Appendix C - INNOVATIVE TECHNOLOGIES

The Alaska Department of Transportation and Public Facilities is a recognized leader in remote, cold climate, and seismic bridge engineering. Our current $2.6 million research portfolio includes partnerships with North Carolina State University, Texas A&M Transportation Institute, and the University of Alaska, with project topics ranging from material properties to examination of shear capacity of longitudinal keyways in decked bulb-tee girders.[1]

This emphasis on investigation stems from the fact that bridge design in Alaska's environment must consider multiple concurrent severe hazards and limitations. This combination of challenges makes extremes the "Alaska normal." Out of necessity, Accelerated Bridge Construction (ABC) has been standard practice in Alaska for decades. The challenges of design and construction in Alaska are presented below followed by summaries of the innovations applied to this project to address these challenges.

Alaska Challenges

Geography. Alaska DOT&PF manages an inventory of approximately 1,000 bridges, spread over 570,641 square miles; to put this in perspective, total land area of the next three largest states combined (California, Montana, and Texas) is only 562,557 square miles.[2] Many bridges are in communities only reachable by air or water; even those on the main NHS road system might be several hundred miles from the nearest gas station or other commercial services.

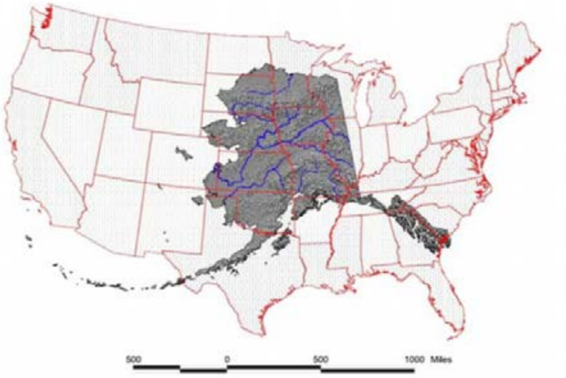

Figure 1 Alaska Superimposed over Contiguous U.S.

Extreme Seismicity. Alaska has the highest seismicity in the nation: epicenters of 9 of the 10 largest earthquakes in the North America since 1900 are in Alaska.[3]

Non-Redundancy. Most of Alaska's highways – and therefore, communities – do not have detour routes, because there is generally only one road in or out. When a bridge is out of service, traveling hours out of the way is the best case scenario; the worst case involves chartering a plane or helicopter or simply waiting until water has frozen thick enough for an ice road.

Short Construction Season. Excluding the most extreme areas, the Alaskan construction season is approximately May through September. Cold weather construction – generally considered to

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[1] See Alaska DOT&PF Current Bridge Research Projects 2018. Unpublished Report, Prepared by DOT&PF Research, Development & Technology Transfer Section.

[2] Land area from U.S. Census Bureau, "State Area Measurements and Internal Point Coordinates", Accessed November 15, 2018.

[3] Research Query: Largest North America Earthquakes since 1900. USGS Earthquake Catalog. Accessed November 13, 2018.

be after October or before April – increases the costs of work to such an extent that contractors avoid it when possible. This is one of the prime reasons that Alaska is at the forefront of research and implementation of Accelerated Bridge Construction innovations.

Environmental Constraints. Alaska produces the highest volume of fish and seafood of any state in the United States.[4] Subsequently, protection of streams is critical to the economy, but permitted "fish windows" – time periods during which in-stream work is allowed – also constrain the amount of time contractors can accomplish in-stream work.

Climate. According to the National Oceanic and Atmospheric Administration, Alaska's record low temperature (-80° F) occurred less than 150 miles from its record high temperature (100° F),[5] and as a result, DOT&PF bridge design practice calls for standard temperature ranges of up to 160° F.[6] Material properties can change over a temperature range of this magnitude, which is particularly relevant to seismic design.

