The Use of Nontraditional Stabilizers for Construction of Airports in Alaska

B. Connor
Alaska University Transportation Center, University of Alaska, Fairbanks, USA

S. Saboundjian
Alaska Department of Transportation and Public Facilities, Anchorage, USA

ABSTRACT: The cost of constructing unsurfaced gravel airports in rural Alaska can easily reach between $30 and $40 million due to the lack of gravel. The lower Kuskokwim and Yukon River delta soils consist entirely of fine silts and sands. Consequently, any gravel required must be imported at a cost of $300 to $600 per cubic yard ($392 to $785 per cubic meter). In an effort to reduce these costs, the Alaska University Transportation Center, in partnership with the Alaska Department of Transportation and Public Facilities developed the use of two part chemical stabilizers to stabilize local marginal materials. Several stabilizing products were incorporated in silt and sand in an effort to find the optimal and most cost-effective stabilizer. These products included geofiber, chemical stabilizers, and curing agents. Laboratory work included California Bearing Ratio and unconfined compressive strength tests on Horseshoe Lake sand, Fairbanks silt, and other standard sands. Test results revealed that sand-geofiber mixtures should contain an optimum amount of fines (silt) to mobilize the mix strength effectively. It was also found that the inclusion of an optimum geofiber content in Fairbanks silt (0.2% geofiber by weight) and in Horseshoe Lake sand (0.5% geofiber by weight) maximizes their bearing capacity. Using chemical stabilizers in conjunction with curing additives, bearing capacity was also enhanced as evidenced by unconfined compressive strengths of 1,100 psi (7.6 MPa) achieved for the sands and 600 psi (4.1 MPa) for the silts. This research showed that strength and bearing capacity enhancement of Alaskan marginal soils at airfield construction sites is feasible and cost-effective through the use of nontraditional stabilizers. Future research will evaluate the durability and freeze-thaw susceptibility of these optimized soil-stabilizer mixes.

KEY WORDS: Stabilization, marginal soils, geofiber, chemical stabilizer, curing agent.

1 INTRODUCTION

Soil Stabilization has long been used to improve the engineering properties of soils such as soil strength and bearing capacity. It is used for temporary wearing surfaces, for enhancing marginal soils and dust management. Soil stabilization techniques include:

- Mechanical stabilization including modifying the gradation,
- Soil additives including asphalt, Portland cement, lime/fly ash, salt and chemicals,
- Soil reinforcement through the use of geosynthetics, addition of geofibers and soil confinement systems.

Recent advances in chemical stabilizers and soil reinforcement fibers offer new opportunities to reduce the cost of road and airport construction where quality construction materials are unavailable. Western Alaska, especially in the Kuskokwim and Yukon River deltas, lack gravel suitable for construction. Consequently, gravel is typically imported at a cost between \$300 and \$600/yd^3 (\$392 to \$785/m^3). As a result, the construction of a 1,220 meter runway can often reach \$40 million. Soil stabilization offers the opportunity to reduce these costs by 25% (Collins and Connor 2011).

The Alaska University Transportation Center (AUTC) in partnership with the Alaska Department of Transportation and Public Facilities (ADOT&PF), and the US Department of Transportation's Federal Highway Administration (USDOT-FHWA), evaluated the use of geofibers and chemical stabilizers to stabilize sands and silts commonly found in Alaska.

2 BACKGROUND

The use of geofibers and chemical stabilizers were introduced to Alaska at Cape Simpson in 2005 (Hazirbaba et al. 2007, 2009). The application of 2-inch (51 mm) tape geofibers and a synthetic fluid (EnviroKleen) to a sandy soil was successful in constructing a storage pad for oil exploration.

A follow-on project showed that the California Bearing Ratio (CBR) for Alaska's Bethel silty-sand could be improved by at least 100% with the addition of 0.5% geofiber. The addition of the synthetic fluid along with the geofibers improved the CBR by 340%. In addition, unconfined compression (UC) tests showed that the behavior of the treated silty-sand was similar to a gravelly soil rather than a sandy soil. UC tests also showed that the addition of geofiber increased the apparent cohesion of the Bethel silty-sand from 2.9 psi to 23.5 psi (20 kPa to 163 kPa). The angle of friction increased by about 2 degrees. However, the addition of 3% synthetic fluid by weight resulted in an increase of cohesion to 13.9 psi (96 kPa).

