The Use of Geofibers and Synthetic Fluids Kwigillingok Airport

FINAL REPORT

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Rodney Collins
Billy Connor
University of
Alaska Fairbanks
The Alaska University Transportation Center
Fairbanks, AK 99775

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Executive Summary

AUTC was ask to test the possibility of using geofibers and synthetic fluids to maintain the runway surface at Kwigillingok until a new runway could be constructed. On September 14, 2010 a site investigation was made to Kwigillingok, Alaska by Rodney Collins, a graduate student at the University of Alaska Fairbanks. This trip was made to gain a better understanding of the runway present in Kwigillingok, which is scheduled for maintenance next summer. The runway at Kwigillingok is underlain by clay material, which is difficult to stabilize. Geofibers and synthetic fluid currently under study by AUTC could be used to stabilize the subgrade in Kwigillingok.

The tasks included in this trip are as follows: (1) evaluation of the current runway, (2) take stiffness measurements (3) collect samples of the clay material underlying most soil in the area, (4) Attend a tribal council meeting to discuss the runway. To this end, the following activities were completed:

- The runway was evaluated visually taking into account the surface features on the runway and measuring the depth of gravel at the center and sides of the runway.
- Stiffness measurements were taken using a Humboldt Geogauge to assess the strength of the runway surface.
- Pictures were taken of potholes, ruts, and other irregularities on the runway surface.
- A small sample of gravel material overlying the runway was collected for grain size distribution analysis, and in-situ moisture conditions.
- Soil was collected from a riverbank next to the runway; it is representative of the clay that underlies most of the ground throughout Kwigillingok which will be tested with geofibers and synthetic fluid to improve the bearing capacity.
- The village council was consulted to gain an inside perspective on the conditions of the runway.

Samples of Kwigillingok soil were shipped to the University of Alaska Fairbanks in order to complete an evaluation of the use of geofibers and synthetic fluid. The laboratory evaluation is a multistep process, where the soil properties are first identified to classify the soil. The California bearing ratio (CBR) test is used to measure the effects of mixing in combinations of geofibers and synthetic fluid.

Our initial understanding that the predominate material is sand and that the runway was a sandy material. Our investigation found the runway surface had a crushed gravel surface and that the local material contained high amounts of organic clay. Since our research has focused on silts and sands, the clay found at Kwigillingok is outside our research to date. Further, we were concerned about disturbing the existing runway due to the clay embankment below. Any disturbance might liquefy the underlying soils resulting in an expensive repair.

Discussions with the pilots who fly into Kwigillingok indicate the problem is roughness not bearing capacity of the surface. Consequently, our recommendation is to focus on reducing roughness without disturbing the existing surface.

The greatest increase in soil strength comes from simply drying the soil to near optimum moisture content. However, in-situ moisture contents exceeding 50 % and climatic conditions in Kwigillingok make it unrealistic to expect achieving moisture contents near optimum.

The addition of fiber at in-situ or optimum moisture contents did not yield the anticipated doubling of CBR. However, the mixture did show stain hardening similar to that expected in granular materials. In that we were successful.

When the clayey-silt was tested using synthetic fluid alone, we saw no significant increase in CBR. This is likely due to the high clay content. Since neither synthetic fluid nor fibers had the desired effect, there was no need to test the combination of the two.

Since the greatest improvement was gained in drying the material, Portland cement was added to the sample at 2%, 3%, 4%, 6% and 8% by dry weight of soil at a moisture content of 30%. While we did see a significant increase in CBR , the maximum CBR obtained was 12%, well below desired values.

Finally, a new product consisting of DirtGlue and PolyCure was tested at 30% moisture content. Using this combination, a CBR of 16% was achieved. PolyCure does show an ability to dry the soil and an increase in soil strength when used with other soil stabilizers. We are continuing to test this additive outside this project, but the timeframe of that work does not allow us to make recommendations a this time. The results of our work with PolyCure will be provides as it becomes available.

Problem Identification

Flying into Kwigillingok, the pilot of the plane was asked for his opinion on the state of the runway. The pilot's opinion was that the runway was similar to a "roller coaster", in that it has an uneven landing surface. There was also some concern expressed by the pilot about the high chance of a second takeoff after the plane has initially touched down.