For example, frozen soils behave differently from unfrozen soils, changing the location of the plastic hinge in pile foundations. Permanently frozen soils often underlie unfrozen or seasonally frozen soils, and each soil scenario alters seismic demand and response.

Limited Industrial Capacity. Alaska has no steel manufacturing, a small skilled labor pool, and limited options for construction equipment and materials.

DOT&PF design and construction staff regularly addresses all of these factors, and the innovations described below represent some of the resulting adaptations. Both the ABC and Every Day Counts initiatives have identified Prefabricated Bridge Elements (PBEs) as key tools for reducing construction time. Alaska DOT&PF has been using PBEs for decades and likely leads the nation in use of precast, prestressed concrete decked bulb-tee girders with installations at more than 300 locations.

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[4] *Fisheries of the United States 2016*. NOAA National Marine Fisheries Service. August 30, 2017 (p-12).

[5] State Climate Extremes Committee. NOAA National Centers for Environmental Information. Accessed November 16, 2018.

[6] *Alaska Bridges and Structures Manual*. DOT&PF Bridge Section. Chapter 19: Expansion Joints and Bearings. September 2017 (p 19-1, Table 19-1).

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Innovative Technology: Concrete-Filled Steel Tube (CFST) Substructure Units

Summary of Benefits
• Expedited project delivery – typically requires less than half the time required to construct a conventional pier in a waterway • Expedited project delivery – eliminates need for cofferdams • Expedited project delivery – reduces environmental impacts, and thus permitting time, when compared to conventional cofferdam column-footing pier construction • Added bridge capacity – excellent ductile response to seismic demands and resistance to liquefaction

This innovation will be applied to the following structure in this project:

- Victor Creek Bridge (607)

Description

CFST Substructure Units consist of large diameter (24-inch to 48-inch) steel piles with a reinforced concrete pier cap and eliminating the need for a traditional concrete footing at the groundline. Piles are filled with reinforced concrete and designed to establish a ductile connection to the capacity-protected reinforced concrete cap.

Figure 2 Typical CFST Substructure Units

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Capacity to Implement

Alaska pioneered the use of large-diameter Concrete-Filled Steel Tube Substructure Units as a rapid-build, low-cost, and environmentally appropriate substitute for traditional column-footing foundations. This innovation addresses several challenges faced by bridge designers in the state: short construction seasons, remote and high-cost build locations, relatively high rate of environmentally sensitive fish streams, and extremely high seismicity and liquefaction potentials.

Alaska began development of the CFST Substructure Unit concept for high seismic regions in the 1990s in collaboration with the University of California at San Diego. This full-scale test program resulted in a design procedure and structural detailing that ensure ductile performance under seismic loading. Later work with Oregon State University resulted in the development of design software that greatly increases efficiency and accurately captures nonlinear soil structure interaction, including the effects of frozen soil.

Research conducted in 2013 at North Carolina State University documented that the concrete and steel in the piles act compositely.[7] DOT&PF has completed hundreds of CFST Substructure Units for both piers and abutments, but AASHTO only added concrete-filled steel tubes to the *LRFD Bridge Design Specifications* in the 8th edition released in 2018.

Over time, research and experience have shown CFST Substructure Units provide excellent lateral resistance to seismic loading and are designed to resist settlement from liquefaction. The design has been found to use concrete and reinforcing steel highly efficiently when compared to a traditional column-footing system.

Without a concrete footing, the permitting and construction costs associated with cofferdams are eliminated. This change alone has been found to lower costs by approximately 64 percent when used at piers and reduce construction time by about two-thirds.

Projected Financial and Time Savings

The comparison below uses actual bid costs from a traditional column foundation pier project similar in size to the Victor Creek Bridge's CFST Substructure Unit pier cost estimate. The cost savings in this example by using the CFSTs is around $1.5 million.

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[7] Brown, N.K., Kowalsky, M., Nau, J. "Strain Limits for Concrete Filled Steel Tubes in AASHTO Seismic Provisions", Report No. FHWA-AK-RD-13-05. August 2013.

