



Stabilization of Horseshoe Lake Road using Geofibers and Soil-Sement®

Final Report

AUTC # S12609

DTFH70-09-E-00020



Prepared by:

Billy Connor, PE
Rodney Collins

Date

Prepared for:

Alaska University Transportation Center
Duckering Building Room 245
PO Box 755900
Fairbanks, AK 99775-

Federal Highway Association
1200 New Jersey Avenue, SE
Washington, DC 20590

REPORT DOCUMENTATION PAGE			Form approved OMB No.	
Public reporting for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestion for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-1833), Washington, DC 20503				
1. AGENCY USE ONLY (LEAVE BLANK)		2. REPORT DATE		3. REPORT TYPE AND DATES COVERED
		April 3, 2012		Final Research Report (8/18/2009-12/31/2011)
4. TITLE AND SUBTITLE			5. FUNDING NUMBERS	
Stabilization of Horseshoe Lake Road using Geofibers and Soil-Sement®			G00005806-334659-68102	
6. AUTHOR(S)			DTFH70-09-E-00020	
Billy Connor, PE Rodney Collins			S12609	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)			8. PERFORMING ORGANIZATION REPORT NUMBER	
Alaska University Transportation Center P.O. Box 755900 Fairbanks, AK 99775-5900			S12609	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
Federal Highway Administration 1200 New Jersey Avenue, SE Washington, DC 20590				
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT			12b. DISTRIBUTION CODE	
No restrictions				
13. ABSTRACT (Maximum 200 words)				
One solution to reducing the cost of importing gravel in areas where available soils are predominately silts and sands is to stabilize the local soils with geofibers and synthetic fluids. There have been several studies which have evaluated improvements in soil strength using geofibers. Laboratory work at the Alaska University Transportation Center has shown that the use of geofibers in combination with synthetic fluids has the potential to stabilize silts and sands, making them usable for roadway and airport construction. A test 500 foot test section was constructed on Horseshoe Lake Road, near Wasilla, Alaska. The test section was comprised of 250 feet using six inches of geofiber and Soil-Sement® and 250 feet using twelve inches of geofiber and Soil-Sement®. The test section was monitored over 16 months for performance and soil strength. Overall the test section has performed well.				
14- KEYWORDS : soil stabilization, geofiber, synthetic fluid, silt, sand			15. NUMBER OF PAGES	
			38	
			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	

Table of Contents

List of Figures	III
List of Tables	III
Abstract	- 1 -
Acknowledgements.....	- 1 -
Introduction	- 2 -
Materials	- 4 -
Preliminary Testing	- 6 -
Construction.....	- 10 -
Initial Test Results	- 19 -
Week 1 and Week 3 Measurements (August 7 th and August 28 th , 2010).....	- 22 -
Measurements taken on September 7 th and October 7 th , 2010.....	- 27 -
2011 Field CBR Measurements	- 29 -
Discussion.....	- 32 -
Conclusions	- 34 -
References	- 35 -

List of Figures

Figure 1: CBR values of Horseshoe Lake sand treated with fibers.....	- 4 -
Figure 2: Horseshoe Lake soil gradation.....	- 5 -
Figure 3: Modified Proctor Curve	- 6 -
Figure 4: CBR values of Horseshoe Lake sand treated with fibers.....	- 7 -
Figure 5: CBR results of samples at 8% moisture treated with Soil-Sement	- 8 -
Figure 6: CBR results for samples at 4% moisture with Soil-Sement.....	- 8 -
Figure 7: CBR test results of using both Soil-Sement and geofibers.....	- 9 -
Figure 8: Fibers used on Horseshoe Lake road	- 13 -
Figure 9: Soil-Sement shipping totes	- 14 -
Figure 10: Soil-Sement applied from water truck.....	- 14 -
Figure 11: Roadway after being "fluffed"	- 15 -
Figure 12: Achieving uniform application of fibers.....	- 16 -
Figure 13: Rototilling geofibers	- 16 -
Figure 14: Final mixing of Soil-Sement and geofibers	- 17 -
Figure 15: Shaping and grading	- 17 -
Figure 16: Compacting roadway.....	- 18 -
Figure 17: Completed roadway	- 18 -
Figure 18: Roadway one week after construction.....	- 23 -
Figure 19: Roadway three weeks after construction (August 28 th , 2010)	- 25 -
Figure 20: Test section September 7, 2010	- 28 -
Figure 21: CBR over time	- 31 -

List of Tables

Table 1: CBR values 100 ft. immediately before start of construction (July 30 th)	- 20 -
Table 2: CBR values 100 feet immediately after end of construction (July 30 th).....	- 21 -
Table 3: CBR values of test section immediately after construction (July 31 st)	- 21 -
Table 4: CBR measurements one week after construction (August 7 th , 2010).....	- 24 -
Table 5: CBR measurements three weeks after construction (August 28 th , 2010).....	- 26 -
Table 6: CBR measurements September 7, 2010	- 27 -
Table 7: CBR measurements October 7, 2010	- 29 -
Table 8: CBR measurements May 22, 2011	- 30 -
Table 9: CBR measurements September 9, 2011	- 31 -

Abstract

One solution to reducing the cost of importing gravel in areas where available soils are predominately silts and sands is to stabilize the local soils with geofibers and synthetic fluids. There have been several studies which have evaluated improvements in soil strength using geofibers. Laboratory work at the Alaska University Transportation Center has shown that the use of geofibers in combination with synthetic fluids has the potential to stabilize silts and sands, making them usable for roadway and airport construction. A test 500 foot test section was constructed on Horseshoe Lake Road, near Wasilla, Alaska. The test section was comprised of 250 feet using six inches of geofiber and Soil-Sement[®] and 250 feet using twelve inches of geofiber and Soil-Sement[®]. The test section was monitored over 16 months for performance and soil strength. Overall the test section has performed well.

Acknowledgements

The authors wish to thank Amit Armstrong, Western Federal Lands Highway Division, FHWA for funding this study. The authors also wish to thank Dave Brangan, Peak Oil Industries for his assistance in constructing the test section and Melvin Main, Midwest Industries for his assistance in providing technical expertise and securing the Soil-Sement[®] for the project. We appreciate the work done by Dr. Kenan Harzibaba to develop the project specifications before leaving AUTC.

Introduction

In areas such as Western Alaska where there is little naturally occurring gravel, the cost of transporting gravel to the construction site is very expensive. For example, the cost of importing gravel to the Yukon/Kuskokwim delta can easily exceed \$600/yd. Local material in this area consists of fine sands and silts. In a few areas on the lower Kuskokwim, organic clays can be found. Typical airport embankment construction in these areas proceeds as follows. The local material is embanked and allowed to sit between two and four years to allow the embankment to drain. After the settlement period, a cap of gravel and surface course is placed. The process requires not only importing gravel, but also mobilization of construction equipment twice. The typical cost of a 4,000 foot runway in Western Alaska is between \$25 and \$35 million.

