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Using Geofiber & Synthetic Fluid to Stabilize Marginal Soils

by Kenan Hazirbaba & Billy Connor

Constructing airfields and roadways in Western and Northwestern Alaska is expensive, not only because locations are usually remote, but also because sources for the gravel necessary to a good, stable foundation are scarce. Often, importing gravel to the construction site means a lengthy barge ride at costs in excess of $300 per cubic meter, which can translate to several million dollars for a typical construction project in the North. Consequently, engineers are always looking for ways to use the local silts and sands readily available on site as much as possible, and thus reduce construction costs.

Many Alaskan soils, particularly in the north and northwest, are made up of glacial silt, which is notoriously fine-grained, frost-susceptible, and prone to erosion and collapse if not improved or treated.

In the fall of 2006, Peak Civil Technologies (PCT) took on a project to stabilize a construction site at Cape Simpson in Northern Alaska. The native soils at Cape Simpson consist of poorly graded sand with a typical California Bearing Ratio (CBR) of seven (soft soil with a very low bearing capacity). Working with materials provided by two private companies (Fiber Soils and Earth Armour, Ltd) PCT combined geofibers and a Severely Hydrotreated Paraffinic Liquid to stabilize the sand. Through use of these additives, this company was obtain CBRs of 25 (competent soil with good bearing capacity) at a significant cost reduction. This non-traditional soil stabilization technology has proven to work very well.

(continued on page 6)

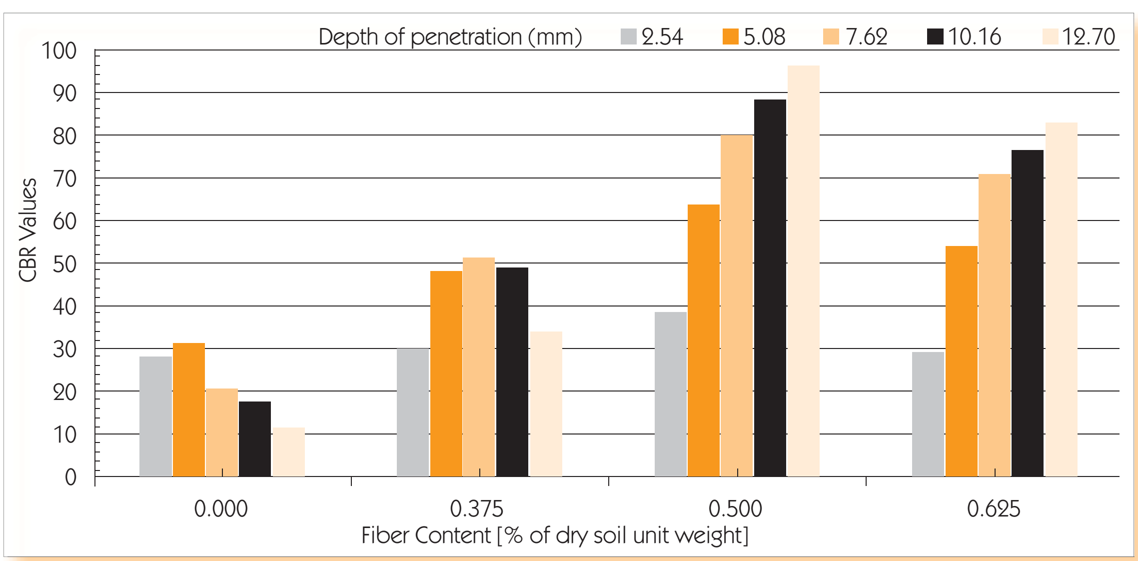

Figure 1 (left). CBR value vs. percent fiber for each depth of penetration at 11% moisture content. Graph produced by K. Hazirbaba.

Figure 2 (above) The UU triaxial compression tests showed the failure mode changes from a distinct failure plane for unimproved soil samples (left) to a bulging-type failure with no distinct failure plane in the case of geofiber-reinforced soil samples (right; dilative to contractive). Photos by Yu Zhang.

Contents

This project could lead to cheaper and better construction foundations throughout the Arctic regions.

"Dusty, unpaved roads affect the quality of life for many villages in cold regions."

AUTC's second call for proposals netted an impressive 61 brief white papers outlining a total request of about $16 million in research.

"The capabilities available at UAS offer a complementary addition to the AUTC in advancing transportation research and education around the state"

Mastering the logistics and organization involved in working with two remote field sites and multiple research partners is a big part of a successful research project.

