    b. *Water Method.* Maintain the concrete surface in a continuously wet condition by ponding, spraying, or covering with materials that are kept continuously and thoroughly wet. Use cotton mats, multiple layers of burlap, or other approved materials that do not discolor or otherwise damage the concrete.

    c. *Liquid Membrane Curing Compound.* Use Type 2, white pigmented, liquid membranes only on the surfaces of bridge decks, on surfaces that will not be exposed to view in the completed work, or on surfaces where their use has been approved. Apply the curing solution uniformly at the manufacturer's specified application rate. Do not use liquid membrane curing compounds on surfaces where a rubbed finish is required or on surfaces of construction joints unless the membrane is removed by sandblasting before placing new concrete against the joint.

        Seal the exposed concrete immediately after the free water has left the surface. Seal formed surfaces immediately after the forms are removed and the concrete finished. Apply the solution by power-operated atomizing spray equipment in one or two separate applications. Apply the second coating within 30 minutes of the first. Use hand-operated sprayers for coating small areas if needed. Thoroughly mix membrane solutions containing pigments. Agitate mixture during application.

        Reapply solution, at the specified rate, to membrane film damaged during the curing period by weather or construction activities.

    d. *Waterproof Cover Method.* Provide a cover of waterproof sheet material to prevent moisture loss from the concrete. Use this method only when the covering can be secured to prevent moisture loss.

        Install the cover when the concrete is wet. Use sheets of the widest practicable width, overlap sheets a minimum of 6 in. (150 mm), and seal tightly with pressure-sensitive tape, mastic, glue, or other approved methods to form a waterproof cover of the entire concrete surface. Secure the paper to prevent displacement by wind. Immediately repair sheets torn or damaged during the curing period.

    e. *Steam or Radiant Heat Curing Method.* Cure precast concrete members that are manufactured in established plants with steam or radiant heat. Use saturated, low-pressure steam in a suitable enclosure to contain the live steam or the heat. Use temperature-recording devices to verify that temperatures are uniform and within specification throughout the enclosure.

        Apply the steam or heat between 2 and 4 h after the placement of concrete to allow the initial set of the concrete to take place. Apply steam or heat cure between 4 and

6 h after placement if retarders are used. Adjust cure time with approval according to AASHTO T 197M/T 197. Maintain the temperature within the curing chamber at 50°F (10°C) or higher, and keep the concrete wet during the waiting period.

Prevent steam from blowing directly onto the concrete or forms. Increase the ambient temperature within the curing enclosure at an average rate not exceeding 40°F (22°C) per hour until the curing temperature is reached. Limit curing temperature to 160°F (71°C) maximum within the enclosure. Cure the concrete until it reaches the desired strength. Decrease enclosure temperature not more than 40°F (22°C) per hour until reaching a temperature 20°F (11°C) above the temperature of the air to which the concrete will be exposed.

Apply radiant heat by pipes circulating steam, hot oil, or hot water, or by electric heating elements. Use a suitable enclosure to contain the heat. Minimize moisture loss by covering all concrete surfaces with a plastic sheeting or by using an approved liquid membrane curing compound on all exposed concrete surfaces. Clear membrane curing compound residue from the surfaces of concrete members to which other materials will be bonded in the finished structure to prevent reducing bond below design limits.

If the ambient temperature remains above 60°F (16°C) during the steam curing or heat curing, the Contractor may immediately transfer the stressing force to the concrete after it has received the desired strength.

2. *Curing Bridge Decks.* Keep concrete bridge decks wet with clean, fresh water for a curing period of at least 14 days after placing concrete. Begin curing by fog spraying during the placing and finishing operations. Apply fogging continuously, rather than intermittently, after the finishing operation until wet covering material has been placed over the concrete surface. Augment with hand-held fogging equipment as needed.

   Use water curing only for bridge decks, medians, sidewalks, and safety curbs. Keep the surface continuously wet for the entire curing period by covering with two layers of wet burlap or one layer of wet burlap with either a polyethylene sheet or a polyethylene coated burlap blanket.

   Apply curing protection within 15 minutes after depositing the concrete and before the surface of the concrete has lost its surface "wetness" or "sheen" appearance. Submerge the burlap in water for at least 8 h before the scheduled start of the concrete placement. Drain the burlap of excess water prior to application. Provide burlap that is free from cuts, tears, uneven weaving, and contaminants. Place the burlap such that the edges are lapped a minimum of 6 in. (150 mm). Commence continuous burlap wetting 10 minutes after its placement and keep continuously wet and protected from displacement for the entire curing period.

   Keep bridge decks, medians, sidewalks, and safety curbs covered and continuously wet for the entire curing period by the use of soaker hoses. Provide a system of soaker hoses that circulate water continuously and that are located to ensure a completely wet surface for the entire curing period.

Ensure that adequate personnel are available at the site to carry out the placement, screeding, finishing, fogging, and curing operations simultaneously. To overcome shrinkage problems, use wind screens and sun shades as conditions require.

In the event of an unavoidable delay during concrete placement, the Contractor may substitute the required water curing with the application of two coats of an impervious liquid membrane curing compound. If used, spray curing compound onto the concrete that has been deposited and not screeded. If a pour cannot be completed, do the following: a) form an approved construction joint; b) remove the partial pour; and, c) take other remedial measures as directed by the Engineer. Use a curing compound that meets the requirements of ASTM C309. Mix the curing compound into the concrete using the finishing machine. Do not apply curing compounds to the screeded surfaces of bridge decks.

Limit the maximum concrete temperature to 154°F [68°C], and control the temperature of the concrete to ensure that it does not fall below 57°F [14°C]. Control concrete heat through a combination of selecting cement concrete ingredients that will undergo minimal cooling prior to placement, post-placement cooling, controlling the cement concrete placement rate, insulating the cement concrete surface, and providing supplemental heat to prevent heat loss.

Measure and record concrete and ambient air temperatures on an hourly basis for at least the first 72 h after placement, or for 168 h during hot or cold weather conditions. Furnish log records of the temperatures recorded at a minimum frequency of once per hour. Submit temperature data to the Agency at a minimum frequency of once per day.

J. *Finishing Formed Concrete Surfaces.* Provide finished surfaces as follows:

1. *Class 1—Ordinary Surface Finish.* Finish formed concrete surfaces with a Class 1, ordinary surface finish upon removal of forms. Immediately remove fins and irregular projections from surfaces that are to be exposed or waterproofed. Remove surface bulges or offsets with carborundum stones or discs. Remove and replace localized poorly bonded rock pockets or honey-combed concrete with sound concrete or packed mortar as specified in Subsection 808.3(L).

   Removal or replacement of portions or all of the structure may be required if the rock pockets are extensive enough to materially affect the strength of the structure or reduce the life of the reinforcement.

   Clean and saturate with water all cavities produced by form ties and all other holes, broken corners or edges, and other defects, and then point and true with mortar. For exposed surfaces, add white cement to the mortar to achieve a patch that, when dry, matches the surrounding concrete and is true and uniform. Use mortar in pointing that is less than 1 h old. Rub the concrete if required or continue curing. Tool and leave construction and expansion joints free of mortar and concrete. Leave the joint filler exposed for its full length with clean and true edges.

2. *Class 2—Rubbed Finish.* Finish exposed surfaces with a Class 2, rubbed finish, except the soffits and the interior faces, and bottoms of concrete girders. Rub concrete as soon as its condition will allow. Saturate with water before starting this work. Allow mortar used in pointing and patching to set before finishing. Rub surfaces with a medium-coarse carborundum stone, using a small amount of mortar on its face. Mix the mortar using the same proportions of cement and fine sand used in the concrete being finished. Continue rubbing until form marks, projections, and irregularities have been removed, voids have been filled, and a uniform surface has been obtained. Leave the paste produced by this rubbing in place. Produce the final finish by rubbing with a fine carborundum stone and water. Continue rubbing until the entire surface is of a smooth texture and uniform color. Rub the completed surface with burlap to remove loose powder and leave the surface free from unsound patches, paste, powder, and objectionable marks.

   Use a Class 1 finish for metal forms, fiber forms, lined forms, or plywood forms in good condition, and when the Class 1 finish is equal to that which could be attained with the application of a Class 2, Rubbed Finish. Grind with powered disc or sandblast with fine sand to achieve a Class 1 finish when approved.

3. *Class 3—Tooled Finish.* Provide a Class 3, tooled finish, when specified. Finish panels and other similar work with a bushhammer, pick, or crandall. Conduct work only after 14 days or when aggregate cannot be picked out of the surface. Provide a tooled finish surface that shows a grouping of broken aggregate particles in a matrix of mortar, each aggregate particle being in slight relief.

4. *Class 4—Sandblasted Finish.* Provide a Class 4, sandblasted finish, when specified. Sandblast the cured concrete surface with hard, sharp sand to produce an even, fine-grained surface in which the mortar has been cut away, leaving the aggregate exposed.

5. *Class 5—Wire Brushed or Scrubbed Finish.* Provide a Class 5, wire brushed or scrubbed finish, when specified. Scrub the green concrete surface with stiff wire or fiber brushes. Use a muriatic acid solution of 1 part acid to 4 parts water by volume. Remove the cement film or surface, and expose the aggregate particles. Leave an even pebbled texture presenting an appearance ranging from fine granite to coarse conglomerate, depending upon the size and grading of aggregate used. Wash the surface with water mixed with a small amount of ammonia to remove all traces of acid.

K. *Precast Concrete Members:*

1. *Working Drawings.* Provide working drawings for precast members. Include in the drawings details not provided in the plans for the construction and erection of the members. Cast members only after working drawings are approved. Use precast methods for cast-in-place elements when approved. Submit working drawings, showing construction joint details and other required information. Construct and place precast concrete members according to the details specified.

2. *Manufacturing.* Monitor the quality of the concrete when casting in an established yard. Perform tests for materials and strength according to appropriate AASHTO or ASTM methods.

   Cast members on rigid beds or pallets. Use care in casting the bearing surfaces so that they will join properly with other elements of the structure. Allow multiple casting of prestressed precast units in one continuous line and stress at one time. Leave space between ends of units to allow access to cut tendons after the concrete has attained the required strength.

   Remove side forms only after it will not distort the concrete surface and providing that the curing is not interrupted. Lift members from casting beds only after their strength is sufficient to prevent damage.

   Finish surfaces to a coarse texture with a stiff coarse broom when cast-in-place concrete will later be cast against the top surfaces of precast beams or girders. Clean these surfaces of laitance or other foreign material by sandblasting or other approved methods prior to shipment.

   Match-cast each member with its adjacent segments to ensure proper fit during erection, when precast members are designed to abut together in the finished work. Align the match-cast segments to achieve the final structure geometry. Adjust during the alignment to compensate for deflections.

3. *Curing.* Cure precast members by the steam or radiant heat method, or by the water method.

4. *Storage and Handling.* Carefully handle and move precast, prestressed concrete members. Store and transport precast girders in an upright position with the directions of the support reactions on the member during storage or transport as if in the final position. Locate support points during transport and storage within 30 in. (750 mm) of their final position, or as shown on approved shop drawings. Ship only after tests on specimens cured identically to the member show the member has attained the design strength. Replace precast units that are cracked or damaged by improper storage or handling.

5. *Erection.* Lift members so they do not bend or twist. Secure the member to the structure, and provide temporary braces as necessary to resist wind or other loads. Erect and place precast deck form panels so that the mating surfaces do not allow excessive grout leakage. Dry-pack or seal with an acceptable caulking compound any joints where excessive grout leakage may occur prior to placing the cast-in-place concrete. Saw end panels on skewed structures to fit the skew.

6. *Mixing Epoxy and Installing Epoxy-Bonded Precast Segments.* Follow the manufacturer's recommendation. Apply the epoxy material to all surfaces to be joined. Check the joint immediately after erection to verify uniform joint width and proper fit. Remove excess epoxy from the joint where accessible. Swab all tendon ducts after stressing, while the epoxy is in the nongelled condition, to remove or smooth out any epoxy in the conduit and to seal any pockets or air bubble holes that may have formed at the joint.

L. *Mortar and Grout:*

1. *Mixing.* Use a grout or mortar of Type 1A, air-entraining, portland cement, fine aggregate and water to fill voids less than $^{3}/_{4}$ in. (20 mm), and modify sand gradation so that all material passes the No. 8 (2.36-mm) sieve. Proportion cement to sand by loose volume using 1 part cement to 2 parts sand for mortar and 1 part cement to 1 part sand for grout. When nonshrink mortar or grout is specified, use either a nonshrink admixture or an expansive hydraulic cement meeting ASTM C845/C845M. Use only sufficient water to allow placing and packing. For mortar, use only enough water so that the mortar will form a ball when squeezed gently in the hand.

   Mix by hand methods or with rotating paddle type mixing machines. Continue mixing until all ingredients are thoroughly mixed. Place mortar or grout within 1 h. Do not retemper by adding water.

2. *Placing and Curing.* Clean concrete surfaces that will be in contact with the mortar or grout of loose or foreign material that would prevent bonding. Flush surface with water and allow to dry to a saturated surface dry condition immediately prior to placing the mortar or grout. Fill and tightly pack the mortar or grout into recesses and holes on surfaces, under structural members, and at other locations specified. Cure all surfaces of mortar or grout by the water method as specified in Subsection 808.3(I)(1)(b) for at least 3 days.

   Prevent mortar from escaping keyways, spaces between structural members, holes, spaces under structural members, or other locations where mortar could escape. Do not load mortar or grout before the end of the curing period. Remove or replace improperly cured or defective mortar or grout.

M. *Application of Loads.* Apply loads to concrete structures only after the concrete has attained sufficient strength, and, when applicable, sufficient prestressing has been completed.

1. *Earth Loads.* Place backfill around structures so that overturning or sliding forces are minimized, and when the concrete has reached at least 80 percent of its specified strength.

2. *Construction Loads.* Allow light materials and equipment on bridge decks only after the concrete has been in place for at least 24 h. Ensure the loads will not interfere with curing and will not damage the surface texture. After the last-placed deck concrete has attained a compressive strength of at least 2,465 psi (17 MPa), allow on the bridge deck construction vehicles, having a weight (mass) between 1,000 and 4,000 lb (450 and 1,800 kg), and comparable materials and equipment loads. Do not place loads in excess of the above until the deck concrete has reached its specified strength. Post-tension structures before loading with vehicles and other comparable material and equipment loads of more than 4,400 lb (2,000 kg). Place steel or precast concrete girders on substructure elements only after the substructure concrete has attained 70 percent of its specified strength. Keep all loads below the load-carrying capacity of the structure.

3. *Traffic Loads.* Allow regular traffic on concrete decks 14 days after the last placement of deck concrete, or after the concrete has attained its specified strength.

808.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will use plan quantities to measure concrete.

B. The measurement will include quantities of concrete from fillets, scorings, and chamfers of 1 in.^{2} (650 mm^2) or more in cross-sectional area.

808.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Concrete (Class)	yd^3 (m^3)
(B) Precast concrete members	each

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 809
REINFORCING STEEL

809.1 DESCRIPTION

Place reinforcing steel.

809.2 MATERIALS

Provide materials as specified in:

Deformed and plain billet steel bar	Subsection 711.1(A)
Deformed and plain rail steel bar	Subsection 711.1(B)

809.3 CONSTRUCTION

Use deformed reinforcing bars. Plain bars may be used for spirals and ties.

Place and secure steel reinforcement in position. Tie bars at all intersections around the perimeter of each mat, and not less than 2-ft (600-mm) centers or at every intersection, whichever is greater. Tie bundled bars together at not more than 6-ft (1,800-mm) centers. Use plastic-coated or epoxy-coated tie wire and metal clips for fastening epoxy-coated reinforcement.

Use precast concrete blocks, wire bar supports, supplementary bars, or other approved devices to support reinforcing steel in its proper position and to maintain the distance between the reinforcing steel and the formed surface or the top surface of deck slabs within $^{1}/_{4}$ in. (6 mm) of that specified.

Provide precast concrete blocks, having a comparable compressive strength, color, and texture to that of the concrete in which they are to be embedded, with an embedded wire for securing the block. Limit the size of the face of blocks in contact with forms to 2 in. by 2 in. (50 mm by 50 mm).

Adjust or relocate non-prestressed reinforcement used in post-tensioned concrete during the installation of prestressing ducts or tendons to provide planned clearances to the prestressing tendons, anchorages, and stressing equipment.

Splice sheets of welded wire fabric or bar mat by overlapping at least one mesh in width plus 2 in. (50 mm).

Substitute different size reinforcing bars only with authorization. Ensure substituted bars have an area equivalent to the design area, or larger, and meet *AASHTO LRFD Bridge Design Specifications*.

809.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will compute the theoretical weight (mass) of the reinforcing steel placed, excluding from the measurement the weight (mass) of wire mesh or clips, wire, separators, wire chairs, and other material used in fastening the reinforcement in place.

B. The Engineer will exclude the weight (mass) of epoxy coating from the measurement of the weight (mass) of epoxy-coated reinforcing steel.

809.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Reinforcing steel (Type)	lb (kg)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 810
PRESTRESSED CONCRETE

810.1 DESCRIPTION

Furnish, place, and tension prestressed steel for prestressing precast or cast-in-place concrete.

810.2 MATERIALS

Provide materials as specified in:

Portland Cement, Types I, II, or III	Subsection 701.2
Reinforcing Steel	Sections 711, 809
Concrete	Subsection 713.1(B), Section 808
Approved Anchorages, Couplers, Ducts, and Grout	*AASHTO Guide Specifications for Design and Construction of Segmental Concrete Bridges*, *AASHTO LRFD Bridge Design Specifications*
Corrosion Inhibitor	Federal Specification MIL-PRF-3420H

810.3 CONSTRUCTION

Select a system that provides the required magnitude and distribution of prestressing force and ultimate strength without exceeding allowable temporary stresses.

Perform the prestressing by either pretensioning or post-tensioning methods, or a combination of the two methods.

A. *Submittals.* Submit for approval working drawings including complete details and substantiating calculations of the method, materials, and equipment proposed for use in the prestressing operations, any additions or rearrangement of reinforcing steel, and any revision in concrete dimensions.

   Submit for approval a quality-control program that verifies that the materials and workmanship incorporated into the precast prestressed concrete members meet the requirements.

   Include on working drawings embedded items such as the prestressing ducts, vents, anchorage reinforcement and hardware, reinforcing steel, anchor bolts, earthquake restrainers, deck joint seal assemblies, drainage systems, utility conduits, and other related items. Ensure that there will be no conflict among the planned positions of embedded items and that the concrete cover will be adequate.

B. *Placing Ducts, Steel, and Anchorage Hardware.* Rigidly support ducts in the forms using ties, supplementary support bars, and hold-down ties to prevent displacement during concrete placement and to maintain proper alignment of the duct.

Couple joints between sections of duct with positive connections that do not result in angle changes at the joints and that will prevent the intrusion of cement paste.

Vent ducts for continuous structures at the high points of the duct profile, except where the curvature is small. Install drains at the low point in ducts.

Remove the ends of vents and drains 1 in. (25 mm) below the surface of the concrete after grouting is completed. Fill the void with mortar.

Install prestressing steel accurately in the forms and hold in place by the stressing jack or temporary anchors and, when tendons are to be draped, by hold down devices.

Place and hold accurately in position during concrete placement all prestressing steel pre-assembled in ducts and installed prior to placing concrete. Set and hold anchorage devices or block out templates for anchorages with their axes parallel to the axis of the tendon, and anchor plates perpendicular to the tendon.

Use a corrosion inhibitor placed in the ducts or applied directly to the steel to protect prestressing steel installed in members or ducts, but not grouted within the time limit, against rust or other corrosion. Protect the prestressing steel until grouted or encased in concrete.

Seal the openings at the ends of the ducts to prevent entry of moisture after tendons are placed in ducts. Do not install steel for post-tensioning until after steam curing is completed.

C. *Tensioning.* Tension prestressing steel by hydraulic jacks to produce the forces shown on the approved working drawing with appropriate allowances for all losses. For post-tensioned work, the losses must also include the anchor set loss appropriate for the anchorage system employed.

Limit the strand stress in pretensioned members before seating (jacking stress) to the values set forth in the *AASHTO LRFD Bridge Design Specifications*. Limit the standard stress in post-tensioned members prior to seating (jacking stress), and the stress in the steel immediately after seating, to the values allowed in *AASHTO LRFD Bridge Design Specifications*.

Apply or transfer prestressing forces to the concrete after the concrete has attained the strength specified for initial stressing. Stress the post-tensioning tendons and release pretensioned tendons as specified.

Provide a record of gauge pressures and tendon elongations for each tendon for review.

Determine the stress in tendons during tensioning by the gauge load cell readings and verify with the measured elongations using the modulus of elasticity, based on nominal area, as furnished by the manufacturer for the lot of steel being tensioned, or as determined by a bench test of strands used in the work.

Use a dynamometer or other approved method to measure the initial force so that its amount can be used as a check against elongation computed and measured. Mark each strand prior to final stressing to allow measurement of elongation and to ensure anchor wedges set properly.

1. *Pretensioning.* Stress strands by either single-strand stressing or multiple-strand stressing.

   Bring strands to be stressed in a group (multiple strand stressing) to a uniform initial tension, prior to being given their full pretensioning, that is within the range specified and sufficient to eliminate slack and equalize the stresses in the tendons.

   Use approved low-friction devices at all points of change in slope of tendon trajectory when tensioning draped pretensioned strands, regardless of the tensioning method used.

   Tension draped strand from both ends of the bed if the load, as determined by elongation measurements, is more than 5 percent less than that indicated by the jack gauges. Ensure the computed load from the sum of elongation at both ends is within 5 percent of that indicated by the jack gauges.

   Perform only one splice per strand when using single-strand jacking. Splice all strands or splice no more than 10 percent of the strands when using multistrand jacking. Splice strands with similar physical properties, from the same source, and with the same "twist" or "lay." Locate splices outside of the prestressed units.

   Cut pretensioned prestressing strands flush with the end of the member. Clean and paint the exposed ends of the strand and a 1-in. (25-mm) strip of adjoining concrete.

2. *Post-Tensioning.* Stress all strands in each tendon simultaneously with a multistrand jack, except for those in flat ducts with not more than four strands. Tension tendons in continuous post-tensioned members by jacking at each end of the tendon. Provide the prestressing steel with permanent protection and bond to the concrete by completely filling the void space between the duct and the tendon with grout.

D. *Grouting.* Flush ducts with concrete walls (cored ducts) to ensure that the concrete is thoroughly wetted. Remove water from ducts with oil-free compressed air.

Add water to the mixer first, followed by portland cement and admixture, or as required by the admixture manufacturer. Mix to obtain a uniform, thoroughly blended grout, without excessive temperature increase or loss of expansive properties of the admixture. Agitate grout continuously until it is pumped. Limit the water content to the minimum necessary for proper placement, and when Type I or II cement is used, to a water cement ratio of 0.45.

Open grout and high point vent openings when grouting starts. Allow grout to flow from the vent nearest the inlet pipe until residual flushing water or entrapped air has been removed. Cap or otherwise close the vent.

Inject grout at any vent that has been, or is ready to be, capped if the grouting pressure exceeds the maximum recommended pumping pressure to maintain a one-way flow of grout.

Pump grout through the duct and continuously waste at the outlet pipe until no visible slugs of water or air are ejected and the efflux time of the ejected grout, as measured by a flow cone test, if used, is not less than that of the injected grout. Close the outlet and build the pumping pressure to a minimum of 70 psi (0.50 MPa) before the inlet vent is closed.

Ensure the temperature of the concrete is 36°F (2°C) or higher from the time of grouting until job-cured 2-in. (50-mm) cubes of grout reach a minimum compressive strength of 800 psi (5.5 MPa). Ensure the temperature of the grout is below 90°F (32°C) during mixing or pumping.

810.4 MEASUREMENT

No measurement required.

810.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

A. *Precast Members.* The Agency will pay for the prestressing of precast concrete members in the contract price paid for the precast members under Section 808.

B. *Cast-in-Place Concrete.* The contract lump sum price paid for prestressing cast-in-place concrete is full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all work involved in furnishing, placing, and tensioning the prestressing steel in cast-in-place concrete structures, complete in place.

C. Full compensation for furnishing and placing additional concrete and deformed bar reinforcing steel required by the particular system used, ducts, anchoring devices, distribution plates or assemblies and incidental parts, and for furnishing samples for testing, for preparing working drawings, and for pressure grouting ducts is included in the contract lump sum price paid for prestressing cast-in-place concrete or in the contract price for furnishing precast members. The Agency will provide no additional compensation for such items.

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Prestressing (Type)	lump sum
(B) Post-Tensioning (Type)	lump sum

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 811
STEEL STRUCTURES

811.1 DESCRIPTION

Furnish, fabricate, and erect steel structures and structural steel elements of other structures.

811.2 MATERIALS

Provide materials as specified in Section 710. Where steel components, including those made of stainless steel, are in contact with aluminum alloy components in the presence of an electrolyte, the aluminum shall be kept from direct contact with the steel.

(Refer to Section 6.4.9, Dissimilar Metals, of the 2018 *AASHTO LRFD Bridge Design Specifications*, including any supplemental information or corrections.)

811.3 CONSTRUCTION

A. *Documentation:*

1. *Notice of Beginning of Work.* Provide written notice (30) calendar days before work begins at the mill or shop. Begin work only after receiving notice back from the Agency.

2. *Inspection.* Furnish copies of all mill orders and certified mill test reports. Include the chemical analysis and physical test results for each heat of steel used in the work. The Contractor may furnish certificates of compliance in place of mill test reports for material normally not supplied with mill test reports, and for items in small quantities taken from stock.

   Include the Charpy V-notch impact test results in certified mill test reports for steels with specified impact values. For specified fine-grain practice, include in the test report confirmation that the material was produced using the practice. Furnish copies of mill orders at the time the order is placed. Furnish certified mill test reports and certificates of compliance before beginning fabrication. Ensure the certificate of compliance carries the manufacturer's signature and that the material meets specifications.

   Make material available for inspection by the Engineer at the fabrication site. Provide free access at all times to any portion of the fabrication site.

B. *Working Drawings.* Approval of working drawings covers only the requirements for strength and detail. The Agency assumes no responsibility for errors in dimensions.

   Begin work only after receiving approval for the submitted working drawings. Approval does not relieve the Contractor of contract requirements.

1. *Shop Drawings*. Submit copies of detailed shop drawings for approval at least (30) calendar days before starting the work to allow time for review by the Engineer and correction by the Contractor.

   Ensure shop drawings fully detail dimensions and sizes of structure components and associated parts.

   Where specific orientation of plates is required, show the direction of rolling of plates.

   Identify on working drawings the ASTM material specification for the main and secondary steel members, bolts, shear studs, and each piece made of steel that is not AASHTO M 270M/M 270, Grade 36 steel.

2. *Erection Drawings*. Submit drawings from a licensed professional engineer that completely illustrate the proposed method of erection. Show details of falsework bents, bracing, guys, dead-men, lifting devices, and attachments to the bridge members. Show erection sequence, location of cranes and barges, crane capacities, location of lifting points on the bridge members, and weights of the members. Ensure the drawings completely detail all anticipated phases and conditions during erection. Furnish calculations showing that factored resistances are not exceeded and that member capacities and final geometry will be correct.

3. *Camber Diagram*. Furnish a fabricator-prepared diagram showing the camber at each panel point for trusses or arch ribs, at field splices, and fractions of span length (quarter points minimum) for continuous beam and girders or rigid frames. Include calculated cambers to be used in the structure's preassembly.

C. *Fabrication:*

1. *Identifying Steel during Fabrication*. Use a system of assembly marking individual pieces and cutting instructions to the shop that maintains the identity of the original piece.

   The Contractor may furnish material taken from stock that is identifiable by heat number and mill test reports, with the Engineer's approval.

   During fabrication, up to the point of assembling members, ensure that each member, clearly displays its ASTM specification, grade, and heat number as a minimum. Mark and identify all structural steel in accordance with ASTM A6/A6M.

   Ensure steel pieces are grade-marked by low stress-type steel die stamping or by a firmly attached tag. Do not use paint or color-coded markings on any piece of steel which may be subject to blast cleaning, galvanizing, heating for forming, or painting that might obliterate the markings before assembling into members in accordance with ASTM A6/A6M and the *AASHTO LRFD Bridge Construction Specifications*, Section 11.4.1.

   Furnish an affidavit certifying the steel identification was maintained throughout fabrication, as requested.

2. *Storing Materials.* Store structural steel, plain or fabricated, above the ground on platforms, skids, or other supports. Keep steel free from dirt, grease, and other foreign matter, and protect it from corrosion. Store high-strength fasteners as specified in Subsection 811.3(D)(6)(c)(i).

3. *Plates:*

   a. *Direction of Rolling.* Cut and fabricate steel plates for main members, splice plates for flanges and main tension members so the primary direction of rolling is parallel to the main tensile or compressive stresses, or both.

   b. *Plate Cut Edges.* Plane, mill, grind, or thermal cut to a depth of $^1/_4$ in. (6 mm) the sheared edges of plates more than $^5/_8$ in. (16 mm) thick that carry calculated stress.

      i. *Oxygen Cutting.* Meet *AASHTO/AWS D1.5M/D1.5 Bridge Welding Code*.

      ii. *Visual Inspection and Repair of Plate Cut Edges.* Meet *AASHTO/AWS D1.5M/D1.5 Bridge Welding Code*.

   c. *Bent Plates.* Take plates to be bent from the stock plates to ensure the bend line is at right angles to the direction of rolling. Cold bent ribs for orthotropic deck bridges may be bent with the bend lines in the direction of rolling only with approval. Before bending, round the plate corners to a $^1/_{16}$-in. (2-mm) radius where the bend will be placed.

      i. *Cold Bending.* Cold bend steel without cracking the plate. Bend radii for cold-bending (at room temperature), measured to the concave face of the plate, shall be kept to a minimum of 5.0*t* for all grades and thicknesses of steel conforming to AASHTO M 270M/M 270 (ASTM A709/A709M) where *t* is the thickness of the plate in inches. Follow the minimum bend radii recommendations from the plate producer for all other grades of steel, as long as radii are not less than the minimums specified.

         For cross-frame or diaphragm connection plates up to 0.75 in., minimize bending radii to 1.5*t*. Wherever possible, orient bend lines perpendicular to the direction of final rolling of the plate. If the bend lines are parallel to the direction of final rolling, increase minimum bend radii to 7.5*t*.

      ii. *Hot Bending.* Bend plates and bars hot at a temperature above the blue brittle temperature of steel (700°F (370°C)), but not greater than 1200°F (650°C), excluding AASHTO M 270M/M 270 (ASTM A709/A709M) Grades HPS 70W and HPS 100W for which plates and bars shall be bent hot at a temperature not greater than 1100°F (594°C). Limit the temperature of heat straightening and heat curving of quenched-and-tempered steel plates to 50°F (10°C) below the minimum required tempering temperature. Grade HPS 70W is limited to 1,050°F (565°C) since the minimum tempering temperature is 1100°F (594°C).

4. *Fit of Stiffeners.* Mill or grind end-bearing stiffener for girders and stiffeners supporting concentrated loads to bear (either milled, ground, or on weldable steel in compression areas of flanges, welded as specified) at the flange. Ensure intermediate stiffeners that do not support concentrated loads fit tightly against the compression flange.

5. *Abutting Joints.* Mill or saw cut abutting ends in compression members of trusses and columns to provide a square joint and uniform bearing. The maximum opening in unfaced joints is $^3/_8$ in. (10 mm).

6. *Facing Bearing Surfaces.* Ensure the surface finish for bearing, base plates, and other bearing surfaces that contact each other or concrete meet ASME B46.1, as specified in Table 811.3-1.

Table 811.3-1. ANSI Surface Roughness Values

Bearing Surface	Surface Roughness Value in. × 10^{-6} (μm)
Steel slabs	2000 (50)
Heavy plates in contact in shoes to be welded	1000 (25)
Milled ends of compression members, milled or ground ends of stiffeners and fillers	500 (12.5)
Bridge rollers and rockers	250 (6)
Pins and pin holes	125 (3)
Sliding bearings	125 (3)

7. *Straightening Material.* Straighten plates, angles, other shapes, and built-up members without fracturing or injuring the metal. Use mechanical means to straighten distorted members by applying limited, localized heat. Perform heat straightening of AASHTO M 270M/M 270 (ASTM A709/A709M) Grades HPS 70W and 100W (485W and 690W) steel members only under rigidly controlled conditions subject to approval. Do not exceed the temperature values specified in Table 811.3-2.

Table 811.3-2a. Maximum Straightening Temperature (U.S. Customary Units)

Material to Be Straightened	Maximum Temperature (°F)
Grade 70W > 6 in. from weld	1,050
Grade 70W < 6 in. from weld	900
Grade 100 and 100W > 6 in. from weld	1,100
Grade 100 and 100W < 6 in. from weld	950

Table 811.3-2b. Maximum Straightening Temperature (SI Units)

Material to Be Straightened	Maximum Temperature (°C)
Grade 485W > 150 mm from weld	565
Grade 485W < 150 mm from weld	480
Grade 690 and 690W > 150 mm from weld	595
Grade 690 and 690W < 150 mm from weld	510

The maximum straightening temperature for all other steels is 1,200°F (650°C). Measure temperature using temperature-indicating crayons, liquids, or bimetal thermometers. The Engineer will reject material heated in excess of the specified limits unless testing verifies material integrity.