There is a 500 foot section on the northern portion of the runway that is not used. The pilot explained that this portion of runway is not used because it is difficult for pilots to slow down before a large bump is reached which can make the plane re-launch. Upon further investigation into the northern end of the runway it was evident that there is some melting permafrost in this area. The thaw-pond forming from this is shown as Fig.1. The northern end of the runway was apparently slightly higher in elevation that the rest of the runway, this is evident in Fig.2 which was taken approximately 800 feet from the northern end. Also, shown in Fig.2 are the cones which mark the section of runway that is avoided.

The depth of the gravel on the runway surface was checked on the northern and southern sections of runway, also on the sides of the runway. The depth of gravel at both the north and south ends of the runway was approximately eight inches; no further digging could be done after this depth was reached because it was heavily compacted and only a spade shovel was used, the image showing where the hole was dug is shown as Fig.3, One hole was dug on the side of the runway to find the depth of gravel throughout the runway; this showed the gravel to be nearly one inch thick on the side of the runway which is shown in Fig.4. It is apparent that the many of years of grading had resulted in the variable thickness of the gravel surface. However, it is not clear whether this is due to differential settlement. Unfortunately, we did not have the equipment to determine this.

There are few ruts and potholes on the Kwigillingok runway. However, the northern end of the runway where the permafrost has melted the subgrade has become very soft Fig.5.

Overall, the runway appeared to be in fair condition, the surface of the runway appeared to be stable enough for the expected traffic.

Description of Proposed Solution

The combination of geofibers and synthetic fluid for soil stabilization is a new technique currently being researched at the University of Alaska Fairbanks. The option of sending geofibers and synthetic fluid to Kwigillingok could provide a cheap alternative to available construction methods. Kwigillingok soil material shipped to the University of Alaska Fairbanks will undergo a rigorous testing regime. California Bearing Ratio (CBR) is used as an index property to identify the influence of geofibers and synthetic fluid. Several combinations of additives will be used in an attempt to stabilize the Kwigillingok material. The additives used to stabilize the material chemically will consist of Portland cement and polymer emulsion. Geofibers will increase the strain hardening characteristics of the Kwigillingok soil. If an additive is found that provides adequate stabilization of the soil geofibers will be used as an added benefit.

Evaluation of existing runway conditions

Stiffness measurements

Stiffness measurements were taken at eight locations along the runway. The Geogauge measures to a depth of nine inches. The first measurement was taken on the south end and readings were taken at nearly even distances to the north end of the runway. At least two measurements were taken in each location. In a few locations, three were taken because the first two did not agree with each other. A table summarizing the results of the Geogauge testing is presented as Table 1. An aerial photo of the Kwigillingok runway is shown as Fig.6 shows the test locations.

The results of the stiffness measurements indicate the surface of the runway is sufficiently stiff without any added stabilization. Further, disturbing the surface could cause the underlying clays to weaken requiring costly remediation.

Sample Collection

Material was needed for use in laboratory testing. This will be treated with geofibers and synthetic fluid in an attempt to improve the strength and stability of the soil. The material collected is clay from the riverbank. This is representative of the soil found throughout Kwigillingok. A picture showing the site the clay was collected from is presented as Fig.7. The site is also indicated by a star on Fig.6.

Discussion with tribal council

A short meeting was made with the Kwigillingok community. The main concern with the people in Kwigillingok is the roughness the runway and the dangers they pose for planes while landing. There is some concern about the environmental impact of any type of construction on the runway, especially about the use of fluids because of the runways proximity to the river.

The river is starting to erode the ground near the southern end of the runway and this is of some concern to the villagers. Overall, the people of Kwigillingok are excited to have some maintenance on their runway, as long as it will not negatively affect their way of life.

Possible solution and laboratory tests

(a) Soil Properties

The Kwigillingok soil is first tested to determine its characteristics for classification purposes. These tests include in-situ moisture content (ASTM D2216), sieve analysis (ASTM C136), hydrometer (ASTM D422), modified proctor compaction (ASTM D1883), specific gravity (ASTM D854), and Atterberg limits (ASTM D4318). The focus of this investigation is the fine grained clay material.