A more economical solution to importing expensive gravel is to use the local materials. The most common approach has been the use of Soil-Sement® (hereafter Soil-Sement). While successful in Bethel, Alaska, Soil-Sement has not been widely adopted. However, recent work using synthetic fluids and fiber reinforcement have shown promise.

Peak Oil Industries pioneered work in Alaska at Point Simpson on the northern coast, between Prudhoe Bay and Barrow (Brangan et. al. 2007). Peak Oil Industries used EnviroClean in concert with fibers to stabilize the sands on a storage pad. While the stabilization technique did not meet the needs of highway and airport construction, it did allow the site to be used for staging of oilfield equipment and supplies without importing gravel. Further, the technique allowed oil exploration to begin a year earlier.

Peak Oil Industries then hired the Alaska University Transportation Center to explore the use of synthetic fluids and geofibers on the sands common to Bethel, Alaska (Harzibaba et. al. 2007). In this study, the fluid used was Earth Armour Arctic. The study concluded that the use of 0.5% fibers increased the laboratory CBR from 31 to 62. The results of the Unconsolidated-Undrained Triaxial

Compression tests also showed an increase in friction angle from 41.8° to 53.6° and an increase in cohesion from 2.9 psi to 23.5 psi. The failure mode of the fiber-treated soil was similar to that of a granular material. The study also concludes that the fiber-treated soil became strain-hardened, which is again similar to the behavior of a granular soil. When 5% Earth Armour was added and aged for 10 days, CBR strengths of 124 were achieved. The study showed the combination of fibers and synthetic fluid could be used to stabilize fine-grained sands.

Geofibers and synthetic fluid is a developing technology. Additional laboratory work at the University of Alaska Fairbanks has shown that this technology can be used on a wide range of sands and silts to increase the bearing capacity of these soils ([Gullu and Hazirbaba, 2010](#)). Work by Jeb Tingle and others has also shown the value of this technique. (Tingle and Santoni, 2003)

The combination of geofibers and synthetic fluid have not been used extensively in the field yet, so moving the concept from laboratory experiments to field applications is the next step. Test sites are the only way of proving the performance of this technology. FHWA Federal Lands graciously funded the construction of a test section at Horseshoe Lake.

Horseshoe Lake is located near Houston, Alaska. The site is a road that travels around the perimeter of the lake; the section of road containing the soil used in this investigation is 520 feet long. The site was chosen because of the presence of poorly graded sand that is similar in nature to material found in more rural portions of Alaska. Visual inspection of the soil at Horseshoe Lake showed a small amount of fines, and very few large cobbles. A satellite picture of the site appears in [Figure 1](#). The Horseshoe lake site presents the advantage of being relatively close to Wasilla, making monitoring the road easy and affordable. The construction of the test site was provided by Peak Civil Technologies, a company based in Anchorage, Alaska.

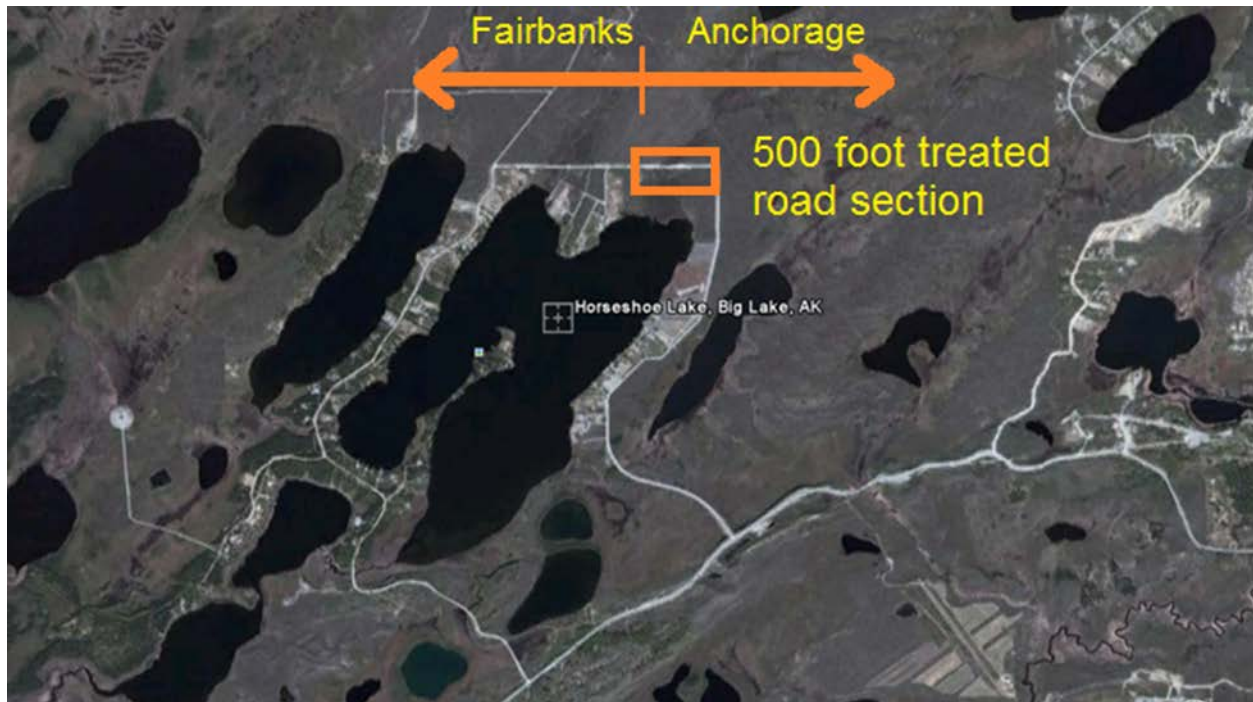


Figure 1: CBR values of Horseshoe Lake sand treated with fibers

Materials

The sand available at the site was tested for general soil properties in the laboratory at the University of Alaska Fairbanks. Tests performed to determine general soil properties were Sieve Analysis ([ASTM 422](#)), Modified Proctor Compaction ([ASTM D1557](#)), and Specific Gravity ([ASTM 792](#)). The particle size distribution curve is shown as [Figure 2](#). The original Horseshoe Lake samples are represented as S1, S2, and S3 on the particle distribution curve. Additional Horseshoe Lake sand was collected for testing because the initial collection did not yield enough material to finish all testing. In order to verify that the second material collected was relatively similar to that of the first samples, the grain size was examined. In [Figure 2](#), the curve titled "2nd collection of material" corresponds with these samples. The material that did not pass a #4 sieve was discarded prior to the ASTM 422 standard sieving process. This was done to remove some small organic material; there are no data points on the graph for that region. It should be noted that all tests after sieve analysis (CBR, specific gravity, modified

proctor compaction) were conducted with the material retained on the #4 sieve removed. The Horseshoe Lake sand is classified as SP, poorly graded sand according to USCS classification. The in-situ moisture content was found to be 3.3% and the specific gravity was determined to be 2.73.