This preliminary research and field application described above showed that soil properties and bearing capacity could be improved with the addition geofibers and synthetic fluids. As a result, the ADOT&PF funded a study in partnership with AUTC to further investigate the effects of incorporating geofibers and synthetic fluids in common Alaskan soils to enhance their bearing capacity.

3 STABILIZATION WITH GEOFIBERS

The first phase of the laboratory investigation studied the effect of geofiber addition to the following soil types:

- Ottawa sand, and silt modified Ottawa sand,
- Monterey sand, and silt modified Monterey sand,
- Horseshoe Lake sand, and
- Fairbanks silt.

The Ottawa and Monterey sands were included in the study for benchmarking purposes. To evaluate the load-bearing capacity of the soil-geofiber mixes and to assess the effectiveness of the addition of geofiber, CBR tests (ASTM D1883) were performed on soil specimens prepared in the laboratory according to ASTM D1557 procedures. Reported test results are the average of three replicate specimens. Material properties, sample preparation and testing details are presented elsewhere (Collins 2011).

Two types of fibers were used in this phase, tape and fibrillated. Fiber length varied between 0.75 and 1.5 inches (19 – 38 mm). The optimum length of fiber was found to be 1.25

inches (32 mm) for most soil. While tape fibers performed slightly better for the tested sands, the benefits shown were not great enough to specify one type of fiber over the other (Collins 2011).

3.1 Ottawa Sand Stabilization

The first series of tests used Ottawa sand (CBR=19) to which Fairbanks silt being added as fines. To evaluate the influence of the addition of tape geofiber and fines on the Ottawa sand, an analysis of variance (ANOVA) was performed on the test results. Equation 1 shows the resulting multiple linear regression. The analysis revealed that there is a significant effect of % geofiber, % fines, and their interaction (at a 95% confidence level) on the CBR value of the stabilized Ottawa sand.

$$CBR = 2.245\,X_1 + 81.326\,X_2 - 2.052\,X_1X_2 \qquad (R^2 = 0.845) \qquad \text{Equation 1}$$

Where X_1 = % geofiber; X_2 = % fines.

Figure 1 shows that, when no geofiber is used, the addition of 30 % silt increased the soil CBR significantly. At 20% fines content and below, the impact was minimal on CBR. As the silt content increased, so did the effectiveness of the geofiber until the silt content reached 30%. At this point, the addition of geofiber decreased the bearing capacity of the soil. At the 20% fines level, the influence of the fines on the geofiber performance limits the amount of geofiber to 0.5 %. This is probably due to the silt beginning to fill the voids in the sand likely reducing the friction between fibers and sand particles.

3.2 Monterey Sand Stabilization

Soil-geofiber mixtures of Monterey sand (CBR=18) and Mabel Creek silt (fines) were tested next. Using CBR test results, the ANOVA assessed the influence of the addition of geofiber and fines on the modified Monterey sand. The resulting multiple linear regression is shown in Equation 2. The analysis showed that there is a significant effect of % geofiber, % fines, and their interaction (at a 95% confidence level) on the CBR value of the stabilized Monterey sand.

$$CBR = 1.427\,X_1 + 98.606\,X_2 - 2.379\,X_1X_2 \qquad (R^2 = 0.854) \qquad \text{Equation 2}$$

Where X_1 = % geofiber; X_2 = % fines.

As depicted in Figure 2, when no geofiber is used, the addition of fines between 20% and 50% increased the CBR of the Monterey sand. At 10% fines, the presence of silt had little impact. At the 70% fines level, the CBR of the sand began to decrease. It appears that a 50/50 blend of sand and silt is about optimum to maximize the sand's bearing capacity when no geofiber is used.