The in-situ moisture content of the fine grained clay material found throughout Kwigillingok is 56.5%. The runway base course had in-situ moisture of 8.6%. The clay material was collected in an area that was exposed and there had been enough precipitation in recent months to help raise the water content. It is safe to assume that the soil underlying the village would have lower moisture content if there is sufficient cover in place.

The gravel material found on the runway, and the clay material underlying Kwigillingok was compared with sieve analysis results provided by AKDOT Fig.8. The uniformity coefficient (C_u) and the coefficient of curvature (C_c) is 70.8 and 2.2 for the gravel material and 9.7 and 1.3 for the clay material. The gravel is classified as well graded gravel (GW) according to the United Soil Classification System (USCS).

Hydrometer analysis was used to find the particle sizes from the material passing through the No. 200 sieve, this in conjunction with Atterberg limits were used to classify the clay material. The Hydrometer results showed that around 9% of the material is classified as clay. The plasticity index for the soil is 7 with a liquid limit of 41 and a plastic limit of 34. This classifies the material as low plasticity clay (CL).

The specific gravity of the clay material was needed for calculations during hydrometer analysis. The specific gravity was measured as 2.64.

The maximum dry density curve was found using mechanical compaction. The optimum moisture content of the Kwigillingok soil is 18% with a maximum dry density of 97.4 lb/ft^3. The moisture density curve is presented as Fig.9.

(b) Kwigillingok Soil treated with geofibers subjected to soaked and unsoaked conditions

The geofibers used for this stabilization are two inch long fibrillated type fibers (3627 BF). The fiber concentrations used for the stabilization are 0.2%, 0.4%, and 0.5%, by the dry weight of the soil. The soil samples were carefully prepared at optimum moisture content. Geofibers were added immediately before compaction. Soil was placed in alternating layers with geofibers in a large bowl and mixed by hand until uniformity was observed. The samples were compacted using a mechanical compactor. After compaction the samples were measured for unit weight. Unsoaked samples were tested immediately after compaction.

The only difference between the soaked and unsoaked samples is a 96 hour soaking period. After compaction of the soaked samples a 10-lb surcharge mass is placed on the sample and subjected to soaking for 96 hours. After the soaking period samples were tested after 15 minutes of draining the free standing moisture from the sample.

As shown in Figure 10, the unsoaked CBR was 45% while the soaked CBR was 30%. The 33% reduction in CBR indicates the material is moisture sensitive. The addition of fiber shows little improvement in the design CBR. However, further inspection shows the untreated silt is strain softening which is consistent with our experience and the literature. The fiber treated material is strain stiffening which is also consistent with our experience and the literature.

(c) Improvement with Portland cement

Due to the large amount of moisture (55%) found in the in-situ Kwigillingok samples it is unrealistic to believe a soil condition near optimum moisture (18%) could be achieved in a cost effective manner. In an embankment the moisture content expected would be lower than 55%, but higher than 18%, so 30% moisture was chosen to represent that condition. One sample was prepared at 30% moisture without any added Portland cement to provide a control sample. The measured CBR value for the control sample was zero at all depths of penetration.

Dry Kwigillingok clay was mixed with type I Portland cement. Samples were prepared at 2%, 3%, 4%, 6%, and 8% by the dry weight of the soil. The preparation process consisted of weighing the dry Kwigillingok clay to an amount necessary to fill a CBR mold, then adding the Portland cement while both were still dry. The sample was then mixed to relative homogeneity, when finished water was added at amount of 30%. Once the sample appeared to have moisture evenly distributed throughout the soil it was compacted using a mechanical compactor following ASTM D1557. The sample was then put on the shelf in the laboratory at 30°C for seven days to cure. At the end of the seven day cure period the samples were moved to a soak tank for four days.   After the four day soaking period the samples were removed from the soak tank and allowed to drain for fifteen minutes. Any standing water remaining on the sample was removed using a paper towel.

The addition of Portland cement does seem to have an influence on the CBR value; however there is little influence on the moisture contents of the samples. The control sample when tested in the CBR apparatus had zero bearing capacity. The results of the CBR testing are presented in Fig.11, where the CBR value is shown versus the depth of penetration for the samples. There are two things of interest in this figure, the first and most obvious is the increase in CBR performance with increasing up to 6% cement content, the sample with 8% cement did not perform as well as the 6% sample. It should be noted that as the cement percentages increased there was increased difficulty in mixing the samples homogenously, this probably explains the decrease in bearing capacity for the 8% sample. The second interesting piece of information that comes from Fig.11 is the strain hardening achieved with increasing amounts of Portland cement.

