Evaluation of Soil Stabilization Practices in Alaska

Phase I – Interim Report

by

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Prepared for

State of Alaska
Department of Transportation and Public Facilities
Research & Technology Transfer
Fairbanks, AK 99709-5399

January 2001

REPORT DOCUMENTATION PAGE	Form approved OMB No.

1. AGENCY USE ONLY (LEAVE BLANK)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
FHWA-AK-RD-01-06A	January 2001	Interim July-December 2000

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
Evaluation of Soil Stabilization Practices in Alaska – Phase I	
6. AUTHOR(S) R. Gary Hicks, P.E.	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Department of Civil Engineering Oregon State University Corvallis, OR 97331	8. PERFORMING ORGANIZATION REPORT NUMBER TRI-00-XX
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Alaska DOT&PF Research and Technology Transfer Fairbanks, AK 99709-5399	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLENMENTARY NOTES

Conducted in Cooperation with the U S Department of Transportation, Federal Highway Administration

12a. DISTRIBUTION / AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
No restrictions	

13. ABSTRACT (Maximum 200 words)

A survey of current and past practices with soil stabilization in Alaska has been completed. The results indicate that ADOT&PF has used a variety of admixtures with local materials for both surface and base materials. The performance of the admixtures used has been mixed. An outline for a design guide to increase the use of soil stabilization has been developed.

14. KEYWORDS	15. NUMBER OF PAGES
soil stabilization, asphalt, cement, lime, chemicals, pavement performance	
	16. PRICE CODE N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	N/A

NSN 7540-01-280-5500

STANDARD FORM 298 (Rev. 2-98)
Prescribed by ANSI Std. 239-18 298-102

ACKNOWLEDGMENTS

The author would like to acknowledge the technical support provided by the following ADOT&PF personnel:

- Billy Connor and Steve Saboundjian – Research
- Leo Woster and Dave McCaleb – Northern Region
- Tony Moses, Newt Bingham, Bob Lewis, and Scott Gartin – Central Region
- Pat Kemp and Bruce Brunette – Southeast Region

They assisted by providing the information needed to evaluate current practices. Thanks also to Peggy Blair of Oregon State University who typed the report.

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1.0 INTRODUCTION

Alaska DOT&PF has used a number of soil stabilization techniques to upgrade marginal soils. The proposed research will: 1) evaluate current practices, in terms of use and performance, and 2) develop a soil stabilization manual which provides information on the selection and use of additives most appropriate for Alaskan soils.

1.1 Background

Soil stabilization has been used for a number of reasons including: 1) temporary wearing surfaces, 2) working platforms for construction activities, 3) improving poor subgrade conditions, 4) upgrading marginal base materials, 5) dust control, and 6) recycling old roads containing marginal materials (FHWA, 1992; Austroads, 1998). A wide variety of stabilizer methods (chemical/mechanical) have been used, such as:

1) Cementing (strength gain)
    - lime
    - lime/fly ash
    - portland cement
    - asphalt emulsions
2) soil modifiers
    - lime
    - chemicals
3) water proofers
    - asphalt emulsions
    - chemicals

4) water retainers

   - salts
   - membranes

5) mechanical methods

   - fabrics/geogrids
   - compaction

Selection of the additive types depends on a number of factors including:

- soil type (gradation and PI),
- climate,
- availability and cost of admixture.

A number of excellent references are available which suggest the factors to consider in selecting an admixture for a given situation (FHWA, 1992; Austroads, 1998). An example is given in Table 1.1.

The success (or performance) of a soil stabilization project also depends on a number of other factors including:

1) mix design,
2) construction procedures,

Table 1.1. Most Effective Stabilization Methods for Use with Different Soil Types (after FHWA, 1992)

Soil Types	Most Effective Stabilizers
1. Coarse granular soils	Asphalt, portland cement, lime-fly ash
2. Fine granular soils	Portland cement, lime-fly ash, asphalt, chlorides
3. Clays of low plasticity	Portland cement, chemical waterproofers, lime, lime-fly ash
4. Clays of high plasticity	Lime

3) curing, and

4) need for surface layer.

Best practices used in Alaska and elsewhere will be included in a manual to be developed in Phase II for stabilizing Alaska soils. This will also include reasons for stabilizing as well as "dos" and don'ts" involved with each of the stabilization techniques.

1.2 Research Objectives

The objectives of this study are two-fold and follows:

1) evaluation of the current soil stabilization practices for soils in Alaska and document the performance of the various stabilization techniques, and

2) develop a soil stabilization manual from Alaskan soils using chemical and/or mechanical means.

This report represents the evaluation of the current procedures in Alaska.

1.3 Study Approach

Following are the tasks planned for achieving the project objectives.

Phase 1: Evaluation/Performance of Current Practices

Task 1: Collection of Information. The first task was to determine where soil stabilization has been used in Alaska. This was accomplished by e-mail, a written questionnaire, or through interviews (see Appendix A). Another source of information to be considered as a part of the data collection effort includes evaluating construction histories (available on CDs) for selected projects.

Task 2: Determine the Performance of Each Type of Stabilization Effort. This will be accomplished in part through Task 1. However, a number of representative projects will be identified to assess the performance of the various stabilization techniques. This performance survey was conducted during October 2000. Items to be collected included, but was not limited to:

- type, extent, and severity of distress,
- photos of pavement condition,
- traffic information (ADT, ESALs), and
- climate conditions.

Task 3: Prepare Interim Report. This report documents the results of Tasks 1 and 2. Comments will be incorporated into the final version of the report at the end of the project.

Phase 2: Develop Soil Stabilization Manual

Task 4: Identify Soil Types Appropriate to Stabilize. Based on the findings in Phase 1, the various soil types found in Alaska will be identified and assessed for use with the different stabilization techniques.

Task 5: Identify Stabilization Methods Appropriate for Alaska. This task will evaluate the most promising stabilization techniques for the various soil types based on:

- cost,
- constructability,
- environmental considerations, and
- performance.

Task 6: Prepare Draft Manual. This task will consist of preparing a draft manual which incorporates the following:

- soil types available,
- additives available,
- selection of additives,
- mix design,
- construction, and
- expected performance in each climate type.

It is expected this effort would be completed by September 30, 2001.

Task 7: Finalize Manual and Deliver Workshop. Once the comments from ADOT&PF have been received, they will be incorporated into the final version of the manual. A one-day workshop on the manual will be presented in Anchorage, Fairbanks, and Juneau in the fall of 2001. Deliverables will include a camera-ready (plus electronic version in MS Word) of the manual plus the PowerPoint presentation used in the workshop.

2.0 LITERATURE REVIEW

This chapter provides a summary of past experiences with soil stabilization in the state of Alaska. It presents information on early experiences during and after World War II, experiences in the 1960s and 1970s when Alaska was dealing with frost susceptibility issues, and experiences in the 1980s and 1990s when a number of different admixtures were evaluated as soil stabilizers.

2.1 Experiences in the 1940s and 1950s

2.1.1 The War Years

Alaska's early experiences with soil stabilization began during World War II. For example, the military sponsored massive construction projects in terms of facilities, roads, and airports (Naske, 1983). World War II indicated Alaska's strategic military importance, that construction of facilities continued during the post-war years. Reportedly, the military used portland cement to stabilize local materials for airfield pavements at Galena, Wainwright, Hooper Bay, and McGrath. (**Note: Contact Al Bush for this information.**)

2.1.2 The 1950s

In the 1950s, other airports (e.g., Bethel, Northway) made use of the earlier experiences to build airports in remote areas. (**Note: RGH Will contact Patty Miller for this information.**)

2.2 Experiences in 1960s and 1970s

2.2.1 Soil Stabilization

Peyton and Lund (1964) conducted a study titled "Stabilization of Silty Soils in Alaska – Phase I," followed by a Phase II study in 1966. The primary objective of these studies was to determine the economical method of stabilizing a silt or loess of the A-4 type for use in highway construction in Alaska. Stabilization, in this case, means the prevention (entirely or in some part) of detrimental frost heave and loss of strength upon thawing of the roadbed.

Phase I of this study was a literature review of existing material on soil stabilization and related frost effects. The principal conclusions of this report were that three general methods should be considered as possible solutions to the stabilization problem in Alaska. These were:

1) The addition of a low percentage of portland cement.
2) The addition of a dispersant of the sodium polyphosphate type.
3) Enclosing the fill in a plastic membrane of polyethylene or vinyl.

A detailed discussion of the three methods mentioned above was included in the Phase I report.