The greatest improvement due to the geofiber was found at 20% fines. At this point the optimum fiber content was observed to be 0.5%. At 30% fines, the optimum fiber content was found to be 0.2% after which the strength fell off rapidly. As with the Ottawa sand, it appears that above 30% fines, the amount of sand particles in contact with the fibers is reduced thus decreasing the friction between the soil and the fibers. Above 30% fines, even small amounts of geofiber reduced the sand's CBR. Testing of silt will be discussed later.

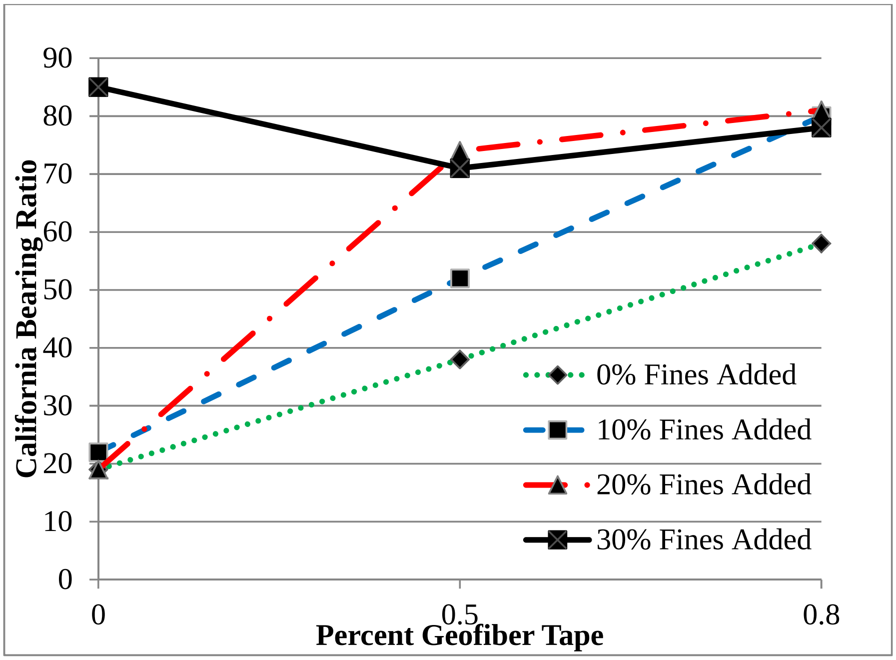

Figure 1: Influence of geofiber and fines on Ottawa sand bearing capacity.

3.3 Horseshoe Lake Sand Stabilization

Horseshoe Lake sand was used in an experimental field application near Wasilla, Alaska, about 40 miles north of Anchorage. Horseshoe Lake sand is an Aeolian sand (CBR=25) which originated in the glaciers of the area. Its gradation is shown in Figure 3 for three replicates. Figure 4 illustrates the influence of geofiber incorporation into the Horseshoe Lake sand. The addition of geofiber to the sand increases its CBR. In this case, an optimum amount of geofiber of 0.5% maximizes the sand CBR.

3.4 Fairbanks Silt Stabilization

To understand the relationship between soil bearing capacity and inclusion of geofibers in silty soils, CBR tests were performed on Fairbanks silt with geofiber contents varying between 0.2% and 1.0%. The properties of the untreated Fairbanks silt are summarized in Table 1. Fairbanks silt is an Aeolian silt possessing a uniform gradation. Consequently, this silt performs much like a very fine sand.

Figure 5 shows the effect of geofiber inclusion on the CBR of Fairbanks silt. It is seen that a small inclusion of 0.2 % geofiber almost doubled the CBR of the silt. An optimum geofiber percentage exits beyond which any strength improvements are minimal or reduced. Consequently, the use of geofiber in silty soils must be carefully controlled.

In summary, from the CBR testing carried out on the four soil-geofiber mixes described above, it was clear that geofibers are beneficial in stabilizing sand, silt and silty sands. However, geofibers' impact is questionable when the sand contains more than about 30% silt. In this case, test results suggest that the inclusion of geofibers may cause a reduction in soil CBR. However, when 100% silt is used (e.g. Fairbanks silt), there is a benefit to adding a small percentage of geofiber of about 0.2%.