The moisture conditions of the samples before compaction and after soaking are presented in Table 2. The moisture content was measured twice, the first measurement comes as the average readings taken before and after compaction, the second is taken after the CBR test is finished. The first measurements are small representations of the sample while the second is a complete measurement of the entire remaining sample. The moisture contents show that there is a slight loss of moisture with increasing amounts of cement, however it is not significant.

The dry density of the samples was measured during compaction and after testing for each sample, the results are summarized in Table 2. Due in part to the added moisture loss there is a slight gain in the dry density for increasing amounts of Portland cement.

(c) Improvement with DirtGlue and PolyCure

DirtGlue is a polymer emulsion produced for soil stabilization and dust control. PolyCure is a drying agent produced by DirtGlue. In laboratory tests using silty sand a combination of 3.3% polymer emulsion and 10% PolyCure gave a 295% improvement over the untreated value. This technique was applied to the Kwigillingok soil at the same mixture percentages. The CBR test results show that the combination of DirtGlue and PolyCure provides greater improvement than any dosage of Portland cement. Test results are shown with cement improvement in Figure 11. In evaluating CBR values ranging from 7-20 are considered fair. The addition of geofibers would add a slight advantage however the moisture conditions of the soil are above a range that would provide adequate stabilization of the soil.

Test synopsis

The greatest increase in strength comes from simply drying of the material. This is common with high clay content materials. However, untreated high clay content materials also exhibit a rapid loss of strength as water content increases. In the case of Kwigillingok clay, the soil does not easily absorb water after compaction. Consequently, if the material can be dried, embanked and compacted, it should perform well with a surface course over the top. Weather in the Kwigillingok area may preclude drying by aeration alone. The addition of drying agents such as lime, Portland cement or PolyCure could overcome this.

We do not get the initial doubling of CBR that we saw with Bethel silt. We suspect this is due to the high clay content which increases the unsoaked CBR at optimum moisture content to about 45. Addition of fiber causes the silt to gain strength with deformation. This is the result of mobilizing the strength of the fibers as they are put in tension which can be accomplished using rubber tired or pads foot compaction equipment. It is important to note that dense graded granular materials are typically strain stiffening. Since our goal is to cause the silt to act more like gravel, this is a good sign.

There are no tests presented that provide a combination of geofibers and synthetic fluid. This is due to limited material available for testing. Once a sample is treated with synthetic fluid it is discarded. The strength of the material will almost certainly increase with the addition of geofibers based on the strain hardening characteristic of geofibers. The focus of the testing performed was to find a chemical additive that would address the high moisture conditions.

Recommendations and Conclusions

The surface of the runway is sufficiently hard for the type of traffic it currently receives. One intermediate course of action at this time would be simply adding enough surface course to level the existing surface. This should improve runway surface and minimize surface hazards.

The surface material on the runway at Kwigillingok is already stable. The addition of fibers will not add strength. However, a dust palliative may reduce grading and loss of fines. The underlying clay material could be treated, but the risk would be breaking the surface layer and not being able to make it any better than it currently sits.

The use of fibers and synthetic fluids are not recommended for use at Kwigillingok at this time. The addition of Portland cement did provide some improvement. However, the improvement was not great enough to suggest its use.

Finally, a new product, PolyCure does show promise, but testing has not been completed at this time. AUTC will provide information as it becomes available.

The best alternative at this time is to add granular material to the existing surface without disturbing it. The greatest problem to be overcome is to move the material from the docks to the runway. The roadway connecting the two is incapable of handling heavy traffic required.