The AUTC Newsletter is published semi-annually by the **Alaska University Transportation Research Center**, Institute of Northern Engineering, University of Alaska Fairbanks, to inform readers about our research and outreach activities.

AUTC addresses issues related to research and technology themes as identified in the Highway Research and Technology Report (April, 2002), including the impact of climate change on permafrost, reducing construction and maintenance costs of transportation infrastructure, improving air quality during the winter months, and other measures to address multi-modal issues facing Alaska and the nation's transportation community.

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UNIVERSITY OF ALASKA FAIRBANKS

Director's Notes

The latest responses to the AUTC Request for Proposals drew an interesting reaction from our project selection committee. The list of projects made us painfully aware that our approach to research is woefully inadequate. Each project aimed for "the topic of the day" rather than addressing a clear strategic goal. For example, we had a large number of proposals dealing with seismic impacts on bridge structures over frozen ground. None of us could visualize how the proposed projects fit together, whether they overlapped, or the over-arching goal of the research. We saw the same problem in most other interest areas. As a result, the selection committee asked AUTC to focus and narrow the research goals provided by the Governing Board.
This will provide clearer guidance to researchers about our priorities.

A look at the Transportation Research Board Research in Progress pages (http://rip.trb.org/default.asp) suggests that our experience is not unique. While each project is valuable, there seems to be a lack of sustained direction in any field. Looking back on my own career at the Alaska DOT&PF, I realized that most of our research was aimed at solving a problem confronting us at that moment; we did not consider how each problem might fit into "the big picture." I also realized that on occasion, interest in a certain line of research dwindled because the problem under study ceased to be an issue.

AUTC is developing strategic goals consistent with our center theme, 'Safety, Security and Innovation in Cold Regions.' Rather than focusing on solving "the problem of the day", we seek to focus on a larger goal. As an analogy, consider Henry Ford's development of the automobile. His goal was not to invent the auto, or introduce the internal combustion engine, or develop the assembly line; all had already been done. Instead he combined these technologies with a much more ambitious goal in mind: to produce an affordable automobile for the masses.

The articles in this newsletter feature AUTC projects aimed at bigger goals. The lead article focuses on reducing construction costs in western Alaska and other locations that have only fine-grained soils. Use of geofiber offers us the potential to reach this goal. A related problem is dust control in rural Alaska. Our guiding light here is to improve air quality in rural areas. We are looking at a number of techniques both new and old to accomplish this goal.

A series of workshops will be held over the next few months to develop strategic goals and road maps to achieve these objectives. The first, to be held in April, 2008, will develop goals related to bridges and transportation structures. We will invite not only Alaskans, but also participants from FHWA and other organizations outside the state. Associate Director Dr. Leroy Hulsey leads this effort. AUTC will use the experience gained from this workshop to develop additional workshops.

I encourage other UTCs and agencies to move toward a more strategic research program. Ask yourselves what you want to accomplish over the next 10, 20 or even 30 years, then focus your programs to meet those goals. The answers will vary for each UTC. In the end, the impact of our research will be far greater than simply solving the problems on our desk today — some of which may not be important tomorrow.

Dust Measurement to Determine Effectiveness of Rural Dust Control Strategies

by David L. Barnes, Ron Johnson, and Richard Wies

Dusty, unpaved roads affect the quality of life for many villages in cold regions; in Alaska alone, 60% of the roads are unpaved. Dust can cause or aggravate respiratory ailments and affect food harvests for people who live off the land, as well as reducing visibility for drivers and pedestrians.

In addition, loss of this fine material also degrades road surface quality, increases maintenance costs, and wear and tear on vehicles.

Many communities expect that paving their roads will solve all these problems. While paving may help, in many cases it only leads to other worries. Paving requires expensive materials, which must often be shipped in. Paved roads require sturdy foundations, and local materials may be unsuitable, leading to higher costs and a shorter working life for the paved surface. Pavements tend to break down more quickly in these extreme climates, and many small, sparsely populated areas don't have the resources or equipment to maintain paved roads. In no time, the road is as dusty as ever.

A more suitable option may be dust palliatives (such as applying a commercial material that will help the soil clump together) and institutional controls (controlling vehicle speed, so that less dust is stirred up by each vehicle).

Possibilities for dust control abound, but which will best fit a subsistence lifestyle, and what can a given community afford? There is no consensus on how to measure the effectiveness of any given dust control strategy, much less the economic and environmental impacts of the various possibilities.