The objectives of Phase II of the study were to:

1) study the effectiveness of the methods determined potentially feasible in Part I by laboratory testing on Alaskan silty soils,
2) determine the economic feasibility of using on Alaskan highway projects the soil stabilization methods which show promise in the laboratory tests, and
3) make recommendations concerning a field test project.

The results of Phase II are as follows:

1) Low percentages of portland cement are detrimental and cause heave in excess of that for untreated silt.

2) The best sodium polyphosphate studied was tetra-sodium phosphate which had nil heave rate, nil heave ratio, and nil total heave when applied at 0.5%. The CBR bearing strength upon thawing is about 10 and the cost of treatment is about $\$2.00/yd^3$.

3) Sodium hydroxide proved to be effective and had nil heave rate, nil heave ratio, and nil total heave when applied at 0.3%. The CBR bearing strength upon thawing is about 13 and the cost of treatment is about $\$1.70/yd^3$.

4) Providing a closed system by use of plastic membrane was successful. Heave rate and ratio are meaningless in a closed system, but the total heave is low at 8 mm for a saturated soil. The CBR bearing strength upon thawing is about 36 for a soil with an initial moisture content of 13%. The cost of membrane treatment over and above normal fill costs is about $\$1.40/yd^3$.

5) Field test section recommendations are made for both new construction and reconstruction.

In 1975, Alaska DOT evaluated the use of a lignin product on Dennis Road and Cushman extension in Fairbanks. The lignin product, supplied by Scott Paper, was used to treat the alluvial barrow material. This treated material was compared with an aggregate base, both of which were capped with a chip seal. The lignin section potholed shortly after construction. No other performance information was provided.

2.2.2 Frost Susceptibility

Esch conducted a number of in-house studies dealing with frost susceptibility of soils in Alaska (1974). Beginning in the late 1960s and continuing on through the 1970s, he evaluated heaving rate of soils, with and without soil additives using the classification system given in Table 2.1. The crushed aggregate bases evaluated in the late 1960s were classified as having low to negligible frost susceptibility as long as the fines content (P200) remained low (< 3%).

Work on frost susceptibility continued throughout the 1970s to evaluate various base materials and to improve on the test procedure used. In the late 1970s, Esch conducted studies to evaluate ways of reducing frost susceptibility using small amounts of asphalt emulsions. The results that the frost susceptibility of base course aggregates can be reduced with as little as 1% emulsion (Esch, 1978).

Table 2.1. Frost Susceptibility Classification (Lambe and Kaplar, 1971)

Heave Rate mm/day	Frost Susceptibility
0.0-0.5	Negligible
0.5-1.0	Very low
1.0-2.0	Low
2.0-4.0	Medium
4.0-8.0	High
> 8.0	Very high

2.2.3 Fines Content Studies

McHattie et al. (1980) also conducted a series of studies to evaluate the effect of fines content on pavement performance. Beginning in the late 1970s, projects were evaluated for P200 at various depths and pavement performance. A three year study was implemented to review the construction and performance of pavement structures in Alaska. One hundred twenty uniform pavement sections were chosen and characterized by fatigue (alligator) cracking, thermal cracking, roughness of ride, and peak springtime deflection levels. Sections were distributed throughout each principle climatic zone within the state. Materials were sampled to a depth of 54 inches and analyzed to determine their relationships to pavement performance.

Results indicate correlations between soil fines content and several of the performance factors. Performance relationships were also found involving asphalt concrete thickness, pavement age, and accumulated traffic loadings. Climate variables showed little correlation with performance except with major transverse thermal cracks.

Deficit thickness-design requirements based on both supporting soils stability (R-value) and frost susceptibility were compared with performance for a number of locations. While a trend was observed between existing overlay deficit and performance, the extra materials required by present Alaskan design methods apparently led to overly conservative structures in many cases. This study formed the basis of the current pavement design procedure used in Alaska and is referred to as AKPAVE (ADOT&PF, 1997).

2.2.4 Alyeska Studies

During the construction of the pipeline, soil stabilization techniques were used on a limited basis. (**Note: Need a contact for work by Alyeska on soil stabilization.**)

2.3 Experiences in 1980s and 1990s

2.3.1 Substitute Materials in Frost Protection

Phukan (1981) conducted a literature search on soil stabilizers to reduce frost action in highways, railways, and airfields. He evaluated soil cement, asphalt emulsions, chemicals, and membrane encapsulated soil layers (MESL) for possible use by ADOT&PF. This study showed that different soil types can be stabilized with cement, asphalt emulsions, and chemical compounds to meet the requirements of "substitute materials" in place of non-frost susceptible soils in frost protecting layers. The engineering properties of soils can be beneficially modified by admixture stabilization procedures. Guidelines are available for mixture design, construction specifications, and procedures on the stabilization techniques. However, information pertaining to use of frost prone materials in frost protection layers is limited. A complete investigation of the use of in-situ materials, which may not satisfy the frost susceptibility criteria, is needed to replace the often expensive non-frost susceptible soils.

He indicated that treated soils with portland cement admixtured with various agents like calcium lignosulfonate and hydroxylated carboxylic acid show promising results of improved physical properties. They are effective in increasing bond between subsequent layers of soil-cement and generally improved the durability of the stabilized material. Studies abroad indicated the reduction of potential frost heave by the use of lignosulfonate admixture in cement treated frost susceptible soils. However, studies in the USA show the opposite effects. As such, the limitations on the use of such admixtures in the treated soils remain to be seen.

The use of various additives appears to reduce plasticity and frost susceptibility. Dispersants such as sodium carbonate, sodium hydroxide, sodium sulfate, and potassium permanganate have improved the strength of soils treated with portland cement. However, their influence in the reduction of potential frost heave is not clearly established.

Other chemical compounds may be successfully used to stabilize soils; however, they are not suitable for large-scale use for one or more of the following reasons:

- The stabilizing agent and soil cannot be blended and intimately mixed because of the high plasticity, high clay content, excessive moisture content, lack of workability of the natural soil,
- general construction problems such as effective dispersion, time limitations,
- logistics with storage and transportation,
- high cost,
- it may be dangerous to work with some stabilizers,
- water attack and leaching to pollute environments.

Further, the MESL concept and the related field-laboratory studies were reported to be a viable construction technique to use frost susceptible soils as base or subbase materials. However, there are some limitations as to the compacting effort, density, and moisture content. Additional field tests are needed to further evaluate higher density soils to determine moisture content and redistribution, heave, freezing rates, and post-thaw deflection. Additional stabilization with soil reinforcement at the upper layer may dramatically improve the performance of MESL system.

2.3.2 Stabilization Using Emulsions

In 1982, a portion of the Alaska Highway (MP 1253 to 1235) was reconstructed. During the construction of this section of roadway it was decided (in 1984) to treat the base material with 4% CSS-1 emulsified asphalt. The emulsion treated base was overlain with 1.5 inch of hot mix. The completed appearance of the project was rated as very good (Herning, 1984). The pavement currently shows no sign of major distress. Its performance has been satisfactory.

Gentry and Esch (1985) reported on a laboratory study in which sands to silty sands from remote areas were stabilized with emulsified asphalt and portland cement. The report summarizes a two-year laboratory testing program directed toward the development of soil treatments for fine silty sands, using combinations of three types of emulsified asphalts and type III portland cement for stabilizing agents. The primary objective of the study was to determine if the soils used in the testing program could be stabilized to levels that would allow the use of locally available soils, similar to those tested, to serve as alternatives for expensive imported gravel for road and airfield construction in the Yukon and Kuskokwim River Delta areas of Alaska.

The first phase of the laboratory work consisted of testing to characterize the soils available at 13 locations in the Delta area. One hundred twenty-seven samples from 22 specific sites were tested for gradation, organic content, Atterberg limits, and natural moisture content. Using the data obtained from the first phase work, soils from the Hooper Bay, Bethel, and St. Michael areas were selected for additional testing. Two types from Bethel were selected, sand and silty sand. These soils were described as fine sands and silty sands, with 100% of the particles passing a #10 sieve and from 0% to 20% passing a #200 sieve. St. Michael sand had 100% passing a #8 sieve and 94% passing a #16 sieve. The Yukon-Kuskokwim Delta area contains few deposits of coarse gravels and sands to silty sands that are available for construction purposes near populated areas. The predominating soil type is organic silt which exists in a permafrost state with high frozen moisture content.