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Cost Comparison for the substructure of one pier for Bridges 0547 and 0607

		Pay	Estimating	Unit	Hicks Creek (0547)		Victor Creek (0607)	
Item Number	**Item Descriptions**	**Unit**	**Unit**	**Price**	**Quantity**	**Amount**	**Quantity**	**Amount**
205.0001.0000	Excavation for Structures	LS	CY	$ 25.00	1089	$ 27,236.31	0	$ -
205.xxxx.xxxx	Cofferdam	LS	LS	$ 200,000.00	All Req'd	$ 200,000.00	0	$ -
501.0001.0000	Class A Concrete	LS	CY	$ 1,750.00	220	$ 384,161.86	173	$ 303,256.89
501.xxxx.xxxx	Class S Concrete*	CY	CY	$ 950.00	190	$ 180,788.06	0	$ -
501.0009.0000	Class DS Concrete (1'-8" Diameter)	LF	LF	$ 250.00	398	$ 99,471.72	0	$ -
501.xxxx.xxxx	Class DS Grout	LS	LS	$ 7,000.00	All Req'd	$ 7,000.00	0	$ -
503.0001.0000	Reinforcing Steel	LS	LB	$ 2.30	117141	$ 269,423.78	35335	$ 81,270.10
503.0002.0000	Epoxy-Coated Reinforcing Steel	LS	LB	$ 2.75	0	$ -	1428	$ 3,927.00
505.0005.0000	Furnish Structural Steel Piles (4'-0" dia. Pipe Piles)	FT	FT	$ 500.00	0	$ -	646	$ 323,160.00
505.0006.0000	Drive Structural Steel Piles (4'-0" dia. Pipe Piles)	EA	EA	$ 35,000.00	0	$ -	4	$ 140,000.00
515.0001.0000	Drilled Shaft	LS	LS	$ 900,000.00	All Req'd	$ 900,000.00	0	$ -
515.0002.0000	Unclassified Shaft Excavation (1'-8" Diameter)	LF	LF	$ 625.00	390	$ 243,757.79	0	$ -
515.0004.0000	Shaft Casing (1'-8" Diameter)	LF	LF	$ 410.00	235	$ 96,209.42	0	$ -
				Total Pier Costs:		**$ 2,408,048.94**		**$ 851,614.00**

CFST Substructure Units at piers can be about twice as fast to construct as conventional column bents. A comparison of typical in-water pier construction sequences is detailed below.

Construction Time Comparison			
Conventional Footing / Column Pier		**CFST Substructure Unit**	
Drive cofferdam sheets & excavate	1 week	Drive piles	1 week
Drive piles, place seal, de-water cofferdam	2 weeks	Clean out piles & place reinforcement	1 week
Place footing reinforcement	1 week	Place & cure pile concrete	1 week
Cast & cure footing	1 week	Place & cure cap concrete	1 week
Form, place & cure columns	2 weeks	Strip forms	1 week
Strip forms, remove cofferdam, backfill	1 week		
Place & cure cap concrete	1 week		
Strip forms	1 week		
Total	**10 weeks**	**Total**	**5 weeks**

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Innovative Technology: "Alaska-style" Precast Prestressed Concrete Decked Bulb-tee Girders (DBTs)

Summary of Benefits
• Expedited project delivery – saves 50% to 75% of deck construction time compared to a conventional Cast-In-Place concrete bridge decks • Expedited project delivery – design, fabrication and construction standards are mature in Alaska • Added bridge capacity – superior overload capacity (operating load rating) due to zero tension design standard • Improved bridge durability – high quality plant-cast concrete eliminates inadequate reinforcing cover, the leading cause of premature deck deterioration in the state

This innovation will be applied to the following structures in this project:

- Victor Creek Bridge (607)

Description

Precast, prestressed concrete decked bulb-tee girders leverage traditional technology into a single innovation addressing multiple construction challenges. A standard precast concrete bulb-tee girder is fabricated with the final deck installed. Edge girders are cast with curb hardware.