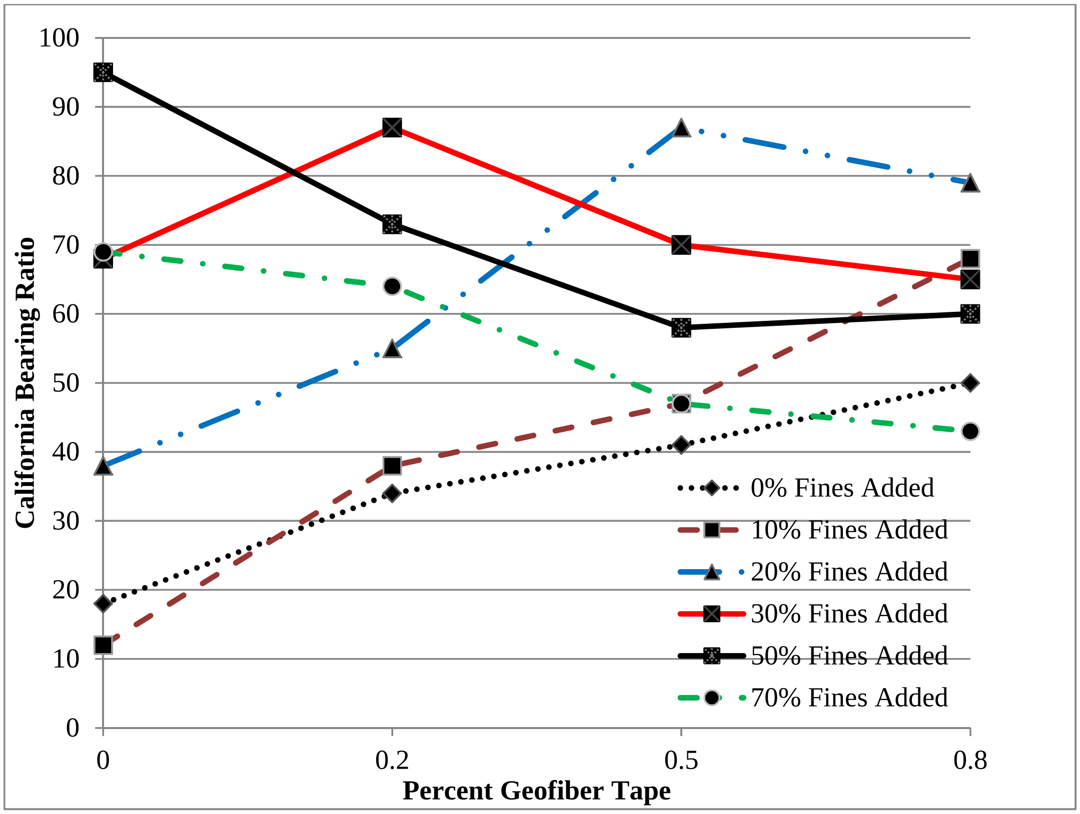

Figure 2: Influence of geofiber and fines on Monterey sand bearing capacity.

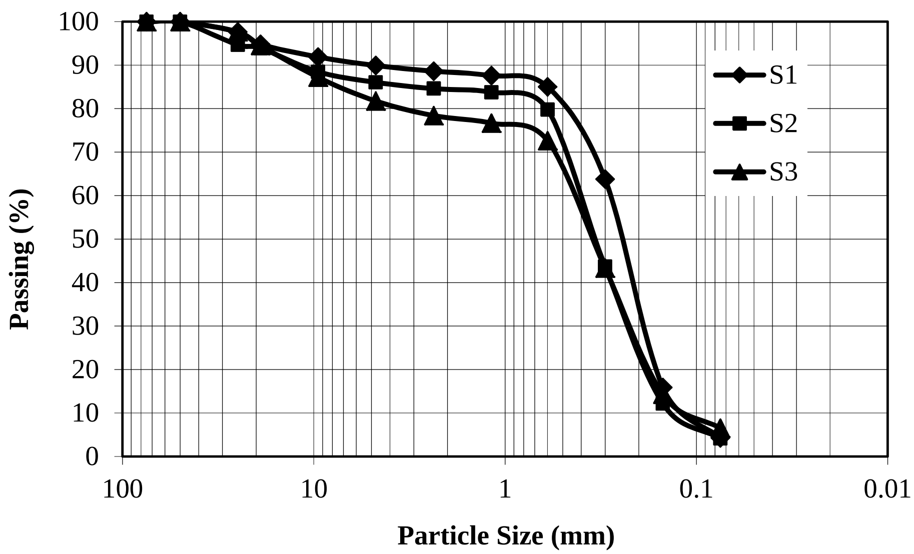

Figure 3: Horseshoe Lake sand gradation.