The literature search for this study indicated that a large amount of research effort has been invested in soil stabilization methods and materials using a wide variety of test methods and stabilizing agents with many soil types. Based upon the literature review, it was decided that this study should be conducted with cement and asphalt emulsion stabilizing agents which were available in Alaska and which were most likely to produce good results. The emulsified asphalts selected were types SS-1, CSS-1, and CMS-2S. Type III portland cement was used as an admixture for several of the tests. Tests were performed using the Hveem procedure for stabilometer (S) and cohesiometer (C) values. The R-value (resistance to deformation) is calculated for the data obtained during testing.

The second phase of the laboratory work involved the testing of samples prepared with various combinations of the four soils, three types of emulsified asphalts, type III cement, and water. The initial emulsion content to be used for each soil was determined by the Centrifuge Kerosene Equivalent (CKE) test which determines an oil ratio for the soil. All mixes were prepared using emulsion contents of 1.3 or 1.5 times the oil ratio. The scope of this study did not allow for sufficient testing to determine the optimum emulsion-cement content for a mix made up from any of the soils. A total of 46 different mixes were prepared for testing from which approximately 368 individual test briquets were made, resulting in sets of eight briquets for S, C, and R values after the following curing conditions:

1) Test immediately after compaction.
2) Air dry 3 days @ 72 ± 3°F.
3) Air dry 3 days followed by vacuum saturation for 1/2 hour.
4) Air dry 3 days and vacuum saturated 1/2 hour, followed by one 2-day freeze-thaw cycle.

Of all the mixes tested, St. Michael sand mixed with 7.5% water, 5.4% CSS-1, and 1.5% portland cement resulted in the best strength properties. The same sand mixed with 7.5% water, 4.7% SS-1, and 1.5% portland cement resulted in nearly the same values. These mixes appear to be suitable in stability for use as a surface wearing course. Both mixes showed stabilized R-values of 89 as compared to unstabilized values of 67. More than half (56%) of the soil-emulsion mixes tested, including all three types of emulsion and all four soil types, resulted in test values that indicate suitability for use as a treated base material (R-value > 77). Two-thirds of these successful mixes contained portland cement as an additive. Stabilized R-values ranged from 72 to 89, as compared to unstabilized values ranging from 66 to 69.

The best results were obtained with mixes using the cationic slow-set emulsions CSS-1, with slow-set anionic (SS-1) being a close second. A cationic emulsion with some solvent added (CMS-2) did not produce as many suitable mixes and was more difficult to mix than the other two emulsions. This study indicated that fine sands containing as much as 20% silt, from the Yukon-Kuskokwim Delta area of Alaska, can be significantly improved or stabilized by the use of emulsified asphalt and portland cement. This would allow use of locally available soils for the construction of roadway and airport surfacing and base stabilization projects.

Gartin and Esch (1991) summarized work regarding the use of asphalt stabilized treated bases and compared their performance with untreated base courses using back calculation and layer moduli. The sections evaluated included:

1) Richardson Highway – Tiekel River and Thompson Pass areas
2) Alaska Highway near Northway
3) Elliot Highway near Fox

The results of the study indicated the following:

1) Stiffness of the treated bases are greater than the untreated bases.
2) Pavement designs for asphalt treated bases should consider horizontal strain at the bottom of the layer and vertical stress in the underlying layers.

2.3.3 Soil Stabilization Studies at Airfields

Koehmstedt (1986) conducted a study which involved extensive testing of two soil samples from the Bethel, Alaska, area to determine if these soils can be stabilized with a combination of cement and asphalt emulsions for use as subbase and base course materials for airfield and roadway applications. Three cationic slow-set (CSS-1) emulsions from different manufacturers were compared. Two of these were of standard manufacture and the third was produced after selecting an emulsion based on the zeta potential and surface area of the test soils.

Test results demonstrated that the use of an emulsion specially selected for the particular soil properties can result in major performance improvements over standard production emulsions of the same grade. For the soils tested, similar strength levels were reached with 30 to 40% less of the specially select emulsions.

Cement contents between 0.5 and 2.0% were added to a series of soil-emulsion mixes. Cement contents below 1.5% were generally of no benefit and in several cases actually reduced strength values. Cement contents of 2% consistently increased the mixture cohesive strengths by 20 to 80%. Tests of sands having different fines contents indicated that the optimum fines content for emulsion stabilization falls between 12 and 20%.

The author indicated that sufficient information was derived from this initial study to proceed toward the ultimate goal of airfield/highway construction projects in the Yukon and Kuskokwim Delta areas of western Alaska. The following studies/projects were recommended in pursuance of the ultimate goal:

1) Softer Asphalt. All tests in this program involved emulsions prepared from AC-5 asphalt, primarily because of (a) AC-5 emulsion samples were readily available, and

(b) to provide a common basis of asphalt stiffness for all emulsions. If a softer grade of asphalt is to be used it would be expected that stability, cohesion, resilient modulus, and CBR values would be significantly different from those of this program. Tests should be conducted for pavement design information which would involve emulsions prepared from asphalt of specified hardness.

2) Use of Geotechnical Fabrics. The use of fabrics was not a part of this program. The use of fabrics to improve subgrade support capability and to increase pavement support strength was evaluated in another study (**Ref.**). The use of fabrics may cost effectively reduce the need for imported materials. These programs should be followed.

3) Field Tests. An installation involving test sections exposed to aircraft taxi traffic is needed to demonstrate that load bearing capability of admixtures measured in the laboratory perform as predicted in the field. The field test will expose candidate admixtures to conditions very difficult to duplicate in the laboratory.

4) Optimized Admixtures. The formulations of Bethel soils, cement, asphalt emulsion, and water selected and tested in this laboratory study produced mixtures with mechanical properties suitable for field testing in runway and highway applications. This laboratory study did not optimize these mixtures for load bearing properties or minimum cost. If the results reported in this report are encouraging, optimization studies are probably warranted.

5) Prototype Installation. A high priority site should be selected with the Alaskan Delta region for a prototype airfield runway upgrading. The runway requirements should be established, the aggregate source must be thoroughly characterized, the materials

and equipment logistics clarified. A prototype installation is needed for proceeding to multi-instillations throughout the Delta region.

Danyluk (1986) also conducted a laboratory study to determine the feasibility of stabilizing an organic silt for use in subbase or base courses for all weather, low volume roads and airfields in Alaska. The soil used in this study had an organic content of 12% and a modified Proctor value of 79.1 lb/ft^3 at a 29% moisture content. The stabilizers evaluated were: cement, cement with additives (calcium chloride, hydrogen peroxide, sodium sulfate, and lime), lime/fly ash, asphalt emulsion, tetrasodium polyphosphate, and calcium acrylate.

Cement had very little effect on the soil properties. The organics apparently interfered with the cement's reaction and, in turn, the inactive cement caused detrimental side effects (i.e., higher frost-heave ratios). Best results were obtained at a 20% cement content, which exhibited an unconfined compressive strength of 39 lb/in.^{2} and an after-thaw CBR value of 3.1. Using the additives calcium chloride and sodium sulfate with cement increased the soil parameters slightly. The most promising results were obtained with 20% cement and 2% calcium chloride. The permeability and frost susceptibility were reduced and an unconfined compression strength of 64 lb/in.^{2} and an after-thaw CBR value of 7.2 were obtained with these percentages.

An attempt was made to counteract the effects of the organics by pre-treating the soil with lime or hydrogen peroxide prior to adding the cement. Neither stabilizer showed significant promise; the peroxide slightly improved the soil's parameters, but the lime had negative effects. The lime and lime/fly ash tests indicated that the lime was an ineffective stabilizer for this soil, which had a high organic content.

Asphalt emulsion was most effective at the 8 to 10% range. The permeability and frost-heave ratio were lowered to 0.18×10^{-5} cm/sec and 0.81, respectively. An unconfined compressive strength of about 50 $lb/in.^2$ and an after-thaw CBR value of about 4 were obtained. Adding cement or lime to the soil before adding the emulsion caused no improvements in the soil parameters.

Calcium acrylate caused the highest strength values of all the stabilizers tested, an unconfined compressive strength of about 350 $lb/in.^2$ and an after-thaw CBR value of about 21. Since acrylate is effective only at concentrations exceeding 5% and the stabilizer is not manufactured on a large scale, it becomes uneconomical for all but special uses.

Tetrasodium pyrophosphate effectively reduced the frost susceptibility of the soil. The stabilizer was most effective at the 0.3-0.5% concentration; using percentages higher than this resulted in little improvement. The stabilizer had little effect on improving the strength of the soil.