Ensure parts to be heat-straightened are free of stress and external forces, including stresses from mechanical means used to apply the heat.

The Engineer will reject straightened pieces showing evidence of fracture.

8. *Bolt Holes for High-Strength Bolts and Unfinished Bolts:*

   a. *Punch or drill bolt holes as follows:*

      i. Standard hole size is bolt diameter plus $^1/_{16}$ in. (For metric bolts, standard hole size for bolts M24 and smaller is the bolt diameter plus 2 mm. For bolts M27 and larger, the standard hole size is the bolt diameter plus 3 mm.) in accordance with *AASHTO LRFD Bridge Construction Specifications*, Section 11.4.8.1.1.

      ii. For members composed of not more than five thicknesses of metal, the Contractor may punch bolt holes full size, provided the thickness of the material is not greater than $^3/_4$ in. (20 mm) for structural steel, $^5/_8$ in. (16 mm) for high-strength structural steel, and $^1/_2$ in. (12 mm) for quenched and tempered alloy steel.

      iii. If the material is thicker than $^3/_4$ in. (20 mm) for structural steel, $^5/_8$ in. (16 mm) for high-strength structural steel, and $^1/_2$ in. (12 mm) for quenched and tempered alloy steel, either subdrill and ream or drill full size all holes. Meet Subsection 811.3(C)(8)(h).

      iv. When required, subpunch or subdrill all holes (subdrill if thickness limitation governs) $^3/_{16}$ in. (6 mm) smaller and, after assembling, ream or drill to full size in accordance with *AASHTO LRFD Bridge Construction Specifications*, Section 11.4.8.1.1.

      v. When specified, the Contractor may use enlarged or slotted holes for high-strength bolts.

   b. *Punched Holes.* Ensure that die diameter does not exceed the punch diameter by more than $^1/_{16}$ in. (1.5 mm). Ream undersized holes. Ensure holes are clean cut, without torn or ragged edges. Slightly conical holes resulting from punching operations are acceptable.

c. *Reamed or Drilled Holes.* Ream or drill holes perpendicular to the member to meet the above size requirements. Where practical, use mechanically directed reamers. Remove burrs on the outside surfaces. Ream and drill using twist drills, twist reamers, or rotobroach cutters. Assemble and securely hold connecting members while reaming or drilling holes. Match-mark before disassembling.

d. *Accuracy of Holes.* Acceptable holes are those not more than $^{1}/_{32}$ in. (1 mm) larger in diameter than the decimal equivalent of the minimal diameter resulting from the drill or reamer.

e. *Accuracy of Hole Group:*

   i. *Before Reaming.* Accurately punch full-sized, subpunched, or subdrilled holes so that, after assembling (before any reaming is done), a cylindrical pin, $^{1}/_{8}$ in. (3 mm) smaller in diameter than the nominal size of the punched hole, may be inserted into the member, without drifting, in at least 75 percent of the contiguous holes in the same plane. The Engineer will reject pieces not meeting this requirement. The Engineer will also reject holes not large enough to pass a pin that is $^{1}/_{4}$ in. (5 mm) smaller than the nominal size of the punched hole.

   ii. *Accuracy After Reaming.* Ensure that when holes are reamed or drilled, 85 percent of the holes in any contiguous group show no offset greater than $^{1}/_{32}$ in. (1 mm) between adjacent pieces.

   Use steel templates that have hardened steel bushings in the holes and that are accurately dimensioned from the connecting centerlines as inscribed on the template. Use the centerlines to locate the template from the milled or scribed ends of the members.

f. *Numerically Controlled (N/C) Drilled Field Connections.* The Contractor may drill or punch bolt holes full size in unassembled pieces or connections, or both, including templates for use with matching subsized and reamed holes, using a numerically controlled (N/C) drill or punch. Meet the full size punched hole requirements above.

   If N/C drilling or punching equipment is used, use check assemblies to demonstrate that the accuracy of this drilling or punching procedure meets *AASHTO LRFD Bridge Design Specifications*, Article 6.13.2.4.

   Punch or drill N/C holes through individual pieces or through any combination of pieces securely fastened together.

g. *Holes for Ribbed Bolts, Turned Bolts, or Other Approved Bearing Type Bolts.* Subpunch or subdrill holes $^{3}/_{16}$ in. (5 mm) smaller than the nominal bolt diameter. Ream when assembled, or drill using a steel template or, once assembled, drill from the solid to ensure the finished holes provide a driving fit.

h. *Preparing Field Connections.* Subpunch or subdrill holes in all field connections and field splices of main truss members, arches, continuous beam spans, bents, towers (each face), plate girders, and rigid frames. Ream holes with material assembled or drill full size through a steel template once assembled. Holes for field splices of rolled beam stringers continuous over floor beams or cross frames and all holes for floor beams may be drilled full size unassembled to a steel template.

Subpunch and ream holes for floor beam and stringer field end connections while assembled, or drill full size to a steel template. Accurately locate steel template before reaming and drilling. Use exact duplicates of templates for reaming matching members or the opposite faces of a single member. Accurately locate templates used for connections on similar parts or members so match marking is not required.

Full-size drill holes may be used instead of subpunching and reaming or subdrilling and reaming for all thicknesses.

9. *Heat Curving*. Flanges of curved, welded girders may be cut to the radii specified or curved by applying heat. Ensure that the radii are not less than that allowed by Article 11.4.12.2.4 of the *AASHTO LRFD Bridge Construction Specifications*.

   a. *Materials*. Heat curve steel to a minimum yield point specified in the *AASHTO LRFD Bridge Construction Specifications*.

   b. *Type of Heating*. Curve beams and girders by either continuous or V-type heating. For the continuous method, heat a strip or intermittent strips along the edge of the top and bottom flange simultaneously. Ensure the strip has sufficient width and temperature to obtain the required curvature.

      For V-type heating, heat the top and bottom flanges in truncated triangular or wedge-shaped areas having their base along the flange edge and spaced at regular intervals along each flange. Ensure the spacing and temperature are sufficient to obtain the required curvature. Heat along the top and bottom flange at the same rate. Terminate the apex of the truncated triangular area applied to the inside flange surface before the juncture of the web and the flange is reached. Avoid applying heat directly to the web. When the radius of curvature is 1,000 ft (300 m) or more, extend the apex of the heating pattern applied to the outside flange surface to the juncture of the flange and web. When the radius of curvature is less than 1,000 ft (300 m), extend the apex of the heating pattern applied to the outside flange surface past the web for a distance equal to one eighth of the flange width or 3 in. (75 mm), whichever is less. Size the pattern with an included angle of approximately 15 to 30 degrees, and a base less than 10 in. (250 mm). Obtain approval to vary the pattern.

      For both heating methods, heat the flange edges that will be on the inside of the horizontal curve. Heat both inside and outside flange surfaces concurrently when the flange thickness is $1^1/_4$ in. (32 mm) or greater.

   c. *Temperature*. Conduct heat curving operations at temperatures less than 1,150°F (620°C) and at temperatures less than 1100°F for Grades HPS 70W and 100W in accordance with *AASHTO LRFD Bridge Construction Specifications*, Article 11.4.12.2.4.

Do not artificially cool the girder until it has naturally cooled to 600°F (315°C). Obtain approval for the method of artificial cooling.

d. *Position for Heating.* Heat curve the girder with the web in either a vertical or a horizontal position. When curved in the vertical position, brace or support the girder to prevent lateral deflection and keep the girder from overturning.

When curved in the horizontal position, support the girder near its ends and at intermediate points to obtain a uniform curvature. Ensure the bending stress in the flanges caused by the dead load of the girder and externally applied loads remains within the allowable design stress. When the girder is positioned horizontally for heating, maintain intermediate safety catch blocks at the mid-length of the girder within 2 in. (50 mm) of the flanges at all times during the heating process to guard against a sudden sag resulting from plastic flange buckling.

D. *Assembly:*

1. *Bolting.* Clean metal contact surfaces before assembling. Assemble the member before drilling, reaming, or bolting. Remove all burrs and shavings and ensure the member is free from twists, bends, and other deformations.

2. *Welded Connections.* Ensure that surfaces and edges to be welded are smooth, uniform, clean, and free of defects. Prepare edges according to *AASHTO/AWS D1.5M/D1.5 Bridge Welding Code*.

3. *Preassembly of Field Connections.* Preassemble field connections of main members of trusses, arches, continuous beams, plate girders, bents, towers, and rigid frames prior to erection as necessary to verify the geometry of the completed structure or unit and to verify or prepare field splices. Submit the method and details of preassembly for approval by the Engineer. Use methods and details of assembly that are consistent with the erection procedure shown on the approved erection plans and camber diagrams.

Preassemble at least three contiguous panels or sections that are accurately adjusted for line and camber. For successive assemblies, include at least one section or panel of the previous assembly (repositioned if necessary and adequately pinned to ensure accurate alignment), plus two or more sections or panels added at the advancing end. In the case of structures longer than 150 ft (45 m), make each assembly not less than 151 ft (46 m) long regardless of the length of individual continuous panels or sections. The sequence of assembly may start from any location in the structure and proceed in one or both directions, provided the preceding requirements are satisfied.

Use the Progressive Truss and Girder Assembly, unless specified otherwise.

a. *Bolted Connections.* Prepare holes as specified in Subsection 811.3(C)(8). Where applicable, assemble major components with milled ends of compression members in full bearing and then ream their subsized holes to the specified size while the connections are assembled.

b. *Check Assembly—Numerically Controlled Drilling.* When using numerically controlled drilling, furnish a check assembly for each major structural type for each project. Unless otherwise designated, fabricate the check assembly of at least three contiguous shop sections or, in a truss, of all members in at least three contiguous panels but not less than the number of panels associated with three contiguous chord lengths (i.e., length between field splices).

Use as the check assemblies the first sections of each major structural type to be fabricated.

If the check assemblies fail in some specific manner to demonstrate that the required accuracy is being obtained, the Engineer may require additional check assemblies. Provide these additional check assemblies at no cost to the Agency.

Obtain the Engineer's approval for each assembly, including camber, alignment, accuracy of holes, and fit of milled joints, before reaming is commenced or before an N/C drilled check assembly is dismantled.

c. *Field Welded Connections.* Prepare or verify the fit of members including the proper space between abutting flanges, with the segment preassembled.

4. *Match Marking.* Match mark connecting parts preassembled in the shop to ensure proper fit in the field. Provide a diagram that shows such marks.

5. *Connections Using Unfinished, Turned, or Ribbed Bolts.* When specified, furnish unfinished, turned, or ribbed bolts meeting the requirements for Grade A bolts of standard specification for carbon steel bolts and studs, ASTM A307, 60.-ksi tensile strength. Provide bolts with single self-locking nuts or double nuts, unless otherwise specified. Use beveled washers where bearing faces have a slope of more than 1:20 with respect to a plane normal to the bolt axis. The specifications of this section do not pertain to the use of high-strength bolts, which are addressed in Subsection 811.3(D)(6).

a. *Unfinished Bolts.* Furnish unfinished bolts unless otherwise specified.

b. *Turned Bolts.* Ream turned bolt holes and turn the bolt to a driving fit with the threads entirely outside of the holes. Use hexagonal-headed bolts and nuts and provide washers. Turned bolts must be finished cut.

c. *Ribbed Bolts.* Ensure the body of ribbed bolts is of approved form with continuous longitudinal ribs. The maximum diameter of the body measured on a circle through the points of the ribs is $^1/_{16}$ in. (2 mm) greater than the nominal diameter specified for the bolts.

Furnish ribbed bolts with round heads meeting ASME B18.5-2012 (R2017). Provide hexagonal nuts either recessed or with a washer of suitable thickness. Ensure ribbed bolts make a driving fit with the holes. Provide sufficiently hard ribs to ensure they do not distort to allow the bolts to turn in the holes during tightening. If the bolt twists before drawing tight, ream the hole and provide an oversized replacement bolt.

6. *Connections Using High-Strength Bolts.* Use ASTM F3125/F3125M Grades A325 and A490 high-strength bolts, or equivalent fasteners, installed to develop the minimum required bolt tension specified in Table 811.3-3. Install bolts in holes formed as specified in Subsection 811.3(C)(8).

    a. *Bolted Parts.* Use steel for all material within the grip of the bolt. Do not use compressible material such as gaskets or insulation within the grip. Ensure that bolted steel parts fit solidly together after the bolts are tightened. Limit the maximum slope to 1:20 for the surface parts in contact with the bolt head or nut with respect to a plane normal to the bolt axis.

    b. *Surface Conditions.* At the time of assembly, ensure that all joint surfaces, including surfaces adjacent to the bolt head and nut, are free of scale, except tight mill scale, and free of dirt or other foreign material. Remove burrs that would prevent solid seating of the connected parts in the snug condition.

       The faying surface may have paint, except in slip-critical joints as designed in the *AASHTO LRFD Bridge Design Specifications*.

       Meet the following requirements, as applicable for the faying surfaces of slip-critical connections:

       i. *Uncoated Joints*. Exclude paint, including any inadvertent overspray, from areas closer than one bolt diameter, but not less than 1 in. (25 mm), from the edge of any hole and all areas within the bolt pattern.

       ii. *Joints with Painted Faying Surfaces*. Blast clean and coat with a paint qualified under *AASHTO LRFD Bridge Design Specifications*.

       iii. *Coated Joints*. Assemble after the coating has cured for the minimum time used in the qualifying test.

    c. *Installation:*

       i. *Fastener Assemblies*. Hot dip faying surfaces to be galvanized according to AASHTO M 111M/M 111. Roughen by hand wire brushing. Prohibit power wire brushing. Assemble and assign lot numbers prior to shipping. Protect from dirt and moisture at the job site. Remove from protective storage only the number of anticipated assemblies to be installed and tensioned during a work shift. Return unused assemblies to protected storage at the end of the shift. Do not clean assemblies of lubricant that is required to be present in as-delivered condition. Clean assemblies for slip-critical connections that accumulate rust or dirt resulting from job site conditions. Clean, relubricate, and test for rotational capacity prior to installation. Lubricate galvanized nuts with a lubricator containing a visible dye. Ensure plain bolts are "oily" to touch when delivered and installed. Remove lubricant on exposed surfaces before painting.

Use a bolt-tension measuring device at the job site to perform the rotational capacity test and to confirm the ability to satisfy the requirements of Table 811.3-3.

ii. *Calibrating Wrenches*. For short grip bolts, the Contractor may use direct tension indicators (DTI) with solid plates to perform the calibrated wrench verification test instead of a tension measuring device. Verify the DTI lot first with a longer grip bolt in the tension measuring device. The Agency will specify test frequency. Calibrate the device annually.

iii. *Tensioning Fastener Assemblies*. Tension and inspect bolt/nut/washer assemblies to the minimum tension specified in Table 811.3-3. Use impact wrenches to tension each bolt in approximately 10 seconds.

Table 811.3-3a. Minimum Required Bolt Tension (U.S. Customary Units)

Bolt Diameter (in.)	ASTM F3125 Grade A325 (lb)	ASTM F3125 Grade A490 (lb)
$^{1}/_{2}$	12,000	15,000
$^{5}/_{8}$	19,000	24,000
$^{3}/_{4}$	28,000	35,000
$^{7}/_{8}$	39,000	49,000
1	51,000	64,000
$1^{1}/_{8}$	56,000	80,000
$1^{1}/_{4}$	71,000	102,000
$1^{3}/_{8}$	85,000	121,000
$1^{1}/_{2}$	103,000	148,000

Table 811.3-3b. Minimum Required Bolt Tension (SI Units)

Bolt Size	ASTM F3125M Grade A325M, (N)	ASTM F3125M Grade A490M, (N)
M16	91,000	114,000
M20	142,000	179,000
M22	176,000	221,000
M24	205,000	257,000
M27	267,000	334,000
M30	326,000	408,000
M36	475,000	595,000

Do not reuse ASTM F3125 Grade A490 (ASTM F3125M Grade A490M) fasteners and galvanized ASTM F3125 Grade A325 (ASTM F3125M Grade A325M) fasteners. The Contractor may reuse other ASTM F3125 Grade A325 (ASTM F3125M Grade A325M) bolts, if approved. Prohibit touching up or retorquing previously tensioned bolts that may have been loosened by the tensioning of adjacent bolts as the torquing continues from the initial position and that do not require greater rotation, including the tolerance, than that required by Table 811.3-4.

Table 811.3-4. Nut Rotation from the Snug Condition

Bolt length measured from underside of head to end of bolt	Geometry of Outer Faces of Bolted Parts		
	Both faces normal to bolt axis	One face normal to bolt axis and other face sloped not more than 1:20. Bevel washer not used.	Both faces sloped not more than 1:20 from normal to bolt axis. Bevel washers not used.
£4 diameters	$^{1}/_{3}$ turn	$^{1}/_{2}$ turn	$^{2}/_{3}$ turn
>4 diameters, but £8 diameters	$^{1}/_{2}$ turn	$^{2}/_{3}$ turn	$^{5}/_{6}$ turn
>8 diameters, but £12 diameters	$^{2}/_{3}$ turn	$^{5}/_{6}$ turn	1 turn

Install bolts in all holes of the connection and bring the connection to a snug condition.

Snug systematically from the most rigid part of the connection to the free edges. Repeat until the full connection is in a snug condition.

The minimum required bolt tension is 70 percent of the specified minimum tensile strength of bolts [ASTM Specifications for tests of full-size Grade A325 (A325M) and Grade A490 (A490M) bolts, loaded in axial tension] rounded to the nearest 1,000 lb (4,500 N).

For situations in which the bolt length measured from the underside of the head to the end of the bolt exceeds 12 diameters, determine the required rotation by tests in a suitable tension device simulating the actual conditions.

iv. *Rotational Capacity Tests*. Test after galvanizing. Perform tests for all fastener assemblies. Include washers as part of the test even if they are required as part of the installation procedure.

Perform the rotational capacity test according to ASTM F3125 Grade A325 (ASTM F3125M Grade A325M) and as follows: Test each combination of bolt production lot, nut lot, and washer lot as an assembly. The Contractor does not have to include washers not required by the installation procedures in the lot identification. Assign a rotational capacity lot number to each combination of lots tested. Test a minimum of two assemblies per rotational capacity lot.

For bolts that are long enough to fit in a Skidmore-Wilhelm Calibrator, assemble the bolt, nut, and washer assembly in this device or an acceptable equivalent as approved by the Engineer

Ensure the torque necessary to produce the required fastener tension does not exceed the value obtained by the following equation:

Torque $0.25PD$

where:

Torque = measured torque (ft-lb)

P = measured bolt tension (lb)

D = bolt diameter (ft)

Or, for metric units,

Torque $\leq 340PD$

where:

Torque = measured torque (Nmm)

P = measured bolt tension (N)

D = bolt diameter (mm)

Test bolts that are too short to test in a Skidmore-Wilhelm Calibrator in a steel joint. Do not apply the tension requirement specified above. Instead, compute the maximum torque requirement, $0.25PD$ ($340PD$), using a value of P equal to the turn test tension taken as 1.15 times the bolt tension specified in Table 811.3-3.

v. *Washer Requirements*. Where the outer face of the bolted parts has a slope greater than 1:20 with respect to a plane normal to the bolt axis, use a hardened beveled washer to compensate for the lack of parallelism.

Ensure that hardened beveled washers for American Standard Beams and Channels that are square or rectangular meet ASTM F436/F436M, and taper in thickness.

Hardened washers are not required in this installation method, except as may be specified in *AASHTO LRFD Bridge Design Specifications*.

vi. *Turn of Nut Installation Method*. Check a representative sample of not fewer than 3 bolt and nut assemblies of each diameter, length, and grade to be used in the work. Use a device capable of indicating bolt tension. Demonstrate that the method used by the bolting crew to develop a snug condition and to control the turns develops a tension of not less than 5 percent greater than the tension required by Table 811.3-3. Retest as required.

Following the snug-tightening operation, tension bolts in the connection by the amount of rotation specified in Table 811.3-4. During the tensioning operation, ensure that there is no rotation of the part not turned by the wrench. Tension systematically from the most rigid part of the joint to the free edges.

vii. *Calibrated Wrench Installation Method*. Use this method only when wrenches are calibrated on a daily basis and when a hardened washer is used under the turned element. Standard torques determined from tables or from formulas that relate torque to tension are acceptable.

When using calibrated wrenches for installation, set them to deliver a torque calibrated to produce a tension of not less than 5 percent in excess of the minimum tension specified in Table 811.3-3. Calibrate the installation procedures by verification testing at least once each working day for each fastener assembly lot that is being installed that day. Verify by testing three typical fastener assemblies from each lot in a tension-measuring device capable of indicating actual bolt tension. Sample bolts, nuts, and washers under the turned element from production lots. Recalibrate wrenches when there is a significant difference in the surface condition of the bolts, threads, nuts, or washers. Verify during installation in the assembled steel work that the wrench adjustment selected by the calibration does not produce a nut or bolt head rotation from snug condition greater than that allowed in Table 811.3-4. For manual torque wrenches, measure as nuts are torqued in the tensioning direction.

When using calibrated wrenches to install and tension bolts in a connection, install bolts with hardened washers under the turned element. Snug and then tension the connection using the calibrated wrench. Tension systematically from the most rigid part of the joint to its free edges. Return the wrench to "touch up" previously torqued bolts that may have relaxed as a result of the subsequent tensioning of adjacent bolts. Continue until all bolts are tensioned as required.

viii. *Alternative Design Bolt Installation Method*. When fasteners that incorporate a design feature intended to indirectly indicate the required bolt tension, or to automatically develop the tension required by Table 811.3-3, are to be installed, test a representative sample of at least three fastener assemblies of each diameter, length, and grade to be used in the work. Perform tests at the job using the appropriate device. Include in the test assembly flat-hardened washers, if required in the connection, arranged in the connections to be tensioned. Demonstrate that each bolt develops a tension of not less than 5 percent greater than the tension required by Table 811.3-3. Follow the manufacturer's procedure for installing bolts in the calibration device and in all connections. Perform periodic retesting as required by the Agency.

When using alternative design fasteners intended to control or indicate bolt tension of the fasteners, install bolts in all holes of the connection and initially torque sufficiently to bring all plies of the joint into firm contact, but without yielding or fracturing the control or indicator element of the fasteners. Further torque all fasteners, progressing systematically from the most rigid part of the connection to the free edges, in a manner that will minimize relaxation of previously tensioned bolts. In some cases, proper tensioning of the bolts may require more than a single cycle of systematic partial torquing before final twist off of the control or indicator element of individual fasteners. If twist-off occurs before the final tightening cycle, replace the individual fastener assembly with a new one.

ix. *Direct Tension Indicator Installation (DTI) Method*. When using DTIs that meet the requirements of Subsection 710.2, with high-strength bolts to indicate bolt tension, subject them to the verification testing specified in Subsection 811.3(D)(6)(c)(x) and install as specified in Subsection 811.3(D)(6)(c)(xi). Install the DTIs under the head of the bolt and the nut turned to tension the bolt. Follow the manufacturer's recommendations for the proper orientation of the DTI.

x. *Verification*. Perform verification testing in a calibrated bolt-tension measuring device. Use a special flat insert in place of the normal bolt head holding insert. Test three verification samples for each combination of fastener assembly rotational-capacity lot, DTI lot, and DTI position relative to the turned bolt head or nut to be used on the project. Install the fastener assembly in the tension measuring device with the DTI located in the same position as in the work. Restrain the bolt or nut intended to be stationary from rotating.

   Conduct the verification tests in two stages. Install the bolt nut and DTI assembly so that at least 3 and preferably not more than 5 threads are located between the bearing face of the nut and the bolt head. First, tension the bolt to the load listed in Table 811.3-5 under Verification Tension for the grade and diameter of the bolt. When using an impact wrench, develop a tension that is no more than two-thirds of the required tension. Use a manual wrench to attain the required tension. Record the number of refusals of the 0.05 in. (0.125 mm) tapered feeler gauge in the spaces between the protrusions. Keep the number of refusals for uncoated DTIs under the stationary or turned element, or coated DTIs under the stationary element, within the number listed under Maximum Verification Refusals in Table 811.3-5 for the grade and diameter of bolt used. Ensure that the maximum number of verification refusals for coated DTIs (galvanized, painted, or epoxy-coated), when used under the unturned element, is no more than the number of spaces on the DTI less one. Reject the DTI if the number of refusals exceeds the values in the table or, for coated DTIs, if the gauge is refused in all spaces.

   After the number of refusals is recorded at the verification load, further tension the bolt until the 0.05 in. (0.125 mm) feeler gauge is refused at all the spaces and a visible gap exists in at least one space. Record the load at this condition and remove the bolt from the tension measuring device. Run the nut down by hand for the complete thread length of the bolt, excluding thread runout. Reject the DTI lot if the nut cannot be run down for this thread length, unless the load recorded is less than 95 percent of the average load measured in the rotational capacity test of the fastener lot as specified.

If the bolt is too short to be tested in the calibration device, verify the DTI lot on a long bolt in a calibrator to determine the number of refusals at the Verification Tension listed in Table 811.3-5. Ensure that the number of refusals remains within the values listed under Maximum Verification Refusals in Table 811.3-5. Verify another DTI from the same lot with the short bolt in a convenient hole in the work. Tension the bolt until the 0.05-in. (0.125-mm) feeler gauge is refused in all spaces and a visible gap exists in at least one space. Remove the bolt from the tension measuring device and run down the nut by hand for the complete thread length of the bolt excluding thread runout. Reject the DTI lot if the nut cannot be run down this thread length.

Table 811.3-5a. Direct Tension Indicator Requirements (U.S. Customary Units)

Bolt Size (in.)	Verification Tension (kips)		Maximum Verification Refusals		DTI Spaces		Minimum Installation Refusals	
	Grade		Grade		Grade		Grade	
	A325	A490	A325	A490	A325	A490	A325	A490
1/2	13	16	1	2	4	5	2	3
5/8	20	25	1	2	4	5	2	3
3/4	29	37	2	2	5	6	3	3
7/8	41	51	2	2	5	6	3	3
1	54	67	2	3	6	7	3	4
1 1/8	59	84	2	3	6	7	3	4
1 1/4	75	107	3	3	7	8	4	4
1 3/8	89	127	3	3	7	8	4	4
1 1/2	108	155	3	4	8	9	4	5

Table 811.3-5b. Direct Tension Indicator Requirements (SI Units)

Bolt Size (in.)	Verification Tension (kips)		Maximum Verification Refusals		DTI Spaces		Minimum Installation Refusals	
	Grade		Grade		Grade		Grade	
	A325M	A490M	A325M	A490M	A325M	A490M	A325M	A490M
M16	96	120	1	1	4	4	2	2
M20	149	188	2	2	5	6	3	3
M22	185	232	2	2	5	6	3	3
M24	215	270	2	2	5	6	3	3
M27	280	351	2	3	6	7	3	4
M30	342	428	3	3	7	8	4	4
M36	499	625	3	4	8	9	4	5

xi. *Installation*. Install fastener assemblies using DTIs in two stages. Prevent the stationary element from rotating during each stage. Snug the connection with bolts installed in all the holes of the connection. Tension sufficiently to bring all the plies of the connection into firm contact. Ensure that the number of spaces in which a 0.05-in. (0.125-mm) feeler gauge is refused in the DTI after snugging remains within those listed under Maximum Verification Refusals, Table 811.3-5. If the number of spaces exceeds the values in the table, remove the fastener assembly and install another DTI.

For uncoated DTIs used under a stationary or turned element, and for coated DTIs used under a stationary element, further tension the bolts until the number of refusals of the 0.05-in. (0.125-mm) feeler gauge is equal to or greater than the number listed under Minimum Installation Refusals in Table 811.3-5. If the bolt is tensioned so that no visible gap in any space remains, remove the bolt and DTI, and replace with a new properly tensioned bolt and DTI.

When coated DTIs (galvanized, painted or epoxy-coated) are used under a turned element, ensure the 0.05-in. (0.125-mm) feeler gauge is refused in all spaces.

xii. *Lock Pin and Collar Fasteners*. Install using approved methods.

xiii. *Inspection*. Inspect, in the presence of the Engineer, the tightened bolts using a calibrated torque wrench, unless alternate fasteners or direct tension indicator devices are used, allowing verification by other methods. Conduct the inspection before a loss of lubrication or corrosion influences the tightening torque.

Place three fastener assembly lots in the same condition as those under inspection in a device calibrated to measure bolt tension. Conduct this calibration operation at least once each inspection day. Use a washer under the turned element in tensioning each bolt if washers are used on the structure. If washers are not used, ensure that the material used in the tension-measuring device abutting the part turned is of the same specification as that used on the structure. In the calibrated device, tension each bolt to the specified tension. Apply the inspecting wrench to the tensioned bolt to determine the torque required to turn the nut or head 5 degrees [approximately 1 in. (25 mm) at a 12-in. (300-mm) radius] in the tensioning direction. The job inspection torque is the average of the torque required for all three bolts.

Randomly select 10 percent (at least two) of the tensioned bolts in each connection. Apply the job inspection torque to each selected bolt with the inspecting wrench turned in the tensioning direction. If this torque turns no bolt head or nut, consider the bolts in this connection to be properly tensioned. If the torque turns one or more bolt heads or nuts, apply the job inspection torque to all bolts in the connection. Retorque and reinspect any bolt whose head or nut turns.

7. *Welding.* Ensure that welding, welder qualifications, and prequalification of weld details and inspection of welds meet *AASHTO/AWS D1.5M/D1.5 Bridge Welding Code*.

Do not weld or tack brackets, clips, shipping devices, or other material not required to any member, unless specified.

E. *Erection:*

1. *Falsework and Forms.* Meet Section 803.

2. *Handling and Onsite Storing of Materials.* Store material on skids. Keep storage area clean and properly drained. Store girders and beams upright. Support long members to prevent damage from deflection. If the Agency is furnishing the material, check material received against the shipping lists and report shortage or damage promptly in writing. Upon receipt of said material the Contractor assumes responsibility for damaged or lost material.

3. *Bearings and Anchorages.* Meet Section 818. Verify substructure dimensions and elevations before ordering superstructure materials for staged construction projects.

4. *Erection Procedure.* Follow erection procedures as detailed in the submitted erection drawings. Prepare and submit revised erection drawings from a licensed professional engineer detailing all proposed deviations. Recalculate and submit erection stresses that differ from the planned method. Document changes in stresses or in behavior for the temporary and final structures. Provide additional material required to keep both the temporary and final stresses within the allowable limits used in design.

   Provide temporary bracing or stiffening devices to accommodate handling stresses in individual members or segments of the structure during erection.

   Support segments of the structure to produce the proper alignment and camber in the completed structure. Install cross frames and diagonal bracing to provide stability and ensure correct geometry. Provide all required temporary bracing.

5. *Field Assembly.* Assemble using match marks. Ensure parts are not damaged or distorted. Clean bearing surfaces and surfaces to be in permanent contact before assembly. Fill a minimum one half of the holes in splices and field connections with bolts and cylindrical erection pins (half-bolts and half-pins) before installing and tightening the balance of high-strength bolts.

   Fitting-up bolts may be the same high-strength bolts used in the installation. If other fitting-up bolts are required, use the same nominal diameter as the high-strength bolts. Use cylindrical erection pins that are $^{1}/_{32}$ in. (0.75 mm) larger than the bolts.

6. *Pin Connections.* Furnish pilot and driving nuts in driving pins. Drive pins to take full bearing. Tighten pin nuts and bur the thread at the face of the nut with a pointed tool.

7. *Misfits.* Correct minor misfits by a minor amount of reaming, cutting, grinding, and chipping. Errors in shop fabrication or deformation resulting from handling and transporting is cause for rejection.

811.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will compute pay quantities for each type of steel and iron from plan dimensions using Table 811.4-1:

Table 811.4-1. Mass Densities of Steel and Iron

Material	Unit Weight, lb/ft^3 (kg/m^3)
Cast Iron	445 (7,130)
Malleable Iron	470 (7,530)
Wrought Iron	487 (7,800)
Steel-rolled or cast	490 (7,850)

B. The Engineer will compute the weight (mass) of rolled shapes on the basis of nominal weight per foot (mass per meter) as specified, or listed in handbooks.

C. The Engineer will compute the weight (mass) of plates on the basis of the nominal weight (mass) for width and thickness as specified, plus an estimated overrun computed as one half the "Permissible Variation in Thickness and Weight" as tabulated in ASTM A6/A6M-07.

D. The Engineer will compute the weight (mass) of castings from the dimensions shown on the approved shop drawings, deducting for open holes. The Engineer will add to this mass a 5 percent allowance for fillets and overrun. The Engineer may substitute scale weight (mass) for computed weight (mass) in the case of castings or of small complex parts.

E. The measurement will exclude the weight (mass) of temporary erection bolts, shop and field paint, boxes, crates, and other containers used for shipping, and materials used to support members during transportation and erection.

   The measurement will also exclude the weight (mass) of any additional material required to accommodate erection stresses resulting from the Contractor's choice of erection methods.

F. The Engineer will determine the weight (mass) of galvanizing for metal, to be added to the weight (mass) of base metal, from the weight (mass) of zinc coatings specified by AASHTO M 111M/M 111. The measurement will make no allowances for the weight (mass) of paint.