This project seeks to develop a methodology and instrumentation to accurately monitor dust production on roads, and to use these tools to support field testing of various control strategies in various locations.

Understanding How Unpaved Roads Degrade

Technically, those plumes trailing behind every vehicle on a dirt road are made up of solid particulate matter, both mineral and biological, small enough to float in the air for hours. Dust is a little smaller than grit and a little larger than smoke (Foley et al. note that the size is between 0.1 microns and 75 microns).

Although many researchers have extensively studied different dust control strategies, none have thoroughly studied and compared how effective various strategies are in rural villages located in cold climates, like those found in Alaska, and none have focused on winter dust production.

For example, the regular freezing and thawing of a road surface will most likely over time affect the integrity of any palliative applied. In addition, the preferred modes of travel in rural Alaska are snow machines and those all-terrain vehicles commonly called "four wheelers." How such activity affects dust palliatives and dust emission from unpaved roads is currently unknown.

The material deterioration also causes the road wearing surface to degrade. Typically, the fine soil particles (that is, soil particles with mean diameters less than 0.075 millimeters) in unpaved road surfaces mix with water to act as a binder that holds coarser material together, providing a smooth driving surface. The abrasive action of the vehicle tires pulverizes the fines over time, more acutely during dry conditions. The pulverized fines then leave the road through wind action or vehicle motion and settle in the areas surrounding the road. The coarse aggregate, exposed by the escaping fine material, is pried lose through vehicle activity; then ruts, potholes, and washboards form. Water from rain or melting snow forms in these ruts and holes, and more fines are washed or splashed away, making the holes deeper and the road rougher.

Left: David L. Barnes, AUTC researcher and UAF Civil & Environmental Engineering. Photo by K. Hansen.

Opposite page, bottom: A boy crosses a dusty street in the town of Kotzebue, Alaska. Photo by Jeff Hickman, Alaska Department of Environmental Conservation.

Right: Electrical engineer Rich Wies and Payal Jalan, graduate student in Electrical Engineering, discuss instrumentation for measuring dust concentration & particle size. Photo by K. Hansen.

Developing the Right Measurement Tools

Identifying successful dust control strategies for rural Alaska requires a reliable means of comparing the effectiveness of different dust control strategies. One way to compare them is to measure the dust escaping as a result of vehicle traffic off different sections of roadway that have been treated with different dust suppressants. While other researchers have used this method, each research group developed an instrument customized to the conditions they studied – and none of these targeted dust production from four wheelers.

The AUTC team is developing their own instrumentation; once it is complete, they will begin by comparing the effectiveness of several different chemical dust suppressants of interest to the Alaska Department of Transportation & Public Facilities. This instrument will measure the amount of dust liberated from the wearing surface by a moving four wheeler. These measurements are made by passing dust collected by a vacuum system positioned behind one of the rear tires through a laser instrument that will determine the amount of dust produced. Measurements will also be made by passing the collected dust through a filter. The filters will be analyzed in UAF laboratories to quantify the amount of dust produced.

Determination of dust palliative effectiveness will be made by comparing different palliatives against each other. In addition, researchers can also take measurements as to the effectiveness of controlling speed on dust production and on how tire selection may improve dust suppression.

Development of this instrument requires a multidisciplinary team of engineers. Mechanical engineer Ron Johnson and student Tom Marsik are working on designing the portable collection system and instrumentation. Electrical engineer Rich Wies and student Payal Jalan are working together to design the power system that will support this instrumentation and assisting with designing the instrumentation. Civil engineer Dave Barnes is supplying his knowledge of roads and soils, which is key to identifying the most promising dust control measures, as well as contextualizing the team's new data in terms of earlier studies.

To date, this diverse team has designed the dust measurement instrumentation and begun laboratory testing. Once snow-free driving surfaces are available, they will begin field testing, with their equipment mounted on the back of a four wheeler. This field testing will allow them to determine how the instrument responds to different configurations and different driving conditions.

Mechanical engineer and air quality specialist Ron Johnson (left) discusses with graduate student Tom Marsik how to best adjust their air quality instrumentation for use on the back of an all terrain vehicle. Photo by K. Hansen.

New Research Projects in the Pipeline

AUTC issued its second call for proposals on 13 September 2007; by 29 October we had received an impressive 61 brief white papers outlining a total request of about $16 million in research. We are now in the process of reviewing and ranking each of these; soon we will invite the top ranking projects into our Phase II Review process. Watch for updates at our web site: www.uaf.edu/AUTC/AUTCproposals.html

2007 Project Update

As you may remember, our first RFP netted 65 original submissions, and 20 projects made it to the Phase II Review.