A preliminary economic analysis was performed on the following stabilizers: cement, cement plus calcium chloride, asphalt emulsion, and tetrasodium pyrophosphate. The estimated prices (in 1986) ranged from $18/$yd^3$ for TSSP to $39/$yd^3$ for cement plus calcium chloride. These estimates are conservative and one should expect the costs to be higher depending on: 1) location in Alaska (prices FOB Anchorage), 2) in-situ moisture content, 3) mixability of the soil and chemicals on a large scale, 4) actual production rate, and 5) length of construction season. Based on the high unit cost and limited benefits achieved with the stabilizers, a field study with these stabilizers was not recommended. However, the laboratory study produced results that warrant the following recommendations:

1) Consider using the stabilized soil in conjunction with another stabilizing systems (e.g., TSSP-stabilized silt in a membrane-encapsulated soil layer (MESL)).

2) Evaluate adding limited quantities of an acceptable fill to the stabilized silt to improve soil properties otherwise unaffected by the stabilizer.
3) Depending on the additive, find an effective method of combining a stabilizer with a fine grained soil (i.e., silt).
4) Further evaluate an effective means of neutralizing the effects of the organics in a soil.

Sand confinement grids (Coetzee, 1983) were used to stabilize local materials for the runway and apron at Shishmareh Airport in 1992. The product used, "Geoweb," was filled with local sand to create the pavement base layer for the airport. A modified chip seal was placed as the wearing surface. Both pavements (runway and apron) are performing satisfactorily.

2.3.4 Soil Stabilization – Bethel

Kozisek and Rooney (1986) reported on the construction of field test strips in Bethel, Alaska, using both asphalt emulsions and portland cement to stabilize the local silty soils. Mix designs for both the emulsion and portland cement treated materials were performed followed by construction of test strips in August 1985. The authors concluded that both mixes were constructible with minimal equipment. However, they recommended barging in better equipment for future work. They also suggested future study was needed on mix design, construction mixing methods, etc. They recommended the test strips be monitored for performance.

Vita et al. (1986) presented results of a study to evaluate the performance of the Bethel Airport pavement structure consisting of asphalt concrete over cement treated base. They concluded that the use of cement treated base (CTB) at Bethel Airport was operationally successful. Compared to untreated crushed gravel base, CTB is economically and structurally superior in terms of pavement performance. In all cases of CTB use, proper design and construction is essential to a successful product. Current design practices for CTB appear suitable for cold regions. Good construction control and quality are essential, as the 1970 construction deficiencies at Bethel demonstrated.

There does not seem to be any special technological reasons for inadequate performance of properly designed and constructed CTB in cold regions. In fact, the high quality of the 1958 CTB at Bethel has shown adequate performance for nearly 30 years, and the results of the mechanistic analysis described here indicates a very long remaining fatigue and rutting life for the current CTB pavement structure.

Reflection cracking, a common and general condition of all CTB pavements, is generally controlled with adequate AC thickness to reduce surface cracking and crack sealing as part of routine maintenance. Surface cracking on the Bethel Airport runway includes thermal cracking effects (similar to those found, for example, in the Fairbanks area) and CTB-induced reflection cracking. However, CTB reflection cracking does not appear to be a particular problem at the Bethel Airport.

The operationally successful use of CTB at Bethel provides support to the general use of CTB at other locations in cold regions. Of course, any given candidate location for CTB must be evaluated for case specific conditions, needs, and constraints. For example, CTB does not have any special advantage in overcoming adverse effects of thaw in areas of thaw unstable permafrost, although pre-thawing of subgrade permafrost several years in advance (as was done for the Bethel runway) may, in the right situation, improve foundation soil performance. Further, the performance of CTB in poorly draining soils (unlike Bethel soils) with a high groundwater table is unknown. Also, in cases where abundant crushed gravel is locally available, there may be no economic advantage to CTB. Further, where a superior natural subgrade exists there may be no advantage to CTB.

The CTB experience at Bethel indicates that: in many poor subgrade areas where gravel is not economically available, CTB can provide a cost saving solution which will contribute to high quality pavement performance. Following proper planning, design, construction, and maintenance, CTBs can be used in cold regions to effect superior economic and long-term pavement performance.

2.3.5 Soil Stabilization – Effect of Salts

Kinney and Reckard (1986) conducted a study in which salt was evaluated as a material to reduce frost susceptibility. A frost heave test performed on a base course material as part of an earlier study indicated that the addition of 0.1% calcium chloride reduced heave by 50%, while 0.5% reduced heave by 95%. The gravel was of a type widely used in interior Alaska for highway base and subbase materials.

In response to this, a more detailed study was undertaken to assess the effects of salt on soil stability, principally frost heaving. Gravels from the original study source and others typical of interior Alaska were used. Frost heave tests were performed in the laboratory under various conditions of soil salt content, temperature, temperature gradient, and overburden pressure. CBR tests were also performed to assess thaw weakening. Field samples were also gathered from highway locations where known quantities of calcium chloride had been applied in the past. The dissipation rate of field applied salts was examined by analyzing the salt content of these samples.

The study found that frost heave effects due to salt varied widely with soil type and freezing conditions and could not be predicted using standard soil tests. It also indicated that little salt remains in a road section several years after application. It was concluded that the use of salt is probably not a practical or economical design alternative for increasing the frost stability of embankment materials.

2.3.6 Stabilization Using Lignins

Mazuch and Ticot (1989) presented the results of a new base stabilizing agent, a blend of emulsified bitumen and lignosulphonate which was developed by the British Columbia Ministry of Transportation and Highways. The stabilizing agent was used in nine field construction projects between 1984 and 1988 for a total length of 115 km.

The stabilizing agent reportedly increases load bearing capacity of roads, improves compaction and dispersion of fines. Stabilized bases do not bleed, rut, or crack. The use of a stabilizing agent is economically attractive. Savings are achieved on the lower cost of the stabilizing agent, smaller amount of binder required, and the ability to stabilize marginal or rejected aggregates.

The following general conclusions and suggestions were reported from this study.

1) A new road stabilizing agent, based on asphaltic emulsion, water, and lignosulphonate, was developed and patented. The new stabilizing agent (called B.C. Stabilizer) is reportedly inexpensive, easy to apply, and made from readily available materials.

2) B.C. Stabilizer can stabilize a wide range of granular materials including fine sands. It improves compaction and dispersion of fines. The cured base does not rut, has a high load bearing capacity, and possesses self-healing properties.
3) The field-proven stabilization technique is suitable for both small and large paving projects. B.C. Stabilizer should be used on roads with good drainage and a dry environment. The constructed base must be protected by means of a water impervious wearing surface.
4) The use of B.C. Stabilizer is economically very attractive. Significant savings are achieved through the low cost of stabilizer and the possibility to utilize marginal or rejected aggregates. Economical benefits extend to manufacturers of asphaltic emulsion and sulphite pulp and paper industries.

2.3.7 Recycling

Alaska DOT&PF has also experimented with cold recycling. In 1993, the Sheep Creek Road rehabilitation project involved the recycling of the existing surface, stockpiling the milled material, then mixing it (in a pugmill) with 0.5 to 0.7% CMS-2 emulsified asphalt. The material was hauled to the site and laid with a conventional paving machine and then compacted. An asphalt concrete overlay was placed on the recycled mix. The pavement was performing well as of December 2000.

The Goldstream project (1994) also involved milling the existing asphalt surface and reusing it as a base. In this case, the milled material was heated to 140°F and then mixed with 1% CRS-2. The warm mix was laid and compacted in thicknesses varying from 4.5 to 7 inches. No information on the performance of this project was included in the project history.

Alaska DOT&PF has also used deep cold recycling (both the base and surface layer) with and without the addition of emulsified asphalts. An example of this was the Steese Highway overlay, MP 11-22. A portion of this project consisted of grinding the 25-year-old 2-inch asphalt surface and blending it with 4 inches of the gravel base. The grinding actually went deeper in patched or heaved areas. The materials were compacted and then primed with a MC-30 prior to the placement of the new asphalt concrete overlay. Again no information on long-term performance was available.

2.3.8 Chemical Stabilization

Alaska DOT&PF has reportedly used a number of chemicals to stabilize local soils including:

- Perma-Zyme
- EMC^2
- Stabilizer
- Mountain Grout
- Star Seal 96

Brownfield (1994) reported on the use of Perma-Zyme, a liquid product which reportedly alters the properties of certain soils to produce a solid, almost rock-like material. It was used in the central region on several roads. However, no information on long-term performance was provided.

McHattie (1994) reported on the use of EMC^2 and commercially package clay used as dust palliatives. The performance of these projects was compared with the standard treatment using calcium chloride ($CaCl_2$). The materials were placed on the Elliott Highway between MP

28 and 36 in 1991 and evaluated just after construction in the summer of 1992 and spring of 1993. The performance after one year was good for all products. However, the performance of all products had diminished in 1993 such that they required a treatment of $CaCl_2$). In conclusion, McHattie indicated the EMC^2 was an attractive alternate to $CaCl_2$. The clay additive was substantially more expensive.