G. The Engineer will compute the weight (mass) of plates on nominal weight (mass) according to ASTM A6/A6M of net furnished dimensions.

H. The Engineer will measure all metal parts other than metal reinforcement for concrete, such as anchor bolts and nuts, shoes, rockers, rollers, bearing and slab plates, pins and nuts, expansion dams, roadway drains and scuppers, weld metal, bolts embedded in concrete, cradles and brackets, railing, and railing pots, as structural steel, unless otherwise stipulated.

I. The Engineer will compute pay weight (mass) on the basis of computed net weight (mass) using one of the following:

1. The Engineer will compute the weight (mass) on the basis of the net finished dimensions of the parts as specified, deducting for copes, cuts, clips, and all open holes, except bolt holes.

2. The measurement will include the weight (mass) of heads, nuts, single washers, and threaded stick-through of all high tensile strength bolts, both shop and field, on the basis of Table 811.4-2.

3. The measurement will include the weight (mass) of fillet welds as specified in Table 811.4-3.

Table 811.4-2a. Weight per 100 Bolts (U.S. Customary Units)

Bolt Diameter (in.)	Weight/100 Bolts (lb)
1/2	19.7
5/8	31.7
3/4	52.4
7/8	80.4
1	116.7
1 1/8	165.1
1 1/4	212.
1 3/8	280.
1 1/2	340.

Table 811.4-2b. Mass per 100 Bolts (SI Units)

Bolt Size	Mass/100 Bolts (kg)
M16	14.4
M20	23.8
M22	36.5
M24	53.
M27	75.
M32	96.4
M36	127.3

Table 811.4-3. Mass of Fillet Welds

Fillet Weld in. (mm)	Weight lb/ft (kg/m)
3/16 (5)	0.8 (0.12)
1/4 (6)	0.14 (0.21)
5/16 (8)	0.22 (0.33)
3/8 (10)	0.30 (0.45)
1/2 (12)	0.55 (0.82)
5/8 (16)	0.80 (1.19)
3/4 (20)	1.10 (1.64)
7/8 (22)	1.50 (2.23)
1 (25)	2.0 (2.98)

811.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Structural steel (Type)____	pound (kg)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 812
STEEL GRID FLOORING

812.1 DESCRIPTION

Construct steel grid flooring of the open type or concrete filled type.

812.2 MATERIALS

Provide materials as specified in:

Concrete, Class C	Subsection 713.1(B), Section 808
Reinforcing Steel	Section 809
Paint	Section 813, except that dipping is allowed
Steel	AASHTO M 270M/M 270 Grade 36, 50, or 50W (250, 345 or 345W); 0.2 percent copper unless galvanized or epoxy coated
Skid-resistant, open type grid	Serrated
Hot-Dipped Galvanized	AASHTO M 111M/M 111

812.3 CONSTRUCTION

Submit shop drawings. Weld according to *AASHTO/AWS D1.5M/D1.5 Bridge Welding Code*.

A. *Arrangement of Sections:*

1. Where main elements are normal to the centerline of roadway:

    a. Extend units over the full width of roadway up to 40 ft (12 m).

    b. Extend units at least three panels.

c. Where joints are required, weld the ends of main floor members at the joints over their full cross-sectional area or connect using other methods to provide full continuity.

2. Where main elements are parallel to the centerline of roadway:

a. Extend sections over three or more panels.

b. Weld ends of abutting units over their full cross-sectional area or connect using other methods to provide full continuity.

B. *Shop Camber Rigid Units.* Cant stringers or shop-weld beveled bearing pads so the bearing surface is parallel to the crown of roadway, except when field-placed, full-depth concrete filling is attached to the deck with welded shear connectors. Fillet weld beveled bars continuously along the centerline of the stringer flange. Design the span length based on the width of the bearing bar. Mill camber longitudinal stringers or provide bearing strips to conform with the completed floor after dead load deflection. Adjust full-depth filled-grid floors vertically, when needed, by adjusting bolts through nuts welded to the grid and bearing on the top flange of framing members, or by shims. Use only shims for adjustment when construction equipment is allowed on the floor prior to attachment.

C. *Assembly.* Lift and place without overstressing grid units, with main elements continuous as specified in Subsection 812.3(A). Connect sections along edges. Use shims to support elements of differential elevation of $^{1}/_{4}$ in. (6 mm) or more over 4 ft (1.2 m). Ensure floor bearing is fully supported by temporary load or clamps. Support floor connected to steel by welding at least every fourth main member, but not greater than 15 in. (400 mm) on center, in accordance with *AASHTO LRFD Bridge Construction Specifications*, Section 12.6. Fasten ends of main steel members securely around the perimeter of continuous units by plates or angles welded to members or by encasing ends with concrete. Repair abraded or damaged galvanized surfaces by thoroughly cleaning and applying two coats of unthinned commercial quality zinc-rich primer.

D. *Placing Concrete.* Install wooden or metal forms. Extend metal form strips not more than 1 in. (25 mm) onto the edge of support, allowing adequate bearing of slab on the support. Make flooring mortar tight. Galvanize or protectively treat stay-in-place metal forms by the same method as grid. Place concrete filling, except concrete in cells where shear connectors are to be installed, in either an upright position or in an inverted position prior to installation when the concrete filling does not extend to the bottom of grid. Embed tertiary bars and shear connector studs fully, if used. Encase shear connecting studs fully in concrete, filling the entire area between the top flange of the supporting member and the bottom of the grid with concrete. The filled or partially filled grids or reinforced concrete slabs incorporating grids act as a composite with their supporting members. Mix, place, and cure concrete for grid floors as specified in Section 808. Compact concrete by vibrating. Provide concrete with a skid-resistant texture as specified in Subsection 808.3(H)(3).

812.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will base area measurements on the dimensions of the flooring in place, making no deduction for joints.

812.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Steel grid flooring (Type)	ft^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 813
PAINTING

813.1 DESCRIPTION

Prepare surfaces and apply paint to specified surfaces. Provide protective devices so as not to damage the work, facilities, or traffic. Dispose of waste.

813.2 MATERIALS

Provide prime coat and finish coat of the thickness and color specified on the plans.

813.3 CONSTRUCTION

A. *Protecting the Public and Property.* Comply with all applicable environmental protection and occupational safety and health standards, rules, regulations, and orders. Failure to comply is sufficient cause for suspension or disqualification.

Contain waste materials, such as used blasting material and old paint, classified as hazardous, and dispose of according to the applicable Federal, State, and local laws.

Provide protective devices such as tarps, screens, or covers as necessary to prevent damage to the work and to other property or persons from cleaning and painting operations. Assume responsibility for damage to vehicles, persons, or property resulting from the painting operations.

Remove or obliterate paint or paint stains that result in an unsightly appearance on surfaces not designated to be painted.

B. *Protecting the Work.* Protect the surface from contamination before and during the application process.

Protect the work against disfigurement by splatters, splashes, and smirches of paint materials.

Repair painted surfaces that are marred or damaged during the operation to a condition equal to that of the coating specified.

Sprinkle the adjacent roadbed and shoulders with water or dust palliative for a sufficient distance on each side when traffic causes an objectionable amount of dust.

After painting operations are complete, thoroughly clean the painted surfaces of any other work that would cause dust, grease, or other foreign materials to be deposited on the painted surfaces.

C. *Thickness and Color.* Ensure the dry film thickness of each coat and total thickness of the finished product is as specified. Determine the thickness of previously applied coatings, or an existing coating that is to be topcoated, according to Steel Structures Painting Council SSPC-PA 2, Procedure for Determining Conformance to Dry Coating Thickness Requirements, before applying the next coat.

Separately apply each coat of paint to ensure complete coverage. Hide the previous coat by a single coat of the next application.

D. *Painting Metal Structures.* Apply the coating system and paints as specified.

E. *Weather Conditions.* Apply paint only on thoroughly dry surfaces and under the following conditions:

1. The atmospheric temperature, paint, and surface to be painted are between 40°F (5°C) and 100°F (38°C) when metal surfaces are 5°F (3°C) above the dew point.

2. The humidity is less than 85 percent at the work site.

3. Damage by rain, fog, or dust is not possible.

4. The anticipated atmospheric temperature will remain above 40°F (5°C) during the drying period.

   Provide a suitable enclosure to allow painting during inclement weather. Control atmospheric conditions inside the enclosure throughout the painting operation. Remove the enclosure when the paint is dry or weather conditions allow open exposure.

   Perform all blast cleaning, except that performed within closed buildings, and all painting during daylight hours.

F. *Preparing the Surface.* Clean and paint exposed surfaces of structural steel, except galvanized or metal surfaces.

Clean surfaces of new structural steel by the blast-cleaning method.

Repair damage to sound paint on areas not designated for treatment caused by the operations.

Ensure the methods used to clean metal surfaces meet specifications.

G. *Blast Cleaning.* As the abrasive for blast cleaning, the Contractor may use clean, dry sand, mineral grit, steel shot, or steel grit. Use a suitable grade to produce satisfactory results. Do not use unwashed beach sand containing salt or excessive amounts of silt.

Remove dirt, mill scale, rust, paint, and other foreign material from exposed steel surfaces according to SSPC-SP 10/NACE No. 2, Near-White Blast Cleaning. Leave surfaces with a dense and uniform anchor pattern of not less than 1 mil (25 µm) or more than 2 mils (50 µm), as measured with an approved surface profile comparator.

Seal journals, bearings, motors, and moving parts of machinery before blast cleaning begins.

Prime or treat blast-cleaned surfaces the same day of blast cleaning. Reblast surfaces before painting if there is rust or contamination from foreign material.

H. *Steam Cleaning.* Remove dirt, grease, loose chalky paint, or other foreign material that has accumulated on the previously painted or galvanized surface with a steam-cleaning apparatus before other phases of cleaning. Avoid removing sound paint by this process. Remove paint that becomes loose, curled, lifted, or loses its bond with the preceding coat or coats after steam cleaning to sound paint or metal surface.

Add a biodegradable detergent to the feed water of the steam generator or apply to the surface to be cleaned.

Remove residue, detergent, or other foreign material that may accumulate on cleaned surfaces by flushing with fresh water.

Perform steam cleaning within 2 weeks before painting or other phases of cleaning.

Allow cleaned surfaces to thoroughly dry for at least 24 h before painting.

I. *Solvent Cleaning.* Use solvents to remove oil, grease, and other soluble contaminants according to SSPC-SP 1, Solvent Cleaning. Perform solvent cleaning prior to blast cleaning. If contamination remains after blasting, reclean the area with solvent.

J. *Hand Cleaning.* Use hand or powered wire brushes, hand scraping tools, power grinders, or sandpaper to remove dirt, loose rust, and mill scale, or paint not firmly bonded to the metal surfaces.

K. *Power Washing.* Power wash at a water pressure between 800 to 1,500 psi (5.5 to 10.3 MPa) applied with the nozzle no further than 12 in. (300 mm) from the surface of the steel.

L. *Applying Paints.* Notify the Engineer in writing at least 1 week prior to the start of the cleaning and painting operations.

Paint in a neat manner. Apply paint by brush, spray, or roller, or any combination thereof, as necessary for the paint being applied.

Thoroughly cure each application of paint. Correct all skips, holidays, thin areas, or other deficiencies before the succeeding applications. Ensure the surface of the paint being covered is free from moisture, dust, grease, or other deleterious materials that would prevent the bond of the succeeding applications. In spot painting, remove old paint that lifts after the first application by scraping, and repaint the area before the next application.

The Contractor may use paints that are specified to be "formulated ready for application and no thinning" unless otherwise provided in the applicable materials specification for the paint being used.

Brushes need to have sufficient body and bristle length to spread the paint in a uniform film. Use round, oval-shaped brushes, or flat brushes not wider than $4^1/_2$ in. (115 mm). Evenly spread and thoroughly brush out paint.

On surfaces that are inaccessible for painting by regular means, apply the paint by sheepskin daubers, bottle brushes, or other means approved by the Engineer.

Ensure rollers leave an even texture in the paint film. Use rollers only on flat, even surfaces to produce a paint film of even thickness with no skips, runs, sags, or thin areas.

The Contractor may apply paint with airless or conventional spray equipment.

Install suitable traps or separators in the air line to each spray pot to exclude oil and water from the air.

The Engineer will consider as unsatisfactory any spray method that produces excessive paint buildup, runs, sags, or thin areas in the paint film, or skips and holidays. If such unsatisfactory results occur, the Engineer may require modification of the spray method or will prohibit its use and require brushing instead.

Use mechanical mixers to mix paint. Prior to application, mix paint a sufficient length of time to thoroughly mix the pigment and vehicle together. Keep paint thoroughly mixed during its application.

Measure the dry film thickness of the paint in place with a calibrated magnetic film thickness gauge according to SSPC-PA 2.

Limit the thickness of each application to obtain a uniform drying throughout the paint film.

For succeeding applications of paint, provide a contrasting shade to the paint being covered.

Blast clean and paint structures with the total thickness of undercoats before erection. After erection and before applying subsequent paint, thoroughly clean and spot paint areas where paint has been damaged or has deteriorated and all exposed unpainted surfaces with the total thickness of undercoats.

Paint surfaces exposed to the atmosphere that will be inaccessible for painting after erection. Paint the full number of applications prior to erection.

Apply vinyl wash primer, if required, at least 12 h before application of the succeeding coat of paint. Apply the vinyl wash primer by spraying to produce a uniform wet film on the surface. Ensure the dry film thickness is between 0.3 and 0.5 mils (7.6 and 12.7 μm).

Paint areas under joint connection and splice plates as specified in Subsection 811.3(D)(6)(b)(ii).

M. *Applying Zinc-Rich Primers.* Apply organic and inorganic zinc-rich primers by spray methods. On areas inaccessible to spray application, apply the paint by brush or daubers.

Use mechanical mixers to mix the primer. Strain zinc-rich primers through a metal 30–60 mesh screen or a double layer of cheesecloth immediately before or during pouring into the spray pot.

Use an agitating spray pot in all spray application of zinc-rich primers. Ensure the agitator or stirring rod reaches to within 2 in. (50 mm) of the bottom of the spray pot. Keep the agitator in motion at all times during primer application. Apply sufficient motion to keep the primer well-mixed.

Provide spray equipment, the proper pot pressure and atomization pressure to produce a coating that complies with the specifications for zinc paint. Use a hose no longer than 75 ft (23 m) long from pot to nozzle. Use the hose within 15 ft (45 m) above or below the pot.

Keep cured, zinc-rich primer free from dust, dirt, salt, or other deleterious deposits and thoroughly dry before applying vinyl wash primer.

N. *Applying Inorganic Zinc Paints.* Apply succeeding applications of inorganic zinc paints within 24 h, but not less than 30 minutes, after the previous application of such paint.

When mud cracking occurs in the inorganic zinc paint, blast clean back to soundly bonded paint and recoat to the same thickness by the same methods specified for the original coat.

Cure paint for 48 h at a relative humidity of at least 45 percent before applying vinyl wash primer. When vinyl wash primer is not applied within 3 weeks after the inorganic zinc paint is applied, or when there is evidence of dust, dirt, salt, or other deleterious deposits on the inorganic zinc paint, hose the cured inorganic zinc paint down with water. Apply the vinyl wash primer when a surface dry condition exists.

O. *Painting Galvanized Surfaces.* Clean galvanized surfaces that are to be painted. Wash with mineral spirit solvent sufficient to remove oil, grease, or other materials foreign to the galvanized coating.

After cleaning, apply vinyl wash primer by spraying to produce a uniform wet film on the surface. Ensure the dry film thickness is between 0.3 and 0.5 mils (7.6 and 12.7 μm).

Use finish paint the same as that used on adjacent metal work.

P. *Painting Timber:*

1. *Preparing Surfaces.* Remove cracked or peeled paint, loose chalky paint, dirt, and other foreign material by wire brushing, scraping, or other means immediately before painting. Ensure the moisture content of the timber is less than 20 percent at the time of the first application.

2. *Paint.* The paint, as specified, is intended for use in covering previously painted surfaces. When applying paint to unpainted timber, add turpentine and linseed oil, as required by the character of the surface, in an amount not to exceed one-eighth of the paint as specified. Use white or tinted paint. Use three applications to paint new timber requiring painting.

   When a black finish paint is required, use the same first or prime coat as specified above.

3. *Application.* After the first application has dried and the timber is in place, putty cracks, checks, nail holes, or other depressions flush with the surface. Allow to dry before the second application of paint.

   Apply paint by brush, air spray, or roller, spread evenly, and work thoroughly into seasoning cracks, corners, and recesses. Apply another coat when the full thickness of the previous coat has dried.

   Make final brush strokes with aluminum paint in the same direction to ensure that powder particles "leaf" evenly.

4. *Painting Treated Timber.* Do not paint timber treated with creosote or oil-borne, pentachlorophenol preservatives.

   Use clean timber treated with waterborne preservatives and reduce the moisture content to no more than 20 percent before painting. Wash and brush away visible salt crystals on the wood surface. Cover stored timber awaiting painting. Stack with spreaders to ensure air circulation.

Q. *Painting Concrete:*

1. *Preparing the Surface.* Remove laitance and curing compounds from the surface before painting the concrete surfaces. Use abrasive blast cleaning.

   At the time the paint is to be applied, ensure the surface is thoroughly dry and free of dust.

2. *Paint.* Use acrylic emulsion paint that meets Master Painters Institute specification MPI #10. This paint may be tinted by using "universal" or "all purpose" concentrates.

3. *Application.* Apply acrylic emulsion paint in at least two applications to produce a uniform appearance.

   Paint only when the ambient temperature is 50°F (10°C) or above for the application and drying of the paint.

813.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. *Structural Steel*. No direct measurement specified.

B. *Galvanized Surfaces*. No direct measurement specified.

C. *Timber*. No direct measurement specified.

D. *Concrete*. No direct measurement for preparing and painting concrete paid for on a lump sum basis. When painting is to be measured on an area basis, the Engineer will base measurement on the surface area painted.

813.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Painting, existing steel	lump sum
(B) Painting, new steel	incidental
(C) Tie coat, galvanized surfaces	incidental
(D) Painting, new timber	incidental
(E) Painting, existing timber	lump sum
(F) Painting, concrete surfaces	yd^2 (m^2), lump sum
(G) Disposal of waste	incidental, lump sum

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 814
STONE MASONRY

814.1 DESCRIPTION

Construct stone and rubble masonry structures and the stone masonry portions of composite structures.

814.2 MATERIALS

Provide materials as specified in:

Portland Cement	Subsection 701.2
Masonry Cement	Subsection 701.4
Masonry Mortar Aggregate	Subsection 703.13
Rubble Stone	Subsection 706.4(A)
Ashlar Stone	Subsection 706.4(B)
Concrete	Subsection 713.1(B), Section 808
Chemical Admixtures	Subsection 713.3(B)
Grout or Mortar for filling voids	Subsection 713.5(D)
Water	Subsection 714.1(A)
Hydrated Lime for Masonry Purposes	Subsection 714.3(D)
Quicklime for Structural Purposes	Subsection 714.3(E)

814.3 CONSTRUCTION

A. *Manufacture of Stone.* Furnish stone masonry containing no depressions and producing the general characteristics specified. Ensure thickness of courses, if varied, diminishes from bottom to top of structure. Provide surface finish of stone as follows:

1. *Smooth Finish.* Surface variations from pitch line are less than $^1/_{16}$ in. (1.5 mm).
2. *Fine Finish.* Surface variations from pitch line are less than $^1/_4$ in. (6 mm).
3. *Rough Finished.* Surface variations from pitch line are less than $^1/_2$ in. (12 mm).
4. *Scabbled.* Surface variations from pitch line are less than $^3/_4$ in. (20 mm).
5. *Rock-faced.* Irregular projecting face without tool marks, projections beyond pitch line are less than 3 in. (75 mm), and no part of face recedes in back of the pitch line.

B. *Rubble Stone.* Furnish stone with a minimum thickness of 8 in. (200 mm), a minimum width of 1.5 times the thickness, and a minimum length of 1.5 times the width, except headers. Ensure that the angle between the joint surface and face stone is not less than 45 degrees. Install joints and bed lines of face stones so that they vary by no more than $1^1/_2$ in. (38 mm).

C. *Ashlar Stone.* Furnish large, well-proportioned ashlar stone with a thickness of 12 to 30 in. (300 to 750 mm), dressed to specified dimensions before laying. Allow no overhanging tops. Ensure no undercut contour adjacent to bottom arris on face side. Finish bed surfaces of face stones, fine finished, for a depth of 12 in. (300 mm). Finish vertical surfaces of face stones, fine finished and full to the square, for a depth of 8 in. (200 mm). Chisel drafts $1^1/_2$ in. (38 mm) wide at exterior corners.

D. *Arch Ring Stones.* Install joint surfaces radial and at a right angle to the front. Ensure back surfaces in contact with concrete are parallel to front face and dressed for 6 in. (150 mm) from the intrados. Install top perpendicular to front face and dressed 3 in. (75 mm) from front. Adjacent ring stones may vary 6 in. (150 mm) in depth when concrete is placed after masonry construction. Ensure stratification in ring stones is parallel to radial joints, and other stones are parallel to bed.

E. *Mortar.* Meet Subsection 713.5(D)(1).

F. *Laying Stone.* Construct masonry when materials are frost-free and when ambient air temperature is above 40°F (5°C). Provide weep holes, through the wall, with 2 ft^3 (0.6 m^3) of pervious backfill material wrapped in filter fabric.

Prepare foundation bed to be firm and normal to, or in steps normal to, the face of the wall. Clean the bearing surface of the foundation masonry and adjust moisture to a saturated, surface dry condition when the mortar bed is spread. Clean and saturate each stone with water before setting. Clean and moisten the bed to receive mortar. Set face stones in random bond. Uniformly distribute stones by size, weathering, color, or texture. Use large stones for the bottom courses and for the corners. Grade the stones to decrease in size from the bottom to the top of work.

Bed stones in fresh mortar. Place with full mortar joints and settle stones before the mortar has set. Do not pin stones in the bed with spall, mar the wall, or jar previously laid stone. Handle stones in a manner that will not cause disfigurement. Remove and replace any stone that has been disturbed.

Lay rubble masonry to line and in courses roughly leveled. Offset vertical joints a minimum 6 in. (150 mm). Locate vertical joints not to occur directly above or below a header.

Place ashlar masonry stones to form bonds of not less than 12 in. (300 mm) with the stones of adjoining courses. Place headers over stretchers. Ensure the headers of each course equally divide the spaces between the headers of adjoining courses. Place no header over a joint and make no joint over a header. Lay rubble masonry to have beds and joints with an average thickness not to exceed 1 in. (25 mm). Lay ashlar masonry to have beds and joints not less than $^3/_8$ in. (10 mm) nor more than $^1/_2$ in. (13 mm) in thickness, which may vary from the bottom to the top of the work. Maintain uniform thickness beds in each course. Break straight bed lines after more than five stones. Construct joints in ashlar masonry vertical and in other masonry at angles with the vertical from 0 degrees to 45 degrees. Lay each face stone to bond with all contiguous face stones at least 6 in. (150 mm) longitudinally and 2 in. (50 mm) vertically. Construct ring stone joints on the faces and soffits to be $^1/_4$ to $1^1/_2$ in. (6 mm to 38 mm) in thickness. Construct cross beds for vertical walls level. Battered walls may vary from level to normal to the batter line of the face of the wall. Fill joints with mortar.

Place headers to occupy one-fifth of the face area of the wall and distribute evenly. Extend headers 12 in. (300 mm) into the core or backing.

Extend headers in rubble masonry walls 24 in. (600 mm) into the core or backing, or entirely through the wall, whichever is less.

For ashlar masonry, select headers having a width of at least 1.5 times the thickness. Place headers in each course. Select headers with a length of at least 2.5 times the thickness or 4 ft (1.2 m), whichever is less. Extend headers in ashlar masonry walls 4 ft (1.2 m) into the core or entirely through the wall, whichever is less. Space headers less than 8 ft (2.4 m) apart, center-to-center, with at least one header to every two stretchers.

Construct cores and backing of roughly bedded and jointed headers and stretchers, as specified above, or of Class B or C concrete. Select stone for cores or backing, at least 50 percent of which are of the same size and character as the face stone. Select stones with parallel ends and place in courses of no less than 8 in. (200 mm) thick. Construct bed and vertical joints in cores and backing not to exceed 1 in. and 4 in. (25 mm and 100 mm) in thickness, respectively. Point all joints and clean excess mortar from face stones.

814.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure, and the Agency will pay for, stone masonry based on plan dimensions.

B. The Engineer will measure, and the Agency will pay for, concrete under Section 808.

814.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Stone masonry	yd^2 (m^2), yd^3 (m^3)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 815
CONCRETE BLOCK AND BRICK MASONRY

815.1 DESCRIPTION

Construct cement mortar block and brick masonry, steel reinforced or unreinforced, as specified.

815.2 MATERIALS

Provide materials as specified in:

Portland Cement	Subsection 701.2
Masonry Cement	Subsection 701.4
Masonry Mortar Aggregate	Subsection 703.13
Brick	Subsection 706.1(B)
Concrete Masonry Block	Subsection 706.3, Type I moisture-controlled units (Grade N-I), ASTM C90
Concrete for Coping	Subsection 713.1(B), Class A
Chemical Admixtures	Subsection 713.3(B)
Grout or Mortar for Filling Voids	Subsection 713.5(D)
Water	Subsection 714.1(A)
Hydrated Lime for Masonry Purposes	Subsection 714.3(D)
Quicklime for Structural Purposes	Subsection 714.3(E)

815.3 CONSTRUCTION

A. *Laying Block and Brick.* Construct masonry when materials are frost-free and when ambient air temperature is above 40°F (5°C). Moisten brick before laying; apply no water to concrete block before laying. Lay brick or block in mortar using "shove joints." Fill joints. Ensure joints are $^1/_4$ to $^5/_8$ in. (6 to 16 mm) and uniform in thickness. Strike "weather" joints on exposed faces; use full brick or block except around irregular openings and where required. Use full brick at corners. Remove and replace masonry units disturbed once mortar has set.

B. *Reinforcement and Grouting Voids.* Place reinforcing steel within a $^1/_2$-in. (12-mm) transverse and 2-in. (50-mm) longitudinal tolerance. Install cleanouts in the bottom course and at each vertical bar and at maximum 32-in. (810-mm) spacing. Ensure vertical cells are unobstructed when filling with grout. Ensure grout is fluid and nonsegregated before placement. Mechanically vibrate grout pours exceeding 12 in. (300 mm) in height. Place grout in a continuous pour not exceeding 72 in. (1,800 mm) high. Provide construction joints in grout columns at least $1^1/_2$ in. (38 mm) below the mortar bed joint. Place grout according to AASHTO's *Standard Specifications for Highway Bridges*. Puddle all other grout. Remove and replace segregated grout and damaged masonry.

C. *Copings, Bridge Seats, and Backwalls.* Cope retaining wall tops, abutment wingwalls, and similar block or brick masonry equal to or exceeding 4 in. (100 mm) thick. Thin coping blocks 36 to 60 in. (900 mm to 1500 mm) long may be made of mortar. Batter the underside of coping or provide a drip bead at least 1 in. (25 mm) from the masonry face. Use ashlar masonry, as specified in Subsection 814.3(C), or concrete for coping piers and abutment bridge seats.

815.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure, and the Agency will pay for, concrete block and brick masonry based on plan dimensions.

815.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Concrete block	unit price
(B) Brick masonry	unit price

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 816
TIMBER STRUCTURES

816.1 DESCRIPTION

Construct timber structures and the timber portions of composite structures including furnishing, preparing, fabricating, erecting, treating, and painting of timber and hardware.

816.2 MATERIALS

Provide materials as specified in Section 717.

816.3 CONSTRUCTION

Ensure that all framing is true and exact. Drive nails and spikes with force just sufficient to set the heads flush with the surface of the wood. The Engineer will consider deep hammer marks in wood surfaces as evidence of poor quality and as sufficient cause to require contractor to remove and replace work. The Engineer may require removal and replacement of damaged timber.

Stack untreated material on supports at least 12 in. (300 mm) above the ground surface and open-stacked. Provide a cover to protect the material from the weather.

A. *Treated Timber:*

   1. *Handling.* Avoid damage to treated timber and handle the timber only with web slings. Provide corner protectors when metal bands are used to bundle members.

2. *Framing and Boring.* Cut, frame, and bore treated timbers before treatment insofar as is practicable. Place untreated cuts, borings, or other joint framings above the high-water elevation when treated timbers are to be placed in waters infested by marine borers.

3. *Cuts and Abrasions.* Field-treat cuts and abrasions and recesses formed by countersinking in creosote-treated piles or timbers. Coat the cuts and recesses with two applications of a mixture of 60 percent creosote oil and 40 percent roofing pitch, or brush coat with at least two applications of hot creosote oil, and cover with hot roofing pitch. Fill recesses likely to collect injurious materials with hot roofing pitch. Prepare hot preservatives by heating to a temperature between 150°F and 200°F (66°C and 93°C). Prepare a suitable plastic compound by mixing 10 to 20 percent of creosote and 80 to 90 percent of coal tar roofing pitch, where particularly heavy coatings are required.

   Field-treat all cuts, abrasions, and recesses that occur after treating timbers originally treated with pentachlorophenol, creosote, creosote solutions, or waterborne preservatives, with two liberal applications of a compatible preservative according to the requirements of the American Wood Preservers Association Standard M4, "Standard for the Care of Preservative-Treated Materials."

4. *Bored Holes.* Treat holes bored after treatment by filling the holes with the preservative used for field treatment. After treatment, plug holes that are not filled with bolts or other items with preservative-treated plugs.

5. *Temporary Attachments.* Treat holes resulting from forms or temporary braces that are attached to treated timber with nails or spikes, as required for bored holes, and fill by driving galvanized nails, spikes, or preservative-treated plugs flush with the surface.

B. *Installing Connectors.* Install split ring and the shear plate types in precut grooves of the specified dimensions or as recommended by the manufacturer. Force spike grids into the wood so that timbers will be in firm contact. Use pressure equipment that does not damage the wood. Replace temporary high-strength bolts with specified bolts for the final installation. Embed all connectors at the joint simultaneously and uniformly.

   Cut connector grooves in timber, concentric with the bolt hole. Make grooves conform to the cross sectional shape of the rings, and provide a snug fit. Make the inside groove diameter larger than the nominal ring diameter.

   Fabricate structural members using connectors prior to preservative treatment. Drill bolt holes within $^1/_{16}$ in. (1.5 mm) from required placement. Drill bolt holes $^1/_{16}$ in. (1.5 mm) larger than the finished bolt diameter and perpendicular to the face of the timber.

   Store timber, after fabrication, in a manner that will prevent changes in the dimensions of the members before assembly. Cure the timber before fabrication so that its dimensions remain stable. Reject timber that shrinks during storage, causing predrilled grooves for split rings, plate size, or bolt hole spacing to change.

C. *Fastenings.* Drill the holes for round drift bolts and dowels $^{1}/_{16}$ in. (1.5 mm) less in diameter than the bolt or dowel. Drill holes for square drift bolts or dowels equal in diameter to the least dimension of the bolt or dowel. Drill the holes for machine bolts the same diameter as the finished bolt. Drill the holes for rods $^{1}/_{16}$ in. (1.5 mm) greater in diameter than the finished rod. Drill the holes for lag screws with a bit not larger than the body of the screw at the base of the thread. Drill the hole for the shank the same diameter and to the same depth as the shank. Drill the depth of holes for lag screws approximately 1 in. (25 mm) less than the length under the head.

Use a washer under bolt heads and nuts that would otherwise come in contact with wood (except for timber bolts with economy type heads). Lock the nuts of bolts after final tightening.

D. *Countersinking.* Countersink hardware when smooth or flush surfaces are required. Treat all recesses formed for countersinking in treated timber, as specified in Subsection 816.3(A)(3).

E. *Framing.* Cut and frame lumber and timber to a close fit so that the joints will have even bearing over the entire contact surfaces. Cut mortises and tenons true to size for their full depth to allow for a snug fit without shim. Reject open joints.

F. *Framed Bents:*

1. *Mud Sills.* Embed the mud sills firmly and evenly to solid bearing and tamp in place. Use pressure preservative-treated mud sills for ground contact.

2. *Concrete Pedestals.* Finish concrete pedestals to provide an even bearing. Use dowels for anchoring sills or posts with a minimum $^{3}/_{4}$-in. (20-mm) diameter. Form the concrete pedestal around the anchor sill or post so that the anchor projects at least 6 in. (150 mm) above the top of the pedestal. Use concrete and reinforcing steel meeting Sections 808 and 809.

3. *Sills.* Provide sills with a true and even bearing on mud sills, piles, or pedestals. Drift bolt sills to mud sills or piles, with bolts of not less than $^{3}/_{4}$ in. (20 mm) diameter and extending into the mud sills or piles at least 6 in. (150 mm). Remove earth in contact with sills to ensure free air circulation around the sills.