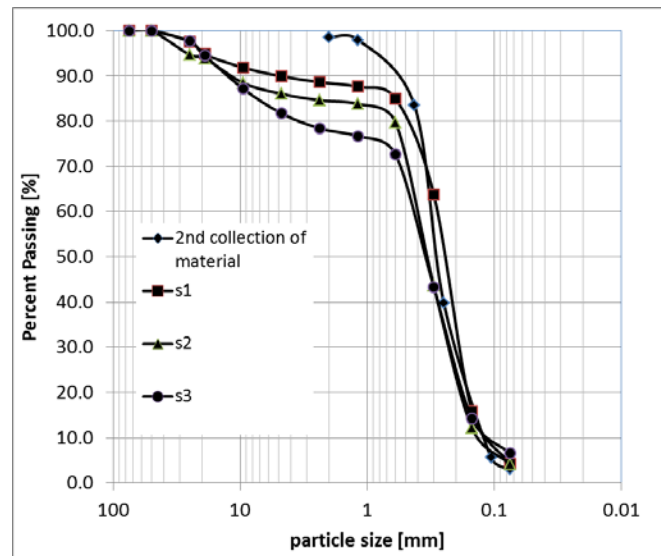


Figure 2: Horseshoe Lake soil gradation

Modified proctor compaction tests were used to determine the optimum moisture content and maximum dry density of the Horseshoe Lake sand. The samples were compacted using a mechanical compactor in a four inch mold. The maximum dry density obtained is 110.5 lb/ft^3 ; this was reached at the optimum moisture content of 13%, and Figure 3 shows the optimum moisture content curve.

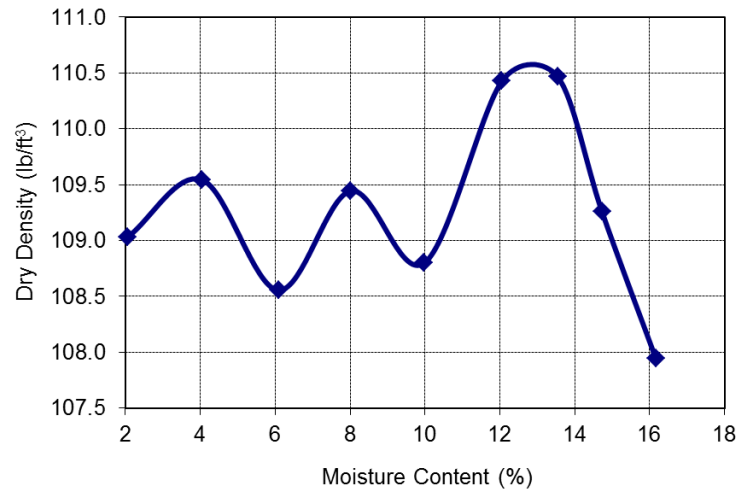


Figure 3: Modified Proctor Curve

Preliminary Testing

The test used to determine material strength in the laboratory was the California Bearing Ratio (CBR) test ([ASTM D1883](#)). Prior to construction at the Horseshoe Lake site, laboratory tests were completed to determine the amount of geofiber and Soil-Sement required to produce the greatest increase in strength.

The initial phase of laboratory testing examined the CBR value when varying amounts of fiber percentages were included. The fiber percentages used were 0.2%, 0.5%, and 0.8% by the dry weight of the soil; these were chosen based on the previous research by [Gullu and Hazirbaba \(2010\)](#). The fibers used during testing were fibrillated fibers two inches in length. The samples used in the fiber-only tests were unsoaked (that is, immediately after compaction the samples were tested). Only two moisture content levels were tested, 4% and 8%, because the change in dry density is fairly low (less than 1 lb/ft³). The results of the fiber-only testing are presented in [Figure 4](#). The optimum fiber content in both cases is 0.5% by the dry weight of the soil.

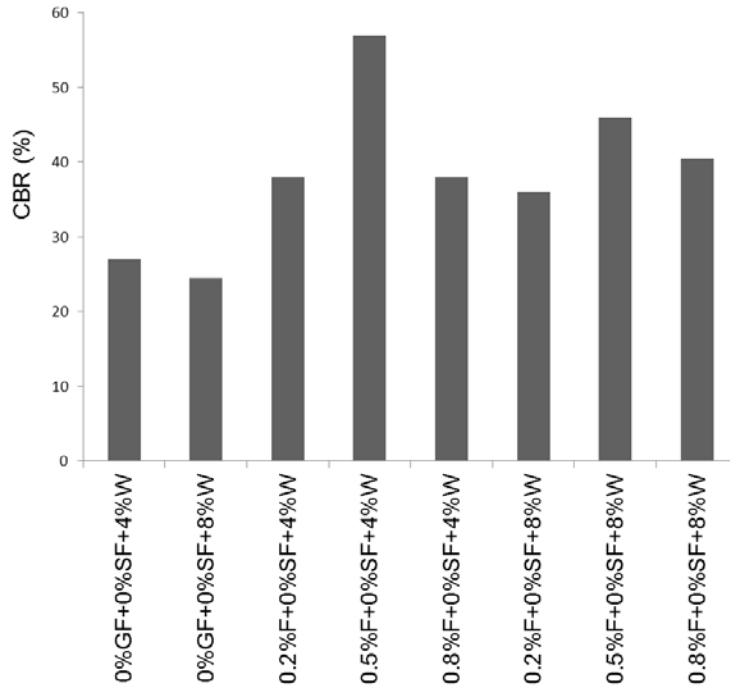


Figure 4: CBR values of Horseshoe Lake sand treated with fibers

The Soil-Sement came with a manufacturer's recommendation to use 1 gallon of Soil-Sement for a section of 20 square feet and a section depth of 4 inches. The unit weight of the Soil-Sement is 1.08g/mL based on our laboratory evaluation; this yields a dosage percentage of nearly 2% by the dry weight of the soil. The final dry-weight percentages of Soil-Sement used for testing were 1%, 1.5%, and 2%. Two moisture contents, 4%, and 8%, were examined for testing with Soil-Sement with and without fibers. The results showed that for samples containing 8% moisture and treated with Soil-Sement, all treatment dosages produced relatively similar CBR results (around 40; see Figure 5). The samples with 4% moisture content and 2% Soil-Sement start to show a noticeable increase in the CBR value. Test results for samples with 4% moisture, Soil-Sement, and geofibers is shown in Figure 6.