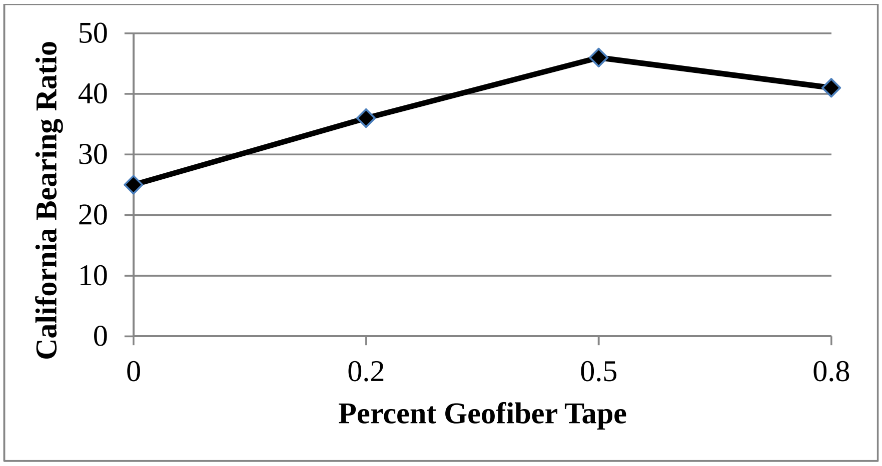

Figure 4: Influence of geofiber on Horseshoe Lake sand bearing capacity.

Table 1: Characteristics of untreated Fairbanks silt compacted specimens.

Unsoaked dry density, pcf (KN/m^3)	107 (16.7)
Optimum moisture content, w, %	12
Initial Modulus, psi (MPa)	1564 (11)
Undrained shear strength, psi (KPa)	11 (77)
Unsoaked CBR	34
Soaked dry density, pcf (KN/m^3)	106 (16.7)
Soaked w, before shear, %	21
Initial Modulus, psi (MPa)	374 (3)
Undrained shear strength, psi (KPa)	6 (40)

4 STABILIZATION WITH CHEMICAL STABILIZERS AND GEOFIBERS

In this phase of the laboratory work, the Fairbanks silt was stabilized by adding separately two different chemical stabilizers along with the addition of 0.5 % geofibers. The chemical stabilizers used were:

- SoilTac: A vinyl copolymer emulsion produced by Soilworks. Also available in powdered form. It was added to the silt at dosages of 0.66%, 1.1 %, and 4% by weight.
- DirtGlue: An aqueous acrylate polymer emulsion manufactured by DirtGlue Enterprises. It was added at a rate of 3.3%. In addition, PolyCure, a curing agent was added at two dosages of 5% and 10% by weight.

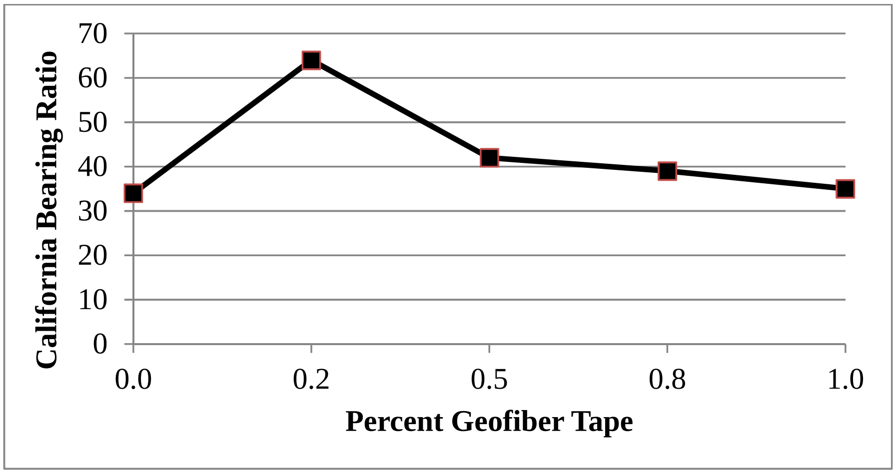

Figure 5: Influence of geofiber on Fairbanks silt bearing capacity.