McHattie (1997) reported on the use of EMC^2 along a section of the Alaska Highway. This product is a proprietary organic chemical which is designed to improve the cementation and stability of compacted aggregate and soil materials. The section of the Alaska Highway treated was between MP 1222 and 1270. Both EMC^2 and control sections were selected, then constructed in 1996. Both sections were then covered with 4 inches of an emulsified stabilized base and a high-float surface treatment.

Monitoring of the sections began in April 1997 and would continue for four years. Visual assessment of pavement condition and surface deflection is being monitored. At the end of year 1, the pavement conditions were reported to be similar for both sections, but the deflection analysis indicated lower strength for the EMC^2 section. The current (2000) performance of these sections is not known.

Hopper, Moore, and Sterley (1997) reported on an experimental soil stabilization project near Haines, Alaska. The project consisted of constructing a walking trail 6 feet wide by about 1.5 miles long. The majority of the trail was surfaced with asphalt, except for about 400 feet of boardwalk and three test sections of 300 feet with the following stabilizers

1) Stabilizer – manufactured by Stabilizer, Inc., of Phoenix, Arizona
2) Mountain Grout – manufactured by Green Mountain International, Inc., of Waynesville, North Carolina

3) Star Seal 96 – distributed by Advanced Soil Systems Technology of Anchorage, Alaska.

All three stabilizers were applied to the 4.5 inch base course used on the project.

Preliminary findings suggest the Mountain Grout product performed best of the three.

(**Note to Bruce: We need a current evaluation.**)

3.0 FIELD SURVEY RESULTS

3.1 Initial E-Mail Survey

A survey form was distributed to each of the three regions (northern, central, and southeast) to obtain information on current practices with soil stabilization in Alaska. The survey form is given in Appendix A and the results of the survey are given in Table 3.1.

3.2 Field Visits (October 23-27, 2000)

As a follow-up to the initial e-mail survey, visits with each of the ADOT&PF regions were conducted during the week of October 23-27, 2000. The purpose of this visit was the following.

1) Confirm the information collected with the initial survey.
2) Collect information on projects constructed in each region using soil stabilization. Table 3.2 (field project check list) was developed for this purpose.
3) Summarize the relevant information collected during the visit and from the field project check lists provided by each region.
4) Identify the issues/items to be covered in the design guide to be developed in Phase 2 of this study.

A detailed summary of the meeting notes is given in Appendix B.

3.3 Field Project Summaries

Field project summaries were requested from each of the regions. At the time of this draft (December 31, 2000), no summaries had been received.

Table 3.1. Summary of Soil Stabilization Practices – ADOT&PF

1) What soil stabilization techniques have been used in your region?

	Northern	Central	Southeastern	Comments
Portland Cement		X (not sure)	X (limited)	
Hydrated Lime				
Emulsified Asphalt	X	X	X	Northern region mixes RAP with aggregate base
Chemicals	X	X		CaCl, Road Oyl ?
Mechanical		X	X	Compaction, vibro flotation, geotextiles
Other			X	"Stabilizer" "Mountain Grout" "Star-Seal 96"

2) What are the predominant soil types in your region?

	Northern	Central	Southeastern	Comments
Sandy Soils			X	
Silty Soils	X	X	X	
Clayey Soils				
Peat/Muskeg		X	X	

3) What types of additives have been used with the following soils?

	Northern	Central	Southeastern	Comments
Sandy Soils			Emulsions + 1% PC	
Silty Soils	Emulsions	Emulsions Chemicals		
Clayey Soils				
Peat/Muskeg		Geotextiles	Geotextiles	

4) Do you have paper records on the number and location of projects for which soil stabilization treatments have been used?

Region	Yes	No	Comments
Northern		X	
Central		X	
Southeastern	X		Will provide during visit

5) What factors are considered when selecting a treatment for a given soil type?

Factors	Northern	Central	Southeastern	Comments
Traffic	X	X	X	
Climate	X	X	X	
Construction Equipment Availability			X	
Soil Type	X	X	X	

Table 3.1. Summary of Soil Stabilization Practices – ADOT&PF (continued)

6) What procedures have been followed to design soil stabilization projects?

	Northern	Central	Southeastern	Comments
a) Mix Design				
Portland Cement		?		
Hydrated Lime				
Emulsified Asphalt	Experience Based/ Marshall	Experience Marshall Frost Heave	Modified Marshall	
Chemicals	Supplier Recommendation	Supplier Recommendation		
b) Thickness Design				
Portland Cement				
Hydrated Lime				
Emulsified Asphalt	Mechanistic Design	Pavement Design		
Chemicals	Supplier Recommendation	Supplier Recommendation		

7) How have the various soil stabilizers performed in your region?

	Northern	Central	Southeastern	Comments
Portland Cement		?	Fair to Good	
Hydrated Lime				
Emulsified Asphalt	Good	Good	Good	Includes RAP mixes too
Chemicals	Poor to Fair	Fair		
Mechanical Methods		Good	Good	

Do you have reports describing the performance?

	Northern	Central	Southeastern
Yes		X	X
No	X		

8) What sort of information would be useful to you in a soil stabilization manual?

	Northern	Central	Southeastern	Comments
Types of Additives	X	X	X	
Soil Types	X	X	—	Consider washing base materials as a form of stabilization
Selection of Additive	X	X	X	Options for organic soils
Mix Design Procedures	X	X	X	
Construction Procedure	X	X	X	
Expected Performance	X	X	X	

Table 3.2. Field Project Check List

Project ID:		ADOT Region:	
Date Constructed:		Date of Last Evaluation:	
Traffic Data:	ADT:	% Trucks:	ESALs:
Pavement Structure: (Type and Thickness)	Surface:		Base:
	Subgrade:		
Climate:	Temperature Ranges:		Rainfall:
Stabilizer Type:			% Additive:
Soil Type Treated:			
Mix Design Procedure:			
Thickness Design Procedure:			
Construction Procedures:			
Construction Problems:			
Performance Information			
Design Life (Expected):		Current Overall Condition:	
Distress Type:	Extent	Severity	
Cracking			
Rutting			
Other			
Photos of Pavement:	Yes ☐	No ☐	
Other Comments:			
Date:	Source of Information:		

3.4 Identified Needs for Design Guide

Based on the comments provided by the ADOT&PF interviewed, the design guide to be developed as a part of Phase 2 should include the elements given in Table 3.3.

Table 3.3. Outline of Design Guide for Soil Stabilization

1) Overview of additives available
2) Summary of soil types in Alaska
3) Procedure for selection of additives
4) Bituminous stabilization
    - Mix and thickness design
    - Construction
    - Expected performance
    - Costs
5) Cement stabilization
    - Mix and thickness design
    - Construction
    - Expected performance
    - Costs
6) Lime / lime/fly ash
    - Mix and thickness design
    - Construction
    - Expected performance
    - Costs
7) Chemical stabilization
    - Mix and thickness design
    - Construction
    - Expected performance
    - Costs
8) Salt stabilization
    - Mix and thickness design
    - Construction
    - Expected performance
    - Costs
9) Stabilization using drainage
    - Types of drains
    - Design considerations
    - Construction

Each chapter of the guide is envisioned to be a stand alone chapter. The total length of the guide should not exceed 50 pages if it is to be widely used by ADOT&PF personnel.

4.0 SUMMARY AND RECOMMENDATIONS

4.1 Summary

This report presented a summary of past and current practices with soil stabilization in Alaska. The study indicates:

1) A variety of stabilizer types have been used in Alaska with both good and bad results.
2) Soil stabilization has been used on mainline roads as well as remote villages and airports.
3) Soil stabilization practices have not been well documented. With turnovers of personnel, a design guide on selecting and using soil admixtures is needed.

4.2 Recommendations

The outline for the design guide given in Section 3.4 is recommended for completion in Phase 2 of this study. Once comments are received on the outline, the guide will be developed in time for training sessions in Fall 2001. A first cut at the training materials is given in Appendix C.

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APPENDIX A
E-Mail Survey

SOIL STABILIZATION PRACTICES IN ALASKA

Survey Form

The following questions are to be used to gather information on past and current experiences with different soil stabilizers used in Alaska. The questions will be emailed to each of the regions prior to a visit to assess the performance of selected stabilizers.