4. *Posts.* Fasten posts to pedestals with dowels at least $^{3}/_{4}$ in. (20 mm) in diameter, extending at least 6 in. (150 mm) into the posts. Fasten posts to sills using dowels that are at least $^{3}/_{4}$ in. (20 mm) in diameter and extend at least 6 in. (150 mm) into posts and sills, or by using drift bolts at least $^{3}/_{4}$ in. (20 mm) in diameter driven diagonally through the base of the post and extending at least 9 in. (225 mm) into the sill. Drive drift-bolts into holes, as required above, at a 45-degree angle and so that they enter the post at least 6 in. (150 mm) above the post base.

5. *Caps.* Place timber caps, with ends aligned, in a manner to secure an even and uniform bearing over the tops of the supporting posts or piles. Secure caps by drift-bolts at least $^{3}/_{4}$ in. (20 mm) in diameter, extending at least 9 in. (225 mm) into the posts or piles. Place the drift-bolts approximately in the center of the post or pile.

6. *Bracing.* Bolt bracing through the pile, post, or cap at the ends and at intermediate intersections using a bolt of not less than $^5/_8$ in. (16 mm) in diameter. Use bracing of sufficient length to provide a minimum distance of 8 in. (200 mm) between the outside bolt and the end of the brace.

G. *Stringers.* Size stringers at bearings and place in position so that knots near edges will be in the top portions of the stringers.

Join outside stringers with lap joints or butt joints with the ends cut on a taper. Lap join interior stringers to take bearing over the full width of the floorbeam or cap at each end. Separate the lapped ends of untreated stringers at least $^1/_2$ in. (12 mm) for the circulation of air and securely fasten by drift bolting. Stagger the joints when stringers are two panels in length.

Place cross-bridging or blocking at the center of each span. Frame the cross-bridging between stringers neatly, and toenail securely with at least two nails in each end. Provide full bearing of cross-bridging members, at each end, against the sides of stringers. Cut blocking to a snug fit and hold in place by either prefabricated galvanized steel beam hangers or tie rods.

H. *Plank Floors.* Use planks for flooring that are surfaced on four sides. Provide single plank floors, as required, consisting of a single thickness of plank supported by stringers or joists. Lay the planks heartside down. Lay planks with $^1/_4$-in. (6-mm) openings between them when using seasoned material. Lay planks with tight joints when using unseasoned material. Firmly spike each plank to each joist. Lay planks so that no two adjacent planks vary in thickness by more than $^1/_8$ in. (3 mm).

Provide two-ply timber floors consisting of two layers of flooring supported on stringers or joists. Lay the top course diagonally or parallel to the centerline of roadway as required and securely fasten each floor piece to the lower course. Stagger joints in adjacent timbers at least 3 ft (1 m). Securely fasten the ends of the flooring when the top flooring is placed parallel to the centerline of the roadway. Bevel these members at each end of the bridge.

I. *Nail-Laminated or Strip Floors.* Place the strips on edge, at right angles to the centerline of roadway. Nail each strip to the preceding strip. Provide nails of sufficient length to pass through two strips and at least half way through the third strip.

Toenail every other strip to every other support when using timber supports. Attach the strips to steel supports firmly, using approved galvanized metal clips. Take care to have each strip vertical and tight against the preceding strip, and bearing evenly on all the supports.

J. *Glue-Laminated Panel Decks.* Prepare glue-laminated deck panels by pressure preservative treatment with creosote or pentachlorophenol with Type A, C, or D carrier. Apply a preservative treatment to untreated field cut or drilled areas when it is not possible to complete the fabrication and drilling of members before treating.

Handle and transport glue-laminated deck panels in a way to prevent bending the panels. Support the panels at a sufficient number of points to avoid overstressing, and protect the edges from damage.

Drill dowel holes in deck panels using a template or drilling jig. Drill the holes to a depth $^1/_4$ in. (6 mm) greater than one-half the dowel length and of the same diameter as the dowel. Use a temporary dowel as a check for snug fit prior to production drilling. Round and taper the dowels slightly. Use a lubricant to facilitate the connection process. Place the tips of the dowels into the holes of the two panels and draw the panels together, keeping the edges parallel, until the panels abut tightly. Fasten each panel to the stringers or girders.

K. *Composite Wood Concrete Decks.* Furnish and install shear connectors between timber and concrete elements. Submit working drawings to the Engineer for approval before beginning the work.

L. *Wheel Guards and Railing.* Frame and erect wheel guards, true to line and grade. Use wheel guards, rails, and rail posts that are surfaced on four sides. Lay wheel guards in sections not less than 12 ft (3.6 m) long, except where necessary to match expansion joints or end joints.

M. *Trusses.* Fabricate trusses with no irregularities of line. Provide chords that are straight and true from end to end in horizontal and vertical projection. Provide chords showing a smooth curve through panel points and conforming to the correct camber. The Engineer will reject pieces containing uneven or rough cuts at the points of bearing.

N. *Painting.* Paint rails and rail posts of timber with three coats as specified in Section 813. Provide metal parts, except for hardware, galvanized or cadmium-plated metal, and malleable iron, with one coat of shop paint and, after erection, two coats of field paint, as specified in Section 813.

816.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure timber and lumber by the thousand feet board measure, MBM (m^3), of each species and grade of lumber and timber listed in the contract documents, complete in place and accepted, computed from the nominal dimensions and actual lengths.

B. The measurement will include timber in wheel guards.

C. The measurement will exclude timber, piling, railing or other items for which separate payment is provided.

D. The Engineer will measure glued laminated girders and beams using the finished cross-sectional dimensions and actual lengths. The Engineer will measure quantities for glued-laminated girders and beams by the thousand feet board measure, MBM (m^3), for each size and stress combination.

E. The measurement of lumber and timber and of glued laminated girders and beams includes only such material as is a part of the completed and accepted work, and does not include materials used for erection purposes, such as falsework, bracing, and sheeting.

F. The Engineer will measure, and the Agency will pay for, metal parts (other than hardware and timber connectors), railings, and concrete as provided in Sections 823, 820, and 808, respectively.

816.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Lumber	MBM (m^3)
(B) Timber	MBM (m^3)
(C) Glued-laminated girders and beams (Type or size)	MBM (m^3)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 817 RESERVED

SECTION 818 BEARING DEVICES

818.1 DESCRIPTION

Install bridge bearings, and place bedding materials under masonry plates. Paint or galvanize as required.

818.2 MATERIALS

Provide materials as specified in:

Elastomers	AASHTO M 251, ASTM D4894 and D4895 for PTFE
Bedding Materials	ASTM B29 for Lead
Manufacture	*AASHTO/AWS D1.5M/D1.5 Bridge Welding Code* unless *AWS D1.1 Welding Code* is specified
Anchor Bolts	ASTM A307
Rolled Steel	AASHTO M 270M/M 270 (ASTM A709/A709M), Grade 36 (250)
Steel Laminates	AASHTO M 251, Grade 36 (250)

Cast Steel	ASTM A802/A802M
Forged Steel	ASTM A788/A788M
Stainless Steel	ASTM A240/A240M, Type 304
Galvanizing	AASHTO M 111M/M 111
Brass	ASTM B36/B36M and B121/B121M
Bronze	ASTM B22/B22M
Rolled Copper-Alloy	ASTM B100
Mortar	Subsection 713.5(D)(1)
Grout	Subsection 713.5(D)(2)
Paint	Section 813

818.3 CONSTRUCTION

Design, submit working drawings, manufacture, and test bearings according to *AASHTO LRFD Bridge Design Specifications.*

Install bearings to the positions shown. Set bearings according to manufacturer's recommendations and with the Engineer's approval. Adjust as necessary to anticipate movements of the bridge, release of falsework, and shortening resulting from prestressing.

Locate each bridge bearing within $\pm^{1}/_{8}$ in. (3 mm) of its correct position in the horizontal plane and orient to within an angular tolerance of 0.2 radians. Orient guided bearings and bearings that rotate on only one axis in the direction specified to within a tolerance of 0.05 radians. Set all bearings, except those placed in opposing pairs, horizontal to within an angular tolerance of 0.05 radians. Maintain full and even contact with load plates. Set the superstructure supported by the bearing so that, under full dead load, its slope lies within an angular tolerance of 0.05 radians of the design value. Correct any departure from this tolerance. If needed to level the bearing, remove the shim stacks after grouting and before the weight of the superstructure acts on the bearing.

Use a filler or fabric material to bed metallic bearing assemblies not embedded in the concrete. Machine the supporting surface of bearings that seat directly on steel work to provide a level and planar surface for placement.

Install bearings or masonry plates resting on steel supports within a tolerance of 0.02 times the nominal dimension, and sufficiently rigid so as not to deform under specified loads.

A. *Elastomeric Bearings.* Design, manufacture, and test elastomeric bearings according to *AASHTO LRFD Bridge Design Specifications*.

   The Contractor may place elastomeric bearings without external load places directly on a concrete or steel surface, provided that it is flat to within a tolerance of 0.05 of the nominal dimension for steel reinforced bearings and 0.1 of the nominal dimension for others. Place these bearings within 0.1 radians. Use grout or other directed means to correct any lack of parallelism between the top of the bearing and the underside of the girder that exceeds 0.1 radians.

Weld exterior plates of the bearing only if there is $1^1/_2$ in. (38 mm) of steel between the weld and the elastomer. Subject the elastomer or bond to temperatures less than 390°F (200°C).

B. *Pot and Disc Bearings.* Design, submit working drawings, manufacture, and test pot and disk bearings according to the *AASHTO LRFD Bridge Design Specifications*. Ensure that the manufacturer's representative or the Engineer inspects bearing components upon final installation to ensure that they are level and parallel to within 0.3 in./ft (2.6 mm/m). Correct any deviations.

C. *Rocker and Roller Bearings.* Design and manufacture rocker and roller bearings according to the *AASHTO LRFD Bridge Design Specifications*.

Lubricate gear mechanisms and other required components of roller bearings according to manufacturer's recommendations.

Allow for variation from the mean temperature of the supported span at time of setting. Anticipate other changes in length of the supported span, so that the rockers and rollers will be vertical at mean temperature after release of falsework, and any shortening caused by prestressing force and shrinkage. Ensure the full and free movement of the superstructure at movable bearings.

Coat contact surfaces thoroughly with oil and graphite before placing roller bearings.

Position cylindrical bearings so their axes of rotation are aligned and coincide with the axis of rotation of the superstructure.

D. *Spherical Bearings.* Fabricate, test, and install spherical bearings as specified.

E. *Bronze- or Copper-Alloyed Plates for Bearings.* Meet ASTM B22/B22M, alloy C91100, C86300, or C90500 for bronze bearing and expansion plates. Furnish Alloy C91100, as specified.

Furnish cast, rolled, or forged components. Ensure castings are free of blow-holes larger than $^1/_8$ in. (3 mm) and contact surfaces are free of blow-holes of any size.

Cast bronze plates as specified. Plane sliding surfaces parallel to the movement of the spans, and polish unless detailed otherwise.

For copper-alloy bearing and expansion plates, meet ASTM B100 alloy C51000 or C51100, as specified.

Furnish copper alloy plates as specified. Rolled plates, having a true and smooth surface do not require finishing.

Perform material certification tests for bronze- or copper-alloy bearings to verify the material properties.

The Engineer may require bearing friction tests or material friction tests.

F. *Masonry, Sole, and Shim Plates for Bearings.* Use metal plates in masonry, sole, and shim plates, unless otherwise specified, that meet AASHTO M 270M/M 270 Grade 36 (250). Ensure that bronze- or copper alloy bearing and expansion plates also conform.

Form holes in bearing plates by drilling, punching, or using accurately controlled oxygen cutting. Remove burrs by grinding.

Set bearing plates in a level position as shown and to have a uniform bearing over the whole area. Make provisions to keep plates in correct position during concrete placement for plates embedded in concrete.

G. *Polytetrafluoroethylene (PTFE) Surfaces for Bearings.* Manufacture and test polytetrafluoroethylene (PTFE) surfaces according to the *AASHTO LRFD Bridge Design Specifications*.

H. *Anchor Bolts.* Use anchor bolts that meet ASTM A307, or as otherwise specified. Provide anchorage details that allow development of the full tensile strength of the bolt for anchor bolts. Use hooks or end plates, as practicable.

Swedge or thread the anchor bolts to secure a grip on the material used to embed them in the holes.

Drill holes for anchor bolts and set them in portland cement grout, or approved equal, preset them as shown, or as specified or directed by the Engineer.

Locate anchor bolts to anticipate variation from mean temperature of the superstructure at time of setting. Anticipate lengthening bottom chord or bottom flange resulting from dead load after setting, with the intent that, as near as practicable, the anchor bolts at expansion bearings will center their slots at mean temperature and under dead load. Ensure that anchor bolts or nuts allow full and free movement of the superstructure at movable bearings.

I. *Bedding of Masonry Plates.* Place filler or fabric materials as bedding material under masonry plates providing full bearing on contact areas when shown.

Thoroughly clean the contact surfaces of the concrete and steel immediately before placing the bedding material and installing bearings or masonry plates.

Use as bedding preformed fabric pads composed of multiple layers of 8-oz/yd^2 (270-g/m^2) cotton duck impregnated and bonded with high-quality natural rubber or equally suitable materials compressed into resilient pads of uniform thickness to produce the specified thickness, after compression and vulcanizing. Ensure the finished pads can withstand compression loads perpendicular to the plane of the laminations of at least 10,150 psi (70 MPa) without detrimental reduction in thickness or extrusion.

For sheet lead used as bedding, use common desilverized lead meeting ASTM B29. Use sheets of uniform thickness, free from cracks, seams, slivers, scale, and other defects. Unless otherwise specified, furnish $^1/_8$ in. (3 mm) thick lead sheets with a permissible tolerance of ±0.3 in. (0.76 mm).

For caulking material used as bedding, use a nonsag polysulfide or polyurethane material meeting ASTM C920.

Use grout and mortar to fill under masonry plates.

J. *Fabrication Requirements for Guides.* Attach guide bars to the body of the bearing using a method that minimizes distortion and allows the flatness tolerance on all bearing parts after attachment. Make guide system sliding surfaces flat and parallel.

To attach the guide bars to their supporting plates, use bolts or threaded fasteners that have an embedded thread length adequate to develop their strength.

For low-friction material used at the contact interface, use two or more of the following methods to simultaneously attach to its backing piece:

1. Bonding,
2. Recessing, or
3. Mechanical attachment with countersunk fasteners.

For bonded material, etch by the material or bonding agent manufacturer's recommended method. Recess one-half of the material thickness. Countersink fasteners to a depth that ensures that they will not touch the mating material after allowing for wear.

K. *Load Plates.* Make load plates from a single plate or build up from several steel laminates. Orient each in the plane perpendicular to the direction of the load. Join built-up load plates by complete seal welding to prevent ingress of moisture. Provide welds of sufficient shear strength to resist the applied loads. Ensure that there are no sharp corners or edges on the load plates. Form holes by drilling, punching or accurately controlled oxygen cutting. Remove burrs by grinding.

818.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. For each type of bearing assembly listed, the Engineer will measure quantities either by the in-place weight in lb (mass in kg) as determined from scale weight (mass), or by a unit basis, as specified. Scale weight (mass) is not required when calculated weight (mass) is shown; in this case, the Agency will use the weight (mass) shown as the basis of payment.

818.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Bearing device (Type)	each, lb (kg)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 819
BRIDGE DECK JOINT SEALS

819.1 DESCRIPTION

Furnish and install joint sealing systems in bridge decks.

819.2 MATERIALS

Provide materials as specified in:

Poured Joint Seals	Subsection 707.1(A)(2)
Elastomeric Joint Seals	Subsection 707.1(B)(2)
High-Strength Bolts	Subsection 710.2
Reinforcing Steel	Sections 711 and 809
Concrete	Subsection 713.1(B), Section 808
Aluminum Extrusions	Subsection 716.1(C)
Steel and Fabricated Steel Components	Sections 811 and 823
Painting	Section 813
Lubricant Adhesive for Preformed Elastomeric Seals	ASTM D4070
Nuts	ASTM A563
Bolts not designated as high-strength	ASTM A307
Galvanizing for Plates	AASHTO M 111M/M 111
Galvanizing for nuts and bolts	AASHTO M 232M/M 232

819.3 CONSTRUCTION

A. *Deck Joint Assemblies.* Use approved deck joint seal assemblies for each size required. Ensure that assemblies meet the specifications provided by the manufacturer at the time of approval. Ensure joint seals prevent the intrusion of material and water through the joint system.

Deliver fabricated expansion joint assemblies to the bridge site completely assembled. Only splice preformed elastomeric joint seals with the Engineer's approval.

B. *Working Drawings.* Prepare calculations showing joint settings for installation before installing joints in any bridge deck. Submit working drawings showing the installation procedure and joint assembly for bridge decks using proprietary joint systems. Submit shop drawings for approval for joints having a total movement of more than $1^3/_4$ in. (45 mm).

Do not begin work on the deck joint seal before working drawings are approved.

C. *Installation.* Protect joint materials and assemblies stored at the job site from damage. Support assemblies to maintain their true shape and alignment. Construct and install deck joint seals to provide a smooth ride. Cover installed bridge deck joints with protective material until final cleanup of the bridge deck.

Test deck joint seals for water leakage, after installation, in the presence of the Engineer. Leakage of the joint seal is cause for rejection.

Cast joints to be sealed with compression seals to a narrower width than required for the preformed material.

Minimize spalling when making saw cuts. Cut both sides of a groove simultaneously to proper depth and alignment. Control saw alignment at all times with a rigid guide. Bevel the saw-cut lip. Repair spalls, popouts, or cracks before placing the lubricant sealant.

Saw cuts are not required where armor plates are used.

Install the joint sealing system so that it is clean and dry, and free from spalls and irregularities. Remove deleterious material from concrete or metal surfaces where the joint seal is made. Use hand methods or machine tools to install premolded elastomeric compression joint seals without damaging the seal. Apply lubricant adhesive according to the manufacturer's instructions to both faces of the joint before installing the seal. Compress the preformed elastomeric seal to the thickness for the rated opening and ambient temperature at the time of installation. Ensure there are no loose-fitting or open points between the seal and the deck.

Construct expansion joint seal assemblies to provide absolute freedom of movement through a movement range consistent with the design. Install the assembly according to the manufacturer's recommendations.

819.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

819.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Bridge deck joint seal (Type)	ft (m)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 820
RAILS

820.1 DESCRIPTION

Furnish materials and construct rails on structures, including furnishing and placing mortar or concrete, anchor bolts, reinforcing steel dowels, or other devices used to attach the rails to the structure.

820.2 MATERIAL

Metal Beam Rails	Subsection 712.4
Timber Rails	Subsection 712.5
Steel Box Beam Rail	Subsection 712.9
Concrete Rails	Subsection 713.1(B), Sections 808 and 809
Aluminum Rails	Section 716
Aluminum Extrusions	Subsection 716.1(C)
Steel Rails	Section 811
Painting	Section 813
Stone Rails	Section 814
Brick Rails	Section 815
Miscellaneous Metal	Section 823
Nuts and Bolts not designated as high-strength	ASTM A307
Cast Posts	ASTM B108/B108M
Galvanizing Rails	AASHTO M 111M/M 111
Galvanizing Nuts and Bolts	AASHTO M 232M/M 232

820.3 CONSTRUCTION

Place rails after falsework for the span has been released, rendering the span self-supporting. Construct the rails true to the line and grade specified. This may include an allowance for camber in each span, but do not follow any unevenness in the superstructure. Construct rails on bridges, with or without superelevation, vertical.

A. *Metal Rails.* Fabricate formed sections of steel rail from mild steel. Pipe sections may be of standard steel pipe. Finish exposed welds by grinding or filing to give a smooth surface. Weld aluminum materials by inert gas shielded electric arc welding process using no welding flux. Cut aluminum by other means than torch or flame cutting.

   Adjust metal rails before anchoring to ensure proper matching at abutting joints, correct alignment, and camber throughout their length. Drill holes for field connections with the rails in place and at proper grade and alignment.

   In areas where aluminum alloys come in contact with other metals or concrete, coat surfaces with a dielectric aluminum-impregnated caulking compound or place a synthetic rubber gasket between the two surfaces.

   Galvanize anchor bolts, nuts, and all steel portions of rails. Leave aluminum portions unpainted. Repair minor abrasions to galvanized surfaces with zinc-rich paint. Remove sharp protrusions and clean the rails of discoloring foreign materials after rail has been erected.

B. *Concrete Rails.* Construct concrete rails by the cast-in-place or precast method. Use Class AE concrete, except in areas where the minimum thickness of the rails is less than 4 in. (100 mm), in which case use Class C (AE) concrete. Remove forms used for cast-in-place rails after adequate measures to protect and cure the concrete are in place and the concrete has sufficient strength to prevent surface or other damage caused by form removal. Use Class 2—Rubbed Finish, as specified in Subsection 808.3(J)(2), on rails constructed with fixed forms. Use Class 1—Ordinary Finish, as specified in Subsection 808.3(J)(1), on rails constructed with slip forms and for temporary rails.

C. *Timber Rails.* Seal the surfaces of all elements of treated wooden rails with two coats of an acceptable sealer in areas where contact with people could occur. Treat timber with preservatives as specified in Subsection 712.5.

D. *Temporary Rails.* Install temporary precast barriers on a solid base. Maintain the temporary rails and leave in place until all work requiring the rails has been completed. Use new or previously used units, provided they are in a clean and undamaged condition. Retain temporary rails after removal.

820.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will base quantities on the length of rail in ft (m), measured along the face of the rails, between the ends of the rails or the outside ends of end posts, whichever is greater, and will make no deductions for joints or other small openings.

820.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Rail (Type)	ft (m)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 821
WATERPROOF OR DAMPPROOF CONCRETE OR MASONRY SURFACES

821.1 DESCRIPTION

Construct either a constructed-in-place asphalt membrane system or a preformed membrane system, including appropriate priming materials and required protective coverings. Unless specified, the selection of either waterproofing system used is at the Contractor's option and approved by the Engineer. Provide dampproofing, including a primer coating and two moppings of waterproofing asphalt.

821.2 MATERIALS

Provide materials as specified in:

Asphalt	ASTM D449. Type I used below ground; Type II used above ground
Primer	ASTM D41/D41M
Fabric	ASTM D173/D173M
Primer for use with rubberized-asphalt membrane	Neoprene-based material of a type recommended by the manufacturer
Primer for the modified bitumen membrane	Resin- or solvent-based material of a type recommended by the manufacturer
Preformed Membrane Sheet	*AASHTO LRFD Bridge Design Specifications*
Mastic for Preformed Rubber Sheets	Rubberized asphalt cold-applied joint sealant
Mastic for Modified Bitumen Sheet	Blend of bituminous and synthetic resins
Protective Covers	$^{1}/_{8}$-in. (3-mm) hardboard of approved equivalent
Roadway Surfaces of Bridge Decks	Layer of special asphalt concrete, as specified
Adhesive	Type recommended by waterproofing manufacturer

821.3 REQUIREMENTS

A. *Preformed Membrane Waterproofing Systems:*

1. *Installing on Bridge Decks.* Store fabric rolls on their sides in a dry, protected place.

   In the absence of the Engineer's acceptance of the manufacturer's recommendations, the following shall be performed. Contractor is directed to install according to manufacturer's recommendations and contractor shall include details in submittal, subject to approval by the Engineer. Clean surface thoroughly. Place oil-resistant construction paper mask to deck areas that will be covered later by expansion dams or headers. Secure with tape or adhesive.

   Thoroughly mix primers and agitate during application. Apply one coat of neoprene-based primer by spray or squeegee at a rate of approximately 310 ft^2/gal (7.4 m^2/L). Apply resin- or solvent-based primer at a rate of approximately 120 ft^2/gal (2.9 m^2/L). Allow primers to dry to a tack-free condition.

   Place membrane seal and asphalt concrete across the paper masks. Cut the mask and the preformed sheet at or near the expansion joint. Reprime solvent-based primed surfaces not covered with membrane sheets within 24 h. Reprime neoprene-based primed surfaces not covered with membrane sheets within 36 h. Reprime resin-based primed surfaces not covered with membrane sheets within 8 h.

   Place a minimum 12-in. (300-mm) wide membrane sheet along the juncture of deck and base or barrier railing or curb face at the low side of the deck and then on the high side. Extend the membrane sheet 3 in. (75 mm) up the face of the rail or curb.

   Lay subsequent sheets longitudinally in a shingling pattern in the direction that water will drain. Lap adjacent sheets at least $2^3/_8$ in. (60 mm) along the side and 6 in. (150 mm) along the end. Cut and turn the membrane sheet into the open joint or bleeder as the sheet is laid. Use hand rollers or other devices to achieve a firm, uniform bond with the primed concrete with minimal wrinkles and air bubbles.

   Repair tears, cuts, or narrow openings with an adhesive. Cover the defective area with section of membrane sheet. Extend the repair at least 6 in. (150 mm) beyond the defect.

   Use a permanent polyester film on the section to be patched, and place the patch over the heated surface. Roll or press patches firmly onto the surface. Apply a bead of mastic along the exposed rubber-asphalt sheets and modified bitumen sheets extending up the barrier rail or curb face.

2. *Installing on Other Surfaces.* Trowel bead of manufacturer's recommended mastic or sealing tape to exposed membrane sheet edges. Ensure watertight construction by flashing protruding pipe, conduits, sleeves, or other facilities projecting through the membrane with prefabricated or field-fabricated boots, fitted coverings, or other devices. Install protective covers the following workday, or within 72 h after installing the preformed membrane.

   Apply sufficient adhesive to hold the covering in position until the backfill is placed.

B. *Dampproofing*. Clean surface thoroughly and apply primer evenly. Follow with a uniform first coat of waterproofing asphalt and allow to set. Apply second coat.

C. *Special Details*. Prevent water from collecting between the waterproofing and the waterproofed surface. Pay close attention to membrane edges and points where drains, pipes, or other protrusions puncture the membrane.

Place separate sheets to lap the main membrane at least 12 in. (300 mm) to form flashing at curbs and against girders and spandrel walls. Seal flashing with a metal counter-flashing or by embedding the upper edges in a groove filled with hot joint filler. Caulk joints that are essentially open, but that are not designed for expansion, first with oakum and then with hot joint filler.

Provide sheet copper or lead in U- or V-form at both vertical and horizontal expansion joints. Fill the joint with hot joint filler after the membrane is placed. Continue the membrane across all expansion joints.

Carry the membrane well down on the abutments at the ends of the structure. Provide for all movement.

821.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will take measurements along the surface placed, limited to the specified dimensions.

821.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Waterproofing	ft^2 (m^2)
(B) Dampproofing	ft^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 822
SLOPE PROTECTION

822.1 DESCRIPTION

Construct bank and slope protection using riprap, concrete slope paving, and precast concrete slope paving.

822.2 MATERIALS

Portland Cement	Subsection 701.2
Aggregate for Riprap	Subsection 703.15
Aggregate for Underdrains	Subsection 703.17
Filter Blanket Sand	Subsection 703.18(B)
Filter Fabric	Subsection 705.1
Precast Concrete Units	Subsections 706.3 and 714.6
Expansion Joint Filler	Subsection 707.1
Reinforcing Steel	Sections 711 and 809
Gabion Mesh and Tie Wire	Subsection 712.10
Concrete	Subsection 713.1(B), Class B or Class B(AE), 1 in. (25 mm) maximum combined grading
Pneumatically Applied Mortar	Subsection 713.5(C)
Mortar	Subsection 713.5(D)(1)
Grout	Subsection 713.5(D)(2)
Geocomposite Drain	Manufacturer's certification for AASHTO's *Standard Specifications for Highway Bridges*, Division II, Construction, Subsection 22.3.10
Concrete for Sacked Concrete Riprap	Mixture of clean pit run or washed sand and gravel, cement and water, minimum 14 lb/ft^3 (223 kg/m^3) of portland cement, slump of 3 to 5 in. (75 to 125 mm)
Sacks for Sacked Concrete Riprap	0.2 lb/ft^3 (0.34 kg/m^3) burlap or equal, 20 in. by 36 in. (500 mm by 900 mm) measured inside the seams when the sack is laid flat, capacity of 1.25 ft^3 (0.35 m^3). Sound, reclaimed sacks may be used.

822.3 CONSTRUCTION

A. *Preparing the Slope.* Shape slopes to the specified lines and grades. Compact soil to [95] percent standard density. Place filter fabric uniformly over the slope. Provide 12-in. (300-mm) laps in each direction, and anchor. Place filter fabric without tearing, puncturing, or shifting fabric. Keep tracked or wheeled equipment off fabric-covered slopes.

B. *Stone Riprap:*

1. *Hand-Placed Stone.* Place larger stones first, and fill voids with smaller stones and spalls.

2. *Machine-Placed Stone.* Place larger stones in the toe course and the outside surface. Place stone underwater using controlled methods to the point of placement.

3. *Grouted Riprap.* Place stone in maximum 12-in. (300-mm) lifts. Apply grout while stone is moist and fill the interstices. Construct succeeding lifts before grout in the previous lift has set. Provide weep holes through the riprap as specified. Protect grout from freezing for 4 days.

C. *Sacked Concrete Riprap.* Fill sacks with approximately 1 ft^3 (0.3 m^3) of concrete. Place filled sacks immediately and trample to conform with the ground surface and adjacent sacks. Double row the first course of stretchers. Install the second course in header rows. Stagger subsequent courses. Place stretchers so the folded ends are not adjacent. Place headers with the folds toward the ground. Cure for 4 days with a fine spray of water applied every 2 h during the daytime, or with a blanket of wet earth.

D. *Gabions.* Divide diaphragms equally into cells with the length not exceeding the width. Secure perimeter edges so joints formed by tying edges have strength equal to the body of mesh. Ensure that cells with heights of between one-third and two-thirds the width have two cross-connecting wires, and cells with heights of more than two-thirds the width have four cross-connecting wires. Connect basket lids and adjacent baskets with tie wire or hog rings at a spacing no greater than 6 in. (150 mm), or continuously stitch around edges with a coil approximately every 4 in. (100 mm).

Stagger vertical joints at one-third to one-half the length of the baskets. Uniformly space and securely fasten internal tie wires in each cell of the structure. Fill gabions with stone while maintaining alignment and avoiding bulges. Bend lid into position and secure to the sides, ends, and diaphragms.

E. *Geocomposite Drain.* Install drain with the filter fabric side facing the embankment. Overlap fabric 3 in. (75 mm) at all joints, and wrap around the exterior edges a minimum of 3 in. (75 mm) beyond the edge. Provide and attach additional fabric to overlap at joints and wrap around at edges on the geocomposite drain a minimum of 6 in. (150 mm). Replace torn or punctured fabric, or repair by covering the damaged area and 6 in. (150 mm) around the damaged area with fabric.

F. *Concrete Slope Paving.* Submit working drawings detailing proposed materials and construction and performance characteristics for approval. Construct slope paving using pneumatically applied mortar, cast-in-place, or precast portland cement concrete slope paving, or, when permitted, use woven fabric forms filled with fine-aggregate portland cement concrete grout.

When steep slopes prevent normal consolidation, tamp concrete and trowel on a minimum $^1/_4$ in. (6 mm) thick mortar surface. Finish with hand floats after striking off to grade. Shape edges and joints with a $^1/_4$-in. (6-mm) radius edger. Apply a broom surface parallel to the edges of the panel.

Lay precast slabs, blocks, and shapes on a 3-in. (75-mm) bed of sand. Position blocks and shapes in place to provide a uniform surface and solid bedding. Lay blocks in running bond with the length parallel to the slope and with $^1/_4$-in. (6-mm) joints where grouting is required. Fill joints with mortar sand to 4 in. (100 mm) from the surface in areas to be grouted. Wet blocks before grout is placed. Place grout when temperature is above 40°F (5°C). Fill joints with grout flush with the top of the block. Wet blocks after initial set of grout. Cure grout for 7 days.

Fill woven fabric forms with pumpable fine aggregate portland cement concrete grout.

Construct transverse expansion joints at intervals of 20 ft (6.1 m) and longitudinal expansion joints as specified. Fill expansion joints with expansion joint filler $^1/_2$ in. (12 mm) thick. Cure concrete or pneumatically-applied mortar. Provide weep holes through the slope paving with 2 ft^3 (0.6 m^3) of pervious backfill material wrapped in filter fabric. Fill footing trenches with excavated material.

822.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure stone riprap in yd^2 (m^2) along the upper surface actually placed, limited to the specified dimensions, or will compute the volume of stone riprap in yd^3 (m^3) based on the specified thickness and the area measured along the upper surface actually placed, limited to the specified dimensions.

B. The Engineer will base quantities of in-place sacked concrete riprap on mixer volumes.

C. The Engineer will measure gabions along the upper surface actually placed, limited to the specified dimensions.

D. The Engineer will measure concrete slope paving (cast-in-place concrete, pneumatically applied mortar place, or precast portland cement concrete) in yd^2 (m^2) along the upper surface actually placed, limited to specified dimensions, or will compute the volume of concrete slope paving (cast-in-place concrete or pneumatically applied mortar) in yd^3 (m^3) based on the specified thickness and area measured along the upper surface actually placed, limited to the specified dimensions.