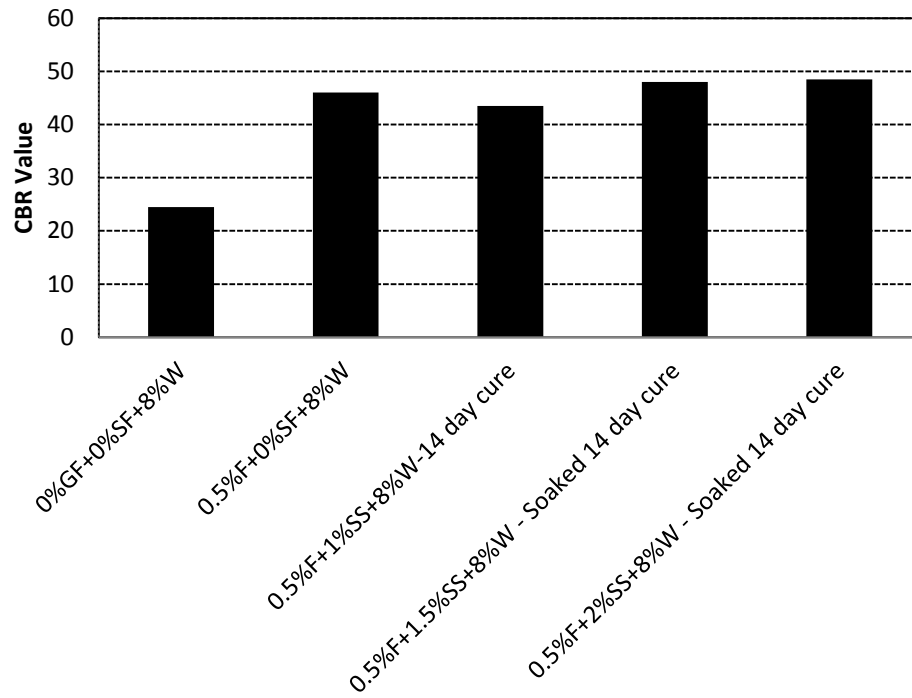


Figure 5: CBR results of samples at 8% moisture treated with Soil-Sement

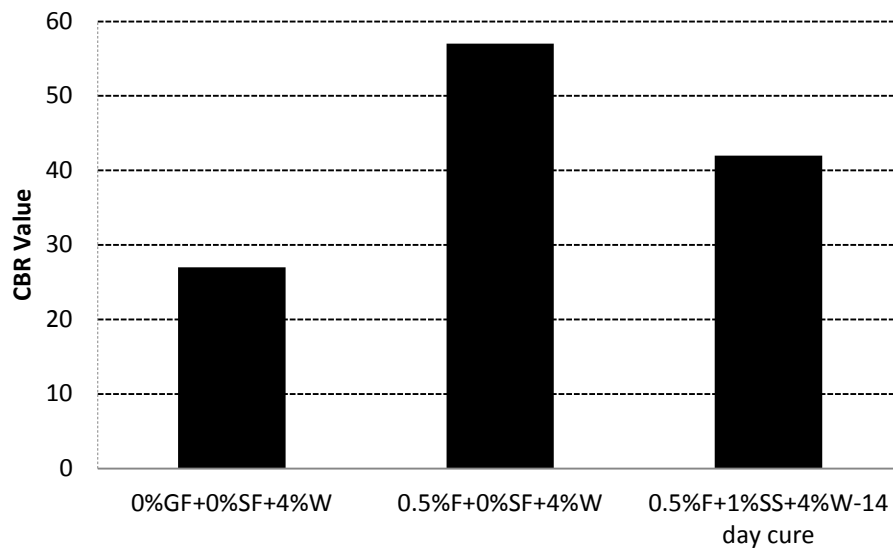


Figure 6: CBR results for samples at 4% moisture with Soil-Sement

The final series of laboratory tests evaluated the use of Soil-Sement in a freeze-and-thaw condition. Test samples were prepared in two ways: (1) samples were cured for 14 days in an open air environment, soaked for 96 hours, frozen in a closed system environment for 24 hours, then allowed to thaw for 24 hours at 100% relative humidity before CBR testing; and (2) Samples were allowed to cure for 14 days, then frozen and thawed according to the same process, with no soaking prior to freezing and thawing.

The results of the freeze-thaw testing showed that samples treated with Soil-Sement showed little to no degradation in CBR value for either the soaked or the un-soaked samples. The results of the freeze-thaw CBR testing are presented in [Figure 7](#). The data indicates the material is not freeze-thaw susceptible, an important consideration in cold climates.

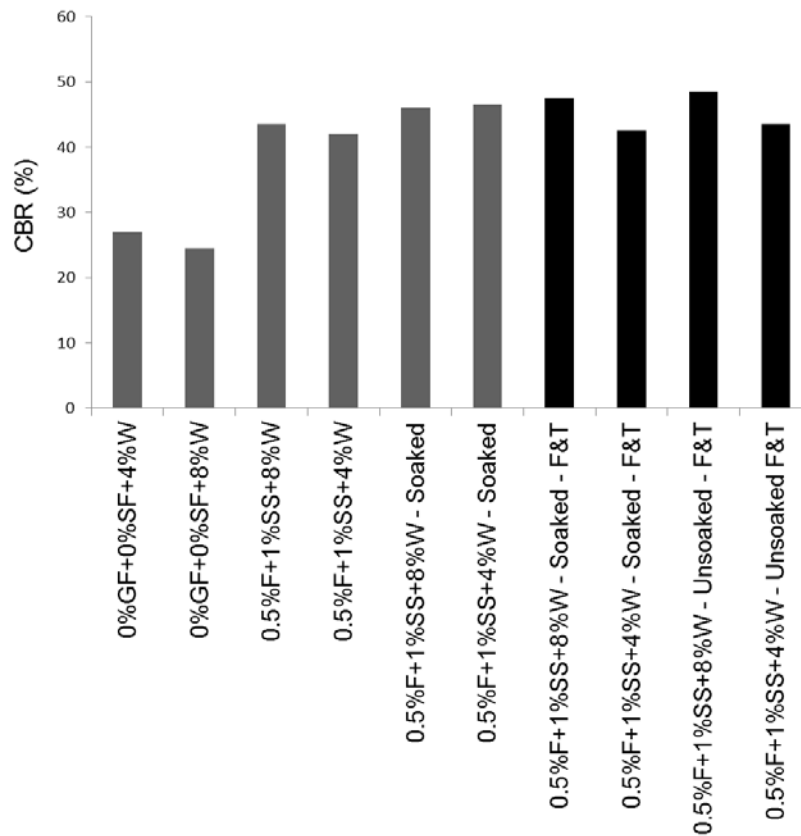


Figure 7: CBR test results of using both Soil-Sement and geofibers

Construction

The test section at Horseshoe Lake consisted of two subsections of 250 feet each. The eastern end of the section was 6 inches in thickness while the western end of the test section was 12 inches thick. The 12 inch section was constructed in two layers, and each layer was compacted with a minimum of six coverages by a 4 ton steel-wheeled roller.