Currently 18 projects are up and running. To date, the Alaska Department of Transportation & Public Facilities has been our biggest partner, providing cost share and expertise for 14 of these projects.

AUTC has also formed partnerships with other universities in the Northwest region, local companies and other private organizations, and the Canadian Government for additional technical and financial resources.

Our goal is to expand industry participation in upcoming funding cycles.

Stabilizing Marginal Soils *(from p.1)*

A Joint Research Venture

Following the success of the Cape Simpson project, the Alaska Department of Transportation & Public Facilities (AKDOT&PF) expressed an interest in using this technology for a roadway project in Bethel, Alaska. The Alaska University Transportation Center (AUTC) and PCT co-sponsored a research effort to explore the feasibility of using the new soil stabilization technique in Bethel.

The research team, led by Dr. Kenan Hazirbaba, Civil & Environmental Engineering faculty at the University of Alaska Fairbanks, formulated a set of questions to produce the material design best suited for the Bethel project:

- What is the optimum fiber content?
- What is the optimum synthetic fluid content?
- What is the strength contribution of each of these additives?
- What additional strength can be expected from the combination of geofiber and synthetic fluid?

To explore these questions, the team developed an experimental program consisting of CBR tests and undrained-unconsolidated (UU) triaxial compression tests at varying moisture, fiber and synthetic fluid contents. All tests were performed according to appropriate ASTM or AASHTO test procedures in University of Alaska laboratories. Valuable data indicating potential for significant cost savings and promising results were obtained from this research.

What the Data Show:

- Bethel silty sand has an optimum moisture (water) content of 11%.
- The CBR value at this optimum moisture content without stabilizers was found to be 31 (at 5.08 mm penetration). This CBR value falls within the typical range (20-40) for SM type silty sand.
- The optimum geofiber content, which corresponds to the largest CBR value, appears to be about 0.5%. Lower or higher geofiber contents resulted in lower CBR values.
- Adding 0.5% geofiber at the optimum moisture content (11%) increased the CBR value from 31 to 63 at 5.08 mm penetration and to much higher values at larger penetrations. Thus, adding 0.5% geofiber to the soil improved the CBR values by 100% or higher. The geofiber-reinforced (improved) soil appears to be in the range of well-graded gravel or sandy gravel, for which CBR values range from 60 to 80. Figure 1 shows a graph of soil improvement in terms of CBR values with different fiber contents.
- In seeking the optimum synthetic fluid content, researchers found that the synthetic fluid performed successfully only when combined with some original moisture (water) present in the soil. The optimum combination of synthetic fluid content / water content was found to be 5% / 6%. It is also important to note that the total soil liquid content in this case was 11%, which is equal to the moisture content determined for the native (no stabilizer added) soil.
- Adding the synthetic fluid alone did not noticeably improve the CBR values. In general, the CBR values obtained from the samples improved with synthetic fluid were very similar to those obtained from unimproved soil samples at optimum moisture content.

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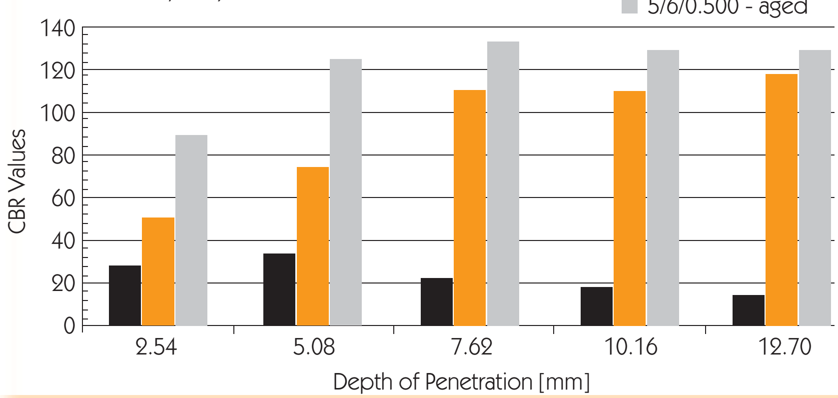
- ► Studies of soil-strength characteristics through UU triaxial compression tests indicated a friction angle of 41.8° and a slight cohesion of 20 kPa from native (no stabilizer added) soil samples compacted (Modified Proctor) at the optimum moisture content of 11%. When 0.5% geofiber was added, the cohesion increased significantly, from 17 kPa to 162 kPa, while the friction angle increased by about 2° only. However, adding synthetic fluid along with geofiber showed a less pronounced increase in cohesion, with a more significant improvement in the friction angle. The cohesion and friction angle for this case were 77 kPa and 53.6°, respectively.
- ► The UU triaxial compression tests also showed the failure mode changes from a distinct failure plane for unimproved soil samples (See Figure 2, left) to a bulging-type failure with no distinct failure plane in the case of geofiber-reinforced soil samples (right; dilative to contractive).
- ► Based on the results of both CBR and UU triaxial compression tests, to get the best performance from the Bethel silty sand, the optimum combination of synthetic fluid /moisture/ geofiber content appears to be 5% / 6% /0.5%.
- ► Aging soil samples by approximately 10 days yielded a further significant improvement in the CBR values. This aging-related improvement, for the optimum combination of 5%/6%/0.5%, was found to be on the order of 340%; the CBR increased from 36 (in an un-aged sample) to 124 (in an aged sample).