E. The Engineer will measure filter fabric on the ground surface, excluding overlaps.

822.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Stone riprap	yd^2 (m^2), yd^3 (m^3), ton (Mg)
(B) Sacked concrete riprap	yd^3 (m^3)
(C) Gabions	yd^2 (m^2)
(D) Concrete slope paving (Type)	yd^2 (m^2), yd^3 (m^3)
(E) Filter fabric	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 823
MISCELLANEOUS METALS

823.1 DESCRIPTION

Furnish and install miscellaneous metal items in structures not otherwise provided for.

823.2 MATERIALS

Provide materials as specified in:

Steel bars, plates, and shapes	ASTM A36/A36M, Grade 36 (250)
Bolts and nuts not designated as high-strength	ASTM A307
High-strength bolts, nuts, and washers	ASTM F3125/F3125M
Mild steel for general application	AASHTO M 103M/M 103
Chromium alloy steel castings	Subsection 710.5(A)(2)
Gray iron castings	Subsection 710.5(B)(1)
Ductile iron castings	Subsection 710.5(B)(2)
Malleable castings	Subsection 710.5(B)(3)
Sheet metal	Commercial quality material
Aluminum extrusions, castings, and forgings	Section 716

823.3 CONSTRUCTION

A. *Fabricating.* Remove flaws, including burrs and rough and sharp edges, after fabrication. Straighten warped pieces after fabricating and galvanizing.

B. *Galvanizing.* Galvanize steel items not embedded at least 2 in. (50 mm) in concrete and cast iron sidewalk frames and covers as specified in Subsection 710.1(A). Galvanize nuts and bolts as specified in Subsection 710.2(D).

823.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. If stated in the contract documents, the Engineer will base quantities on the calculated in-place weight (mass) of each type metal specified. Otherwise, the Engineer will base quantities on the scale weight (mass) using certified weighmaster's tickets furnished by the Contractor at the Engineer's request.

B. The Engineer will measure, and the Agency will pay for, aluminum extrusions, castings, and forgings pay items under Section 831.

823.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Miscellaneous metal (Type)	lb (kg)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 824
PNEUMATICALLY APPLIED MORTAR

824.1 DESCRIPTION

Furnish and place pneumatically applied mortar for the construction of portions of structures, repairing concrete structures, texturing concrete surfaces, encasement of structural steel members, lining ditches and channels, paving slopes, and other miscellaneous work.

Pneumatically applied mortar consists of either dry-mixed fine aggregate and portland cement pneumatically applied by a suitable mechanism, to which water is added immediately before its expulsion from the nozzle; or, mortar premixed by mechanical methods and pneumatically applied through a nozzle onto the prepared surface.

Prepare surfaces to receive the mortar, and furnish and place reinforcing steel and anchors.

824.2 MATERIALS

Provide materials as specified in the following:

Reinforcing steel	Sections 711 and 809
Pneumatically Applied Mortar	Subsection 713.5(C)
Forms	Subsection 803.3(B)
Anchor studs	$^1/_4$-in. (6-mm) minimum diameter expansion hook bolts

824.3 REQUIREMENTS

A. *Proportioning.* Submit the proposed mix design to the Engineer for approval prior to the start of the work. Prepare the mix design as specified in Subsection 713.5(C).

B. *Mixing Mortar.* Mix mortar by the dry-mix or wet-mix process. Mix the materials thoroughly using either a paddle-type or drum-type mixer designed for use with pneumatic application, before being charged into the placing equipment. The Contractor may use transit mix equipment and methods for the wet process.

C. *Preparing the Surface.* Grade the area accurately to the elevation and dimensions specified when pneumatically applied mortar is to be placed against earth. Compact with sufficient moisture to provide a firm foundation and to prevent absorption of water from the mortar, but without free surface water.

Provide joints, side forms, headers, and shooting strips for backing or paneling. Use ground or gauging wires where necessary to establish thicknesses, surface planes, and finish lines.

Remove deteriorated or loose material by chipping with pneumatic or hand tools, when mortar is to be placed against concrete or rock. Cut square or slightly undercut shoulders approximately 1 in. (25 mm) deep along the perimeter of repair areas. Sandblast the surface to clean rust from exposed steel and to produce a clean rough-textured surface on the concrete or rock. Keep the surface against which mortar is to be placed wet for at least 1 h. Allow to dry before applying the mortar.

D. *Installation:*

1. *Placing Reinforcing Steel.* Place reinforcement and secure to ensure no displacement from impact of applying pneumatically placed mortar. When placing mortar against existing concrete or rock, support reinforcing wire fabric or bars using anchor studs consisting of $^{1}/_{4}$-in. (6-mm) minimum diameter expansion hooked bolts placed in drilled holes. Use bolts with sufficient engagement in sound masonry to resist a pull out force of 150 lb (670 N).

   Use driven steel studs of not less than $^{1}/_{8}$-in. (3-mm) diameter and a minimum length of 2 in. (50 mm). Drive studs with equipment that uses an explosive for the driving force and is capable of inserting the stud or pin without damaging the surrounding concrete.

   Space anchors no more than 12 in. (300 mm), center-to-center, on overhead surfaces; 18 in. (460 mm), center-to-center, on vertical surfaces; and 36 in. (920 mm), center-to-center, on top horizontal surfaces. Use at least three anchors in each individual patch area.

   Notify the Engineer when installation of anchor studs is to begin. Locate studs so that there is no damage to prestressing tendons or conduits embedded in the concrete.

   Use reinforcement, when performing repair work, in all areas where the thickness of the mortar exceeds $1^{1}/_{2}$ in. (38 mm) with a single layer of either 2 × 2 – W1.4 × W1.4 (50 × 50 – MW8 × MW8) or 3 × 3 – W1.4 × W1.4 (75 × 75 – MW10 × MW10) welded wire fabric. Use a single layer of wire fabric to reinforce each 4-in. (100-mm) thickness of patch or fractional part in areas where the thickness of the mortar exceeds 4 in. (100 mm). Place wire fabric parallel to the proposed finished surface. Completely encase each layer of fabric in mortar that has taken its initial set before installing the succeeding layer of fabric. Provide a minimum clearance of $^1/_2$ in. (12 mm) for fabric supported adjacent to the prepared masonry surface. Prebend fabric before installing to fit around corners and into re-entrant angles.

Provide a minimum 1-in. (25-mm) clearance between the finished surface of the mortar and all steel items, including anchors, reinforcing bars, and wire fabric.

2. *Applying Mortar.* Apply mortar using pneumatic equipment that sprays the mix onto the prepared surface at the velocity necessary to produce a compacted dense homogeneous mass. Use an air compressor and delivery hose lines to provide a minimum pressure of 35 psi (0.24 MPa) at the nozzle for 1-in. (25-mm) nozzles and proportionally greater for larger nozzles. Maintain uniform velocity of the material as it leaves the nozzle at a rate determined for the given job conditions to produce minimum rebound.

   Supply water at a uniform pressure of at least 15 psi (0.1 MPa) greater than the air pressure at the nozzle.

   Apply the mortar as dry as practicable to prevent shrinkage cracking. Employ shooting strips to ensure square corners, straight lines, and a plane surface of mortar. Place so as to minimize the trapping of rebound. Slope the mortar off to a thin edge at the end of each day's work or at similar stopping periods requiring construction joints. Thoroughly clean and wet in-place mortar before placing an adjacent section. Shoot surfaces so that the stream of flowing material impinges nearly at right angles to the surface being covered, while holding the nozzle 24 to 48 in. (600 to 1,200 mm) from the working surface. Apply a sufficient number of mortar coats to obtain the required thickness. Place the mortar coat on vertical and overhead surfaces in layers not to exceed 1 in. (25 mm) thick. Place the coat so that it neither sags nor decreases the bond of the preceding coat. Provide a sufficient interval between successive layers in sloping, vertical, or overhanging work to allow initial, but not final, set. Clean the surface to remove the thin film of laitance to provide for a bond with succeeding applications.

   Remove rebound or accumulated loose sand from the surface to be covered prior to placing the original or succeeding layers of mortar.

   Use materials that have been mixed for more than 45 minutes.

   Ensure repaired areas are sound after curing and before final acceptance. Remove and replace unsound and cracked areas.

3. *Weather Conditions.* Place pneumatically placed mortar on an unfrozen surface when the ambient temperature is above 40°F (5°C). Place only when it is anticipated that the temperature during the following 24 h will be above 32°F (0°C).

Suspend application if high winds prevent proper application or rain would wash out the pneumatically placed mortar.

4. *Protecting Adjacent Facilities.* Protect adjacent facilities that may be permanently discolored, stained, or otherwise damaged by overspray, dust, or rebound. Clean by early scraping, brushing, or washing, as the surroundings allow.

5. *Finishing Mortar Surfaces.* Use a sharp trowel to cut off high spots after mortar has been placed to the desired thickness, or screed to a true plane as determined by shooting strips or by the original masonry surface. Lightly apply cutting screeds, where used, to surfaces so as not to disturb the mortar for an appreciable depth. Work in an upward direction when applied on vertical surfaces. Give the finished mortar surface a final flash coat of about $^1/_8$ in. (3 mm) of mortar. Obtain a uniform appearance on exposed surfaces.

6. *Curing.* Cure pneumatically placed mortar as specified in Subsection 808.3(L)(2). The minimum water curing duration is 96 h. Protect the mortar from freezing during the curing period.

824.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure quantities on either an area or a volume basis. The Engineer will base area measurements on the surface area of mortar placed along the plane or curve of each surface. The Engineer will base volume measurements on the dimensions of such work as shown on the plans.

824.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Pneumatically applied mortar (Type)	yd^2 (m^2), yd^3 (m^3)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 825
STEEL AND CONCRETE TUNNEL LINERS

825.1 DESCRIPTION

Furnish and install cold-formed steel tunnel liner plates or precast concrete plates.

825.2 MATERIALS

Provide materials as specified in:

Steel Liner Plates	*AASHTO LRFD Bridge Design Specifications*
Bolts	*AASHTO LRFD Bridge Design Specifications*
Precast Concrete Tunnel Liner Plates	Section 808

825.3 CONSTRUCTION

A. *Fabricating Steel Plates.* Submit working drawings for approval. Form steel plates to provide circumferential flanged joints. Flange longitudinal joints in steel plates or use the offset lap seam type. Punch steel plates for bolting on both longitudinal and circumferential seams or joints. Space bolts in circumferential joint of steel plates in a multiple of the plate length such that plates with same curvature are interchangeable, allowing staggered longitudinal seams. Provide grout holes 2 in. (50 mm) or larger in diameter.

B. *Erecting Steel Plate.* Use either the flanged or lapped seam steel liner plates throughout the tunnel. Assemble liner plates according to the manufacturer's instruction. Connect steel plates with bolts on both longitudinal and circumferential seams or joints. Complete erection from the inside of the tunnel. Handle coated steel plates to prevent bruising, scaling, or breaking of the coating. Replace damaged plates at no cost to the Agency.

Pressure grout voids between the liner plate and tunnel wall.

825.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

825.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Tunnel liner	ft (m)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 826
RESERVED

SECTION 827
RESERVED

SECTION 828
LATEX-MODIFIED CONCRETE SURFACE

828.1 DESCRIPTION

Place a wearing surface of durable and impervious material on the prepared roadway surface of bridge decks.

828.2 MATERIALS

Provide materials as specified in:

Portland Cement	Subsection 701.2
Fine Aggregate	Subsection 703.1(A)
Coarse Aggregate	Subsection 703.1(B)
Mixing Water for Concrete	Subsection 714.1(A)
Latex Emulsion	Manufacturer's Certificate of Compliance that the material meet the specified requirements

828.3 CONSTRUCTION

Contractor is directed to include in submittal the method of scarifying, preparing deck, and concrete placement/finishing.

A. *Preparing the Surface:*

1. *New Decks.* Finish the surfaces to a rough texture by coarse brooming. Cure the deck concrete as specified in Section 808.3(I). Clean and prepare surfaces as specified in Subsection 828.3(B).

2. *Existing Decks.* Temporarily cover or plug deck drains, expansion joints, and other openings until operations are completed. Ensure method of containment for water or blasting media used to clean the deck meets any environmental or stormwater control requirements for disposal.

Provide deck surface scarifiers, capable of uniformly removing the existing surface to the depths required without damaging the underlying concrete. The scarifier must be able to remove a minimum $^{1}/_{4}$ in. (6 mm) of material on a single pass.

Avoid damaging hardware such as drain grates and expansion joint armor.

Use hand tools to remove deteriorated or unsound concrete in areas where machine scarifying cannot reach and areas of spalling where reinforcing steel is exposed. Limit pneumatic hammer size to less than 44 lb (20 kg) (nominal).

Wait 48 h after placement of a new overlay before scarifying or chipping within 6 ft (1.8 m) of the new overlay.

Remove deteriorated or unsound concrete to a depth of $^{3}/_{4}$ in. (20 mm) below and $^{3}/_{4}$ in. (20 mm) around the top mat of reinforcing steel, except where lower bar mats make this impractical. Avoid damaging exposed reinforcing steel. Blast clean reinforcing steel.

Clean and prepare surfaces as specified in Subsection 828.3(B).

B. *Surface Cleaning*. Blast clean the deck surface and the vertical faces of curbs, concrete parapets, and barrier walls, to a height 1 in. (25 mm) above the top elevation of the overlay. Blast clean to a bright appearance free of laitance, curing compound, dust, dirt, oil, grease, bituminous material, paint, and other foreign matter. Immediately and thoroughly remove debris, including dirty water resulting from the blast cleaning operations. Protect cleaned areas from contamination before placement of the overlay. Reclean contaminated areas and areas exposed more than 36 h after previous blast cleaning.

Remove dust and other debris by flushing with water or blowing with compressed air just before placing the overlay. Soak the prepared surface with clean water 1 h prior to placing the latex overlay. Remove free water using forced air so the surface appears dry or barely damp. Equip the air supply system for blast cleaning and blowing with an oil trap in the air line. Prevent oil or grease contamination of the surface.

C. *Latex-Modified Concrete.* Store latex admixture in an enclosure protected from freezing and prolonged exposure to temperatures over 86°F (30°C). Limit latex admixture storage at the work site to 10 days.

Proportion concrete mixture to contain 1 part cement, 2.5 parts fine aggregate, and 2 parts coarse aggregate by weight (mass). Use 0.35 gallons latex emulsion admixture per pound of cement (0.3 L/kg). Ensure the plastic concrete has 3 to 6 percent air content, as determined by AASHTO T 152, and a slump of 3 to 6 in. (75 to 150 mm). Adjust the dry mass ratios to produce a workable mix by increasing the mass of sand by as much as 0.2 parts and reducing the coarse aggregate by an equivalent volume.

Ensure formulated latex emulsion admixture is a nonhazardous, film-forming, polymeric emulsion in water to which stabilizers are added at the point of manufacture. The admixture must be homogeneous and uniform in composition. Ensure the latex emulsion admixture meets the requirements specified in Table 828.3-1.

Table 828.3-1. Physical Properties of Latex Admixtures

Physical Properties	Value or Type
Polymer Type	Styrene Butadiene
Stabilizers:	
(a) Latex	Nonionic Surfactants
(b) Portland cement composition	Polydimethyl Siloxane
Percent Solids	46. to 49.%
Density, lb/gal at 77 °F (kg/L at 25 °C)	8.3 (1.)
Color	White

D. *Installation*. Obtain approval for the equipment used to proportion, mix, place, and finish the latex concrete. Ensure a qualified technician is in control of the work whenever operations of proportioning, mixing, placing, and finishing latex-modified concrete are under way. Construct latex-modified concrete wearing surfaces with a minimum thickness of $1^1/_4$ in. (32 mm).

1. *Placement Conditions.* Place concrete only when the temperature is expected to remain between 45˚F and 80˚F (7˚C and 27˚C), and when no high winds, rain, or low humidity conditions are expected before final set of the concrete. Do not place concrete when the evaporation rate exceeds 0.15 pounds per square foot per hour as determined by ACI 305R, Figure 2.1.5. Wind breaks, sunshades, or fogging may be used to reduce evaporation rate to below the maximum allowable rate. Stop placement of concrete and form a straight construction joint when evaporation rate cannot be maintained, or if a flash set of the latex does not produce a suitable placement or finish. Provide adequate light when work is performed at night.

2. *Finishing Equipment.* Place and distribute freshly mixed latex-modified concrete to the correct level with hand tools. If a finishing machine is used, it must:

   a. Be self-propelled and capable of forward and reverse movement under positive control.

   b. Be of sufficient length to extend 6 in. (150 mm) beyond the edge of both ends of the section being placed.

   c. Be capable of consolidating the concrete by vibration and be able to raise all screeds to clear the concrete for traveling in reverse.

   d. Have one or more rollers, augers, and vibratory pans with a frequency of 25 to 40 Hz or have vibrators on the screeds whose frequency of vibration can be varied between 50 and 250 Hz.

   e. Have a metal bottom face not less than 4 in. (100 mm) wide.

   f. Travel on rails sufficiently rigid to support the machine without appreciable deflection.

g. Have rail supports that are placed outside of the overlay area.

h. Have anchored rails providing horizontal and vertical stability (prohibit ballistically shooting anchors into concrete that will not be overlaid).

3. *Placing and Finishing Concrete.* Each day before beginning placement, test run the finishing machine over the entire area to be overlaid.

   Finish concrete behind the finishing machine from a portable lightweight or wheeled work bridge. Finish and consolidate small areas with hand-operated vibrators, screeds, and floats. Form planned construction joints by bulkheads set to grade. Saw construction joint to a straight vertical edge. Blast the face of the joint with sand or water to remove loose material before placing concrete against previously placed concrete. Construct longitudinal construction joints only at the centerline of roadway or at lane lines. Protect concrete at the end of the placement from drying with several layers of clean, wet burlap during delays in the placement operation of less than 1 h. Form unplanned construction joint during delays in the placement operation of less than 1 h by removing all material below the finish grade and sawing the edge in a straight line.

   Brush on and thoroughly scrub a thin coating of the polymer-modified concrete overlay mixture on the horizontal and vertical surfaces before full-depth placement of the overlay. Place the thin coating at a rate so that it will not dry before being covered with the full-depth placement.

   Place latex-modified concrete immediately after mixing. Strike off the concrete approximately $^1/_4$ in. (6 mm) above final grade. Consolidate the concrete by vibration. Use spud vibrators in deep pockets, along edges, and adjacent to joint bulkheads. Finish concrete to final grade. Produce a uniform, smooth, and even-textured surface, varying not more than $^1/_8$ in./10 ft (3 mm/3 m) longitudinally. Finish concrete along the edge of the pour or on small areas of repair with a hand float. After the mixture has stiffened sufficiently, remove the newly placed material from screed rails and construction bulkheads by passing a pointing trowel along their inside face for the entire depth and length. Texture the surface by tining, as specified in Subsection 808.3(H)(3), before the plastic film forms. Promptly cover the surface with a single layer of clean, wet burlap as soon as the surface will support it without deformation.

4. *Curing.* Cover overlay with wet burlap and a layer of polyethylene film meeting ASTM C171 or wet burlap-polyethylene sheets within 1 h after finishing. Lap sheeting by a minimum of 6 in. (150 mm). Wet cure the overlay for 24 h. Extend the wet curing period to 48 h when the temperature falls below 45°F (7°C) during the first 24 h. Remove the curing material and air cure the overlay an additional 72 h. Protect the overlay from freezing during the cure period. Prohibit traffic on the overlay during the curing period.

5. *Inspecting and Repairing Surfaces.* Inspect the overlay for damage. Use a chain drag or other suitable device to inspect for delaminations and bond failures. Seal surface cracks not exceeding $^3/_8$ in. (10 mm) in depth with an epoxy-penetrating sealer followed by an application of approved sand. Crack depths to ¼ in. (6 mm) may also be repaired with a high

molecular weight methacrylate penetrating sealer or a low viscosity epoxy resin. Remove and replace portions of the wearing surface containing cracks exceeding $^{3}/_{8}$ in. (10 mm) in depth or repair by an approved method. Remove and replace delaminated or unbonded portions of the wearing surface or portions damaged by rain or freezing. Test the surface for flatness and correct, if necessary, as specified in Subsection 808.3(H)(4).

828.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

828.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Wearing surfaces	yd^2 (m^2)
(B) Scarifying bridge decks	yd^2 (m^2)
(C) Removal of unsound concrete	yd^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 829
EMBEDMENT ANCHORS

829.1 DESCRIPTION

Install and field test cast-in-place, grouted, adhesive-bonded, expansion, and undercut steel anchors.

829.2 MATERIALS

Provide materials as specified in:

Embedment Anchors	ACI 349-97, Appendix B
Bonding Compounds	ASTM E1512
Expansion Anchors	ASTM E488/E488M
Anchor Systems other than Mechanical Expansion Anchors	Certified test reports prepared by an independent laboratory documenting that the system is capable of achieving the minimum tensile strength of the embed-ment steel

829.3 CONSTRUCTION

A. *Methods.* Provide adequate edge distance, embedment depth, and spacing to develop the required strength of the embedment anchors. Use the correct drill hole diameter as specified by the manufacturer. Use rotary-impact drilling. With the Engineer's prior approval, the contractor may move the hole to a different location or drill through the reinforcing steel using a diamond core bit if a reinforcing bar is encountered during drilling. Patch abandoned holes with an approved bonding material. Thoroughly clean holes.

Remove loose dust and concrete particles from the hole, prepare bonding material, and install anchors. Do not use additives corrosive to steel or zinc/cadmium coatings. Use epoxy, vinylester, or polyester chemical compound for adhesive anchors. Use moisture-insensitive, high-modulus, low-shrinkage, and high-strength adhesives.

Remove and replace embedded anchors or anchors not having the required strength.

B. *Inspection and Testing.* Complete sacrificial tests of the anchor system at the job site to ultimate loads to document the capability of the system to achieve pullout loads equaling the full minimum tensile value of the anchor used. Perform anchor testing on fully cured concrete samples. Test at least 3 anchors according to ASTM E488/E488M.

Torque each anchor system to the specified values after the bonding material has cured.

Provide for an alternative system if proof loading shows the current system is incapable of achieving minimum values.

829.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1.

829.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
(A) Embedment anchors (Type)	each
(B) Embedment anchor, field test	each

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

SECTION 830
RESERVED

SECTION 831
ALUMINUM STRUCTURES

831.1 DESCRIPTION

Furnish, fabricate, and erect aluminum structures and structural aluminum portions of structures. Paint as required.

831.2 MATERIALS

Provide materials as specified in Section 716.

831.3 CONSTRUCTION

A. *Working Drawings.* Submit working drawings and erection drawings prior to performing the work. Ensure design details meet *AASHTO LRFD Bridge Design Specifications*.

B. *Storing Materials.* Place material to be stored at the job site on skids and keep clean and well-drained. Place girders and beams upright and shored.

C. *Erecting Aluminum Structures.* Comply with approved erection procedures and erection drawings.

   Account for erection stresses induced as a result of using an erection method that differs from the plans.

   Provide temporary bracing or stiffening devices to limit stresses in individual members or segments of the structure during erection.

   Support segments of the structure in a manner that will produce proper alignment and camber in the completed structure.

   Drive pins so that the members will take full bearing on them. Snug-tighten pin nuts, and burr the threads at the face of the nut.

   Furnish and install bridge bearings as specified in Section 818.

831.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure pay quantities for each aluminum alloy by the lb (kg) computed from dimensions. The Engineer will use one of the following methods to compute quantities.

1. *Lump Sum Basis.* No measurement required.

2. *Mass Basis.* The Engineer will calculate the weight (mass) for each type of aluminum alloy specified based on the nominal weight (mass) as per Aluminum Standards and Data of net furnished dimensions.

831.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Units
(A) Structural aluminum	lb (kg)
(B) Structural aluminum, testing	lb (kg)
(C) Structural aluminum, erection	lump sum

Such payment is full compensation for furnishing all materials, equipment, labor, and incidentals to complete the work as specified.

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APPENDIXES X1–X7
SPECIAL AND TECHNICAL PROVISIONS

These appendixes contain additional special or technical provisions that may be used with highway construction contracts. These provisions include the following:

Appendix X1	Generic Warranty
Appendix X2	Statistical Evaluation of Work for Acceptance
Appendix X3	Measurement of Pavement Ride Quality Using Inertial Profiling Systems
Appendix X4	Dispute Review Board (DRB) Three-Party Agreement and Operating Procedures
Appendix X5	Pipe Culvert Inspection and Evaluation for New Construction
Appendix X6	Nighttime Construction
Appendix X7	Temporary Noise Suppression Devices

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APPENDIX X1
GENERIC WARRANTY

X1.1 DESCRIPTION

When specified in the plans, warrant the indicated product for the period specified. Perform any required remedial work to correct deficiencies identified in periodic evaluations and, when specified, maintain the product during the warranty period.

Provide acceptable warranty bonds for the warranty period as specified in Subsection 1.2.

Develop, and obtain the Agency's approval of, remedial action(s) for those parts of the warranted product that do not meet specified standards of performance. Complete the approved remedial work, as specified in Subsection 1.3(D), at no additional cost to the Agency.

When specified, maintain the warranted product during the warranty period, as specified in Subsection 1.3(A), at no additional cost to the Agency.

A Conflict Resolution Team will be formed to resolve any disagreements associated with the warranty work as specified in Subsection 1.6.

X1.2 WARRANTY BOND

A. Provide a warranty bond effective for the period of the warranty, including time periods required for remedial actions that may extend beyond the end of the warranty period. These bonds are intended to insure completion of required warranty work, including payments for all labor, equipment, and materials used for all maintenance and remedial work resulting from these warranty provisions.

B. Provide warranty bonds meeting all of the requirements for the construction period bonds as specified in Subsection 103.5, except that the amount of the warranty bonds will be as shown in a supplemental specification.

   [Guarantee option for Failure to Perform]

   If required warranty or maintenance work is not performed, or completed promptly and satisfactorily, the Agency will suspend or revoke the Contractor's certificate of qualification for [months or years], or until the required remedial work has been satisfactorily performed or payment has been made for Agency-performed remedial work, whichever is longer.

X1.3 WARRANTY PROVISIONS

A. *Term.* The warranty period shall be as stated in the plans, or the special provisions, or supplemental specifications for the warranted product. The beginning date of the warranty period is the date of final acceptance of the construction phase of the project or substantial completion of a segment as applicable.

B. *Performance Requirements.* The Agency will list the parameters used to measure performance of the warranted product in the special provision or supplemental specification for the warranted product.

C. *Performance Evaluation.* The Agency will measure each parameter at least annually. The Agency will take more frequent measurements if it deems necessary. The Agency will conduct these evaluations at no cost to the Contractor.

The Agency will notify the Contractor of the evaluation date. The Contractor may have a representative present during the evaluation.

The Agency will provide the evaluation results to the Contractor within [14] days of the completion of the evaluation.

If the Contractor disputes the evaluation results, provide written notification to the Agency within 30 days following the receipt of the evaluation results. If the Contractor and Agency cannot resolve the dispute within the following 30 days, the dispute will be presented to the Conflict Resolution Team.

D. *Remedial Action.* If the annual evaluation results exceed the established threshold levels, develop a remedial action plan that will correct the inadequate condition. Within 30 days of the receipt of the evaluation results, submit the proposed remedial action plan for the Agency's approval. If the Agency does not approve the proposed action, or negotiate a mutually agreeable remedial action with the Contractor within 30 days, the issue will be presented to the Conflict Resolution Team for resolution.

1. *Remedial Action Requirements.* Use materials and construction methods that conform to the specification requirements included in the project for which the warranty applies and which correspond to the remedial action employed. Where no corresponding specification exists, submit appropriate specifications to the Agency for approval.

2. *Schedule for Remedial Work.* Begin the remedial work within 30 days following the Agency's approval of the remedial action unless a later date is mutually agreed upon with the Agency.

3. *Warranty on Remedial Work.* Warranty for all remedial work will be limited to the period of the original contract warranty.

E. *Exclusions*. The Contractor will not be held responsible for distresses caused by factors or conditions beyond its control. These factors include but are not limited to existing base or pavement conditions, accidents or spills, unusually severe weather, Department maintenance, or excessive loads.

F. *Maintenance*. When specified in the special provisions or supplemental specifications for the warranted product, maintain the product for the warranty period.

1. The special provisions or supplemental specifications for the warranted product will outline the respective maintenance responsibilities of the Contractor and the Agency. When specified, submit a plan for approval for all planned maintenance work to be performed during the warranty period. Perform all required maintenance according to the agreed upon scope and schedule during the warranty period

2. Use materials and construction methods conforming to the specification requirements included in the Guide Specifications for Highway Construction, latest edition, and which correspond to the maintenance action employed. Where no corresponding specification exists, submit appropriate specifications to the Agency for approval.

X1.4 EMERGENCY WORK

If, in the opinion of the Agency, conditions require immediate attention for the safety of the traveling public, and the Contractor cannot perform the required work on a timely basis, the Agency can have the work performed, at the Contractor's expense, with Agency personnel or through an Agency procurement. Any work thus performed will not alter the requirements, responsibilities, or obligations of the warranty.

X1.5 EXCEPTIONS

The Agency will be responsible for repairing conditions of the warranted product that are caused by factors beyond the control of the Contractor, such as conditions resulting from major accidents, major flooding, and other acts of God.

X1.6 CONFLICT RESOLUTION TEAM

A Conflict Resolution Team for Warranty Work (CRT) will be established prior to the initiation of the warranty period to resolve any conflicts regarding the warranty requirements. This team will be composed of two representatives appointed by the Contractor, two representatives appointed by the Agency, and an independent party mutually agreed upon by the Contractor and the Agency. The CRT will base decisions on a simple majority vote. The Contractor and the Agency will share the expenses of the independent party. The CRT will initially process any disputes involving the warranty provisions. If resolution is not achieved, follow the Agency's claims procedure as specified in Subsection 105.21.

X1.7 FINAL WARRANTY ACCEPTANCE

The Agency will evaluate the pavement performance [or conduct a final survey] within [calendar days] of the completion of the warranty term. Perform any required remedial work based on the results of the final survey in accordance with Subsection 1.3(D). The Agency will issue a Final Warranty Acceptance Letter [or an equivalent certification] and release final payment [retainage] upon verification that all required performance thresholds are met and after receipt of all required quality control documentation.

X1.8 GENERAL PROVISIONS

Applicable portions of the General Provisions (e.g., Definitions, Maintenance of Traffic, Final Clean Up, Environmental Protection, Inspection of Work, Load Restrictions, Legal Relations, Insurance, Indemnity, and Responsibility to Public, etc.) must remain in effect for the period when the Contractor is performing warranty work. Identify the General Provisions that remain in effect during the warranty.

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APPENDIX X2 ACCEPTANCE OF WORK STATISTICAL EVALUATION OF WORK FOR ACCEPTANCE

Statistical evaluation of work is a method of analyzing inspection or test results to determine the level of conformity with the specification requirements.

X2.1 GENERAL

Where specified, acceptance sampling and testing will be performed by the Agency and statistically evaluated for acceptance according to this specification. All test results for a lot will be analyzed collectively and statistically by quality level analysis procedures to determine the total percent of the lot that is within Specification limits and to determine an appropriate pay factor. Lots and sublots are generally defined in the appropriate specifications for the material being statistically evaluated.

Quality level analysis is a statistical procedure for determining the percent compliance of the material with these Specifications. Quality level is the computed percent of material meeting these Specifications and is determined from the arithmetic mean, ($\bar{X}$), and the sample standard deviation (S), for each constituent of the lot.

For work evaluated based on statistical evaluation, both the Agency and Contractor assume some risk.

The Agency's risk is the probability that work of a rejectable quality level is accepted. The Contractor's risk is either the probability that work produced at an acceptable quality level (AQL) is rejected (α) or the probability that the work produced at the AQL is accepted at less than the contract unit bid price (α100).

For work that is evaluated and accepted by statistical evaluation, if Contractor testing and inspection is verified by the Agency, the Contractor's results may be used by the Agency to evaluate work for acceptance. Contractor data will be verified using the F- and t-test statistics in comparison to Agency test results at a significance level of 0.01.

If the Contractor's data is not verified and the Engineer determines it to be appropriate, the Agency will perform tests associated for that discrete portion of work. In this situation, the Agency test results will control in determining the acceptability and pay factor of the work.

Acceptable quality level is the lowest percentage of work within the specification limits that is considered acceptable for payment at contract unit bid price. There are two categories:

- Category I is based on an AQL of 95 percent.
- Category II is based on an AQL of 90 percent.

In both cases, the Contractor's risk (α100) is 5 percent and the risk of rejection (α) is significantly lower.

As an incentive to produce superior quality material, a pay factor greater than 1.00 may be applied to the unit price of the material with the maximum pay factor of 1.05. A lot containing non-Specification material will be accepted provided the Composite Pay Factor is greater than the minimum pay factor. A lot containing non-Specification material which fails to obtain at least the specified minimum Composite Pay Factor will be rejected by the Engineer. The Engineer will take one or more of the following actions when rejected material has been incorporated into the Work:

1. Require complete removal and replacement with specification material at no additional cost to the Contracting Agency.

2. At the Contractor's written request, allow corrective work at no additional cost to the Contracting Agency with an appropriate price reduction that may range from no reduction to no payment.