The geofibers were shipped on crates in large boxes; each box contained twenty 30 pound bags. The geofibers used at Horseshoe Lake were $\frac{3}{4}$ inch fibrillated fibers, white in color. In contrast, the geofibers tested in the laboratory were 2 inches long and had some added carbon for UV protection. These shorter fibers were selected by the provider who through experience has found the shorter fibers easier to mix with soils. This substitution was made without consultation with the research team. A few images present the fibers in more detail; [Figure 8 shows a close-up of the \$\frac{3}{4}\$ inch fibers](#), held in the palm of a hand. Rather than delay the project, the research team decided to proceed with the $\frac{3}{4}$ inch fibers.

Based on the test results, the synthetic fluid used for liquid stabilization on the Horseshoe Lake test site was the Soil-Sement® engineered formula produced by Midwest Industries. This is a polymer emulsion designed for dust control, erosion control, and soil stabilization. The Soil-Sement was shipped in six 500 gallon totes. [Figure 9](#) shows the six totes at the construction site. The Soil-Sement is white and is highly viscous, which posed problems for pumping the fluid into the water truck. In the end, the contractor elected to lift the totes above the water truck with a fork lift and gravity-feed the Soil-Sement. [Figure 10](#) shows an image of the fluid diluted with water coming out of the back of the water truck.

The equipment used in construction of this project was a rototiller (needed to mix the geofibers with the soil and Soil-Sement), a small rolling compactor (4 ton), a 3000 gallon water truck, and a grader (for cutting and shaping the road). Other equipment included a bobcat used to move the pallets.

Prior to construction, the road was “fluffed” using a rototiller (see [Figure 11](#)). “Fluffing” helps reduce density in the road soils before treatment, which aids in better distribution of the geofibers and Soil-Sement. The fluffing process involves simply running the rototiller over the surface of the test site in situ.

In order to approximate the correct dosage rate, workers emptied each 30lb bag of geofibers at 8 foot intervals. The actual mixture reached was 0.4% geofibers by dry weight of the soil, which is slightly lower than the laboratory-observed optimum fiber point. Because the weight of fiber delivered to the project was lower than expected, the amount of geofiber was reduced in order to get a uniform distribution of fiber. The fibers were placed and spread using a garden rake, as shown in [Figure 12](#).

Once the fibers were placed evenly throughout the road bed, they were mixed into the sand using the rototiller (see [Figure 13](#)). The rototiller made several passes over the surface of the road until the fibers were thoroughly and evenly mixed throughout the test site.

Application of the Soil-Sement was completed using the 3000 gallon water truck ([Figure 10](#)). As noted above, the main problem encountered was transferring the Soil-Sement to the water truck. Elevating the containers so that gravity-feeding increased the pumping speed overcame this issue, albeit with some delay. The Soil-Sement was diluted with water to aid application as well as to bring the soil closer to the optimum moisture content. Field moisture content tests were conducted to determine the in-situ moisture content of the soil, which was found to be 8% on average before construction. Several hours elapsed between mixing the fibers with the soil and application of the Soil-Sement because of the delaying getting the Soil-Sement into the water truck. New measurements, taken after

the Soil-Sement was transferred to the water truck showed that the moisture content had fallen to 6%. A total of 1650 gallons of Soil-Sement was mixed with roughly 1450 gallons of water and applied at the Horseshoe Lake test site. Using these amounts brings the total percentage of Soil-Sement per the dry weight of the soil to be 3.2%, at a moisture content of 8.6%. This is slightly lower than the 4% optimum determined in the laboratory.

The water truck applied the Soil-Sement/water solution a total of four times, twice in each direction of traffic. After the first application on each side, the sand seemed to absorb most of the Soil-Sement; on the second pass the liquid pooled on the top layer of soil several minutes before eventually being absorbed.

Once the Soil-Sement was applied, the rototiller was used to thoroughly combine it with the geofibers and soil. The rototiller combining all the treatment materials is shown in [Figure 14](#). In this picture the noticeable pooling during Soil-Sement application is visible on the parallel tracks in front of the rototiller. After mixing, the road section was then cut and shaped using a grader (see [Figure 15](#)). Once the road was shaped and leveled it was compacted as shown in [Figure 16](#).

The road was prepared initially as though the entire 500 foot section would be shaped in a 6 inch lift. Once the entire 500 foot section was compacted, for half the test section, excess soil on the sides was pushed on top to create a second layer for the twelve inch section. The second 6 inch layer was prepared through the same processes described earlier.

Once thorough mixing was finished and the road was compacted a final application of Soil-Sement was used to seal the top layer of the soil. The sealant application was composed of 1450 gallons of Soil-Sement mixed with a small amount of water. The Soil-Sement sealant keeps the surface fibers in place and provides a stiff surface on the road bed. The completed roadway is shown in [Figure 17](#).

The cost of the 500 foot constructed section was \$50,000, a figure that does not include any profit for either the contractor or the supplier. This equates to about \$180/ton. Assuming addition of a 15% profit, the cost would increase to about \$207/ton. Similar applications in western Alaska could be estimated at about twice that (\$414/ton), a price that is still competitive with that of importing gravel for more traditional construction methods.



Figure 8: Fibers used on Horseshoe Lake road



Figure 9: Soil-Sement shipping totes



Figure 10: Soil-Sement applied from water truck



Figure 11: Roadway after being "fluffed"



Figure 12: Achieving uniform application of fibers



Figure 13: Rototilling geofibers



Figure 14: Final mixing of Soil-Sement and geofibers



Figure 15: Shaping and grading



Figure 16: Compacting roadway



Figure 17: Completed roadway

Initial Test Results

The measure of improvement used to gauge the strength increase in the road over time is the stiffness. The stiffness of the road is a convenient measurement because it can easily be measured using a Humboldt Geogauge, and just as simply, converted to CBR. According to Humboldt, the Geogauge measures the average stiffness up to a depth of 8 inches.

To establish initial stiffness of the original road bed, preliminary stiffness tests were taken at points 100 feet before the treated section of road and 100 feet after. The treated section had already been fluffed using heavy equipment, so it was determined that using the sections of road before and after the treated section would produce stiffness results similar to that of the test section before the soil was disturbed.

Stiffness measurements were taken with a Humboldt Geogauge at 10 foot increments initially (in 2010) and at 50 foot increments in 2011. For each location, three readings were taken; one through the center of the road and one nine feet from the center on either side. The stiffness measurements were converted to CBR values so that they could be compared with the results of the laboratory testing. The stiffness and CBR results for the 100 foot section of road before the test section are presented in [Table 1](#). The results from the stiffness measurements on the 100 foot section after the treated section are presented in [Table 2](#). The 100 foot stretch of road before the treated section had an average CBR of 23; the 100 foot stretch after the treated section had a CBR value of 36 in the center of the road and slightly lower on the sides (12 closest to the lake and 18 on the north side). Informal, prior observation suggested that the test section was softer than these stretches. When the test section was selected, the research team noted that tires made a slight depression in the surface in the test area and not on the

adjacent areas. Unfortunately, the contractor tilled the test section the day before the research team arrived, making it impossible to collect a good set of base measurements.