Table 1: Results of Stiffness testing

Distance measurement Taken	first measurement		second measurement		third measurement		average
[ft]	(MN/m)	CBR	(MN/m)	CBR	(MN/m)	CBR	
0	6.54	7	6.66	7	11.23	31	15
450	7.20	9	7.12	9			9
805	8.79	17	7.44	10			10
1160	8.97	18	5.21	2	6.06	5	8
1515	11.99	36	10.63	27			27
1870	10.31	25	9.16	19			19
2350	10.44	26	9.32	20			20
2820	9.77	22	12.96	44			44
					Average of all readings		19

Table 2: Summary of moisture content results for samples treated with cement

% of cement by dry weight	**Moisture content during compaction (%)**	**Moisture content after testing (%)**	**Dry Density during Compaction (lb/ft^3)**	**Dry Density after testing (lb/ft^3)**
0	30.1	28.5	87.3	87.8
2	29.2	28.6	87.4	87.8
3	28.5	28.0	88.3	88.6
4	28.1	27.6	90.5	90.8
6	27.8	26.7	90.9	91.8
8	27.4	26.5	91.4	92.5

Figure 1: Melting Permafrost puddle on the northern end of runway

Figure 2: Elevated northern section of runway unused for airline traffic

Figure 3: Area disturbed in front of picture is where eight inches gravel was found