The quality characteristics to be evaluated, lot size, sampling frequency, sampling location, test methods, and category are listed in the acceptance subsection for each material. The following general descriptions apply:

1. *Lot size.* A lot is a discrete quantity of work to which the statistical evaluation procedure is applied. A lot normally represents the total quantity of work produced in a production run or day. For analysis purposes, each lot should be divided into no less than three and no more than eight sublots of equal area. More than one lot may occur if changes in the target values, material sources, or job-mix formula are requested in writing and approved.

2. *Sampling frequency.* The frequency rate shown normally requires at least 5 samples. The minimum required to perform a statistical evaluation is 3 samples. The maximum obtainable pay factor with 3, 4, or 5 samples is 1.01. At least 8 samples are required to obtain a 1.05 pay factor. If the sampling frequencies and quantity of work would otherwise result in fewer than 8 samples; submit a written request to increase the sampling frequency to provide for at least 8 samples. Submit the request to increase the sampling frequency at least 48 h before beginning production. An increase in the sampling frequency may result in a reduced pay factor.

3. *Sampling location.* The exact location of sampling will be determined by the Engineer based on random numbers.

4. *Specification limits*. The specification limits for the quality characteristics are listed in the contract for the work in question.

Any lot for which at least three samples have been obtained, and all of the test results meet one of the appropriate criteria listed below, will receive at least a 1.00 Composite Pay Factor if:

a. All test results are within the allowable limits specified for the item,

b. All test results that only have a lower Specification limit are greater than or equal to that limit, or

c. All test results that only have an upper Specification limit are less than or equal to that limit.

Computation of the quality level in these instances will be for determining the amount of any quality incentive that might be warranted. Lots represented by less than three samples or unsampled lots will not use statistical-based acceptance.

X2.2 ACCEPTANCE

The work in the lot will be paid for at a final pay factor when all inspections or test results are completed and evaluated.

Before determining the final pay factor, the work may be incorporated into the project provided the current pay factor does not fall below 0.90. If a lot is concluded with fewer than 3 samples, the material will be not be evaluated using statistical quality-level analysis.

If the current pay factor of a lot falls below 0.90, end production. Production may resume after the Contractor takes effective and acceptable actions to improve the quality of the production.

A lot containing an unsatisfactory percentage of non-specification material (less than 1.00 pay factor) is accepted provided the lowest single pay factor has not fallen into the reject portion of Table X2.2-1.

A lot containing an unsatisfactory percentage of non-specification material with the lowest single pay factor falling into the reject portion of Table X2.2-1 is rejected. Remove rejected material from the work.

Table X2.2-1. Pay Factors

PAY FACTOR		Minimum Required Percent of Work Within Specification Limits for a Given Pay Factor $(P_U + P_L) - 100$														
Category																
I	II	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10 to n=11	n=12 to n=14	n=15 to n=17	n=18 to n=22	n=23 to n=29	n=30 to n=42	n=43 to n=66	n=67 to ∞
1.05		100	100	100			100	100	100	100	100	100	100	100	100	100
1.04		100	100	100		100	99	97	95	96	96	96	97	97	97	97
1.03		100	100	100	100	98	96	94	92	93	93	94	95	95	96	96
1.02		100	100	100	99	97	94	91	89	90	91	92	93	93	94	94
1.01		100	100	100	98	95	92	89	87	88	89	90	91	92	92	93
1.00		69	75	78	80	82	83	84	85	86	87	88	89	90	91	92
0.99		66	72	76	78	80	81	82	83	84	85	86	87	89	90	91
0.98		64	70	74	76	78	79	80	81	82	84	85	86	87	88	90
0.97		63	68	72	74	76	77	78	79	81	82	83	84	86	87	88
0.96		61	67	70	72	74	75	76	78	79	81	82	83	84	86	87
0.95	1.00	59	65	68	71	72	74	75	76	78	79	80	82	83	84	86
0.94	0.99	58	63	67	69	71	72	73	75	76	78	79	80	82	83	85
0.93	0.98	57	62	65	67	69	71	72	73	75	76	78	79	80	82	84
0.92	0.97	55	60	63	66	68	69	70	72	73	75	76	78	79	81	82
0.91	0.96	54	59	62	64	66	68	69	70	72	74	75	76	78	79	81
0.90	0.95	53	57	61	63	65	66	67	69	71	72	74	75	77	78	80
0.89	0.94	51	56	59	62	63	65	66	68	69	71	72	74	75	77	79
0.88	0.93	50	55	58	60	62	64	65	66	68	70	71	73	74	76	78
0.87	0.92	49	53	57	59	61	62	63	65	67	68	70	71	73	75	77
0.86	0.91	48	52	55	58	59	61	62	64	66	67	69	70	72	74	76

PAY FACTOR		Minimum Required Percent of Work Within Specification Limits for a Given Pay Factor $(P_U + P_L) - 100$														
Category																
I	II	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10 to n=11	n=12 to n=14	n=15 to n=17	n=18 to n=22	n=23 to n=29	n=30 to n=42	n=43 to n=66	n=67 to ∞
0.85	0.90	46	51	54	56	58	60	61	62	64	66	67	69	71	72	75
0.84	0.89	45	49	53	55	57	58	60	61	63	65	66	68	70	71	73
0.83	0.88	44	48	51	54	56	57	58	60	62	64	65	67	69	70	72
0.82	0.87	43	47	50	53	54	56	57	59	61	62	64	66	67	69	71
0.81	0.86	41	46	49	51	53	55	56	58	59	61	63	64	66	68	70
0.80	0.85	40	44	48	50	52	54	55	56	58	60	62	63	65	67	69
0.79	0.84	39	43	46	49	51	52	54	55	57	59	61	62	64	66	68
0.78	0.83	38	42	45	48	50	51	52	54	56	58	59	61	63	65	67
0.77	0.82	36	41	44	46	48	50	51	53	55	57	58	60	62	64	66
0.76	0.81	35	39	43	45	47	49	50	52	54	56	57	59	61	63	65
0.75	0.80	33	38	42	44	46	48	49	51	53	54	56	58	60	62	64
REJECT	0.79	32	37	40	43	45	47	48	49	52	53	55	57	59	60	63
	0.78	30	36	39	42	44	45	47	48	50	52	54	56	57	59	62
	0.77	28	34	38	41	43	44	46	47	49	51	53	55	56	58	61
	0.76	27	33	37	39	42	43	45	46	48	50	52	53	55	57	60
	0.75	25	32	36	38	40	42	43	45	47	49	51	52	54	56	59
		Values Less Than Those Shown Above														

If the value of $(P_U + P_L) - 100$ does not correspond to a $(P_U + P_L) - 100$ value in this table, use the next smaller $(P_U + P_L) - 100$ value.

When approved, it is permissible to voluntarily remove non-specification material and replace it with new material to avoid or minimize a pay factor of less than 1.00. New material will be sampled, tested, and evaluated according to the acceptance plan.

Any quantity of material may be rejected based on visual inspection or test results. Do not incorporate rejected material in the work. The results of tests run on rejected material will be excluded from the lot.

X2.3 QUALITY LEVEL ANALYSIS

Unless otherwise indicated, acceptance of material and work shall be based on the method of estimating percent within limits (*PWL*). All Sublot test result values for a Lot will be analyzed statistically to determine the total estimated *PWL*. The *PWL* is computed using the Lot sample average value, $\overline{X}$, the Lot sample standard deviation, Sn, for the specified number of Sublots, n, and the specification Quality Acceptance Limits, where *LQL* represents the Lower Quality Limit, and *UQL* represents the Upper Quality Limit, as they apply to each particular acceptance parameter. From these values, the respective Quality Index (Indices), Q_L for Lower Quality Index and/or Q_U for Upper Quality Index, are computed. Then the *PWL* for the Lot for the specified number of Sublots, n, is determined from Table X2.3-1.

Determine the estimated *PWL* or percentage of work that is within the specification limits for each quality characteristic as follows:

Locate sampling positions, obtain test sample, make specimens, and conduct test.

Calculate the arithmetic mean $\overline{X}$ of the test values

$$\overline{X} = \frac{\sum x}{n} \qquad \text{(X2.3-1)}$$

where:

Σ = summation of x, and

n = total number of test values.

Find the Lot sample standard deviation, S_n, by using the following formula:

$$S_n = \sqrt{\frac{\sum (x_i - \overline{X})^2}{n-1}} \qquad \text{(X2.3-2)}$$

where:

S_n = standard deviation of the Sublot test values

x_i = individual Sublot test values

$\overline{X}$ = Average of Sublot test values

n = number of Sublots

Find the Lower Quality Index, Q_L, by subtracting the Lower Quality Limit, *LQL*, from the Average value, $\overline{X}$, and dividing the result by the Lot sample standard deviation, S_n.

$$Q_L = \frac{\overline{X} - LQL}{S_n} \qquad \text{(X2.3-3)}$$

Find the Upper Quality Index, Q_U, by subtracting the Lot sample average value, $\overline{X}$, from the Upper Quality Limit, *UQL*, and dividing the result by the Lot sample standard deviation, S_n.

$$Q_U = \frac{UQL - \overline{X}}{S_n} \qquad \text{(X2.3-4)}$$

For each quality characteristic, determine the percentage of material above lower tolerance limit, P_L, and the percentage of material below upper tolerance limit, P_U, by entering Table 1 with Q_L or Q_U, or both, using the column appropriate to the total number of sublots, n, and reading the appropriate number under the column heading "PWL".

For quality characteristics with only an Upper Quality Limit, *PWL* equals P_U. For characteristics with only a Lower Quality Limit, *PWL* equals P_L. For quality characteristics with both Upper and Lower Quality Limits, first calculate the Upper Quality Index, Q_U, and the Lower Quality Index, Q_L, by using the Upper Quality Limit, *UQL*, and the Lower Quality Limit, *LQL*, respectively. The limits to be used are stipulated in applicable materials specifications. Then determine *PWL* using the following formula:

$$PWL = \left(P_U + P_L\right) - 100 \qquad \text{(X2.3-5)}$$

The *PWL* from Table X2.3-1 that is to be used is the whole number greater than that found by using the Q_U or Q_L in the table. For example, the *PWL* to be used for n = 4 and a Q_U of 1.4200 would be 98.

Repeat steps 1 through 8 for each quality characteristic listed for statistical evaluation.

Table X2.3-1. Estimated Percent Within Limits (PWL), *n* = Number of Sublots in Lot (Standard Deviation Method)

Estimated Percent within Specification Limits (P_U or P_L)	Upper Quality Index Q_U or Lower Quality Index Q_L														
	n = 3	*n* =4	*n* = 5	*n* = 6	*n* = 7	*n* = 8	*n* = 9	*n* = 10 to *n* = 11	*n* = 12 to *n* = 14	*n* = 15 to *n* = 17	*n* = 18 to *n* = 22	*n* = 23 to *n* = 29	*n* = 30 to *n* = 42	*n* = 43 to *n* = 66	*n* = 67 to ∞
100	1.16	1.49	1.72	1.88	1.99	2.07	2.13	2.20	2.28	2.34	2.39	2.44	2.48	2.51	2.56
99	—	1.46	1.64	1.75	1.82	1.88	1.91	1.96	2.01	2.04	2.07	2.09	2.12	2.14	2.16
98	—	1.43	1.58	1.66	1.72	1.75	1.78	1.81	1.84	1.87	1.89	1.91	1.93	1.94	1.95
97	1.15	1.40	1.52	1.59	1.63	1.66	1.68	1.71	1.73	1.75	1.76	1.78	1.79	1.80	1.81
96	—	1.37	1.47	1.52	1.56	1.58	1.60	1.62	1.64	1.65	1.66	1.67	1.68	1.69	1.70
95	1.14	1.34	1.42	1.47	1.49	1.51	1.52	1.54	1.55	1.56	1.57	1.58	1.59	1.59	1.60
94	—	1.31	1.38	1.41	1.43	1.45	1.46	1.47	1.48	1.49	1.50	1.50	1.51	1.51	1.52
93	1.13	1.28	1.33	1.36	1.38	1.39	1.40	1.41	1.41	1.42	1.43	1.43	1.44	1.44	1.44
92	1.12	1.25	1.29	1.31	1.33	1.33	1.34	1.35	1.35	1.36	1.36	1.37	1.37	1.37	1.38
91	1.11	1.22	1.25	1.27	1.28	1.28	1.29	1.29	1.30	1.30	1.30	1.31	1.31	1.31	1.31
90	1.10s	1.19	1.21	1.23	1.23	1.24	1.24	1.24	1.25	1.25	1.25	1.25	1.25	1.26	1.26
89	1.09	1.16	1.18	1.18	1.19	1.19	1.19	1.19	1.20	1.20	1.20	1.20	1.20	1.20	1.20
88	1.07	1.13	1.14	1.14	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
87	1.06	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.11	1.11	1.11	1.11	1.11	1.11	1.11
86	1.04	1.07	1.07	1.07	1.07	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
85	1.03	1.04	1.03	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
84	1.01	1.01	1.00	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
83	0.99	0.98	0.97	0.96	0.95	0.95	0.95	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94
82	0.97	0.95	0.93	0.92	0.92	0.92	0.91	0.91	0.91	0.91	0.90	0.90	0.90	0.90	0.90
81	0.95	0.92	0.90	0.89	0.88	0.88	0.88	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
80	0.93	0.89	0.87	0.86	0.85	0.85	0.84	0.84	0.84	0.83	0.83	0.83	0.83	0.83	0.83
79	0.91	0.86	0.84	0.82	0.82	0.81	0.81	0.81	0.80	0.80	0.80	0.80	0.80	0.80	0.79
78	0.88	0.83	0.81	0.79	0.79	0.78	0.78	0.77	0.77	0.77	0.76	0.76	0.76	0.76	0.76
77	0.86	0.80	0.77	0.76	0.75	0.75	0.74	0.74	0.74	0.73	0.73	0.73	0.73	0.73	0.73
76	0.83	0.77	0.74	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.70	0.70	0.70	0.70	0.70
75	0.81	0.74	0.71	0.70	0.69	0.69	0.68	0.68	0.67	0.67	0.67	0.67	0.67	0.67	0.66
74	0.78	0.71	0.68	0.67	0.67	0.65	0.65	0.65	0.64	0.64	0.64	0.64	0.64	0.64	0.63
73	0.75	0.68	0.65	0.64	0.63	0.62	0.62	0.62	0.61	0.61	0.61	0.61	0.61	0.61	0.60
72	0.73	0.65	0.62	0.61	0.60	0.59	0.59	0.59	0.58	0.58	0.58	0.58	0.58	0.58	0.57
71	0.70	0.62	0.59	0.58	0.57	0.57	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.55	0.54
70	0.67	0.59	0.56	0.55	0.54	0.54	0.53	0.53	0.52	0.52	0.52	0.52	0.52	0.52	0.52

Estimated Percent within Specification Limits (P_U or P_L)	Upper Quality Index Q_U or Lower Quality Index Q_L														
	$n = 3$	$n = 4$	$n = 5$	$n = 6$	$n = 7$	$n = 8$	$n = 9$	$n = 10$ to $n = 11$	$n = 12$ to $n = 14$	$n = 15$ to $n = 17$	$n = 18$ to $n = 22$	$n = 23$ to $n = 29$	$n = 30$ to $n = 42$	$n = 43$ to $n = 66$	$n = 67$ to ∞
69	0.64	0.56	0.53	0.52	0.51	0.51	0.50	0.50	0.50	0.49	0.49	0.49	0.49	0.49	0.49
68	0.61	0.53	0.50	0.49	0.48	0.48	0.48	0.47	0.47	0.47	0.46	0.46	0.46	0.46	0.46
67	0.58	0.50	0.47	0.46	0.45	0.45	0.45	0.44	0.44	0.44	0.44	0.43	0.43	0.43	0.43
66	0.55	0.47	0.45	0.43	0.43	0.42	0.42	0.42	0.41	0.41	0.41	0.41	0.41	0.41	0.40
65	0.51	0.44	0.42	0.40	0.40	0.39	0.39	0.39	0.38	0.38	0.38	0.38	0.38	0.38	0.38
64	0.48	0.41	0.39	0.38	0.37	0.37	0.36	0.36	0.36	0.36	0.35	0.35	0.35	0.35	0.35
63	0.45	0.38	0.36	0.35	0.34	0.34	0.34	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.32
62	0.41	0.35	0.33	0.32	0.32	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30	0.30
61	0.38	0.30	0.30	0.30	0.29	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
60	0.34	0.28	0.28	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
59	0.31	0.27	0.25	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
58	0.30	0.25	0.23	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
57	0.25	0.20	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
56	0.20	0.18	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
55	0.18	0.15	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
54	0.15	0.13	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
53	0.10	0.10	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
52	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
51	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

If the value of Q_U or Q_L does not correspond to a value in the table, use the next lower Q value. If Q_U or Q_L are negative values, P_U or P_L is equal to 100 minus the table value for P_U or P_L.

X2.4 PAY FACTOR DETERMINATION

The pay factor for a lot will be determined as follows:

A. The pay factor for each quality characteristic will be determined from Table 2 using the total number of test values and the total estimated percentage within the specification limits calculated.

B. When all quality characteristics for a lot are Category I, the lot pay factor is based on the lowest single pay factor for any Category I quality characteristic. The maximum obtainable pay factor is 1.05.

C. When quality characteristics for a lot are both Category I and II, the lot pay factor is based on the following:

   1. When all Category II quality characteristics are 1.00, the lot payment is based on the lowest single pay factor for all Category I characteristics. The maximum obtainable pay factor is 1.05.

   2. When any Category II quality characteristic is less than 1.00, the lot payment is based on the lowest single pay factor for any Category I or II quality characteristic.

D. When all quality characteristics for a lot are Category II, the lot pay factor is based on the lowest single pay factor for any Category II quality characteristic. The maximum obtainable pay factor is 1.00.

E. Alternatively, determine a Composite Pay Factor (CPF) for each lot as follows:

$$CPF = \frac{f_1(PF_1) + f_2(PF_2) + \cdots f_i(PF_i)}{\sum f_i} \qquad \text{(X2.4-1)}$$

where:

i = I to J,

f_i = price adjustment factor listed in these specifications for the applicable material, and

J = number of quality characteristics being evaluated.

F. Adjusted payment for material in a lot will be made at a price determined by multiplying the contract unit bid price by the lot pay factor as determined above, or as described in the Payment Subsection of the contract for the work type.

AASHTO

APPENDIX X3
MEASUREMENT OF PAVEMENT RIDE QUALITY USING INERTIAL PROFILING SYSTEMS

X3.1 PART I: TECHNICAL PROVISION

X3.1.1 DESCRIPTION

Measure and evaluate ride quality on newly constructed paving projects using inertial profiling systems.

X3.1.2 MATERIALS.

None.

X3.1.3 CONSTRUCTION.

A. *Equipment.*

1. *Straightedge.* Provide a straightedge with a minimum length of 10 ft (3 m).
2. *Inertial Profiling System.* Provide an inertial profiling system that meets the requirements of AASHTO M 328. Ensure that the equipment is certified according to AASHTO R 56. Place a current decal on the equipment indicating the expiration date of the certification. Only allow a certified profiler operator to operate the equipment. Submit to the Engineer a copy of the equipment certification and the operator certification.

Operate the equipment according to AASHTO R 57. For consistent pavement profile determination, maintain air pressure on the wheels of the housing vehicle according to the manufacturer's specification. Ensure that the housing vehicle and all system components are in good repair and are within the manufacturer's specifications. Ensure that the operator of the inertial profiler has the tools and components necessary to adjust and operate the inertial profiler according to the manufacturer's instructions.

B. *Profile Measurements.* Measure the finished surface according to Surface Test Type A or B as required.

1. *Surface Test Type A.* Test the surface or intermediate layer longitudinally, transversely, or both, as specified, with an approved straightedge at locations selected by the Engineer.

2. *Surface Test Type B.* Surface Test Type B consists of quality control, quality assurance, and possible referee testing with an inertial profiling system.

   a. *Quality Assurance (QA) Testing.* Perform QA tests using either a high-speed or lightweight inertial profiler. Perform QA tests on the finished surface of the completed project or at the completion of a major stage of construction, as approved by the Engineer. Coordinate with and receive authorization from the Engineer before starting QA testing. Perform QA tests within seven days after receiving authorization and submit results to the Engineer within 24 h of data collection.

      i. *Operating the Inertial Profiler.* Operate the profiler according to AASHTO R 57. The Agency may require that QA testing be performed at off-peak times for traffic flow. Operate the inertial profiler in a manner that does not disrupt traffic flow as determined by the Engineer. When using a lightweight inertial profiler to measure a surface that is open to traffic, use a moving traffic control plan according to the *Manual on Uniform Traffic Control Devices (for Highways and Streets)*. Provide traffic control for both QC and QA testing at no cost to the Agency. Provide profile measurements to the Agency in electronic data files that meet the format specified in AASHTO R 57.

      ii. *Verifying Compliance of the Inertial Profiler.* Within 24 h immediately before and after taking QA measurements, verify the compliance of the inertial profiler by running the profiler over a designated section with a known international roughness index (IRI) value. The Agency will maintain a list of designated verification sections.

   b. *Referee Testing.* Within 10 working days after the Contractor's QA testing is completed, the Agency may perform ride quality testing using a certified inertial profiler meeting the requirements of AASHTO R 56. If the independent testing results produce an IRI of the profile trace averaged over a 0.1-mi (100 m) section that differs from that obtained using the accepted profiler by more than 6.0 in./mi (0.09 m/km), the Agency will attempt to resolve the differences with the Contractor to the mutual satisfaction of both parties.

If the differences cannot be resolved, the Agency will conduct referee testing and will use the results of this referee testing to establish pay factor adjustments. The Engineer will conduct referee testing using an inertial profiler that has been recently certified according to AASHTO R 56. The certification should not be more than 21 days old unless both parties agree otherwise.

If the referee testing confirms the Agency's profiler and fails to confirm the Contractor's profiler, then the Contractor's profiler shall be taken out of service until it has been re-certified according to AASHTO R 56. A similar requirement will apply if the testing confirms the Contractor's equipment but fails to confirm that of the Agency. If the referee testing fails to confirm the equipment of either the Agency or Contractor, then both profilers shall be removed from service until re-certified.

C. *Evaluation of Profiles.* The Agency will evaluate profiles for acceptance, bonus, penalty, or corrective action.

1. *Surface Test Type A.* The Agency will not apply pay adjustments when Surface Test Type A is used. In a manner approved by the Engineer, correct surface areas that have more than $^1/_8$-in. (3-mm) variation between any two contacts on the straightedge at no cost to the Agency. Following the corrective action, retest the area to verify compliance.

2. *Surface Test Type B.* The Agency will use the QA test results to determine pay adjustments for ride quality. Quality Assurance profiling will begin 25 ft (8 m) after the start of the paving operations and end 25 ft (8 m) prior to the end of the paving operation. The Agency will prorate sections that are less than 0.1 mi (100 m) but greater than 50 ft (15 m). The Agency will apply bonuses, but will waive penalties, for sections that include bridge structures, approach slabs, or both, that are overlaid under the project, including 100 ft (30 m) on either side of the bridge structure, approach slab, or both.

D. *Deficiencies and Corrective Work.* Perform all corrective work at no cost to the Agency.

Correct any 0.1-mi (100 m) section having an average IRI of over 95 in./mi (1.5 m/km) to an IRI of 65 in./mi (1.03 m/km) or less. When requested by the Contractor, the Agency may assess a penalty per 0.1-mi (100 m) section instead of requiring corrective action. Obtain the Engineer's approval for the proposed method of corrective work.

After making corrections, re-profile the pavement section to verify that corrections have produced the required improvements. If the corrective action does not produce the required improvement, the Agency may assess the penalty or may require or allow continued corrective action.

The Agency will not allow corrective action on non-deficient sections for the Contractor to obtain bonus payments.

E. *Localized Roughness.* Identify areas of localized roughness using a 25-ft (8-m) moving average filter. Determine the difference between the 25-ft (8-m) moving average and the reported relative elevation for every profile point. Consider deviations greater than 0.15 in. (3.75 mm) to be a detected area of localized roughness. Positive deviations are considered "bumps" and negative deviations are considered "dips." The Agency may use inertial profile data to identify localized roughness, according to the method adopted by Texas DOT in Tex-1001-S (2018). The Agency will either assess a predetermined penalty per occurrence of localized roughness or will require the Contractor to take corrective action. If the Agency requires corrective action, re-profile the corrected area and submit the results to the Agency. If the corrective action is not successful, the Agency may assess the predetermined penalty or may require or allow continued corrective action.

X3.1.4 MEASUREMENT

The Engineer will not measure the work performed or the materials, equipment, labor, and incidentals furnished under this section. Include all costs to comply with this section within the overall contract bid price.

X3.1.5 PAYMENT

The Agency will not make direct payment for the work performed under this section.

X3.2 PART II: CONSIDERATIONS

A. *Pay Adjustment Schedules.* Table X3.2-1 provides an example of a pay adjustment schedule. The pay adjustment under Schedule 2 from the table should be used to determine the level of bonus or penalty for the project, *unless* Schedule 1 or 3 is otherwise specified in the contract. The Agency will make pay adjustments according to the appropriate schedule for each 0.1-mi (100 m) section. In addition to the pay adjustment for each 0.1-mi (100-m) section, the Agency may also make penalties for deficient 0.1-mi (100-m) sections, localized roughness, or both. It is therefore possible to obtain a bonus on a 0.1-mi (100 m) section based on the overall IRI average and receive a penalty for one or more areas of localized roughness within the same 0.1-mi (100-m) section.

B. Pay Adjustments for Segments Less than 0.1 mi (100 m) and greater than 50 ft (15 m). Pay adjustments for segments less than 0.1 mi (100 m) and greater than 50 ft (15 m) can be calculated as shown in the following example.

For this example, assume the following parameters:

1. The length of the short section is 0.075 mi (75 m);
2. The measurement IRI is 37 in./mi (0.58 m/km); and
3. The pay is $460 for a full 0.1-mi (100 m) section with an IRI of 37 in./mi (0.58 m/km).

Thus, the calculation of pay adjustments in this example is:

Pay Adjustment = $460 × (0.075 mi/0.10 mi) = $345

[Pay Adjustment = $460 × (75 m/100 m) = $345].

Table X3.2-1 Pay Adjustment for Ride Quality

IRI for each 0.1-mi (100 m) section in./mi (m/km)	Pay Adjustment Schedule 1[a] $/0.1 mi ($/100 m)	Pay Adjustment Schedule 2[b] $/0.1 mi ($/100 m)	Pay Adjustment Schedule 3[c] $/0.1 mi ($/100 m)
30 or less (0.47 or less)	$$$$$$	$$$$$$	$$$$$$
31 to 40 (0.47 to 0.63)	$$$$$$	$$$$$$	$$$$$$
41 to 45 (0.64 to 0.71)	$$$$	$$$$	$$$$
46 to 50 (0.72 to 0.79)	$$$	$$$	$$$
51 to 55 (0.80 to 0.87)	$$	$$	$$
56 to 59 (0.88 to 0.93)	$	$	$
60 to 65 (0.94 to 1.03)	0	0	0
66 to 69 (1.04 to 1.09)	–$	0	0
70 to 74 (1.10 to 1.17)	–$$	0	0
75 to 79 (1.18 to 1.25)	–$$$	0	0
80 to 84 (1.26 to 1.33)	–$$$$	–$$	0
85 to 95 (1.34 to 1.50)	–$$$$$	–$$$	0
Higher than 95 (1.50)	*Corrective Action	*Corrective Action	*Corrective Action

[a] Pay Adjustment Schedule 1 is typically specified for new construction of flexible pavements or when more than one smoothness opportunity is allowed under the specification. A smoothness opportunity may include level-ups, in-place recycling, or milling.

[b] Pay Adjustment Schedule 2 is typically specified for new construction of rigid pavements or when only one smoothness opportunity is allowed under the specifications.

[c] Pay Adjustment Schedule 3 is typically used when it is difficult to obtain specified smoothness or when the risk associated is unknown. Examples might include concrete paving in urban areas requiring multiple leave-outs, numerous driveways, short vertical curves, etc. However, by providing a bonus situation, the Agency is encouraging the best ride attainable.

AASHTO

APPENDIX X4
DISPUTE REVIEW BOARD (DRB)
THREE-PARTY AGREEMENT AND OPERATING PROCEDURES

X4.1 PART 1: CONTRACTS

DRB THREE-PARTY AGREEMENT

I PARTIES

A. ______________________________, herein after referred to as the AGENCY.

B. ______________________________, herein after referred to as the CONTRACTOR.

C. Dispute Review Board, hereinafter referred to as the DRB, consisting of three members:

1. ______________________________
2. ______________________________
3. ______________________________

II CONTRACT

A. The CONTRACTOR has entered into a PRIME CONTRACT with the AGENCY for the construction of the ______________________ [Project Name], hereinafter referred to as the PROJECT.

B. The PROJECT PRIME CONTRACT provides for the establishment and operation of a DRB to assist in resolving disputes.

C. The DRB is composed of three members, selected in accordance with ______________ [the DRB Specification].

III PURPOSE OF DRB

Assist in and facilitate avoidance of disputes and the timely and impartial resolution of disputes that are referred to it.

IV DRB SCOPE OF WORK

A. *General*:

1. Stay abreast of project developments by means of periodic meetings and site visits, review of progress reports, meeting minutes, and other job documents, and by other means as mutually agreed by all parties.

2. Examine site conditions or specific construction problems relating to an existing or potential dispute, unless such examination is not practical, or, in the judgment of either the AGENCY or the CONTRACTOR, would result in a delay to the project.

3. One of the selected members shall serve as Chair.

4. Execute this Agreement at the first meeting with representatives of the AGENCY and the CONTRACTOR.

B. Establish DRB operating procedures consistent with the requirements and general guidelines set forth in the PRIME CONTRACT DRB SPECIFICATIONS:

1. Establish operating procedures mutually agreeable to all parties, such as administrative duties; content and format of information which may be presented at DRB hearings; conduct of hearings; and invoicing details. Establish these procedures at the first meeting with representatives of the AGENCY and the CONTRACTOR.

2. Initiate new procedures or modify existing procedures as mutually agreed to by all parties.

3. Provide all parties with these operating procedures, including all modified procedures, in written form.

C. *Recommend Resolution of Disputes*:

1. Upon receipt by the DRB of a referral of a dispute from either the AGENCY or CONTRACTOR, schedule and conduct a hearing at a time and location set by the DRB following consultation with the AGENCY or CONTRACTOR.

2. When proper evaluation of the dispute requires expertise that is not within the collective experience of the DRB, engage, with the prior written approval of the AGENCY and the CONTRACTOR, the services of one or more outside consultants as may be needed to advise the DRB.

3. Convene internal meetings as needed to review and discuss the dispute, and to formulate the report.

4. Following each hearing and DRB deliberation, issue timely executed written reports to the AGENCY and the CONTRACTOR, including the supporting rationale.

5. When requested and deemed appropriate by the DRB, provide executed written responses to requests for clarification or reconsideration made by either the AGENCY or the CONTRACTOR.

6. All DRB reports and responses to requests for clarification or reconsideration shall be signed by all three Board members.

D. Perform services and assume responsibilities, as agreed by all parties, as may be required, including those necessary but not listed herein, to achieve the purpose of this Agreement.

V RESPONSIBILITIES OF THE PARTIES

A. *DRB Responsibilities*:

1. Maintain impartiality and avoid conflicts of interest by continuing to meet the specified requirements for nominees for Board members. Promptly advise all parties upon becoming aware of any development that could be perceived as a conflict of interest.

2. Do not discuss, individually or collectively, issues with the AGENCY or the CONTRACTOR that could possibly be construed as compromising the DRB's ability to impartially resolve future disputes, such as the conduct of the work and the resolution of construction problems.

3. Do not express an individual or collective opinion of merit, in whole or in part, for any potential or other dispute at any time prior to the issue of a report, except in the case of an advisory opinion.

4. Except as required when performing the duties of the Chair or conducting a hearing which the AGENCY or CONTRACTOR refuses to attend, do not meet or communicate with either the AGENCY or CONTRACTOR in the absence of the other.

5. Consider the facts and conditions forming the basis for a referred dispute impartially, and independently and evaluate the merits based on careful consideration of all contract requirements, applicable law and regulations, and the facts and circumstances of the dispute. Do not:

   a. Ignore or undermine the clear intent of the contract, or disregard or alter any requirements of the contract or allocation of risk specified therein.

   b. Supplant or otherwise interfere with the respective rights, authority, duties, and obligations of either the AGENCY or CONTRACTOR as set forth in the contract documents.

6. Make every effort to reach unanimous recommendations. If this cannot be accomplished, include written minority recommendations and supporting rationale with the report.

B. *AGENCY Responsibilities*:

1. Except for participation in the DRB's activities as provided in the contract documents and this Agreement, do not solicit advice or consultation from the DRB or its members on matters dealing with the conduct of the work or resolution of problems which might compromise the DRB's ability to impartially resolve future disputes.

2. Furnish to each Board member one copy of the conformed contract documents, progress schedule and updates, weekly progress reports, minutes of progress meetings with the CONTRACTOR, change orders, and other documents pertinent to the performance of the contract and necessary for the DRB to conduct its operations.

3. Coordinate DRB operations in cooperation with the CONTRACTOR.

4. Arrange for or provide conference facilities at or near the site, and provide copying services.

5. Cooperate with the Contractor and the DRB to facilitate prevention of disputes and the timely and impartial resolution of disputes.