Once the test section was completed, a series of stiffness measurements were taken to provide a basis for documenting stiffness improvement over time. These stiffness measurements were taken at 50 foot intervals throughout the full 500 feet of the road, encompassing both the 6 inch and 12 inch lifts. These initial measurements were very low, with an average CBR value of 5 in the center of the road and 3 on the outside measurements. The individual CBR values for the road on July 31st, the day of construction, are presented in [Table 3](#). These results are similar to how the road bed would react without the influence of the treatment, because the Soil-Sement had not cured and the fibers had not undergone enough strain to activate their potential contribution.

Table 1: CBR values 100 ft. immediately before start of construction (July 30th)

Distance measurement Taken	Lake Side		Center of Road		Tree Side	
	(MN/m)	CBR	(MN/m)	CBR	(MN/m)	CBR
0	10.98	30	8.15	14	7.35	10
10	10.21	25	8.21	14	8.29	14
20	10.15	24	10.91	29	8.3	14
30	10.62	27	10.84	29	10.39	26
40	10.79	28	10.15	24	10.58	27
50	11.06	30	9.38	20	9.2	19
60	10.66	28	11.69	34	8.61	16
70	9.14	19	8.85	17	10.81	29
80	10.97	30	7.47	11	10.06	24
90	7.95	13	10.57	27	12.5	40
100	8.26	14	9.9	23	10.66	28
Averages		24.4		22.0		22.1

Table 2: CBR values 100 feet immediately after end of construction (July 30th)

Distance measurement Taken	Lake Side		Center of Road		Tree Side	
	(MN/m)	CBR	(MN/m)	CBR	(MN/m)	CBR
0	7.78	12	11.05	30	8.15	14
10	8.75	17	11.94	36	8.92	18
20	8.8	17	10.59	27	6.04	5
30	6.22	6	12.85	43	10.38	26
40	7.07	9	12.93	43	8.44	15
50	9.1	19	11.43	33	8.52	16
60	7.51	11	12.75	42	8.13	14
70	9.13	19	11.95	36	9.38	20
80	6.76	8	10.63	27	7.19	9
90	6.82	8	12.65	41	11.54	33
100	6.46	6	12.6	41	9.83	23
Averages		12.0		36.3		17.8

Table 3: CBR values of test section immediately after construction (July 31st)

Distance measurement Taken	Lake Side		Center of Road		Tree Side	
	(MN/m)	CBR	(MN/m)	CBR	(MN/m)	CBR
0	6.15	5	9.23	19	5.45	3
50	4.4	0	5.81	4	5.46	3
100	5.46	3	5.36	3	6.51	7
150	6.15	5	7.26	10	7.12	9
200	5.58	3	8.34	15	5.95	5
258	4.79	1	5.99	5	5.66	4
6" Layer Avg		2.8		9.3		5.2
300	5.17	2	4.63	1	4.63	1
350	4.62	1	3.08	0	4.07	0
400	6.06	5	4.54	0	3.98	0
450	5.24	2	3.66	0	4.44	0
500	4.54	0	4.46	0	4.71	1
530	5.75	4	5.2	2	6.05	5
12" Layer Avg		2.3		0.5		1.2

Week 1 and Week 3 Measurements (August 7th and August 28th, 2010)

One week after the completion of the treatment, stiffness measurements were taken were taken again at 25 foot intervals. To visual observation, the test site appeared stiffer and the surface looked more abrasion-resistant than immediately after construction; [Figure 18](#) shows the road a week after construction. The average CBR value in the center of the road is 22, an improvement of 340%. The CBR values on the sides of the road also increased, with values of 17 and 18, on the tree and lake sides respectively. The CBR values obtained throughout the road one week (August 7th) after treatment are presented in [Table 4](#).

It is interesting to note that local residents repeatedly indicate how much better the roadway performed than before. Some even ask if the approach could be used on their driveways.

Some initial visual observations noted that some fibers had collected on the surface of the road near the center; this redistribution was most likely due to the wind from passing vehicles picking up the surface fibers and redepositing them. The fibers in the center of the road are visible in [Figure 19](#). It is evident that at the front of the road (photo foreground) there are fewer fibers on the surface, but closer to where the people are standing it is clear there are significantly more fibers in this area.

The readings taken on the road three weeks after treatment (August 28th) were slightly lower than the ones taken on August 7th. This could be attributed to the low volume of traffic on the road not yet activating the potential stiffness increase offered by the geofibers. The results of the stiffness measurements are presented in [Table 5](#); the average CBR value in the center of the road is 15, with values of 11 and 10 on the tree and lake sides of the road respectively.



Figure 18: Roadway one week after construction

Table 4: CBR measurements one week after construction (August 7th, 2010)

Distance measurement Taken	Lake Side		Center of Road		Tree Side	
[ft]	(MN/m)	CBR	(MN/m)	CBR	(MN/m)	CBR
0	8	13	9.84	23	8.43	15
25	8.43	15	9.06	18	7.56	11
50	7.76	12	9.73	22	8.83	17
75	7.33	10	8.58	16	9.27	19
100	6.68	7	7.04	9	7.55	11
125	6.55	7	7.03	9	7.75	12
150	5.45	3	7.79	12	8.05	13
175	6.19	5	7.59	11	8.35	15
200	7.36	10	12.19	38	7.65	11
225	5.6	3	9.93	23	8.1	13
250	6.56	7	9.41	20	8.03	13
258	6.81	8	8.11	14	6.09	5
6" Layer Avg		8.3		17.9		12.9
275	7.8	12	8.94	18	5.97	5
300	6.52	7	7.98	13	5.91	4
325	8.97	18	7.6	11	7.87	12
350	8.38	15	7.55	11	6.37	6
375	6.09	5	7.58	11	6.32	6
400	8.41	15	7.32	10	6.96	8
425	6.5	7	7.92	13	5.96	5
450	6.94	8	7.08	9	6.45	6
475	7.61	11	6.31	6	8.08	13
516	11.72	35	9.01	18	7.32	10
12" Layer Avg		13.3		11.9		7.5



Figure 19: Roadway three weeks after construction (August 28th, 2010)

Table 5: CBR measurements three weeks after construction (August 28th, 2010)