Figure 4: Hole on side of the runway showing a shallow depth of gravel

Figure 5: Ruts caused from melting permafrost on northern end of runway

Figure 6: Map of Kwigillingok runway with points of interest marked

Figure 7: Area where clay was collected

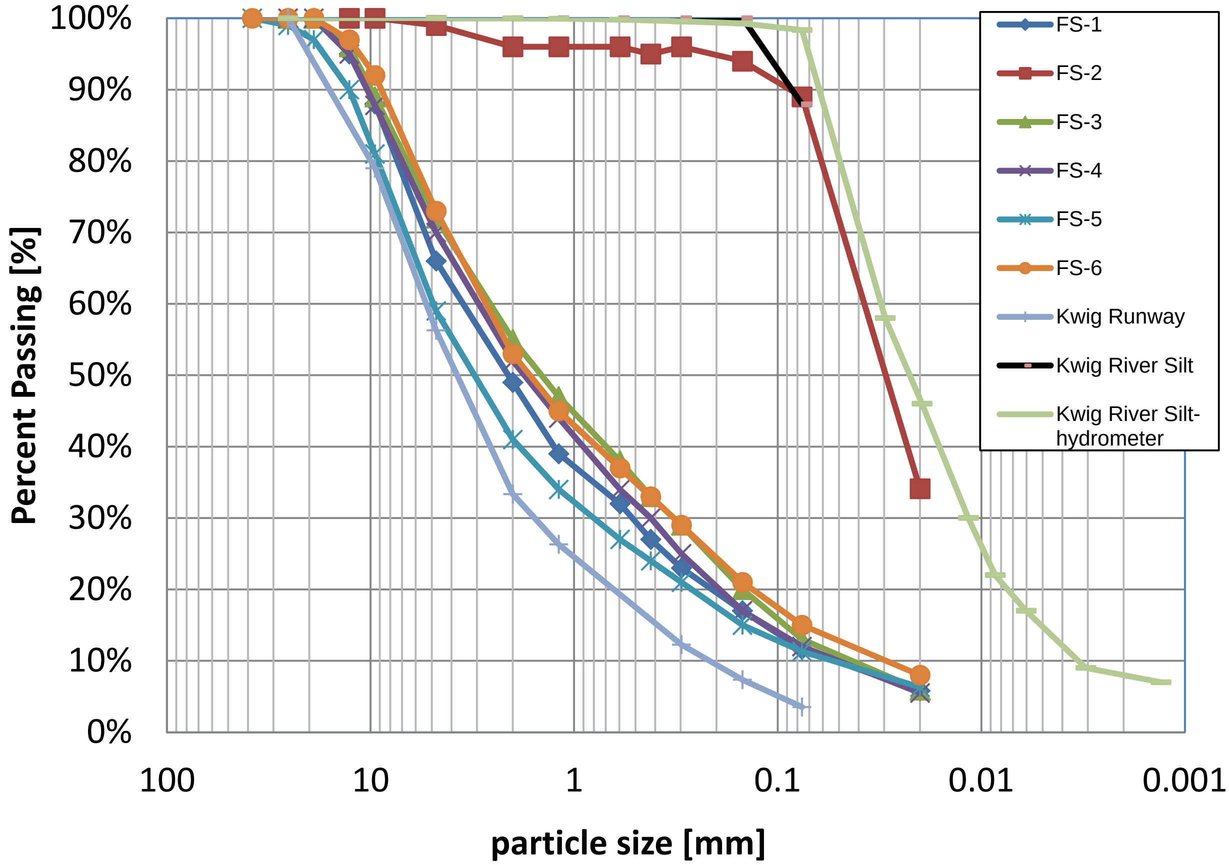

Figure 8: Particle Size Analysis of Kwigillingok Soil