C. CONTRACTOR Responsibilities:

1. Except for participation in the DRB's activities as provided in the contract documents and this Agreement, do not solicit advice or consultation from the DRB or its members on matters dealing with the conduct of the work or resolution of problems which might compromise the DRB's ability to impartially resolve future disputes.

2. Furnish to each Board member and to the AGENCY, one copy of pertinent documents other than those furnished by the AGENCY as may be requested.

3. Cooperate with resolution of disputes that are referred to it.

VI TIME FOR BEGINNING AND COMPLETION OF DRB ACTIVITIES

A. Unless the DRB Chair has been previously identified by the parties, the DRB shall begin its activities by selecting the Chair. After selection of the Chair, DRB activities shall proceed with preparation for the first meeting, including preparation of the DRB operating procedures.

B. This Agreement shall survive the termination, resignation, or death of any member.

C. The DRB's jurisdiction under this Agreement shall end on the date of final payment under the CONTRACT, unless terminated earlier by mutual agreement of the AGENCY and CONTRACTOR.

VII PAYMENT

A. Payments made to the Board members shall constitute full compensation for work performed, travel time and services rendered, and for all materials, supplies, and incidentals necessary to serve on the DRB.

B. Payment for services rendered by Board members shall be at the rate and conditions agreed to between the AGENCY and the CONTRACTOR and each Board member.

C. Board members shall be reimbursed for actual direct, non-salary expenses including automobile mileage, parking, travel expenses from the point of departure to the initial point of arrival, automobile rental, taxi fares, food and lodging, printing, long distance telephone, postage and courier delivery, subject to limitations imposed by the contract.

D. Payment made to Board members in the form of bonus, commission, or consideration of any nature other than that specified hereinabove for performance and service provided under this Agreement, before, during, or after the period that this Agreement is in effect, is prohibited.

E. Board members shall individually submit invoices for work completed to the CONTRACTOR:

1. Not more often than once per month.
2. Based on the agreed billing rate and conditions and on the number of hours expended, together with direct, non-salary expenses including an itemized listing supported by copies of original bills, invoices, and expense accounts.
3. Accompanied by a description of activities performed daily during that period.

F. The CONTRACTOR shall pay acceptable invoices, approved by the AGENCY, within 30 days of their receipt.

G. The CONTRACTOR shall be reimbursed for the AGENCY'S portion of the DRB costs in accordance with payment provisions specified elsewhere in the contract.

VIII CONFIDENTIALITY AND RECORDKEEPING

A. No Board member shall divulge information identified as confidential that has been acquired during DRB activities without obtaining prior written approval from the AGENCY and the CONTRACTOR.

B. Board members shall maintain cost records pertaining to this Agreement for inspection by the AGENCY or the CONTRACTOR for a period of three years following the end or termination of this Agreement.

IX ASSIGNMENT

No party to this Agreement shall assign any duty established under this Agreement.

X. TERMINATION

A. This Agreement may be terminated by mutual agreement of the AGENCY and CONTRACTOR at any time upon not less than four weeks written notice to the other parties.

B. Individual Board members may be terminated only by agreement of both the AGENCY and the CONTRACTOR.

C. If a Board member resigns, is unable to serve, or is terminated, he or she shall be replaced within four weeks in the same manner as he or she was originally selected. This Agreement shall be amended to indicate the member replacement.

XI LEGAL RELATIONS

A. The parties to this Agreement expressly acknowledge that each Board member, in the performance of his or her duties on the DRB, is acting in the capacity of an independent agent and not as an employee of the AGENCY or the CONTRACTOR.

B. Board members shall not participate in subsequent dispute proceedings.

C. The AGENCY and the CONTRACTOR acknowledge that each Board member is acting in a capacity intended to facilitate the resolution of disputes. Accordingly, it is agreed and acknowledged that, to the fullest extent permitted by law, each Board member shall be accorded quasi-judicial immunity for any actions or decisions associated with DRB activities.

D. Each Board member shall be held harmless for any personal or professional liability arising from or related to DRB activities. To the fullest extent permitted by law, the AGENCY and the CONTRACTOR shall indemnify and hold harmless all Board members for claims, losses, demands, costs, and damages (including reasonable attorney fees) for bodily injury, property damage, or economic loss arising out of or related to Board members carrying out DRB activities. The foregoing indemnity is a joint and several obligation.

XII DISPUTES REGARDING THIS THREE-PARTY AGREEMENT

A. Disputes among the parties arising out of this Agreement that cannot be resolved by negotiation and mutual concurrence and actions to enforce any right or obligation under this Agreement shall be initiated in the ______________________ [Court Name] Court of the ____________________ [Jurisdiction].

B. All questions shall be resolved by application of __________________ [Jurisdiction] law.

C. The Board members hereby consent to the personal jurisdiction of the Court of the __________________ [Jurisdiction].

XIII FUNDING AGENCY REVIEW

The ______________________________ [Agency funding the project] has the right to review DRB reports and to attend DRB hearings, but not to attend private DRB deliberations.

XIV THREE-PARTY AGREEMENT

Entered into on ________________ __________ , ____________ between:

(Month) (Day) (Year)

BOARD MEMBERS

By: __________________________ __________________________

(Signature) (Name)

By: __________________________ __________________________

(Signature) (Name)

By:	______________ (Signature)		______________ (Name)
CONTRACTOR		AGENCY	
By:	______________ (Signature)	By:	______________ (Signature)
By:	______________ (Name)	By:	______________ (Name)
Title:	______________	Title:	______________

X4.2 PART 2: DRB OPERATING PROCEDURES

> The Operating Procedures is an informal agreement between the parties and the DRB. The major purpose is to inform the parties of the DRB's plans for implementing the DRB process and to receive feedback, changes, and agreement to these plans from the parties. It is subject to change by agreement with the parties whenever necessary to facilitate optimum application of the DRB process.
>
> These example Operating Procedures should be carefully reviewed and modified to be in accord with the provisions of the contract documents, including the DRB specifications, the Three-Party Agreement, and the procedures deemed most applicable to the project by the DRB.

1. GENERAL

Nothing in these Operating Procedures supersedes the contract documents or the Three-Party Agreement unless mutually agreed by the parties and followed by a contract modification signed by both parties.

These procedures are for the purpose of providing guidelines for operation of the DRB. They are based on the contract documents and current practice of Dispute Review Boards, and are intended to be flexible to meet circumstances that may arise during the life of the project. These procedures may be revised whenever deemed necessary by the DRB and the parties.

The DRB will assist the parties in facilitating the avoidance and, if necessary, timely resolution of disputes, claims, and other controversies arising out of the work on the project.

The parties should not default in their normal responsibility to settle issues by indiscriminately referring disputes to the DRB. The DRB will actively encourage the parties to resolve issues without resorting to the Dispute Review Board procedure.

As provided in the DRB specification contained in the construction contract, except for their participation in the DRB's activities, neither the Contractor nor the Agency will solicit or receive advice or consultation from the DRB or its members on matters dealing with the conduct of the work or resolution of problems. During meetings, hearings, and site visits, no Board member will express any opinion concerning the merit of any facet of a controversy or a potential dispute.

The Agency will furnish to each of the Board members all documents necessary for the DRB to perform its functions, including copies of all contract documents plus periodic reports such as weekly progress summaries, minutes of the weekly progress meeting, and other pertinent information.

2. PERIODIC MEETINGS

The DRB will generally meet at _____ month intervals throughout active construction as agreed with the parties. If conditions warrant, the Chair, after conferring with the other members of the DRB and the parties, may reduce or increase the time between meetings to better serve the parties. Factors to be considered include progress of the work, occurrence of unusual events, and the number and complexity of potential disputes.

In the event that one member of the DRB is unable to attend a meeting, the Chair will attempt to reschedule the meeting. Should rescheduling not be possible, the other two members will attend the meeting without the third. If two Board members are unable to attend, the meeting will be rescheduled.

3. AGENDA FOR MEETINGS

The Chair, after conferring with the other members of the DRB and the parties, will develop an agenda for each meeting. At the conclusion of the meeting, the DRB will observe active sections of the work accompanied by representatives of both the Contractor and the Agency. The parties will point out all areas of the project that could become an issue, claim, or dispute.

4. MINUTES OF MEETINGS

If minutes are desired one of the parties to the construction contract will prepare them. Minutes will be circulated to all parties for comments, additions, and corrections. Minutes as amended will be adopted at the next meeting, but are not an official job record to be relied on in dispute proceedings.

5. PROCEDURES FOR ADVISORY OPINIONS

Both parties must agree to take an issue to the DRB for an advisory opinion. The meeting will be scheduled to allow both parties to prepare a short summary of their position for review by the DRB and the other party prior to the hearing. The parties decide who presents first. Presentations are followed by rebuttal and questions from the Board members, after which the DRB will caucus to agree on their opinion. The handwritten opinion will be read to the Parties after which they may ask for clarifications. If both parties request the opinion to be provided in writing, it will be typed and provided as soon as possible.

6. PROCEDURES FOR DISPUTE HEARINGS

Procedure to Take a Dispute to the DRB

After the parties have diligently attempted to negotiate to resolve an issue or claim, either may refer it to the DRB. After all requirements of the contract documents have been met, the referring party transmits a letter to the Chair requesting a hearing and defining the scope of the desired report, with copies sent to the other party and to the other Board members.

Scope of the hearing and subsequent report can be merit (entitlement) only, merit with guidelines for quantum if merit is found, merit with quantum amount if merit is found, or quantum amount only if merit was found in a previous report and the parties cannot agree on quantum. Usually the DRB will hear entitlement and, if appropriate, give guidelines for quantum. If the parties cannot negotiate quantum, the DRB will consider quantum in a second hearing.

All hearings will be held at the job site except under unusual circumstances.

The parties will prepare three documents in preparation for the hearing. The parties are encouraged to jointly prepare the first two documents.

a. *Statement of Dispute*

The parties will prepare an agreed simple statement of the dispute, ideally limited to one paragraph. This document will usually be a single page and should be completed first.

b. *Common Reference Document (CRD)*

This is a common set of exhibits prepared jointly by the parties to minimize effort in preparing the position papers, to facilitate DRB review and understanding of the position papers, and to minimize confusion during the hearing. The CRD should include stipulations to as many facts, dates, quantities, etc., as possible.

Include every document that either party wants to use in support of their position. There should be no disagreement as to what goes into the CRD.

c. *Position Papers*

Each party will prepare this statement describing the dispute, the party's position on the dispute, and the contractual justification for that position, including reference material and pertinent exhibits. This should be a stand-alone document that clearly states the party's position in entitlement disputes (and the claim amount in time and dollars in quantum disputes) and clearly defines the contractual justification for the stated position, as well as the reasoning as to why the other party's position is not contractually correct and appropriate. Include any referenced exhibits not in the CRD, and to the extent possible, all exhibits to be used in the planned presentation. All arguments that the party intends to put forth during the hearing must be included so that the other party has the opportunity to provide a considered response at the hearing. Position papers must be complete to avoid surprise presentations at the hearing.

The referring party submits the statement of dispute, CRD, and its position paper to the DRB. The respondent simultaneously submits its position paper to the DRB. The parties also exchange position papers at this time.

Two weeks prior to the hearing date, the parties exchange and submit to the DRB a list of the witnesses and representatives that each party intends to have present at the hearing. Only a limited number of personnel from each party should attend the hearing. The list should contain the following information: the person's name, title, professional affiliation, and, if the person will make a presentation or be a fact witness, a brief summary of the matters that the person will address. In exceptional cases and with prior approval of the DRB and the parties, attorneys may be present, but may not make presentations or participate in the hearing in any way.

Other than the list of witnesses, the parties may not send the DRB any further exhibits or correspondence regarding the dispute, without prior approval, between the time of submittal of the above pre-hearing documentation and the hearing.

Presentation of Dispute

The hearing will be informal. The DRB will conduct the proceedings. The referring party will make an initial presentation of its case, followed by the respondent. Then, one or more rebuttals to any assertion by the other party may be presented until the DRB determines that all aspects of the dispute have been adequately covered.

One person for each party should be designated as the primary presenter, although other individuals may give portions of the presentations as required.

The Board members will control the hearings and guide the discussion of issues by questioning the parties or focusing their presentation in order to expeditiously obtain all information that the DRB deems necessary to make its findings and recommendations.

The DRB may ask for additional factual documentation.

If testimony, documents or exhibits are offered that contain information that was not included in the position papers, they will usually be inadmissible. If the DRB decides to permit their introduction, the hearing will be extended as necessary for the other party to review the new information, to reconsider its position, and to present rebuttal. If necessary, the hearing will be adjourned and reconvened at a future date.

The DRB will ensure that the parties have ample opportunity to present their positions, at which point the hearing will be officially closed, unless the DRB requests additional written material.

Redundant Evidence and Oral Statements

The DRB may limit the presentation of documents or oral statements when it deems them to be irrelevant or redundant, or when it determines such material is of no added value to the DRB in understanding the facts and circumstances of the dispute and arriving at its findings and recommendations.

Disputes Involving Subcontractors

The DRB will not consider disputes between subcontractors (including lower tier subcontractors or suppliers) and the prime Contractor unless they are actionable by the Contractor against the Agency and actually "passed through" to the Agency, thus becoming a contractor dispute with the Agency.

The Contractor must clearly identify in all pre-hearing submissions the portions of the dispute that involves a subcontractor(s) (or lower tier subcontractor(s)) dispute or disputes, and the identity of the subcontractor(s). The Contractor must ensure that all subcontractor documents are exchanged on a timely basis and submitted to the DRB as part of the Contractor's package, all as described above.

At any hearing regarding a dispute that includes one or more subcontractor disputes, the Contractor will have a representative of the referring subcontractor with direct and actual knowledge of the dispute present. This representative may assist in or make the presentation of the subcontractor issues and will answer questions from the DRB.

DRB Deliberations

After the hearing is concluded, the DRB will meet to formulate findings and recommendations for resolution of the dispute. All deliberations will be conducted in private and will be and remain confidential. The DRB may request post-hearing submittals including exhibits, job records, and written responses to DRB questions. All such post-hearing submittals and written answers sent to the DRB are to be simultaneously sent to the other party.

Report

Written reports will be forwarded to the parties within the contractual time requirement or as soon as possible after the hearing. The schedule will be discussed with the parties after the hearing. The parties will be notified if the schedule cannot be met.

The DRB will make every reasonable attempt to formulate a unanimous report but in the event this is not possible, a minority or dissenting opinion will be prepared and included with the majority report. The minority position will include information and rationale to aid the parties in fully understanding it. Depending on the circumstances, the dissenting member may or may not be disclosed.

Within the period established by the contract between the parties, both the Agency and the Contractor will respond in writing to each other and to the DRB signifying either acceptance or rejection of the written report. The failure by either party to respond within the specified period will be deemed acceptance of the DRB's report by the non-responding party.

Should the dispute remain unresolved, either party may request clarification of specific elements of the DRB's report within 10 calendar days of receipt of the report. Such requests must be made through the Chair and must not consist of further argument or introduction of issues, or both, not presented at the hearing. Within 10 calendar days of receipt of such request, the DRB will provide any necessary clarification. One request for clarification will be allowed per party.

Either party may request reconsideration of the findings or recommendations, or both, contained in the DRB's report within 10 days of receipt of the report or, if a request for clarification has been made, within 10 calendar days from receipt of the DRB's response. Requests for reconsideration must be based on new facts or evidence that was not known at the time of the hearing. Repeated or new arguments based on the original evidence provided at the hearing will not be considered. Within 10 calendar days of receipt of a request for reconsideration the DRB will either deny the request or, if justified, modify its findings and recommendations.

AASHTO

APPENDIX X5
PIPE CULVERT INSPECTION
AND EVALUATION FOR NEW CONSTRUCTION

X5.1 POST-INSTALLATION INSPECTION OF PIPE

X5.1.1 INTRODUCTION

This Section X5.1, Post-Installation Inspection of Pipe, is a compilation of best practices from AASHTO and other highway agencies across the United States. This document was prepared to be used as a guidance document for the preparation of Post-Installation Inspection and Evaluation specifications.

X5.1.2 PIPE INSTALLATION INSPECTION

Perform the post-installation inspection on 10 percent of all pipelines no sooner than 30 calendar days after completion of the pipe installation and final cover, which includes the embankment and all non-asphalt bases or subgrades, or both. Complete post installation inspection (PII) by either the Remote Inspection Method or the Manual Inspection Method as outlined in Subsection X5.1.3, Post-Installation Methods, Tools, and Report. The Agency or Engineer will note and review conditions including joint gaps, tears, misalignment, cracks, and deformation. Agency or Engineer will evaluate the various conditions noted in PII report as outlined in Section X5.2, Guide for Drainage Pipe Evaluation.

In cases where paving operations will be conducted in less than 30 calendar days after pipe installation, the Engineer will perform a preliminary inspection of the pipe prior to paving to ensure the pipe in areas to be paved meets all evaluation criteria prior to paving operations. Performing a preliminary inspection does not relieve the Contractor from the requirement of completing the post-installation inspection for all pipe, including pipe that is inspected during preliminary inspection, after the prescribed 30 calendar day period.

Deliver a Post-Installation Inspection Report as described in Subsection X5.1.3 to the Agency or Engineer and kept as a permanent record in the project documents. Payment for pipe installation and post installation inspection shall be measured and paid for at the contract unit price as provided by the contract specification and in conformance with this specification.

The Contractor shall be responsible for all necessary remediation or replacement of pipe as required in Section X5.2 or determined to be necessary by the Engineer in conformance with this specification at no additional expense to the Agency. The Contractor shall be responsible for all supplemental work items that are affected by the remediation or replacement of pipe at no additional expense to the Agency. The Agency or Engineer will approve all corrective actions before the work is performed and work shall be completed to the Agency or Engineers satisfaction. If any pipe requires remediation or replacement, the Engineer will re-inspect the pipe after remediation or replacement has been completed. Provide the Final Post-Installation Inspection Report including all notes and data from the initial Post-Installation Inspection and all subsequent Post Installation Inspections necessary to fulfill the requirements of this specification.

Ensure that all post-installation requirements are performed in accordance with this document. Dewater and remove all debris and sediment from the installed pipe before the post-installation inspection. Provide an inspection schedule to the Engineer at least seven days in advance of beginning inspection.

X5.1.3 POST INSTALLATION METHODS, TOOLS, AND REPORT

Ensure that the inspection equipment utilized for all post-installation inspection of all pipe types can deliver accurate, repeatable measurements of all items of interest as described in the Guide for Section X5.2. All individuals performing the in-field inspections and those responsible for preparing the Post-Installation Report must be certified Technicians in a program approved or developed by the Agency. The inspection company and or its employees must be an independent third party to the Contractor and the Agency. The Agency reserves the right to confirm any and all inspection data and defect measurement accuracy to insure the PII report and information included therein meets the requirements outlined in this specification. If the PII report and or data is found to be in non-conformance, the Agency will require that the inspections and the report be corrected as needed. Any re-inspection required by Agency or required due to remediation or replacement shall be the responsibility of and at the expense of the Contractor.

X5.1.4 MANUAL INSPECTION METHOD

Manual inspections are permitted for all pipe and pipe types with a vertical rise of 36 in. and greater. Perform a manual inspection by entering the pipe to document pipe condition and to record any required measurements. The person performing the manual inspection shall use a high-quality hand-held video camera or a digital camera capable of clearly documenting any observed deficiencies. If the pipe is considered a confined space, provide entry for all project inspection personnel according to OSHA requirements.

Furnish pictures, still images, or video recording, or any combination thereof, of areas of the pipe with noted deficiencies. Any deficiency noted shall include information necessary to locate the pipe and the noted deficiencies in the field at a future date. Such factors shall at a minimum include the project number, the station number, the structure number, size of pipe, the date and time of inspection, direction of travel from a given landmark, distance from given landmark for all noted deficiencies, and any other identifying data. Provide a source of light that allows all deficiencies to be readily observed on the camera or video recording. Furnish the still images or video recording in a digital, reproducible format approved by the Engineer.

Measure the crack width or the width of any separation of the pipe wall, in all pipe types using a device or technology capable of measuring cracks from 0.01 in. to 0.10 in. on an accurate and repeatable basis. Measure cracks or tears greater than 0.10 in., and joint gaps with either a metal or a fabric tape capable of measuring to the nearest $^{1}/_{16}$ in. Other measuring devices may be used if approved by the Engineer.

In addition to the items above, measure the deflection of all flexible pipe types using either a metal or a fabric tape and record to the nearest $^{1}/_{16}$ in. Determine deflection by measuring the diameter of the pipe every 10 ft along the length of the pipe. Also measure deflection at any location where deflection, bulging, buckling, or racking is evident. To determine the minimum deflected diameter, take eight measurements at each location at roughly 45-degree angles. Take all diameter measurements on corrugated pipe from the top of corrugation to the bottom of corrugation. Record all measurements and the percent deflection for each location. Calculate percent deflection by the following formulae.

[(MMD – CMD)/CMD]*100 = % deflection

MMD = the minimum of the eight diameter measurements at each location every 10 ft along the length of the pipe or any location where deflection, bulging, buckling, or racking is evident.

CMD = original certified mean diameter as provided by the pipe supplier.

X5.1.5 REMOTE INSPECTION

Perform remote inspection for all pipe types with a vertical rise of less than 36 in. Use a crawler camera and measurement technology to perform remote inspection. Incorporate a camera lens with low barrel distortion and capable of recording video. The measurement technology shall have the capability to make measurements of any small defect on all pipe types. Remote inspections may also be accomplished with digital side scan technology equipment.

Perform a check for deflection on all flexible pipe types by either laser profiling or by use of a mandrel. Deflection testing is not required for rigid pipe.

Certify that laser profiling and crack/joint measurement technology by the company performing the work is in compliance with ASTM E691 and ASTM E177, which includes the following calibration criteria. The equipment and software used must be tested and approved by a recognized independent testing group and include a tested certified accuracy of 0.5 percent or better and a repeatability of 0.12 percent or better. Laser profiling technology may utilize actual pipe diameter as measured with this device to calculate percent deflection and ovality.

The camera technology utilized must be able to deliver a high quality MPEG2 format video with a standard resolution of 720 × 480 or another format acceptable to the Engineer. Use a camera with lighting suitable to allow a clear picture of the entire periphery of the pipe. Center the camera in the pipe both vertically and horizontally, and in such a manner that the camera is able to pan and tilt to a 90-degree angle with the axis of the pipe and rotating 360 degrees. Digital 360 Degree side scanning data collection equipment that will allow an image of the entire pipe surface and joint circumferences to be clearly visualized and evaluated is also an approved inspection tool. Use equipment to move the camera through the pipe that will not obstruct the camera's view or interfere with proper documentation of the pipe's condition. Provide a video image that is clear, focused, and relatively free from roll, static, or other image distortion qualities that would prevent the reviewer from evaluating the condition of the pipe.

Furnish a video recording of 100 percent of all pipe with information at the beginning of the video which clearly identifies the pipe being inspected. The identification shall include the project number, the structure number corresponding to the structure number from project documents, size of pipe, the date and time of inspection, direction of travel from a given landmark, distance from given landmark for all noted deficiencies, and any other identifying factors needed to locate the pipe in the field at a future date. Provide a source of light that allows all areas of concern to be readily observed on the video recording. Furnish the video recording in a digital, reproducible format approved by the Engineer.

Move the camera through the pipe at a speed not greater than 30 ft per minute (if Digital 360 side scan technology is used, the speed may be increased but should never exceed inspection equipment manufacturer's recommendations). Mark the video with the distance down the pipe. The distance shall have an accuracy of 1 ft per 100 ft.

The camera operator (or evaluation technician reviewing side-scan report) shall pan and tilt all joints exhibiting damage or questionable joint gap.

If mandrels are used to check for deflection, they shall be nine (or greater odd number) arm, non-adjustable, fixed-arm mandrels, and shall be sized and inspected by the Agency or Engineer utilizing the appropriately sized proving rings prior to testing. The diameter of the mandrels and matching proving rings shall be based upon the actual certified mean diameter as provided by the pipe manufacturer (0.95 × certified mean diameter for 5 percent deflection or 0.925 × certified mean diameter for 7.5 percent deflection). The diameter of the mandrel at any point shall not be less than the allowable percent deflection of the actual certified mean diameter of the pipe being tested. Fabricate the fixed-arm mandrels in metal, fitted with pulling rings at each end, stamped or engraved with the nominal pipe size and mandrel outside diameter on some segment other than a runner. Pull the mandrel through the pipe or culvert by hand with a rope or cable.

[Note to users: The use of crawler-mounted camera combined with appropriate measurement technology as outlined above has proven to provide inspection data that will allow the evaluation team or Engineer to accurately and objectively evaluate the severity or damage that may be found in the inspection of storm piping systems. However, there are still Agencies who do not have access or wish to utilize some of the advanced measurement technologies available. The document above can be modified as needed to only include crawler-mounted cameras and mandrels for remote inspections if the Agency desires to do so.

At a very minimum, Post Installation Inspection requirements should require crawler mounted cameras be utilized for remote inspection for all pipe that is too small for physical-entry along with a check for deflection for all flexible pipe. Pipe deflection confirmation can be accomplished with fixed-arm mandrels as outlined above for required remote inspections when physical entry is not possible and when use of a laser profiler is not required.]

X5.1.6 POST INSTALLATION INSPECTION (PII) REPORT CRITERIA

Provide a written PII Report to the Engineer along with corresponding video, pictures, and laser profiler data on a digital media storage device. Include a written description of any noted deficiency as outlined in Section X5.2 for each pipe. Also include a still image of these areas along with all field inspection information that indicates why this area is noted. Each still image and description of condition shall also have information that will allow the Agency or Engineer to locate and view this issue in the video recording if the inspection was a remote inspection.

If a condition continuously occurs along the pipe wall, note in the PII the entire area where this condition was found, and include at least one still image that best documents the condition and the information necessary to locate the entire condition in the video recording. If the Manual Inspection Method is utilized, include in the PII Report the actual field measurements taken for all deficiencies noted. Payment will be made for a line of pipe and the Post-Installation Inspection at the appropriate contract unit prices when the Post-Installation Report indicates that all deficiencies have been corrected to the Engineers' satisfaction in conformance with this specification.

The PII shall include type of equipment utilized for the inspection and clearly provide data to prove the equipment used meets this specification. The inspection contractor shall provide a statement of field accuracy achieved for all measurements including plus/minus tolerances. The report shall also include a narrative about required field/measurement calibration and provide proof that all calibration procedures were followed when collecting data within the report. Include documentation in the PII Report that all individuals performing the in-field inspections and preparing the Post-Installation Report are certified technicians in a program approved or developed by the Agency.

Make the PII Report and corresponding electronic media and data as discussed in this specification part of the permanent project public records.

X5.2 GUIDE FOR DRAINAGE PIPE EVALUATION

X5.2.1 OBSERVATIONS TO BE EVALUATED FOR ALL PIPE TYPES

A. *Misalignment*. Check for vertical and horizontal misalignment, faulting (differential alignment between joints of the pipe, creating a non-uniform profile of the pipe), sagging (ponding of water in invert due to vertical misalignment), and invert heaving, that would prevent proper function of the system.

B. *Cracks/Tears*. Note length and location for all cracks or tears.

C. *Joints.* Evaluate joint performance to determine if joints meet the criteria as outlined in Table X5.2.3-1 for silt tight or leak resistant applications. (Note: it is important to evaluate joints based upon the design joint performance criteria of silt tight or leak resistant, most storm culverts and storm drains are designed or required to meet silt tight performance criteria.)

X5.2.2 ADDITIONAL OBSERVATIONS TO BE EVALUATED FOR CONCRETE PIPE CULVERTS AND STORM SEWER

A. *Spalls.* Spalling is defined as a localized delamination of concrete along the wall of the pipe or at the edges of longitudinal or circumferential cracks. Spalling may be detected by visual examination of the concrete along the edges of the crack.

B. *Slabbing.* Slabbing is the result of radial or diagonal tension forces in the pipe. Slabbing is characterized by large slabs of concrete delaminating from the wall of the pipe and a straightening of the steel.

X5.2.3 ADDITIONAL OBSERVATIONS TO BE EVALUATED FOR THERMOPLASTIC AND CMP PIPE CULVERTS AND STORM SEWER

A. *Deflection (x and y plane)/Ovality (out of plane deflection).* Use either a laser profiler or mandrel for remote inspections, or use direct measurement for manual inspections to measure deflection and ovality of flexible pipe. Calculate pipe deflection and ovality based upon actual field measured diameter if laser profiler or direct manual measurements are utilized. If a mandrel is used, size the mandrel to the required percent deflection based upon the actual certified mean diameter as supplied by the pipe producer. Supply the actual certified mean diameter in writing from the pipe manufacturer to the Contractor and the Engineer when the product is shipped to job site and recorded in the Post Installation Report. Note all measurements and subsequent deflections in the inspection report

B. *Buckling, Bulging, and Racking.* Note flat spots or dents at the crown, sides or flow line of the pipe due to racking, wall buckling, and or inverse curvature in the inspection report.

C. *Coating (CMP).* Note and evaluate areas of the pipe where the original coating has been scratched, scoured, peeled, or in some way damaged during the production or installation process.

D. *Evaluation Criteria.* A Guide for Drainage Pipe Evaluation for the above issues of note is provided in Table X5.2.3-1. The Table X5.2.3-1 guide requires the use of recorded measured dimensions provided on the inspection report.

Table X5.2.3-1. Guide for Drainage Pipe Evaluation

Issue	Application	Acceptable	Needs Further Evaluation	Remediation Required
Misalignment (All Pipe Types)	All Applications		Evaluate the impact of the misalignment on the design flow, joints, and wall of the pipe to ascertain if corrective actions are needed.	
Joint Gap (All Pipe Types)	Silt-Tight Systems	Gap less than manufacturer's tolerance and no soil migration observed	Any joint exhibiting an active–continual flow of water through the joint (Evaluation shall be based upon risk of backfill migration through joint.)	Separation/Gap greater than manufacturer's tolerances or Any gap allowing soil migrations
	Leak-Resistant Systems	Separation less than manufacturer's tolerances with no infiltration observed	Any joint exhibiting an active–continual flow of water through the joint (Evaluation will require the actual amount of leakage of line segment to be determined.)	Separation/Gap greater than pipe manufacturer's tolerances, or Any line segment allowing leakage rate greater than 200 in./gal/mile/day or Any joint exhibiting continuous flow or Any gap allowing soil migrations
Joint Offset Vertical/ Horizontal (All Pipe Types)	Silt-Tight and Leak Resistant Joints	Offset less than manufacturer's tolerance	Offset with visible cracks shall be further evaluated based upon crack criteria	Off-set exceeds manufacturer's tolerance and Significantly reduces pipe flow capacity or Any gap allowing soil migrations
Joint–Damage (All Pipe Types)	Silt-Tight Systems	Pipe with small broken or missing area that are not allowing soil migration or RCP—small chips or spalls that do not expose structural reinforcement	Any joint exhibiting an active–continual flow of water through the joint	Chips or spalls in RCP where structural reinforcement is exposed or Chipped/broken/missing area at joint allowing backfill material to migrate through the joint

Issue	Application	Acceptable	Needs Further Evaluation	Remediation Required
Joint–Damage (All Pipe Types)	Leak Resistant System	Spalls, chips or broken areas not allowing any water infiltration or Exposed sealing gasket not allowing any water infiltration	Joint damage allowing dripping water or slow entry of water through the joint	Chips/spalls or broken area exposing Gasket seal or Chipped, broken missing area at joint of any pipe type is large enough to allow a continuous flow of water to migrate through the joint or Chips or spalls at RCP Joint exposing structural reinforcement.
Cracks/Tears/ Splits/Punctures (CMP & Thermoplastic)	All Applications			All anomalies in CMP and Thermoplastic shall be remediated.
Longitudinal Cracks less than or equal to 0.05 in. wide (RCP Only)	All Applications	RCP in non-corrosive environment (pH > 5.5)	RCP with longitudinal cracks ±30 degrees on each side of invert	Pipe is in corrosive environment (pH< 5.5) or crack allowing backfill infiltration
Longitudinal Crack/Tears greater than 0.05 in. but less than 0.10 in. wide (RCP Only)	All Applications	RCP in non-corrosive environment (pH > 5.5)	RCP with longitudinal cracks ±30 degrees on each side of invert	Pipe is in Corrosive environment (pH< 5.5) or crack allowing backfill infiltration
Longitudinal Cracks/Tears greater than 0.10 in. wide (RCP Only)	All Applications		Pipe with crack wider than 0.10 in. but less than 3 ft in length.	All pipe with cracks larger than 0.10 in. and longer than 3 ft shall be remediated or replaced.
Transverse Cracks/Tears (RCP)	All Applications	Crack width less than 0.10 in.	Crack Width Greater than 0.10 in.	Pipe with transverse crack allowing backfill migration
Spalls (RCP Only)		Cracks and small spalls at joint are covered in crack and joint sections of this evaluation table.	Visually check for delamination in areas where spalling is noted.	Spalled areas in pipe wall that exposes the structural steel

Issue	Application	Acceptable	Needs Further Evaluation	Remediation Required
Slabbing RCP Only)	All Applications		Any pipe experiencing slabbing shall be evaluated by an engineer.	If Pipe is stabilized, it may be remediated. Pipe that cannot be stabilized due to magnitude of deformation and magnitude of slabbing shall be replaced.
Deflection (Thermoplastic and CMP)	All Applications	Thermoplastic pipe with deflection or ovality equal to or less than 5% CMP Pipe with deflection or ovality equal to or less than 7.5%	Thermoplastic pipe with deflection or ovality greater than 5% but less than 7.5% requires evaluation	Thermoplastic pipe experiences additional deficiencies combined with deflection or ovality greater than 5% but less than 7.5% shall be remediated or Thermoplastic Pipe with deflection greater than 7.5% shall be replaced or CMP pipe with deflection greater than 7.5% shall be replaced
Buckling, Bulging, Racking (Thermoplastic and CMP)		Small flat spots, bulges or dents that do not reduce flow	Any pipe exhibiting racking shall be evaluated further.	Flat spots, dents, or racking that will reduce flow shall be remediated or Flat spots, dents, or racking that are determined to be detrimental to the long-term performance of the pipe by the Engineer's review shall be replaced. or Any pipe exhibiting wall buckling or inverse curvature shall be replaced.
Coating (CMP Only)				All damage to coating shall require remediation.