Distance measurement Taken	Lake Side		Center of Road		Tree Side	
	(MN/m)	CBR	(MN/m)	CBR	(MN/m)	CBR
0	8	13	9.84	23	8.43	15
25	8.43	15	9.06	18	7.56	11
50	7.76	12	9.73	22	8.83	17
75	7.33	10	8.58	16	9.27	19
100	6.68	7	7.04	9	7.55	11
125	6.55	7	7.03	9	7.75	12
150	5.45	3	7.79	12	8.05	13
175	6.19	5	7.59	11	8.35	15
200	7.36	10	12.19	38	7.65	11
225	5.6	3	9.93	23	8.1	13
250	6.56	7	9.41	20	8.03	13
258	6.81	8	8.11	14	6.09	5
6" Layer Avg		8.3		17.9		12.9
275	7.8	12	8.94	18	5.97	5
300	6.52	7	7.98	13	5.91	4
325	8.97	18	7.6	11	7.87	12
350	8.38	15	7.55	11	6.37	6
375	6.09	5	7.58	11	6.32	6
400	8.41	15	7.32	10	6.96	8
425	6.5	7	7.92	13	5.96	5
450	6.94	8	7.08	9	6.45	6
475	7.61	11	6.31	6	8.08	13
516	11.72	35	9.01	18	7.32	10
12" Layer Avg		14.1		12.0		7.5

Measurements taken on September 7th and October 7th, 2010

Table 6: CBR measurements September 7, 2010

Distance measurement Taken	Lake Side		Center of Road		Tree Side	
[ft]	(MN/m)	CBR	(MN/m)	CBR	(MN/m)	CBR
0	7.62	11	9.97	23	8.75	17
25	9.15	19	9.84	23	7.13	9
50	7.15	9	8.42	15	8.86	17
75	7.85	12	8.68	16	8.2	14
100	8.28	14	8.95	18	7.56	11
125	7.13	9	7.81	12	8.51	15
150	8.87	17	9.46	20	8.17	14
175	8.48	15	11.61	34	8.37	15
200	6.22	6	11.09	30	7.97	13
225	7.92	13	9.69	22	7.49	11
258	7.73	12	7.12	9	6.98	9
6" Layer Avg		12.4		20.2		13.2
275	8.32	15	6.48	7	7.13	9
300	7.65	11	8.32	15	6.99	9
325	8.89	17	6.74	8	6.63	7
350	9.72	22	6.38	6	6.99	9
375	6.88	8	8.05	13	7.15	9
400	6.92	8	7.59	11	6.91	8
425	7.49	11	6.15	5	6.45	6
450	9.41	20	8.95	18	9.28	20
516	11.87	36	7.52	11	8.47	15
12" Layer Avg		16.4		10.4		10.2



Figure 20: Test section September 7, 2010

Table 7: CBR measurements October 7, 2010

Distance measurement Taken	Lake Side		Center of Road		Tree Side	
[ft]	(MN/m)	CBR	(MN/m)	CBR	(MN/m)	CBR
0	9.94	23	12.59	41	7.9	13
25	9.90	23	10.11	24	8.18	14
50	9.34	20	8.16	14	8.99	18
75	9.29	20	6.72	7	8.68	16
100	9.53	21	7.56	11	7.63	11
125	6.26	6	8.32	15	6.81	8
150	9.33	20	10.46	26	8.29	14
175	10.35	26	7.73	12	8.69	16
200	10.78	28	13.65	49	9.61	21
225	6.28	6	8.74	17	9.34	20
258	9.11	19	9.14	19	8.38	15
6" Layer Avg		19.3		21.3		15.1
260	8.20	14	10.26	25	7.28	10
275	7.90	14	8.13	14	5.91	4
300	6.74	13	5.60	3	5.97	5
325	8.12	8	7.39	10	9.88	23
350	8.61	14	5.92	5	7.21	9
375	7.57	16	7.26	10	5.96	5
400	5.97	11	7.32	10	8.03	13
425	6.93	5	8.02	13	6	5
450	7.37	8	5.35	3	7.06	9
475	8.06	10	6.74	8	9.05	18
516	7.73	13	6.88	8	11.03	30
12" Layer Avg		11.4		9.9		11.9

2011 Field CBR Measurements

The first CBR measurements of 2011 were taken on May 22, 2011. As indicated in [Table 8](#), the data shows the CBR values to be slightly higher than those measured the previous fall. Fortunately, there

was no degradation of the surface or soil strength over the winter, a major concern in cold climates. Indeed, the surface looked exactly the same as the previous fall as shown in [Figure 20](#).

[Table 9](#) shows the CBR measurements on September 9, 2011. Again, measurements suggest a slight increase in strength over the summer months. The roadway showed no change in characteristics from the spring visit. However, there appears to be a slight increase in the amount of fiber on the side of the road, indicating that there is some abrasion occurring. Unfortunately, no provision was made in the testing protocol to measure the loss of thickness.

Figure 21 shows the average of CBR values over time for both the 6 inch and 12 inch test sections. Both sections show a steady increase in strength over time. However, the 12 inch section has lower CBR values until the September 9 measurements. This is likely due to inadequate compaction effort on the 12 inch section.

[Table 8: CBR measurements May 22, 2011](#)

Distance measurement Taken	Lake Side		Center of Road		Tree Side	
	(MN/m)	CBR	(MN/m)	CBR	(MN/m)	CBR
0	10.15	24	6.96	8	9.86	23
50	11.45	33	7.94	13	9.72	22
100	8.86	17	7.19	9	7.78	12
150	10.81	29	9.93	23	8.46	15
200	6.43	6	12.02	37	8.84	17
250	7.83	12	9.56	21	10.61	27
6" Layer Avg		20.2		18.5		19.3
260	7.96	13	9.54	21	6.86	8
300	9.62	21	7.70	12	7.88	12
350	9.16	19	9.88	23	7.85	12
400	8.62	16	9.04	18	8.97	18
450	6.79	8	7.46	11	7.11	9
516	7.16	9	10.85	29	11.7	34
12" Layer Avg		14.3		19.0		15.5

Table 9: CBR measurements September 9, 2011

Distance measurement Taken	Lake Side		Center of Road		Tree Side	
[ft]	(MN/m)	CBR	(MN/m)	CBR	(MN/m)	CBR
0	10.91	29	13.10	45	12.06	37
50	9.28	20	8.55	16	10.56	27
100	11.57	34	9.48	21	9.56	21
150	7.72	12	8.92	18	9.6	21
200	8.49	15	8.65	16	8.83	17
250	10.11	24	10.35	26	10.73	28
6" Layer Avg		22.3		23.7		25.2
300	10.48	26	8.51	15	10.88	29
350	9.38	20	10.52	27	9.56	21
400	8.99	18	14.08	52	9.28	20
450	10.73	28	12.66	41	10.51	27
500	9.79	22	9.24	19	11.09	30
12" Layer Avg		20.8		30.8		25.7