Further Plans

This research will be extended to other soil types typically found in Alaska. Ultimately, the research team will also produce a design manual for professionals and state agencies to use.To learn more about this project, visit www.uaf.edu/ine/AUTC.

Figure 3. CBR vs. Depth of Penetration for aged samples with fiber. Graph by Hazirbaba.



Meet Our New Associate Director for UAS Patrick W. Brown

AUTC is happy to introduce the new associate director for the University of Alaska Southeast campus (UAS), Patrick W. Brown

Brown joined UAS in October of 2007 as the Dean for the School of Arts and Sciences and as the Vice Provost for Research. He was previously Director of the Michigan Natural Features Inventory, a research and outreach group within Michigan State University Extension. He also held an appointment in the Fisheries and Wildlife Department at MSU. Prior to that, he served as Director for the Center for Wildlife Ecology in the Illinois Natural History Survey, and as the Department Head of Biology and Chemistry at Lake Superior State University. His degrees include a Ph.D. from the University of Missouri-Columbia in Fisheries and Wildlife Ecology, an M.S. degree in Animal Ecology from Iowa State University and a B.S. in Biology from Central Michigan University.

As Associate Director of AUTC, Brown hopes to bring his passion for interdisciplinary research and undergraduate education into play in linking UAS to transportation issues in the state. UAS has strong expertise in landscape analysis, environmental science, biology, and other areas in the social sciences that overlap with planning for modern transportation systems. UAS is also developing a pre-engineering program intended to link UAS students to engineering programs at UAF and UAA, helping Alaska meet its needs for engineers in the future. Brown believes that the capabilities available at UAS offer a complementary addition to the AUTC in advancing transportation research and education in the state.

Brown has two sons, Daniel and Adam, who are both pursuing graduate programs at Oregon State University (one in Atmospheric Science and the other in Mechanical Engineering). His wife, Mary Ann, works as a child care provider with the Gold Creek Child Development Center in Juneau.

AUTC's Outstanding Student

by Sandra Boatwright

This year's winner of the Alaska University Transportation Center Student of the Year Award is Will Rhodes, a University of Alaska Fairbanks Master's candidate in Environmental Engineering. Rhodes earned his Bachelor of Science degree at UAF in Geology in 2005.

Rhodes' research has centered on "Herbicide Attenuation in Alaskan Soils," a joint project between the AUTC, the Alaska Department of Transportation & Public Facilities, the USDA Subarctic Agricultural Research Unit, and the Salcha-Delta Soil and Water Conservation District. As part of this project, he participated in controlled field testing in Delta Junction and Valdez, Alaska to determine how effective a combination of mechanical brush cutting and herbicide application might be in controlling vegetation.

Rhodes examined soil samples collected over the course of a year from field sites treated with a combination of mechanical mowing and herbicide. He analyzed these samples in the lab to track how quickly the herbicide chemicals diminished under varying climactic conditions, and what simpler compounds they formed as they broke down. Rhodes spent the winter analyzing his data and writing his thesis.

Study results will aid the AKDOT and the Alaska Railroad Corporation in making decisions on herbicide use in Alaska and on best practices for application.

The most challenging part of this project, Rhodes says, was mastering the logistics and organization involved in working with two remote field sites and multiple research partners to develop a strong, reliable experimental methodology.

Rhodes was chosen for this award based on his research achievements and his high GPA.

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