4.1 Stabilization with SoilTac

CBR testing of the Fairbanks silt found that an optimum amount of SoilTac stabilizer (1.1%) maximizes the bearing capacity of the stabilized soil (with 0.5% geofiber). A fourfold increase in CBR was measured (CBR~54) compared to the untreated silt.

4.2 Stabilization with DirtGlue

For the DirtGlue stabilization case, a sevenfold improvement in bearing capacity (CBR~95) was achieved by the addition of 0.5% geofiber, 3.3% DirtGlue stabilizer, and 10% PolyCure curing agent.

Results from this preliminary work were promising enough to continue the testing program in order to find an optimized soil-stabilizer combination. It was clearly evident that the presence of a curing agent had a significant effect on the bearing capacity improvement of the stabilized silt. Therefore it was decided to use such curing agent in the next phase of the study.

5 STABILIZATION USING CHEMICAL STABILIZERS WITH CURING AGENTS

Since the test results from the addition of the curing agent PolyCure (PC) were encouraging, it was decided to test sand and silt specimens where the curing agent PolyCure is incorporated in soil samples in addition to three stabilizers separately:

- SoilTac (ST),
- DirtGlue (DGI), and
- SoilSement (SS).

SoilSement is a polymer emulsion stabilizer (aqueous acrylic vinyl acetate) manufactured by Midwest Industries.

While initial testing showed that the addition of geofiber may improve strength, it was decided to preclude the fiber from this phase of testing in order to isolate the effects of the combination of stabilizers and curing agents. Funding and time constraints did not allow the addition of fiber to be explored.

As the testing proceeded, a second curing agent, Extended Use (EU), manufactured by Midwest Industries, became available. Both curing additives, PC and EU, were tested, in combination with each of the three stabilizers, ST, DGI, and SS. No geofiber was used in this testing phase.

After preliminary testing, the CBR test proved to be inadequate to characterize the strengths achieved by the combination of stabilizer and curing additive. Consequently, unconfined compression testing was adopted to characterize the strength improvements of the stabilized soils.

In each case, the optimum stabilizer content derived from the CBR testing phase was used in testing with the curing agents PC and EU. The stabilizer contents chosen were 1.1%, 3.3%, and 4%, for the SoilTac, DirtGlue, and SoilSement, respectively. The dosage of the PC and EU curing agents was varied between 4 and 12 % in an effort to determine the influence of curing agent content on soil strength.

5.1 Fairbanks Silt Stabilization

As shown in Figure 6, unconfined compressive strength (UCS) of Fairbanks silt (Table 1) was significantly improved. All of the combinations provided reasonable increases in strength (rather linear) although those that contained either SoilSement or EU tended to be higher. At the highest dosage of curing agents (12 %), UCS values ranged between 400 psi and 640 psi (between 2.7 MPa and 4.4 MPa). This represents an increase between 18- and 29-fold in the untreated UCS (22 psi (152 kPa)) of the Fairbanks silt.