If your have any questions, please contact the following individual:

R. Gary Hicks
Department of Civil Engineering
Apperson Hall 202
Oregon State University
Corvallis OR 97331-2302
Phone: 541-737-5318
Fax: 541-737-3052
Email: r.g.hicks@orst.edu

1. What soil stabilization techniques have been used in your region?

- ❐ Portland cement
- ❐ Hydrated lime
- ❐ Emulsified asphalt
- ❐ Chemicals (please identify)________________________________
- ❐ Mechanical methods (please identify)________________________
- ❐ Other ____

2. What are the predominant soil types in your region?

- ❐ Sandy soils
- ❐ Silty soils
- ❐ Clayey soils
- ❐ Other (please identify)_________________________________

3. What types additives have been used with the following soils?

- ❐ Sandy soils____
- ❐ Silty soils____
- ❐ Clayey soils____
- ❐ Other # 1 ____
- ❐ Other # 2 ____

4. Do you have paper records on the number and location of projects for which soil stabilization treatments have been used?

   ❒ Yes
   ❒ No

   If yes, can you please provide this information during the visit?
   If the answer is no, can your provide a copy of the construction histories on CD?

5. What factors are considered when selecting an additive for a given soil type?

   ❒ Traffic
   ❒ Climate
   ❒ Construction equipment availability
   ❒ Other

   Please indicate how each of these are considered ______________________________
   ____
   ____
   ____

6. What procedures have been followed to design (mix and thickness) soil stabilization projects using the following additives?

   ❒ Portland cement ____
   ❒ Hydrated lime ____
   ❒ Emulsified asphalt ____
   ❒ Chemicals ____
   ❒ Mechanical methods ____

   Please provide copies of each design procedure.

7. How have the various soil stabilizers performed in your region?

	Very Good	Good	Fair	Poor
Portland cement	❒	❒	❒	❒
Hydrated lime	❒	❒	❒	❒
Emulsified asphalt	❒	❒	❒	❒
Chemicals	❒	❒	❒	❒
Mechanical methods	❒	❒	❒	❒
Other	❒	❒	❒	❒

   Do you have reports describing the performance?

   ❒ Yes
   ❒ No

   If yes, can you provide a copy of each?

8. What sort of information would be useful to you in the soil stabilization manual to be developed as a part of this project?

- ❒ Description of common additives available, including cost data
- ❒ Description of common soil types available in Alaska
- ❒ Procedure for selecting the most appropriate additive, considering soil type and climate
- ❒ Mix design procedures for the different additives
- ❒ Construction procedures for the different additives
- ❒ Expected performance of the different methods
- ❒ Other ____

9. Can you select a few representative projects for me to review in October/November to collect the following information

- ❒ Construction information
- ❒ Performance information, including photos of pavement condition
- ❒ Traffic information, past and future
- ❒ Climate data, historical temperature and participation

10. Please indicate the best times to meet with you on this project.

	First Choice	Second Choice	Third Choice
October	________________	________________	________________
November	________________	________________	________________

Person Interviewed:

Name: ____

Organization: ____

Address: ____

City: ____________________________ State: ________ Zip: ________________

Phone: ____________________________ Fax: ________________________________

E-mail: ____

APPENDIX B
Meeting Notes
October 23-26, 2000

ADOT&PF – Fairbanks
October 23, 2000

1) Attendees

- Steve Saboundjian
- Billy Connor
- Gary Hicks
- Leo Woster (absent)
- Dave McCaleb
- Denny Wohlgemuth

2) Purpose of Visit

- Performance of selected products
- Check list on field projects
- Soil types available in Northern Region
- Needs for manual – technology transfer. Include a workshop on the manual

3) Northern Region – Products

- Road Oyl – not effective at Birch Creek Airport
- Lignin sulfonate – not effective on South Cushman
- Remote airports – limits size of equipment which can be used to apply products
- CaCl – used on haul roads
- Permizine – not effective for long periods, similar to EMC^2
- EMC^2 – get McHatties notes comparing $CaCl_2$, EMC^2 on the Elliot Highway form ADOT&PF
- Mechanical stabilization – clays used to control dust. Stabilite was used on the Fort Yukon Airport runway to control dust

- Emulsion – CSS-1, Sheep Creek Road, Gold Stream (hot). Major problem with emulsions is curing time
- Lime – not used. Clay soils only found near Valdez and on Glenn Highway (see Gentrys & Esch report)
- RAP + aggregate base without and emulsion covered with 1½″ HMA – good results
- Geoweb – Shishmarif Airport – good performance (Note: McHattie says this included emulsion stabilized sands)

4) Northern Region – Soil Types

- Silty soils – loess or retransported silts
- Soft dirty aggregates – usually schist
- Sandy gravels or clayey gravels
- Shales – clays (Valdez)
- Soil map – get from GI

5) Projects

- Project control list – Dave McCaleb will identify
- Field project check list – Northern Region will provide this info

6) Selecting Treatment

- Material types
- Performance of last job – good or bad (things are not well documented and not much inspection) – past experiences often guide decisions
- Cost
- Contractability

- Traffic – must be able to maintain traffic flow

7) Mix Design

- Emulsions – According to Bob McHattie, criteria for bases was to limit frost susceptibility. Ran frost heave test using test developed by Esch. For surface materials used a variation of TAI mix design method.
- Chemicals – $CaCl_2$, EMC^2. Generally use suppliers recommendations or used frost heave test. Companies will often do the mix design at no cost.

8) Thickness Design

- Fines methods – AKPAVE
- AKOD – mechanistic (added Per Ullidtz base eq.)
- Frost susceptibility – what will reduce effects of frost

9) Performance Reports

- Emulsions – get Esch/Gentry report
- EMC^2 – get brochure including TTI report
- $CaCl_2$ – Dalton Hwy
- Elliot Highway – get experimental features report

10) Design Guide

- Section on each binder type
- When and where to use
- How to deal with frost susceptibility? (Check with Maureen Kestler at CRREL, Tom Scullian at TTI, and Dave van Dueson at MNDOT)
- Village roads and airports – specific guides for dealing with remote locations

ADOT&PF – Fairbanks
October 24, 2000

1) Attendees

- John Bennett
- Steve Saboandjian
- Denny Wohlgemuth
- Bob McHattie

2) Needs

- Types of additives – benefits and limitations
- Selection of additives
- Design contents / procedures
- Construction / constructability issues

3) Combinations of Additives

- Lime for clayey soils or gravels
- Lime-fly ash for non PI soils
- Chemicals – can they be mixed
- Emulsions – use of lime or cement to accelerate cure or deal with charge on aggregate

ADOT&PF – Anchorage
October 25, 2000

1) Attendees

- Bob Lewis
- Scott Gartin
- Tom Moses
- Newt Bingham
- Eddie Wright
- John Rajek

2) Early History – WWII

- COE soil stabilization – WWII airports at Galena, Wainwright, Hooper Bay, McGraff, Bethel (check with Al Bush and Patty Miller, 907-451-2275)
- Check with Billy Conor regarding ADOT&PF history. Get UAF reports by Professor Klaus Naske, Department of History
- Alyeska Pipeline – used some emulsion stabilization (check with Larry Ostermeyor at 970-278-1611)

3) Stabilization Techniques

- Portland cement (PC) – airports, Glen Highway, Bethel, Northern Airport
- PC-emulsion – need a specification
- Emulsions – CSS-1
- Chemicals – $CaCl_2$, Road Oyl (Homer), and Permizine (not effective) – limited use of chemicals

  (How to treat base with high fines. Include typical modulus values.)
- Mechanical stabilization – add fines to sand at airports
- Fabrics – used primarily for separation

- Fin or trench drains – used for drainage. Open-graded hot mix used at Kodiak

4) Soil Types

- Predominate – sily soils
- Some – muskegs
- Wind blow deposits – 10 to 50% passing #200

5) Factors Considered in Selecting Additives

- Cost of additive
- Soil type – has to work
- Constructability in remote areas – simple

6) Mix Design

- Emulsion – experience suggests that emulsion content cannot exceed optimum for compaction (see Section 307 and 308)
- Portland cement – see Bethel specs
- Chemicals – suppliers recommendations followed

7) Thickness – see internet / T^2 training

- AKOD – mechanistic (high traffic)
- AKPAVE – fines content
- Airports – FAA design procedure

8) Performance

- PC – good
- Emulsions – good
- Chemicals – poor to fair

9) Guides

- Include a section on drainage as a stabilizer (intercept water)