X5.2.4 REDUCED PAYMENT

A. *Reduced Payment Option for RCP.* In lieu of the options noted above for remediation of longitudinal cracks in concrete pipe installations, the Contractor may elect to follow the payment schedule below if agreed to by the Agency. Remediation efforts and payment shall apply to the entire section(s) of the pipe experiencing the crack, joint to joint. Payment shall mean to include the complete installed unit bid price including the cost of the pipe, bedding material, backfill material, overfill, and other incidental costs included in the Contractor's original bid amount.

Longitudinal Crack Width	Percent of Payment
≤ 0.05 in.	100% of Unit Bid Price
≤ 0.10 > 0.05 in. with no remediation	75% of Unit Bid
> 0.10 in.	Remediate or Replace

B. *Flexible Reduced Payment Option for Pipe.* In lieu of the options noted above for remediation of deflection in flexible pipe installations, the Contractor may elect to follow the payment schedule below if agreed to by the Agency.

Remediation efforts and percentage of payment shall apply to the entire section of the deflected pipe, joint to joint. Payment shall mean to include the complete installed unit bid price, including the cost of the pipe, bedding material, backfill material, overfill, and other incidental costs included in the contractors original bid amount.

Amount of Deflection/Ovality	Percent of Payment
0.0 % to 5.0%	100% of Unit Bid Price
Greater than 5.0% but < 7.5%	50% of Unit Bid Price
Greater than 7.5%	Remove and Replace at Contractor's Expense

The use of a crawler-mounted camera, combined with appropriate measurement technology, has been proven to provide inspection data that allows the Agency or Engineer to accurately and objectively evaluate the severity or damage of storm piping systems. However, there are still Agencies who do not have access or wish to utilize some of the advanced measurement technologies available. The supplemental evaluation criteria provided below may be utilized when crawler-mounted cameras and mandrels for remote inspections are utilized and no measurements other than deflection (for CMP and Thermoplastic) is provided.

X5.2.5 REMEDIATION

A. *Camera-Only Remote Inspection Evaluation Criteria for Longitudinal Cracks in RCP.* Two longitudinal cracks the length of the pipe section is acceptable when the cracks are within 15 degrees of any quarter point of pipe, i.e., 11 o'clock to 1 o'clock, 2 to 4 o'clock, 5 to 7 o'clock, and 8 to 10 o'clock. Cracks at these points are signs of acceptable stress load cracks and are typically small cracks and do not allow soil infiltration and are not cause for concern unless the pipe is in an acidic condition (pH of soil/runoff less than 5). Pipes with more than two longitudinal cracks the length of the pipe at the quarter points or pipe with cracks at ±30 degrees from invert, i.e., 4 to 5 o'clock or 7 to 8 o'clock, should be further evaluated by an Engineer with experience in RCP pipe design and evaluation. Any crack exhibiting significant vertical offset should be remediated.

B. *Camera-Only Remote Inspection Evaluation Criteria for Transverse Cracks in RCP.* Crack allowing migration of backfill into the pipe shall be remediated.

C. *Camera-Only Remote Inspection Evaluation Criteria of Soil or Silt Tight Joints for All Pipe Types.* Remediate any joint with the following defects or damage: joints allowing soil infiltration, joints with vertical offset where pipe wall at joint area also exhibits large open cracks or tears. Joint with vertical offset exposing backfill, a joint with joint gap that exposes backfill material.

D. *Camera-Only Remote Inspection Evaluation Criteria for Leak Resistant Joint.* Remediate any joint with the following defects or damage: joints allowing soil infiltration, joints allowing a continuous flow of water into the pipe, joints with vertical offset that exposes backfill, or a joint with joint gap that exposes backfill material.

E. *Camera-Only Remote Inspection Evaluation Criteria for Buckling, Bulging, or Racking for CMP and Thermoplastic Pipe.* Any areas of bulging or buckling that exceed 15 percent of the pipe wall surface should be further evaluated by an Engineer experienced in the design and remediation techniques of pipe material being inspected.

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APPENDIX X6
NIGHTTIME CONSTRUCTION

X6.1 TECHNICAL PROVISION

X6.1.1 APPLICABILITY

When nighttime construction activities are performed, whether required by contract or elected by the Contractor, comply with the following requirements.

X6.1.2 NIGHTTIME CONSTRUCTION PLAN

Develop a plan for nighttime construction activities. Submit the plan to the Agency a minimum of [7] days prior to the beginning date of nighttime construction. Do not begin nighttime construction until the plan is approved and implemented. Include the following elements in the plan:

A. *Illumination of Work Zone.* Indicate minimum illumination levels that will be maintained; plans for mounting lights on construction equipment; mounting, aiming, and positioning of both fixed and moveable lights to reduce glare; plans for movement of light devices to keep pace with construction operations; and provisions for minimizing shadows and glare for construction workers.

B. *Traffic Control.* Provide for the safe movement of traffic and the safety of the work zone, including Contractor and inspection personnel during nighttime construction activities. Supplement the project traffic control plan to include special considerations for nighttime construction activities.

C. *Special Safety Considerations:*

1. *Equipment Warning Devices*. Install high visibility flashing beacons or strobes on all mobile powered equipment used on nighttime construction activities. Install flashing beacons or strobes so they have 360-degree visibility. Mount flashing beacons or strobes as high as possible on vehicles. Ensure that all equipment has a minimum of 5 ft^2 (0.5 m^2) of high-intensity retroreflective sheeting toward the extremities of each side of the equipment. Ensure that a minimum of 1 ft^2 (0.1 m^2) of the sheeting is visible from each direction.

2. *Personnel Protective Clothing*. Provide workers involved in nighttime construction activities with safety vests (fluorescent orange or fluorescent lime green) with high visibility reflective strips that are visible from all directions and other personal protective clothing as required by safety regulations.

D. *Additional Plan Elements:*

1. *Abatement of Construction Noise.* Meet Subsection X6.1.5.

2. *Abatement of Construction-Related Vibrations.* Meet Subsection X6.1.6.

X6.1.3 ILLUMINATION OF WORK ZONE

Properly illuminate all operations that are performed during nighttime hours to allow for the complete performance and inspection of the work.

A. Maintain a minimum illumination of 5 fc (55 lx) throughout the entire area of operation except for the set-up and removal of lane closures. The area of operation is a work area that is a minimum of 65 ft (20 m) ahead and behind the employee, where an employee is on or near the roadway, and shall include all work performed by the Contractor's personnel, including layout and measurements ahead of the actual work. Meet the minimum illumination level for specific tasks as specified in Table X6.1.3-1.

Table X6.1.3-1. Illumination Guidelines

Category	Types of Work	Minimum Illumination Level
I	General illumination in the work zone and areas where crew movement takes place	5 fc (55 lx)
II	Illumination on and around construction equipment	10 fc (110 lx)
III	Illumination on tasks that require increased attention	20 fc (215 lx)

B. *Design, install, maintain, and operate all illumination fixtures to:*

1. Avoid glare that interferes with traffic on the roadway or that causes annoyance or discomfort for residences adjoining the work area;

2. Provide the required level of illumination and uniformity in the work area. Design all mountings so that lights can be aimed and positioned as necessary to reduce glare while providing the required level of illumination. Locate, aim, and adjust the illumination fixtures to face away from oncoming traffic; and

3. Reduce lighting losses by performing timely maintenance of the lighting systems. This shall include lamp replacement, cleaning of accumulated dirt from lamps and luminaires, and proper orientation of the lights. Provide a sufficient number of replacement parts and knowledgeable personnel to maintain and repair the illumination units.

C. Vehicle headlights or existing streetlights will not suffice as the required illumination.

D. Provide such screening devices as necessary to reduce the objectionable levels of glare beyond the work site.

X6.1.4 TRAFFIC CONTROL

Implement the approved traffic control plan as specified Section 618.

Use high-intensity reflective sheeting for all signing and traffic control devices. Maintain signs and traffic control devices to meet reflectivity requirements. Replace signing and traffic control devices that have been removed without authorization, damaged, or that do not meet reflectivity requirements.

Use flashing arrow boards to warn traffic of lane closures. Adjust flashing arrow boards to lower intensity during nighttime work to avoid blinding drivers.

Consider the following in developing the traffic control plan:

1. Changeable message signs;
2. Warning signs;
3. Channelizing devices;
4. Sight distances;
5. Arrow boards;
6. Emergency enforcement controls;
7. Deterrent controls;
8. Special controls;
9. Flagging operations and worker visibility;
10. Police patrols; and
11. Moveable barriers.

Use flashing beacons or strobe lights on all vehicles used for the set-up and removal of lane closures during nighttime conditions. In addition, use flashing arrow boards and truck-mounted attenuators as necessary to provide adequate advanced warning to motorists and to protect construction personnel.

X6.1.5 ABATEMENT OF CONSTRUCTION NOISE

Control the noise intensity caused by construction operations and equipment, including equipment used for drilling, pile driving, paving, bridge demolition, blasting, excavating, and hauling not only on the site but also at approved disposal locations.

A. Allowable noise levels are:

1. At sensitive noise receptors, L_{10}—Background level plus [10] dBA or [85] dBA, whichever is less.

2. Equipment, L_{max}—Measured 50 ft (15 m) from equipment at full load.

    a. dBA Impact equipment (e.g., pile drivers, jackhammers)—[95] dBA.

    b. Other than impact equipment—[85].

B. Use an Acoustical Engineer to oversee the requirements of this section. The Acoustical Engineer will have the following minimum education and experience:

1. Bachelor of Science or higher degree from a qualified program in engineering, physics, or architecture offered by an accredited university or college, and five years' experience in noise control engineering and construction noise analysis; or current enrollment as a full Member or Board-certified Member in the Institute of Noise Control Engineering (INCE).

2. Demonstrated substantial and responsible experience in preparing and implementing construction noise controls and monitoring plans on construction projects conducted in an urban setting, calculating construction noise levels, and designing and overseeing the implementation of construction noise abatement measures.

C. Prior to commencement of nighttime construction activities, perform a survey of noise levels at and around the proposed construction site to establish a mean for background noise levels for nighttime operations. Be cognizant of the composition of the surrounding area and the impact upon it as a result of construction activities.

D. Establish mitigation criteria if the anticipated noise levels exceed the allowable levels specified in Subsection 1.5(A).

E. Within forty-five [45] days of award of the contract, submit to the Agency a noise abatement and monitoring plan. The plan shall be prepared by the Acoustical Engineer, if required. Include in the plan the noise monitoring and reporting procedure to be used prior to and during construction. Identify and describe the following in the plan:

1. Construction Equipment to be used (include registration or equipment number).

    a. Measured noise level (L_{max}) of equipment at 50 ft (15 m) under full load.

b. If noise level (L_{max}) at 50 ft (15 m) exceeds the allowable levels, list the noise reduction measures that are to be taken to reduce the noise levels to at least the specified allowable levels.

2. A sketch of the construction site showing equipment locations, receptor locations, noise-sensitive locations, noise monitoring locations, noise mitigation measures to be used, and hauling routes to be used during nighttime activities.

3. The noise monitoring methods, procedures, and data reporting methods to be used.

4. Complaint response and resolution procedures.

F. Provide construction equipment in good operating condition with required noise reduction measures in place and operating. Provide equipment with manufacturer-approved intake and exhaust mufflers, noise shields, and shrouds.

G. Minimize noise from the use of back-up alarms using measures that meet OSHA regulations. This includes the use of self-adjusting or manually adjustable back-up alarms, observers, and scheduling of activities to minimize alarm noise. Set self-adjusting alarms to 5 dBA above the surrounding nighttime background noise levels. Set manually adjusted alarms to the lowest setting required to be audible above the surrounding noise.

H. Use haul routes to and from the work area that minimize the impact on residents and other sensitive noise receptors during nighttime hours.

I. Perform all "impact" work (i.e., jackhammer, pile driving, hydraulic ram, etc.) only between the hours of 7 a.m. and 10 p.m.

J. Monitor noise levels during nighttime operations and submit a weekly report to the Engineer. In the event that levels exceed allowable limits, notify the Agency immediately and implement corrective measures.

K. Provide temporary noise barriers, curtains, or both that meet the requirements of Appendix X7, Temporary Noise Suppression Devices, at locations shown on the plans and where L_{10} noise levels at sensitive noise receptors exceed background levels by more than [10] dBA. Install temporary noise barriers with noise absorptive surfaces facing the noise source. Immediately plug any gaps and holes that develop in the temporary barrier.

L. Immediately notify the Agency when a complaint is received from the general public regarding construction noise. Within 24 h of receipt of complaint, perform noise measurements at a complainant's location during activities representative of the offending activities, and submit the measurements to the Agency. If the measured noise level exceeds the allowable limits specified in the contract, immediately cease operations until such time as the methods are in place to reduce the noise levels to acceptable levels as required by the specifications.

X6.1.6 ABATEMENT OF CONSTRUCTION-RELATED VIBRATIONS

Develop a vibration-monitoring plan. The plan shall, at a minimum, identify historic and other sensitive locations in the immediate vicinity of the construction activities, identify locations at which the vibrations will be measured, and the types of equipment to be used in this monitoring process. Provide the Engineer with vibration data on a weekly basis. Inform any affected residents and businesses adjoining the construction area prior to execution of construction activities that are expected to produce vibrations with peak particle velocities (PPVs) greater than 0.12 in./s (3 mm/s). Should PPVs greater than 0.12 in./s (3 mm/s) be caused such that vibration becomes a nuisance to adjoining residences or other sensitive locations, cease the activity causing vibrations until: (a) daylight hours; or (b) a means is found to mitigate the vibrations. The Contractor may mitigate vibrations by reworking the project layout and access routes, sequences of work, or by using alternative construction methods.

X6.1.7 PAYMENT

Except where otherwise provided (e.g., Traffic Control, etc.), include within the overall contract bid price all costs to comply with this section.

If using the technical provision for this technique, the following modifications should also be made to the Guide Specifications:

A. *General Information, Definitions, and Terms*

The provisions of Section 101.3, Definitions, are supplemented by the following:

1. L_{10}. The sound level exceeded 10 percent of the time for a specified monitoring period.
2. L_{max}. The maximum measured sound at any instant in time.
3. *dBA*. The sound level (in decibels referenced to 20 micro-Pascals) as measured using the A-weighting network on a sound level meter according to ANSI/ASA S1/4-2014/Part 1/IEC 61672:1-2013.
4. *Nighttime*. The period of time between 30 minutes after sunset and 30 minutes before sunrise.
5. *Sensitive noise receptor*. A location where particular sensitivities to noise exist, such as residential areas, institutions, hospitals, and parks.

X6.2 PART II: CONSIDERATIONS

Note: These “Considerations” list options and alternate approaches to the technical provisions.

X6.2.1 APPLICABILITY

Although the use of the nighttime provision will likely be in high-traffic urban conditions, it is possible that it may be used in areas where the adjoining property use would not mandate the abatement of construction-related noise, vibration, or both. In those cases, it would be prudent for the Agency to appropriately modify these requirements.

X6.2.2 NIGHTTIME CONSTRUCTION PLAN

A. *Illumination of Work Zone.* In some circumstances, the Agency may want to specify the number, position, and intensity of lights used on the project. This may be necessary when extremely sensitive neighboring businesses or residents are known to be present, or when the construction activity is a unique or critical type. This should only be done when the Agency possesses enough information to adequately specify lighting requirements, or retains the services of a lighting engineer.

B. *Traffic Control.* A very effective way to control motorist speeds in the work zone is to have a staffed police vehicle with flashing lights at the beginning of the work zone. Many states have also enacted legislation to double speeding fines in the work zone.

C. *Special Safety Considerations for Personnel Protective Clothing.* A more stringent protective clothing requirement that has been used is as follows:

   Provide all workers with high-visibility protective clothing. All workers shall wear full-length, high-visibility reflective clothing (tops and bottoms) during nighttime construction activities.

X6.2.3 ILLUMINATION OF WORK ZONE

A. The New York State DOT has adapted the work from the Ellis and Herbsman Guidelines (Table 1) and placed various construction activities in each Illumination Category. These activities and minimum illumination levels are shown in the following table, "Minimum Illumination Level Guidelines."

Example: Minimum Illumination Level Guidelines (Source: New York State DOT)

Tasks	Minimum Illumination Level	Areas of Illumination
Embankment, fill, and compaction	5 fc (55 lx)	General illumination throughout area of operation
Excavation—regular, lateral ditch, and channel	5 fc (55 lx)	
Landscape, grassing, and sodding	5 fc (55 lx)	
Maintenance of earthwork embankments	5 fc (55 lx)	
Mechanical sweeping and cleaning	5 fc (55 lx)	
Reworking shoulders	5 fc (55 lx)	
Subgrade stabilization and construction	5 fc (55 lx)	
Bituminous concrete milling*	5 fc (55 lx)	General illumination throughout area of operation—minimum of 200 ft (60 m) ahead and 200 ft (60 m) behind equipment
Bituminous concrete paving operation*	5 fc (55 lx)	
Bituminous concrete roller operation*	5 fc (55 lx)	
Placement of barrier walls and traffic separators	10 fc (110 lx)	General illumination throughout area of operation—minimum of 25 ft (8 m) ahead and 25 ft (8 m) behind equipment
Base course construction	10 fc (110 lx)	
Bituminous concrete milling*	10 fc (110 lx)	
Bituminous concrete paving operation*	10 fc (110 lx)	
Bituminous concrete roller operation*	10 fc (110 lx)	
Bridge deck work	10 fc (110 lx)	
Bridge painting	10 fc (110 lx)	
Concrete paving operation	10 fc (110 lx)	
Drainage structures, culverts, storm sewers	10 fc (110 lx)	
Guard rail and fencing	10 fc (110 lx)	
Highway signs installation	10 fc (110 lx)	
Removal of pavement	10 fc (110 lx)	
Concrete structures	10 fc (110 lx)	
Pavement marking/painting	10 fc (110 lx)	
Pothole filling	10 fc (110 lx)	
Repair/patching of concrete pavement	10 fc (110 lx)	
Resetting guide rail and fencing	10 fc (110 lx)	
Sidewalks	10 fc (110 lx)	
Surface treatments	10 fc (110 lx)	
Waterproofing and sealing	10 fc (110 lx)	
Riprap	10 fc (110 lx)	
Any operation not listed in this table	10 fc (110 lx)	
Crack filling, saw cutting, joint sealing	20 fc (215 lx)	Illumination on task
Electrical work	20 fc (215 lx)	
Highway street lighting	20 fc (215 lx)	
Traffic signals	20 fc (215 lx)	
Intelligent transportation system installation	20 fc (215 lx)	

* Both requirements of 5 fc (55 lx) and 10 fc (110 lx)

The New York State DOT also has recommendations regarding the amount of area to be illuminated around various types of construction equipment. The recommendations for illuminated areas for construction equipment are shown in the following table, "Recommended Illuminated Areas for Typical Construction Equipment."

Example: Recommended Illuminated Areas for Typical Construction Equipment (Source, New York State DOT)

Type of Equipment	Illuminated Area (Front and Back)
Fast-Moving Equipment	
Paver	16 ft (4.9 m)
Milling Machine	
Slow-Moving Equipment	
Backhoe Loader	58 ft (17.7 m)
Wheel Loader	
Wheel Tractor	
Scraper	
Compactor/Roller	
Motor Grader	

B. The following lamp characteristics are recommended for highway construction tasks:

- Incandescent tungsten halogen lamps for task-oriented lighting, equipment-mounted lights, small areas, and lights mounted at a low height.
- Metal halide lamps for medium-sized areas when color rendition is not important, and when lights are mounted at varying heights.
- High-pressure sodium lamps for large areas when color rendition is not important, and when lights are mounted at varying heights.

C. The New York State DOT also provides recommendations for the orientation and height of tower lights to control glare. Tower lights are to be oriented such that the angle of the centerline of the beam is not greater than 50 degrees with the vertical, and the maximum tower height for the beam should not exceed 30 ft (9 m). A beam angle of 60 degrees or less is recommended for lights mounted on equipment. These and other more detailed guidelines may be included in the nighttime construction specifications, or may be used by the Agency to evaluate lighting plans submitted by Contractors.

X6.2.4 ABATEMENT OF CONSTRUCTION NOISE

A. This noise level may also be set at 5 dBA above the background noise, not to exceed 80 dBA, particularly for projects of a long duration. The city of Boston, on its Central Artery/Tunnel project, limited nighttime noise to baseline level plus 5 dBA if the baseline is less than 70 dBA, and baseline plus 3 dBA if the baseline is greater than 70 dBA. These are energy-average (L_{10}) sound levels, meaning they may be exceeded 10 percent of the time.

B. Agencies may elect to include specific noise limits for equipment in the technical provisions. An example is included in the following table, 50 ft (15 m) Noise Emission Limits. If used, the Agency should ensure that the information is updated to provide for the current technology in noise-suppressed equipment. These types of requirements could reduce the number of contractors who could bid on a project due to the condition of a contractor's equipment. Enforcement of the table requirements could also be an issue for agencies.

Equipment Category	L_{max} (dBA)[a,b]	Impact/Continuous
Arc Welder	73	Continuous
Auger Drill Rig	85	Continuous
Backhoe	80	Continuous
Bar Bender	80	Continuous
Boring Jack Power Unit	80	Continuous
Chain Saw	85	Continuous
Compressor[c]	70	Continuous
Compressor (other)	80	Continuous
Concrete Mixer	85	Continuous
Concrete Pump	82	Continuous
Concrete Saw	90	Continuous
Concrete Vibrator	80	Continuous
Crane	85	Continuous
Dozer	85	Continuous
Excavator	85	Continuous
Front End Loader	80	Continuous
Generator	82	Continuous
Generator (25 KVA or less)	70	Continuous
Gradall	85	Continuous
Grader	85	Continuous
Grinder Saw	85	Continuous
Horizontal Boring Hydro Jack	80	Continuous
Hydra Break Ram	90	Impact
Impact Pile Driver	95	Impact
In situ Soil Sampling Rig	84	Continuous
Jackhammer	85	Impact

Equipment Category	L_{max} (dBA)[a,b]	Impact/Continuous
Mounted Impact Hammer (hoe ram)	90	Impact
Paver	85	Continuous
Pneumatic Tools	85	Continuous
Pumps	77	Continuous
Rock Drill	85	Continuous
Slurry Trenching Machine	82	Continuous
Scraper	85	Continuous
Soil Mix Drill Rig	80	Continuous
Street Sweeper	80	Continuous
Tractor	84	Continuous
Truck (dump, delivery)	84	Continuous
Vacuum Excavator Truck (vac-truck)	85	Continuous
Vibratory Compactor	80	Continuous
Vibratory Pile Driver	95	Continuous
All other equipment with engines larger than 5 HP (3700 W)	85	Continuous

[a] Measured at 50 ft (15 m) from the construction equipment, with a "slow" (1-second) time constant.

[b] limits apply to total noise emitted from equipment and associated components operating at full power while engaged in its intended operation.

[c] Portable air compressor rated at 750 ft^3/min (0.35 m^3/min) or greater and that operates at greater than 50 psi (350 kPa).

C. Additional specific noise reduction techniques that may be specified include:

1. Use of the following: (1) concrete crushers or pavement saws for concrete deck removal, demolitions or similar activities; (2) pre-auguring equipment to reduce duration of impact or vibratory pile driving; and (3) local power grid to reduce the use of generators.

2. Attaching the following: (1) intake and exhaust mufflers, shields, or shrouds; (2) noise-deadening material to inside of hoppers, conveyor transfer points, or chutes.

3. Maintaining the following: (1) equipment mufflers and lubrication; (2) precast decking or plates; (3) surface irregularities on construction sites.

4. Limiting the following: (1) the number and duration of equipment idling on the site; (2) the use of annunciators or public address systems; (3) the use of air or gasoline-driven hand tools.

5. Configuring, to the extent feasible: (1) the construction site in a manner that keeps loud equipment and activities as far as possible from noise-sensitive locations; (2) barrels or signage to detour traffic away from plated trenches.

6. Scheduling of construction events and limiting usage times to minimize noise.

7. Constructing noise barriers or noise curtain systems, or both.

8. Minimizing noise by the use of backup alarms using measures that meet OSHA regulations. This includes the use of self-adjusting ambient-sensitive backup alarms, manually adjustable alarms on low setting, use of observers, and scheduling of activities so that alarm noise is minimized.

9. Where practical and feasible, configuring construction sites to minimize backup alarm noise. For example, construction site access should be designed such that delivery and dump trucks move through the site in a forward manner without the need to backup.

10. Using only variable message and signboards that are solar powered or connected to the local power grid.

X6.2.5 ABATEMENT OF CONSTRUCTION-RELATED VIBRATIONS

Vibrations may only be a serious issue if pile-driving or demolition operations will take place on a nighttime construction site. If possible, avoid vibration-causing activities during nighttime hours. If this is impossible, some methods to reduce vibrations include re-routing heavy trucks away from residential streets or from sensitive locations, placing the vibration-causing equipment as far as possible from vibration-sensitive receptors, using alternative construction methods, and scheduling vibration-causing activities to occur at different times. Vibration levels caused by multiple operations may add together and produce a vibration level higher than each operation may cause individually. Some alternative construction methods that may be used to mitigate vibrations include: (1) drilled piles or the use of a sonic or vibratory pile driver; (2) use of demolition methods not involving impact (e.g., saw bridge decks into sections for removal); and (3) avoiding use of vibratory rollers and tampers near sensitive areas.

X6.2.6 GENERAL INFORMATION, DEFINITIONS, AND TERMS

A. As an alternative to modifying Subsection 101.3, the following definitions could be incorporated into the technical provision. This may be a more appropriate strategy as these terms are likely used only in the nighttime construction technical provision.

Possible definitions of nighttime or non-daylight hours are as follows:

- The period of time between sunset and sunrise.

  Relating nighttime hours to sunset and sunrise may be too restrictive. Time periods of up to one-half hour or more before sunrise and following sunset allow normal activities without a decline in quality or a threat to safety. An advantage to this definition, however, is the specificity of the time period, the definite time limits, and the ready availability of the sunset and sunrise times.

- The period of the day when natural light conditions are less than _____ fc (lux).
- The periods of the day when reduced natural light conditions prevent the safe conduct of work or hinder the performance of work without artificial illumination.

As another approach to defining nighttime activities, three specific time periods may be specified:

1. Daytime, (2) Evening, and (3) Nighttime. This may be particularly useful for around-the-clock operations. The Boston Central Artery/Tunnel Noise Control Specification defines these three time periods as follows:

    a. *Daytime*—The period from 7 a.m. to 6 p.m. local time daily, except Sundays and Federal holidays.

    b. *Evening*—The period from 6 p.m. to 10 p.m. local time daily, except Sundays and Federal holidays.

    c. *Nighttime*—The period from 10 p.m. to 7 a.m. local time daily, as well as all day Sunday and Federal holidays.

Communication with the public is the key to successful implementation of the nighttime construction program. While information dissemination is very project-specific, it is imperative that affected residents and business-owners be aware of the nighttime construction activities in advance and have a means for communicating complaints to a knowledgeable representative of the Contractor. Timely, comprehensive communications will decrease the complaints received on a nighttime construction job. Door to door visits are the most effective information distribution strategy, but television, radio and newspaper seem to be more commonly used methods.

The following Public Information and Complaint Policy requirement may be applicable for some projects. In some agencies, all or parts of this policy would be developed and implemented by the agency.

B. *Public Information Program and Complaint Policy.* Develop and implement, at the onset of nighttime construction activities, a complaint policy, and a public information program. The complaint policy shall include preactivity notification; public education campaign; noise monitoring; a plan for receiving, handling, and responding to complaints; and investigation and implementation of methods to reduce construction impacts. Distribute information regarding construction-related nuisances to affected residents and businesses. This information shall include:

- Work hours;
- Type of work;

- Type of equipment to be used;
- Type of nuisance to expect;
- Reason for work resulting in nuisance;
- Expected duration of nuisance;
- Where to find more information; and
- Process for voicing complaints.

Distribute the information through any combination of one or more of the following methods:

- Door to door visits;
- Neighborhood letters or fact sheets;
- Local media (newspaper notices, press releases, news conferences);
- Information kiosks in public areas; and
- Brochures or newsletters.

Provide a process for receiving and handling construction-related nuisance complaints to operate during the hours of construction operations.

AASHTO

APPENDIX X7
TEMPORARY NOISE SUPPRESSION DEVICES

X7.1 DESCRIPTION

Construct temporary noise suppression devices.

X7.2 MATERIAL

A. *Temporary Noise Barriers*. Construct noise suppression barriers of material such as $^3/_4$-in. (19-mm) medium density overlay (MDO) plywood sheeting, or other acceptable material with a sound transmission class STC-30 rating or greater as defined by ASTM E90. Line the material on one side with glass fiber or mineral wool type sound absorbing material at least 2 in. thick. Protect the sound absorbing material with wire mesh or perforated sheets that are corrosion resistant and that have at least 30 percent open area with provision for water drainage. Provide materials that are sufficiently weather resistant to last for the duration of the project.

B. *Temporary Noise Curtains*. Construct noise curtains of material consisting of a durable, flexible composite medium that has a noise barrier layer bonded to a sound absorptive material on one side. The noise barrier layer shall consist of a rugged, impervious material with a surface weight of at least 1 lb/ft^2 (5 kg/m^2). The sound absorptive material shall include protective facing and shall be securely attached to one side of the flexible barrier over its entire surface. Noise curtain materials shall be abuse-resistant, corrosion-resistant, fire-retardant, mildew-resistant, vermin-proof, and non-hygroscopic, and shall have superior hanging and tear strength. Meet the following criteria:

1. *Curtain Material*:

    a. Minimum breaking strength of 120 lb/in. (21 N/mm) according to FTMS 191 A-M5102.

    b. Minimum tear strength of 30 lb/in. (5.25 N/mm) according to ASTM D624.

2. *Curtain Absorptive Material*:

    a. Minimum breaking strength of 100 lb/in. (17.5 N/mm) according to FTMS 191 A-M5102.

b. Minimum tear strength of 7 lb/in. (1.2 N/mm) according to ASTM D624.

3. *Noise Curtain*:

a. Sound transmission class rating of STC-25 or greater based upon certified sound transmission data according to ASTM E90.

b. Noise reduction coefficient rating of NRC 0.70 or greater based upon certified sound absorption coefficient data taken according to ASTM C423.

X7.3 CONSTRUCTION

A. *Submittals*. Provide a copy of the support frame plans and design calculations, sealed by a Professional Engineer, to the Agency prior to the installation of the noise suppression devices. Support frames shall be designed by a Professional Engineer licensed in the State of (state name) to withstand an 80-mph (130-km/h) wind load plus a 30 percent gust factor.

B. *Temporary Noise Barriers Installation*. Attach noise barrier panels to support frames constructed in sections to provide a moveable barrier where necessary. Construct the mating surfaces of the barrier sides to be flush with each other. Seal all gaps between barrier units, and between the bottom edge of the barrier panels and the ground with material that will completely close the gaps and be dense enough to attenuate the sound. Construct barriers to a height not less than 8 ft (2.4 m) nor greater than 15 ft (4.5 m).

C. *Temporary Noise Curtains Installation*. Install noise control curtains in vertical segments extending the full curtain height and with a minimum joint and seam overlap of 2 in. (50 mm). Seal seams using velcro or double grommets. Design curtain details according to the manufacturer recommendations. Secure curtains at ground level or at intermediate points, or both, by framework and supports.

X7.4 MEASUREMENT

The Engineer will measure work acceptably completed as specified in Subsection 109.1 and as follows:

A. The Engineer will measure the length as the horizontal distance from the beginning to the end of the barrier or curtain.

B. The Engineer will measure the height as the distance between the ground and the top of the noise barrier panel or curtain.

X7.5 PAYMENT

The Agency will pay for accepted quantities at the contract unit price as follows:

Pay Item	Pay Unit
Temporary Noise Barrier	ft^2 (m^2)
Temporary Noise Curtain	ft^2 (m^2)

Such payment is full compensation for furnishing all materials, equipment, labor and incidentals to complete the work as specified.

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