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Original Research Paper

Comparison of short-term and long-term performances for polymer-stabilized sand and clay

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HIGHLIGHTS

- An MDI-based liquid polymer was used to stabilize poorly-graded sand and sulfate-rich clay.
- The short-term and long-term performances of the stabilized specimens were evaluated.
- The specimens showcased high durability after undergoing different weathering conditions.
- The polymer-stabilized sulfate-rich clay specimens showcased minimal swelling potential.

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ABSTRACT

A series of tests were carried out on sulfate rich, high-plasticity clay and poorly-graded natural sand to study the effectiveness of a methylene diphenyl diisocyanate based liquid polymer soil stabilizer in improving the unconfined compressive strength (UCS) of freshly stabilized soils and aged sand specimens. The aged specimens were prepared by exposing the specimens to ultraviolet radiation, freeze-thaw, and wet-dry weathering. The polymer soil stabilizer also mitigated the swelling of the expansive clay. For clay, the observations indicated that the sequence of adding water and liquid polymer had great influence on the gained UCS of stabilized specimens. However, this was shown to be of little importance for sand. Furthermore, sand samples showed incremental gains in UCS when they were submerged in water. This increase was significant for up to 4 days of soaking in water after 4 days of ambient air curing. Conversely, the clay samples lost a large fraction of their UCS when soaked in water; however, their remaining strength was still considerable. The stabilized specimens showed acceptable endurance under weathering action, although sample yellowing due to ultraviolet radiation was evident on

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the surface of the specimens. Except for moisture susceptibility of the clay specimens, the results of this study suggested the liquid stabilizer could be successfully utilized to provide acceptable strength, durability and mitigated swelling.

1. Introduction

Although cementitious materials such as cement and lime have been widely used as soil stabilizers for many decades, the geotechnical engineering community has never stopped searching for alternative stabilizers for circumstances where traditional cementitious stabilizers are not applicable or favorable.

When cement is used to stabilize soils, shrinkage, caused by hydration of the cement as well as drying, is a commonly observed phenomenon, which significantly reduces the strength and increases the permeability (George, 1973; Nakayama and Handy, 1965; Sebesta and Scullion, 2004). In addition, the stabilized soils, although having a high strength, are rather brittle, especially under dynamic loading (Acar and El-Tahir, 1986; Schnaid et al., 2001). The cracking and brittleness of cement stabilized soils have greatly influenced the long-term performance of stabilized soils for many applications.

In addition to the cracking and brittleness, when used for clay, the cementitious stabilizer can cause significant swelling if excessive sulfate is present (Celik and Nalbantoglu, 2013; Hunter, 1988; Mitchell, 1986; Mitchell and Dermatas, 1992; Puppala et al., 1999, 2005; Wang et al., 2004). The clay with excessive sulfate content is usually called sulfate-rich clay. It has been found that under pH conditions created by the cementitious materials, sulfate reacts with calcium ions to form ettringite ($Ca_6[Al(OH)_6]_2(SO_4)_3 \cdot 26H_2O$) and thaumasite ($Ca_6[Si(OH)_6]_2(SO_4)(CO_3)_2 \cdot 24H_2O$), which are highly expansive. The swelling could be as high as 200% (Faure, 1991; Harris et al., 2004; Little et al., 2010). Such a phenomenon is commonly referred to as sulfate-induced heave by geotechnical engineers.

The advent of unconventional, non-cementitious materials such as foams, emulsions of petroleum, enzymes, acids, and industrial waste materials have shown promising results in stabilizing problematic soils. While these materials are different in nature and chemical composition, they can be used to reduce permeability, mitigate soil liquefaction, and increase soil strength by filling the voids and providing bonding between the particles (Ajalloeian et al., 2013; Ajayi et al., 1991; Al-Khanbashi and Abdalla, 2006; Anagnostopoulos et al., 2013; Mohammad and Vipulanandan, 2013; Moustafa et al., 1981; Naeini et al., 2012; Ohama, 1995; Rauch et al., 2002; Santoni et al., 2002; Zandieh and Yasrobi, 2007). Among these unorthodox stabilizers, liquid polymers have gained attention due to their relative ease of use and promising outcomes. However, there is a lack of systematic studies on the stabilization methods of polymers for different soils, such as mixing or curing methods. As a result, the reported studies showed different outcomes even for the same soil. For instance, varying the polymer content of the specimens did not result in a consistent outcome in terms of resultant UCS (Rauch et al., 2002), and more saliently, in another case, adding polymer to soil samples decreased the strength of the specimens compared to untreated soil (Santoni et al., 2002). This inconsistency hindered the wide applications of polymers as a soil stabilizer for many situations. Considering the dilemma, this study focuses on investigating the mixing and curing methods as well as the short-term and long-term performances for sand and sulfate-rich clay.

The scope of the study includes the following:

1 Determination of suitable mixing and curing methods, and duration for a liquid polymer that was used to stabilize sand and sulfate-rich clay.
2 Determining the short-term behavior of the two stabilized soils. An unconfined compressive stress (UC) test was carried out for such purpose, and the clay samples were tested for their swelling potential.
3 Long-term performance of the stabilized soils was studied. For this purpose, clay specimens were subjected to soaking in water for prolonged time before their UCS and swelling potential were measured. In contrast, sand specimens

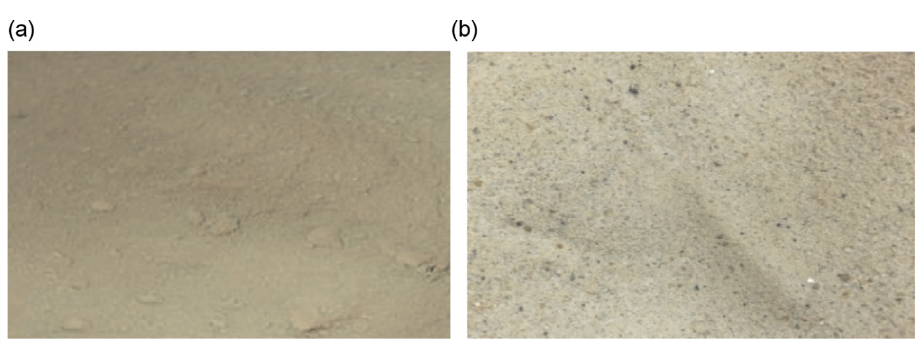

Fig. 1 – Soils used in the tests. (a) Sulfate-rich high plasticity clay. (b) Poorly graded sand.