10) References

- TRR 1440
- TRB State of the Art Report #5 on Lime Stabilization
- NCHRP Synthesis 247
- American Coal Ash Assoc., 202-659-2313, Flexible Pavement Manual
- Soil Stabilization Products Co., 800-523-9992, Geoweb, EMC^2, Road Oyl, Stabilite
- Portland cement – see article by Lutfi Raad, 1988 TRB Record
- Geofoam, 202-974-5227

11) Other Possible Contacts

- Chuck Lloyd (retired) – Lab Manager
- Jim Wright (retired) – Field Inspector

ADOT&PF – Juneau
October 26, 2000

1) Attendees

- Bruce Brunette
- Pat Kemp
- Kirby Wright
- Gary Hayden
- Greg Patz

2) Products used

- PC – City of Juneau
- Emulsion (with and without PC), 1% PC accelerated cure
- Chemicals (stabilizer, etc.) – get report
- Mechanical (geotextiles)
- $CaCl_2$
- Permizine – to be evaluated

3) Soil Types

- Silty soils
- Peat / muskeg
- Silty sands

4) Selection of Additives

- Silty soils – emulsion, chemicals (experimental only)
- Peak /muskeg – geotextiles, geofoam

5) Factors Considered in Selecting Additives

- Cost

- Availability of additive
- Equipment availability

6) Mix Design

- Emulsion – experience based, 50-blow Marshall. They look primarily at stability and unit weight to determine emulsion content. All Marshall tests are performed at room temperature. Generally use about 2% emulsion and add 1% PC to accelerate cure.
- Chemicals – uses suppliers recommendations

7) Thickness Design

- AKOD – mechanistic design
- AKPAVE – fines method

8) Performance

- Emulsion – good
- Chemicals – experimental only
- Fabrics – fair to good (10 oz. Amoco)
- Geofoam – experimental only

9) Design Manual

- How soon can you apply traffic?
- Include other useful references / web sites

APPENDIX C
Slide Presentation

Soil Stabilization Seminar for ADOT&PF

by

R. Gary Hicks (OSU)

and

Jon A. Epps (UNR)

Updated December 2000

Civil, Construction and Environmental Engineering
Oregon State University

Background

- ADOT&PF wishes to increase the use of locally available aggregates.
- Increased use of stabilizing additives can make this happen.
- ADOT&PF needs information to determine the right additive for a given soil type and given use, particularly for use as surface courses.

Purpose of Course

- Provide an overview of various soil stabilization techniques (lime/lime-fly ash, portland cement, asphalt, chemicals)
- Discuss mix properties, mix design, and construction techniques
- Present do's and don'ts for the various stabilization procedures

Reasons for Using Stabilization

- Temporary wearing surface
- Working platform for construction activities
- Improve poor subgrade conditions
- Upgrade marginal base materials
- Dust control
- Salvage old roads containing marginal materials

Scope of Seminar

- Introduction
- Overview of stabilization techniques
- Stabilization with lime/lime-fly ash
- Stabilization with cement
- Stabilization with asphalt
- Stabilization with other additives (salts and chemicals)
- Wrap-up

Overview of Stabilization Techniques

- Types of soils
- Types of stabilizers
- Selection of stabilizer type

Types of Soils - Alaska

- Poor to well-graded gravels
- Coarse to fine sands
- Inorganic to slightly organic silts
- Clayey gravels (rare)
- Clays (rare)

Types of Stabilizers

- Cementing (strength gain)
  - lime
  - lime/fly ash
  - portland cement
  - asphalt
- Modifiers
  - lime
  - chemicals

Types of Stabilizers (cont.)

- Waterproofers
  - bitumens
  - chemicals
- Water-retainers
  - salts

Description of Stabilizer Effect

- Cementing agents
  - Bond together individual or aggregates of soil particles (lime, cement, asphalt)
  - Portland cement and lime react with clay minerals (a *pozzolanic* reaction), lime/fly ash is effective when the clay mineral contents are low.
  - Portland cement - hydrates and produces a strong cementing agent.
  - Increase *strength*. In roads, this can reduce the thickness of pavement needed.

Description of Stabilizer Effect *(cont.)*

- Modifiers
  - Change properties of water (absorbed layer)
  - Reduce plasticity (raise optimum water content)
  - Improve workability
  - Modify clay minerals

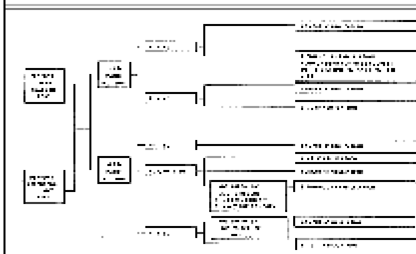
Description of Stabilizer Effect *(cont.)*

- Waterproofers
  - Retard or completely stop water absorption
- Water retainers (e.g. calcium and sodium chloride)
  - Lower vapor pressure - soil stays moist
  - Lower freezing point - mitigates frost damage

Selection of Stabilizer Type

Soil Types	Most Effective Stabilizers
1. Coarse granular soils	Asphalt, portland cement, lime-fly ash
2. Fine granular soils	Portland cement, lime-fly ash, asphalt, chlorides
3. Clays of low plasticity	Portland cement, chemical waterproofers, lime, lime-fly ash
4. Clays of high plasticity	Lime

Guide to Choice of Admixtures



Factors to Consider in Selection of Admixture

- Gradation
- PI
- Availability of admixture
- Economics

(See pps. 13-26, Vol. II)

Climatic Limitations/ Construction Safety Procedures: Lime and Lime-Fly Ash

Climatic Limitations	Construction Safety Precautions
• Do not use with frozen soils	• Quicklime should not come in contact with moist skin
• Air temperature should be 40°F (5°C) and rising	• Hydrated lime [$Ca(OH)_2$] should not come in contact with moist skin for prolonged periods of time
• Two weeks of warm to hot weather are desirable prior to fall and winter temperatures	• Safety glasses and proper protective clothing should be worn at all times

Climatic Limitations/ Construction Safety Procedures: Cement and Cement-Fly Ash

Climatic Limitations	Construction Safety Precautions
• Do not use with frozen soils • Air temperature should be 40°F (5°C) and rising • Complete stabilized layer one week before first hard freeze	• Cement should not come in contact with moist skin for prolonged periods of time • Safety glasses and proper protective clothing should be worn at all times

Climatic Limitations/ Construction Safety Procedures: Asphalt

Climatic Limitations	Construction Safety Precautions
• Air temperature should be above 50°F (10°C) when using emulsions •Air temperature should be 40°F (5°C) and rising when placing thin lifts (1-in.) of hot mixed asphalt concrete • Hot, dry weather is preferred for all types of asphalt stabilization	• Some cutbacks have flash and fire points below 100°F (40°C) • Hot mixed asphalt concrete temperatures may be as high as 350°F (175°C)

Climatic Limitations/ Construction Safety Procedures: Chemicals

Climatic Limitations	Construction Safety Precautions
• Do not use with frozen soils • Chemicals are more active at high temperatures	• Require MSDS for each chemical

Stabilization with Lime/ Lime-Fly Ash

- Suitable types of soils
- Soil-lime/lime-fly ash reactions
- Properties of treated soils
- Mix design
- Construction
- Do's and Don'ts

Definitions: Lime/Fly Ash

- Lime
  - All classes of *hydrated lime or quicklime*, both calcitic and dolomitic (ASTM C593). If there are little or no pozzolans in a soil, these can be provided by *fly ash*.
- Fly ash (pozzolan) - ASTM definition
  - "Siliceous or siliceous and aluminous materials which in themselves possess little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties."