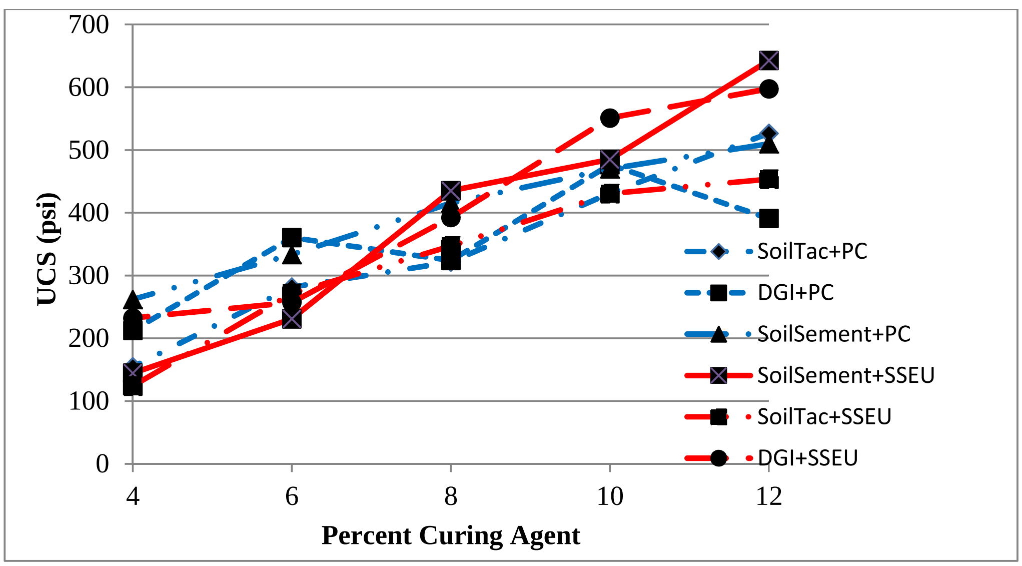

Figure 6: Unconfined compressive strength (UCS) variation with soil stabilizer type and dosage for Fairbanks silt. (1 psi = 6.895 kPa).

5.2 Horseshoe Lake Sand Stabilization

Figure 7 shows UCS values for the Horseshoe Lake sand. The PolyCure curing agent had a pronounced peak indicating that the PC optimum content for this sand was 10% by weight for SS and for DGI. A maximum UCS of 593 psi (4.1 MPa) was reached with a combination of PC and SS. However, curing agent EU behaved differently than PC for each stabilizer. With SS, the optimum strength of about 1100 psi (7.6 MPa) was obtained at 10% EU. With DGI, the maximum UCS of 729 psi (5 MPa) was reached at 8%. When used in combination with ST, the sand was still gaining strength at a EU dosage of 12%, where a UCS of 925 psi (6.4 MPa) was recorded.