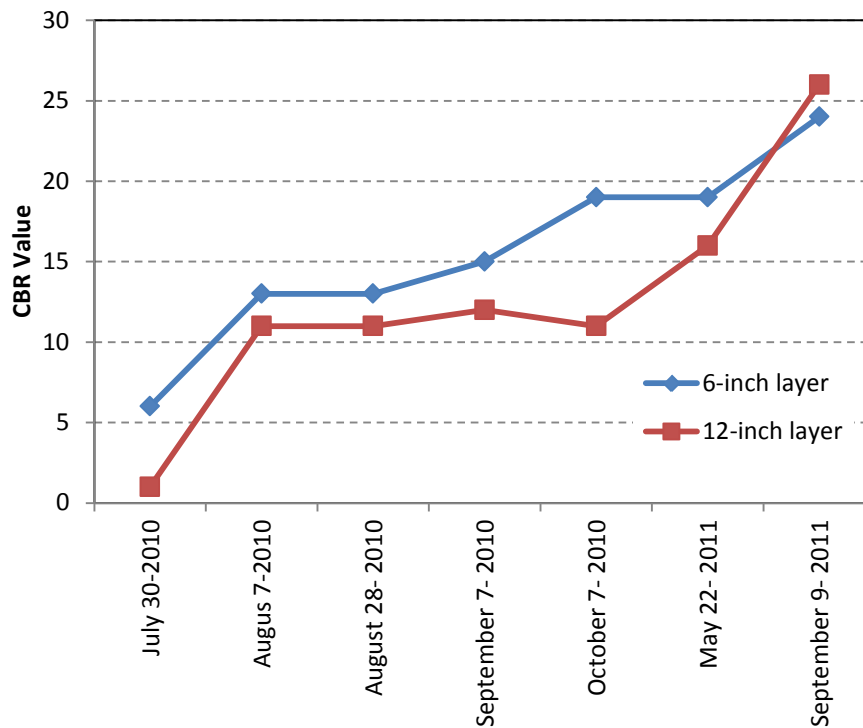


Figure 21: CBR over time

Discussion

The Horseshoe Lake Road test site continues to perform well despite the lower-than-expected CBR measurements. We did anticipate lower CBR values than those obtained in the laboratory since field CBRs do tend to be somewhat lower than laboratory values. Even taking this trend into account, the values were lower than expected. This could be the result of using the Humbolt Gauge, which uses a small vibratory load to estimate the stiffness of the soil. Soil stiffness in turn is correlated to CBR. Since the correlation used was not developed for fiber-reinforced soils, the CBR reported could be a bit low.

Nonetheless, the Humbolt CBRs are valuable. The initial strength increase can be attributed to the curing of the Soil-Sement. The continued increase in strength is likely due to the tensioning of the fibers.

Our greatest concern for the test section was the anticipated abrasion of the surface. While some abrasion is occurring, as evidenced by the continued increase in fiber along the roadway edge, surface loss seems relatively small. However, the traffic volume and speed along the roadway has been low. In the future, treating the surface with additional Soil-Sement or a chip seal to improve abrasion resistance is advisable.

To date, there is no rutting in either the 6 inch or 12 inch lift test sections, which indicates the stability of the treated sections is sufficient to support the light traffic. While the few trucks and school busses that traverse this section have caused no distress, more frequent traffic would allow a more thorough evaluation of the treatment durability.

The field freeze-thaw durability is consistent with the laboratory testing, since there was no noticeable reduction in strength or loss of performance during the spring thaw. As is the custom in the MatSu Borough, two to four inches of snow pack was left on the roadway through the winter months and removed during the thawing period. We had asked the maintenance contractor to be especially

careful not to grade the surface of the road when removing the soft snowpack in the spring. We saw no evidence of damage from the spring grading.

While the construction was not exactly as designed, the section is performing well. To date, we have not repeated the laboratory testing to evaluate the differences between the $\frac{3}{4}$ inch fiber used and the 2 inch fibers specified. The supplier and contractor were quite concerned about the use of longer fibers for this application. They claim the longer fibers are nearly impossible to incorporate into the soil. However, the work by Tingle et. al. (2003) showed that longer fibers could be incorporated. While the research team was disappointed not to have the longer fibers incorporated into the project, the information gained is still valuable. The $\frac{3}{4}$ in fibers do seem to be working well.

The construction did go smoothly. There were two minor problems, both of which are easily resolved. The first was that the viscosity of the Soil-Sement made pumping difficult, primarily because the pumps were sized to pump water. The contractor overcame this by gravity feeding the Soil-Sement directly out of the totes into the water truck. The other option would be to use a suitable pump.

The second problem was that the compaction equipment was undersized. In the future, a 8 ton rubber tire roller is recommended. The kneading action of the rubber tires should help tension the fibers, thus improving the strength of the surface. The additional weight would allow compaction to a greater depth than the compactor used in this first field test allowed. For the 12 inch lift section, the compaction of the lower six inches of the fiber is likely inadequate.

Finally, since the six inch section is performing well, the need for the twelve inch section is unclear due to the light traffic at this site. However, after evaluating the test section, it is recommended that the synthetic fluid be eliminated in the lower six inches of the thicker section. This recommendation is based on the performance of the test section and the laboratory test results, which indicate that most of the strength gain comes from the fibers.

Conclusions

The Horseshoe Lake Road test site provides a good opportunity to carefully examine the use of geofibers and Soil-Sement in a field application. Monitoring this easily accessible site near Wasilla, Alaska will make it possible to note and identify problems that may come up so that contractors can be better prepared in a remote area. The Horseshoe Lake sand is the ideal material to improve because it has little-to-no bearing capacity as it sits untreated.

The use of fiber and Soil-Sement proved effective. Unfortunately, the traffic volumes are not high enough to fully test the treatments. While the performance has been excellent over 16 months since construction, the section should be monitored until the anticipated reconstruction in 2014.

The $\frac{3}{4}$ inch fibers seem to perform well, it is unknown whether the longer fibers would work any better. Additional laboratory work should be performed to compare the fiber length with stiffness. Since contractors claim shorter fibers are easier to handle, the shortest fiber which will provide the desired soil strength should be used.

It is unclear how much the additional 6 inches of treated section adds to the performance, since both sections are performing essentially the same at this point. Both time and traffic are needed to answer this question.

Finally, at an estimated cost of \$415/ton in Western Alaska, this process is competitive with importing gravel.

References

[Gullu and Hazirbaba, \(2010\)](#) Hamza Gullu and Kenan Hazirbaba, California Bearing Ration Improvement and Freeze-Thaw Performance of fine-grained soils treated with geofiber and synthetic fluid, Cold Regions Science and Technology, volume 63, Issues 1-2, August 2010, Pages 50-60.

Hazirbaba, K., Connor, B., Davis, D., and Zhang, Y., (2007), "Final Report: The Use of Geofiber and Synthetic Fluid for Stabilizing Marginal Soils," INE Project Number: RR.07.03, October 1, 2007.

Tingle, JS, Santoni, RL (2003) "Stabilization of Clay Soils with Nontraditional Additives," Transportation Research Record 1819, TRB, National Research Council, Washington DC, 2003, pp. 72-84.