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Field and laboratory performance of a cold-region sand stabilized with geofiber and synthetic fluid

Kenan Hazirbaba

Department of Civil Infrastructure and Environmental Engineering, Khalifa University, United Arab Emirates

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ABSTRACT

This paper presents results from a case study on the improvement of a poorly graded sand through treatment with geofiber and synthetic fluid. The soil improvement technology was applied in the field at a site near Barrow, Alaska. The treatment at dosages of 0.25% geofiber and 1% synthetic fluid was effective and met design requirements based on tests conducted shortly after the completion of the stabilization process. However, after going through a full freeze-thaw cycle, some deterioration in load bearing characteristics was encountered. Field CBR and soil stiffness tests were performed to quantify the strength loss in the soil. Additionally, an extensive and systematic laboratory testing program was implemented to investigate and evaluate the treatment dosages of the additives used. The laboratory tests evaluated each of the additives independently, as well as for their combined use. The best performance in the laboratory was obtained from samples containing 0.35% geofiber and 2% synthetic fluid. Freeze-thaw tests were performed on various compositions of treatment to study the potential factors responsible for the loss of strength encountered in the field. When subjected to freeze-thaw, samples experienced significant decrease in CBR performance. Also, a group of tests on cured samples were conducted to evaluate the time-dependency of soil treatment. The field dosage rates did not show any improvement with curing, however other treatment compositions indicated slight to moderate increase in CBR performance due to curing.

1. Introduction

Stabilization of cold region soils is particularly challenging, because geotechnical properties of soils are affected by extreme ground temperatures and cycles of freezing and thawing. Decreased shear strength and stability of soils after winter seasons, which is known as thaw weakening, is a common engineering problem in cold regions. The other common geotechnical problem is frost heave; as voids within soils are exposed to low temperatures, water transforms into ice particles. When the soil is fully frozen (i.e., water within the voids between soil particles are completely frozen), the volume of water increases approximately by 9% resulting in unavoidable cracks in the soil. The strength of the soil decreases as the size and number of cracks increase (Qi et al., 2006).

The engineers and practitioners of cold regions continually look for innovative and effective methods of soil stabilization that allow the increased use of local materials. Traditional stabilization techniques may not be viable as they require large amounts of additives and specialized skills and equipments (Tutumluer et al., 2004). Technologies that can be implemented with minimal installation equipment and allow for construction in sub-zero environment (i.e., cold region with freeze-thaw exposure) are preferred. Recent research on the combined use of geofiber and synthetic fluid for stabilizing silty soils has reported promising results and a cost-effective solution for cold region construction (Hazirbaba and Connor, 2009; Hazirbaba and Gullu, 2010).

To improve the engineering properties and performance of base and subbase soil, geofibers have been used extensively due to their low cost, light weight, and significant contribution to strength gain. The addition of geofiber increases the load bearing capacity of sands; and improves the shear modulus and liquefaction resistance (Freitag, 1986; Arteaga, 1989; Maher and Ho, 1994). Previous investigations showed that the improvement of soil properties is a function of the type, length, content, and orientation of the geofiber (Gray and Al-Refeai, 1986; Arteaga, 1989). As for the use of synthetic fluid for stabilization purposes, fewer studies exist. Webster and Santoni (1997) and Tingle et al. (1999) reported the use of a synthetic fluid-like material, known as Road Oyl, for pavement application, dust control treatment, and erosion control. In terms of molecular structure, synthetic fluid molecules are formed from wax feedstock consisting of paraffinic carbon chains. Through synthesis, these chains transform into isoparaffins that cannot reorganize into crystals; the resulting new and better performing molecules (i.e., from engineering perspective) are called synthetic fluid. Among the advantages of synthetic fluid are: (i) it is non-toxic and

E-mail address: k.hazirbaba@gmail.com.

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Fig. 1. Location of the site.

thus safe to use without health-hazard concerns; (ii) it maintains its fluid form at sub-zero temperature; and (iii) synthetic fluid is oxidation resistant.

In this case study, field application of the combined use of geofiber and synthetic fluid for stabilization of a cold region sandy soil was investigated. Quality control and assurance tests during the stabilization process and shortly after its completion indicated very favorable results; however reevaluation of the field performance after a complete freeze-thaw cycle showed some deterioration in CBR values and thus the bearing capacity throughout the site. An extensive experimental program was designed and implemented to explore the factors responsible for the decrease in performance and apparent loss of strength with time.

2. Field application and measurements

A trial test pad was used for deployment and field performance of the new soil stabilization technology. The test pad was constructed as part of an extension project of an oil exploration staging site in Cape Simpson, Alaska. The site is located 75 km east of Barrow, Alaska (Fig. 1). It is accessible only by helicopter from Barrow during summer time or by shallow draft barge starting in August due to sea ice. Annual variation of temperature of the Barrow area is presented in Fig. 2. Annual peaks occur between July and August at temperatures slightly above zero without ever exceeding 10 °C. The plan dimensions of the test pad are approximately 210 m by 80 m (Fig. 3). The pad was required to support heavy equipment, storage tanks, modules and other oil exploration and production related activities. The design bearing capacity requirement was specified as a minimum CBR value of 20 for these types of loads and activities. Stabilization of the pad was necessary because initial load bearing characteristics of the site did not meet the minimum acceptable state. A total of 10 representative CBR measurements that were conducted across the site (i.e., prior to stabilization) indicated an average CBR of 6 with a maximum value of 8 and a minimum value of 2, far from the required minimum value of 20, for the entire pad.

A feasibility assessment and thorough evaluation of possible soil stabilization alternatives applicable for this site indicated the use of geofiber and synthetic fluid to be a cost-effective solution. Thus, fibrillated type geofibers and synthetic fluid were selected and used as

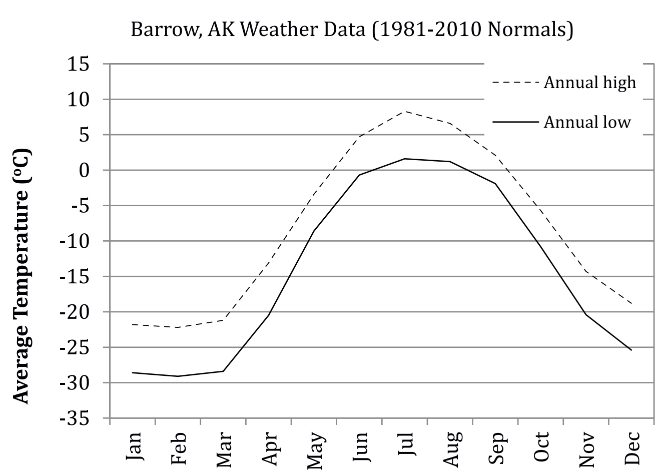

Fig. 2. Annual variation of the temperature for Barrow, Alaska.