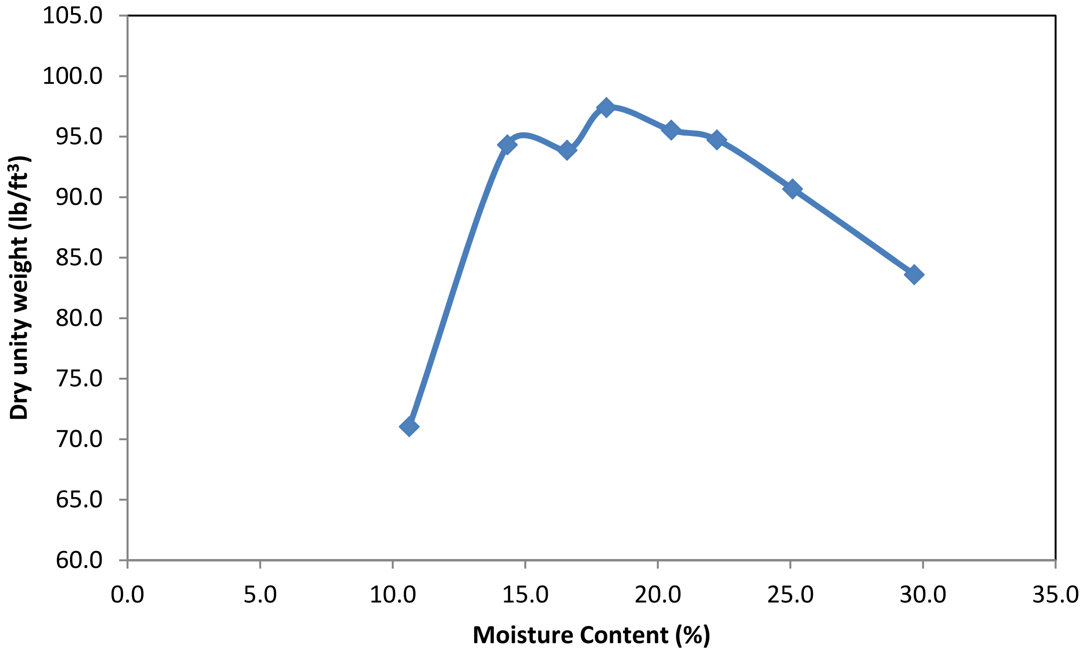

Figure 9: Moisture Density curve for Kwigillingok Clay

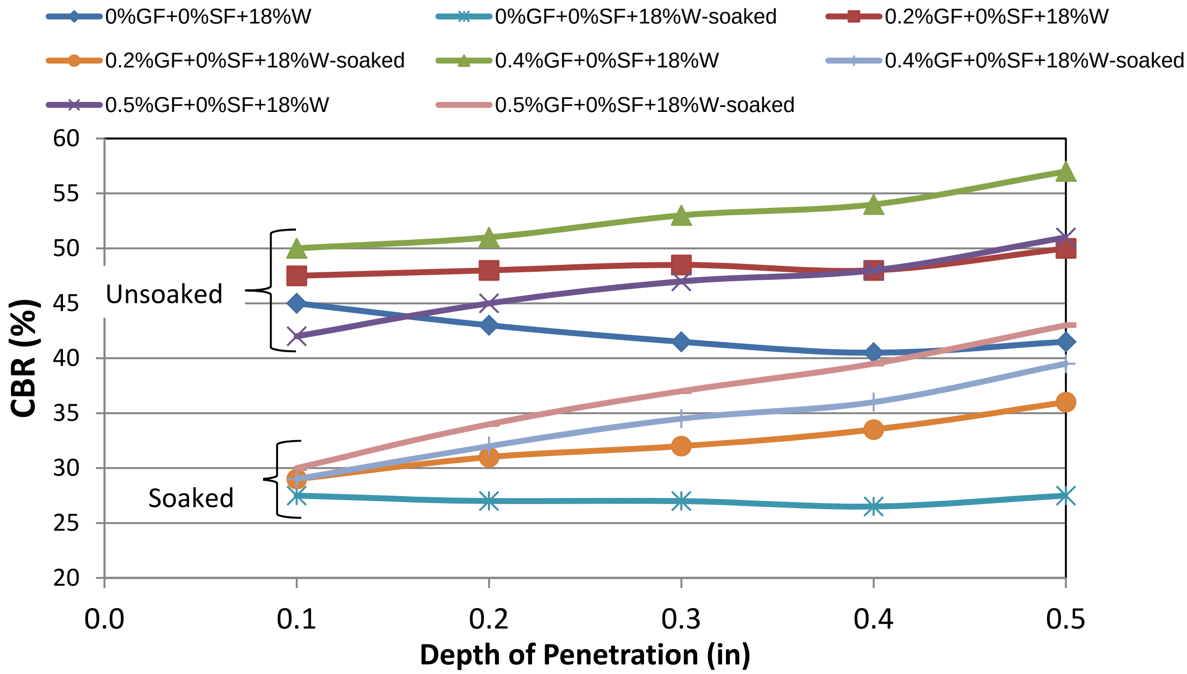

Figure 10: Soaked and Unsoaked CBR test results for samples treated with geofiber

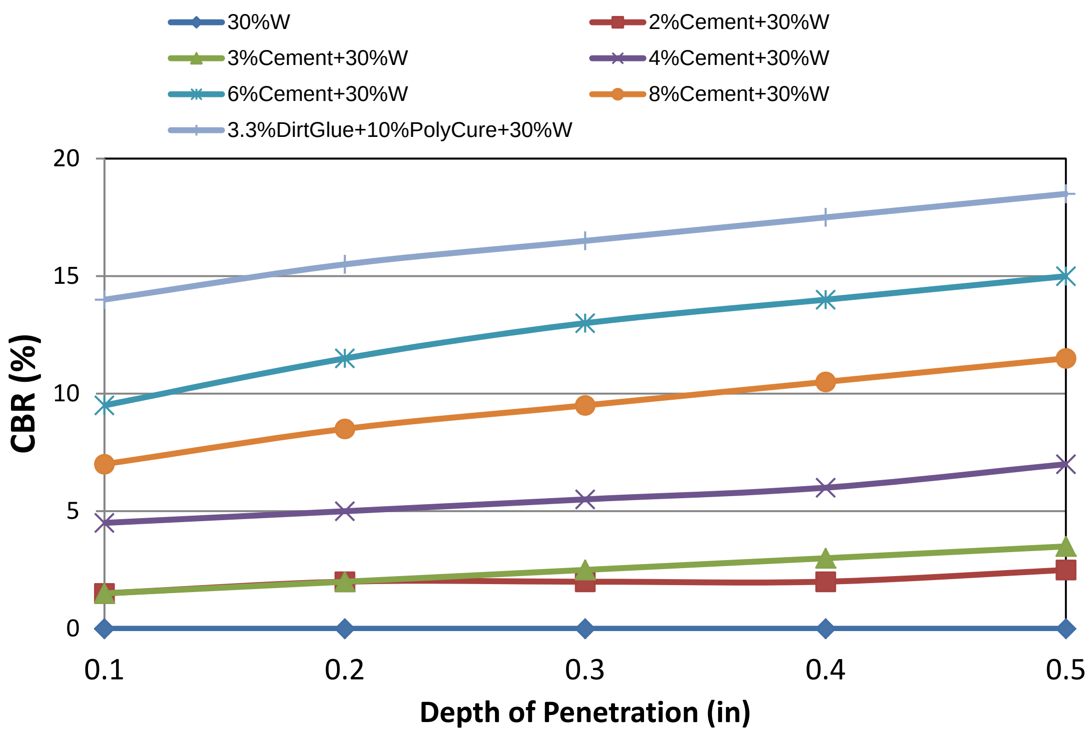

Figure 11: Depth of Penetration versus CBR value for samples treated with cement and DirtGlue