Decked bulb-tee girders are connected by a combination of cast-in-place concrete diaphragms, welded steel connection "tabs" embedded in the edges of the top flanges, and grouted keyway longitudinal joints. "Alaska-style" DBT decks can be used as a riding surface as soon as the grout cures, or a waterproofing membrane with asphalt overlay can be added.

DOT&PF design policy further extends the advantages of DBTs. Girders are designed for zero tension under all loads which results in very high operating load ratings in flexure. To optimize these capacities, enough additional reinforcing is provided so the shear operating rating is roughly equal to the flexure rating resulting in efficient girders with optimal overload capacity.

Capacity to Implement

Alaska DOT&PF first used prototype DBTs in the late 1970s, and since then, they have become the most commonly used bridge superstructure in the state. DBTs are almost always the lowest cost bridge type in Alaska when geometric limitations can be met. Maximum DBT span lengths are typically limited 120 to 140 feet due to shipping and handling concerns.

Figure 3 "Alaska-Style" Prestressed Girder Installation

Example Financial and Time Savings

ABC: DBT bridges can be two to three times faster to construct than structures with conventional cast-in-place concrete decks. A comparison of typical deck construction sequences is detailed below.

Construction Time Comparison			
Conventional CIP Deck		**Decked Bulb-Tee Girders**	
Construct soffit forms	2 weeks	Place girders with integral deck	0.5 weeks
Place reinforcing steel	2 weeks	Weld & grout keyways	0.5 weeks
Place & cure concrete	1 week	Form & cast diaphragms & curbs	1 week
Strip forms	1 week	Install waterproofing membrane & asphalt overlay	0.5 weeks
Total	**6 weeks**	**Total**	**2.5 weeks**

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Innovative Technology: Cold-Climate Polyester Concrete

Summary of Benefits
• Expedited project delivery – allows traffic flow to resume after 4-hour cure time, instead of the 7 days required for traditional concrete • Added bridge capacity – compressive strength roughly twice as strong as required for Class A concrete, coupled with a lower unit weight • Improved bridge durability – impermeable, protects steel reinforcement from chlorides and road salts

This innovation will be applied to the following structures in this project:

- Snow River West Channel (603)
- Snow River Center Channel (605)

Description

States like Washington, Nevada, and California with much higher traffic volumes than Alaska have successfully used polyester concrete for decades. However, Alaska has seen effective materials from the Lower 48 fail quickly in the extreme cold climate, so additional testing and modifications are often necessary to establish whether the material will survive “Alaska normal.”

Polyester concrete is composed of a polyester resin binder and select aggregate material, and its use is typically limited to thin bridge deck overlays. The concrete is rapid-setting, high-strength, and impermeable. It is routinely specified at 10,000 psi, compared to 4,000 psi specified strength of Portland cement concrete. Polyester concrete can be opened to traffic in 4 hours, compared to conventional concrete that must be cured for 7 days according to DOT&PF specifications. Polyester is impervious to water, protecting reinforcing steel from the heavy use of road salts to date, and prolonging deck life.

Capacity to Implement

DOT&PF has implemented four polyester concrete projects: three deck rehabilitations and one full-depth approach slab. The full-depth approach slabs were part of an experimental feature project to test new ABC polyester concrete applications. They are performing well, but did not offer sufficient benefit/cost advantages to be practical for widespread applications.

DOT&PF has also sponsored a research project that is testing polyester concrete in the longitudinal girder joints of DBTs. So far polyester concrete shows promise as a replacement for grout, meaning further time savings because the joint could be placed concurrently with a thin overlay. The monolithic polyester concrete placement would replace the three-step process of grouting joints, placing a waterproofing membrane, and asphalt paving of the deck. While the research will not be completed in time for the bridges in the project, it could be tested within the next 2 years. If feasible, it would be the first use of this combination of ABC materials.