Types of Lime

- CaO - calcitic quicklime
- $CaO+MgO$ - dolomitic quicklime
- $Ca(OH)_2$ - high calcium hydrated lime
- $Ca(OH)_2+MgO$ - monohydrated dolomitic lime
- $Ca(OH)_2+Mg(OH)_2$ - dyhydrated dolomitic lime

By-Product Lime

- Lime kiln dust - draft of lime kilns
- Carbide lime - acetylene gas production

Types of Lime/Fly Ash Mixtures

- LFA - mixture of lime and fly ash with aggregate
- LCFA - mixture of lime, cement, and fly ash with aggregate
- LFS - mixture of lime and fly ash with soil

Suitable Soils

- Without fly ash
  - Clays
  - Clayey soils
- With fly ash
  - Sands
  - Gravels

Problem Soils

- High PI clays
- Soils with sulfates
- organics

Soil-Lime/Lime-Fly Ash Reactions

- Short term
  - Ion exchange
  - Flocculation
- Long term
  - Pozzolanic reaction
  - Carbonation

Cation Exchange and Flocculation-Agglomeration

- Reduction in adsorbed water layer
- Increased shear strength
- Improved workability

Formation of Diffused Water Layer Around Clay Particle

Pozzolanic Reactions

- $Ca^{++} + OH^{-} + SiO_2 \rightarrow CSH$
- $Ca^{++} + OH^{-} + A_2O_3 \rightarrow CAH$

Carbonation

- $CaCO_3 + \text{heat} \rightarrow CaO + CO_2$
- $CaO + H_2O \rightarrow Ca(OH)_2$
- $Ca(OH)_2 + CO_2 \rightarrow CaCO_3$

Properties of Treated Soils

- Uncured mixtures
  - Plasticity and workability
  - Moisture - density relations
  - Swell potential
- Cured mixtures
  - Strength and deformation properties
  - Shrinkage
  - Durability
  - Wear resistance

(See Vol. 2, pp. 56-71)

Mix Design

- Procedures
  - Approximate
  - Based on strength
- Range in contents used
  - Lime - 2 to 8%
  - Fly ash - 8 to 36%

Selection of Lime Content

- PI vs. lime content
- pH 12.4 test
- Strength requirements

Lime-Fly Ash Typical Contents

- Lime - 2.5 to 4%
- Fly ash - 10 to 15%

Construction

- Mixing
- Placing
- Compaction
- Curing
- Need for surface treatment

(See Vol. I, pp. 39-59)

Do's and Don'ts

- Do's
  - Use quality lime
  - Compact after flocculation has occurred
- Don'ts
  - Allow carbonation to take place
  - Use clay with NP soils or soils with organics

Stabilization with Portland Cement

- Suitable types of soils
- Soil-cement/cement hydration reactions
- Properties of treated soils
- Mix design
- Construction
- Do's and don'ts

Portland Cement

- Produced by pulverizing clinker consisting of hydraulic calcium silicates, and usually containing one or more forms of calcium sulfate (ASTM C-1)
- Reactions include both short- and long-term ones

Other Definitions

- *Cement Stabilized Soil*: Mixture of soil and measured amounts of portland cement and water which is thoroughly mixed, compacted to a high density and protected against moisture loss during a specific curing period.
- *Soil-Cement*: Hardened material formed by curing a mechanically compacted intimate mixture of pulverized soil, portland cement, and water. Soil-cement contains sufficient cement to pass specified durability tests.

Other Definitions (cont.)

- *Cement-Modified Soil*: Unhardened or semi-hardened intimate mixture of pulverized soil, portland cement, and water. Significantly smaller cement contents are used in cement-modified soil than in soil-cement.

Suitable Soil Types

- Good for most sands/gravels
- Also suitable for fine-grained soils with low to medium plasticity (< PI 30)

Soil Cement Reaction

- Ion exchange
- Flocculation
- Pozzolanic reaction
- Carbonation
- Portland cement hydration

PC Hydration

- $C_3S + H \rightarrow C_3S_2H_3 + CH$
- $C_2S + H \rightarrow C_3S_2H_3 + CH$
- $C_3A + H \rightarrow C_3A_3C\bar{S}H_{30}$

  $C_3AC\bar{S}H_{12}$

Types of PC

- I - normal
- II - modified
- III - high early strength
- IV - low heat
- V - sulfate resistant

Properties of Treated Soils

- Compaction characteristics
- Strength and deformation characteristics
  - Tensile
  - Moduli
  - Fatigue
- Durability
  - Shrinkage
  - F/T resistance
- Surface wear resistance

Mix Design

- Procedures
  - Approximate
  - Detailed testing
- Typical contents (Tables 14, 15, of Vol. II)

(See pps. 87-91, Vol. II)

Typical Cement Contents

Classifications		Recommended	Allowable
AASHTO	USCS	%PC* (wt)	Loss** (%)
A-1-a	GW, GP, GM, SW, SP, SM	3-5	14
A-1-b	GM, GP, SM, SP	5-8	14
A-2	GM, GC, SM, SC	5-9	14
A-3	SP	7-11	14
A-4	CL, ML	7-12	10
A-5	ML, MH, CH	8-13	10
A-6	CL, CH	9-15	7
A-7	OH, MH, CH	10-16	7

* Range to achieve satisfactory strength and durability

** Loss in weight after freeze-thaw or wet-dry test (ASTM 599 or 560)

Construction

- Mixing
- Placement
- Compaction
- Curing
- Need for surface treatment

(See Vol. I, pp. 39-59)

Do's and Don'ts

- Do's
  - Use good quality cement
  - Provide for thorough mixing
  - Must provide for moist curing
- Don'ts
  - Use with plastic soils

Stabilization with Asphalt

- Suitable types of soils
- Soil - asphalt reactions/asphalt breaking and curing
- Properties of treated soils
- Mix design
- Construction
- Do's and don'ts

Reasons for Use

- Waterproofing fine-grained soils
- Upgrading marginal materials
- Provide temporary/permanent wearing surfaces
- Reduce dusting

Definitions

- *Asphalt Cement*: A flux or unfluxed asphalt specially prepared as to quality and consistency for direct use in such construction industries as highways and structures.
- *Cutback Asphalt*: Asphalt cement that has been made liquid with the addition of petroleum diluents such as naphtha and kerosene.

Definitions (cont.)

- *Emulsified Asphalt*: Asphalt cement that has been mechanically liquified with the addition of emulsifying agents and water.

Types of Asphalts

- Emulsions (Anionic and cationic)
  - Slow setting (SS)
  - Medium setting (MS)
- Cutbacks
  - Slow cure (SC)
  - Medium cure (MC)
  - Rapid cure (RC)
- May be used with lime/cement

Suitable Soils

- Nonplastic sands (PI < 10)
- Nonplastic gravels (PI < 6)

Soil - Asphalt Mechanisms/ Asphalt Breaking and Curing

- Mechanisms
  - Waterproofing
  - Adhesion
- Breaking and curing
  - Breaking (chemical)
  - Curing (evaporation)

Properties of Treated Soils

- Strength and deformation characteristics
  - Compressive
  - Tensile
  - Moduli
- Durability
  - F/T resistance
  - Stripping
- Fatigue
- Surface wear resistance

Mix Design

- Procedures
  - Selection of asphalt type and grade
  - Approximate quantities
  - Detailed testing procedures
- Typical asphalt contents
  - 5 to 10%
  - Depends on aggregate gradation/absorption

Construction

- Mixing (in place or central plant)
- Placement
- Compaction
- Curing
- Need for surface treatment

Do's and Don'ts

- Do's
  - Select the right asphalt for the job
- Don'ts
  - Use asphalt with high plasticity clays
  - Construct in cold weather

Stabilization with Other Additives

- Suitable types of soils
- Reactions between additives/soil
- Properties of treated soils
- Mix design
- Construction and maintenance hints
- Do's and don'ts

Other Additives

- Salts
- Synthetic polymer emulsion
- Tree resin emulsion (e.g., lignins)
- Other snake oils

Salts - General

- Can use either $CaCl_2$ or $MgCl_2$
- Important benefits
  - Improves compaction
  - Retains moisture
- Recommended with >10% P200
- Comes in liquid/pellet form
- Can be used in base or wearing surface

Salts - Design

- Typically use between 6 to 10 lbs of solid per ton of aggregate
- Equates to 1.6 to 2.6 gal/ton of aggregate for 38% solids $CaCl_2$

Salts - Construction Hints

- May have to apply in a series of passes to prevent runoff
- Best to apply when aggregate is damp
- Compact close to optimum moisture content

Salts - Maintenance Hints

- Can be bladed dry, but best if bladed with some moisture present
- Salts will leach with time

Lignins - General

- By-product of wood pulping process
- Physically binds materials together
- Can be used to treat base/surface aggregates

Lignins - Design

- Typically mix 1 part lignin to 1 part H_2O
- Total diluted application rate is close to 2 gals/sy for 4 to 6 in. depth
- Applied in multiple spray applications (~3)

Lignins - Construction Hints

- Mixing
  - Blade
  - Rototiller
- Apply in 3 applications
  - 0.6 gal/sy
  - 1.0 gal/sy
  - 0.4 gal/sy

Lignins - Maintenance Hints

- Hard crust is formed, so blade when road surface is moist
- Lignin is water soluble

Other Stabilizers

- Electrolytes and enzymes
- Latex acrylic polymer emulsions
- Tree resin emulsions

Do's and Don'ts

- Do's
  - Use lime, cement, or asphalt in most cases
  - Ask for experience of others
- Don'ts
  - Be sold on these products as the best solution

Wrap-Up

- General conclusions
- Questions/answers