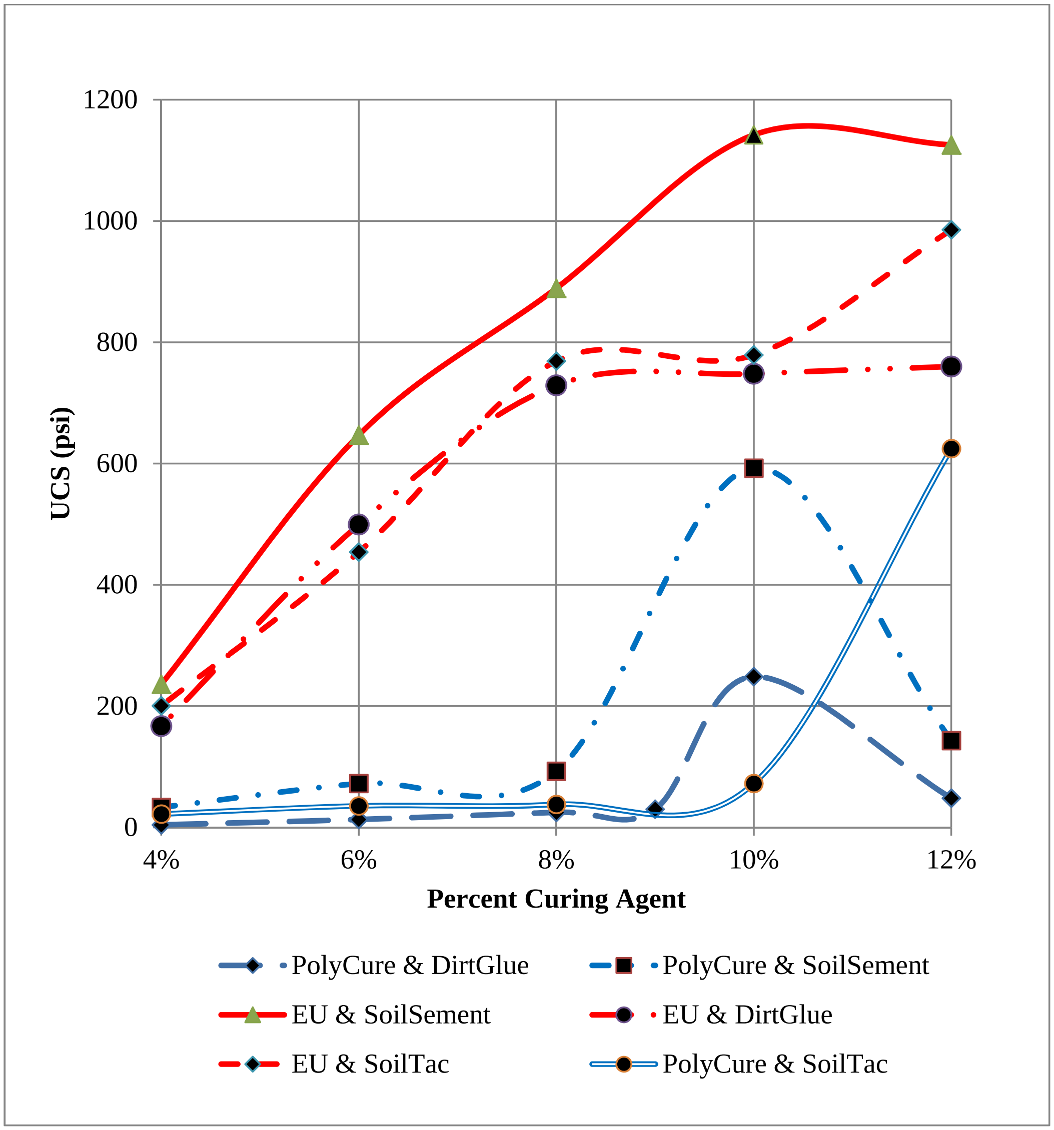

Figure 7: Unconfined compressive strength (UCS) variation with soil stabilizer type and dosage for Horseshoe Lake sand. (1 psi = 6.895 kPa).

6 SUMMARY AND CONCLUSIONS

Based on the laboratory work detailed in this paper, it was shown that bearing capacity enhancements of Alaskan marginal soils can be achieved through the use of non-traditional stabilizers, such as geofibers, chemical stabilizers and curing agents.

It was found that all three stabilization alternatives provided increases in soil strength and bearing capacity. Within the scope of this work, where no clayey soils were tested, it can be concluded that, while the two part systems worked for all soils tested, the use of geofibers should generally be limited to sand and silty sands. The best improvement in bearing capacity was achieved around 0.5% geofiber by weight. Test results revealed that when the amount of silt exceeds 30% by weight, the effectiveness of geofibers is diminished. If fibers are used in silts, the fiber content must be carefully controlled to assure improvement in stability.

Within the scope of this work, it is unclear which types of silt may benefit from the addition of geofibers. However, it is clear that small amounts should be used: the addition of 0.2 % geofiber improved the strength of Fairbanks silt significantly.

The addition of soil chemical stabilizers with geofibers can also provide improved soil strength and bearing capacity. However, the selection of stabilizer is critical since some stabilizers were shown to reduce the strength of the soil-geofiber mix. It is recommended that the proposed stabilizer be tested with the soil to determine its effectiveness and the level of bearing capacity improvement achieved.

The greatest soil strength gain was achieved with the use of a stabilizing fluid with the addition of a curing agent (no geofiber added). Sand had the greatest strength gain when a curing agent was added. Curing agent Extended Use was more effective in both silt and sand than PolyCure, although the difference was significant in sand. Based on the tests performed, the recommended starting dosage for Extended Use curing agent was found to be 10% by weight.

With the lack of suitable gravel for airfield construction in rural Alaska, it is anticipated that the incorporation of nontraditional stabilizers into local silty or sandy soils will significantly improve their strength and bearing capacity.

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