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Use of water reducer to enhance the mechanical and durability properties of cement-treated soil

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HIGHLIGHTS

- Effects of water reducer on compaction of cement-treated soil were investigated.
- Water reducer decreased optimum moisture content of cement-treated soil.
- Water reducer increased maximum dry density of cement-treated soil.
- Water reducer improved the compaction of cement-treated soil.

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ABSTRACT

This study investigated the potential of using water reducer (WR) to enhance the mechanical and durability properties of cement-treated soil. WRs have long been used in Portland cement concrete (PCC) to increase the properties of PCC. When added at a small dosage, WR helps improve the dispersion of cement particles and release the water otherwise entrapped in cement clusters, thus reducing the water demand for the same consistency or increase the consistency of PCC without adding more water. Cement-treated soil uses similar raw materials and has similar chemical compositions to PCC. However, little research has been conducted to explore the potential of using WR in cement-treated soil to improve its compaction and thus its mechanical and durability properties. In this study, a laboratory experiment was conducted to examine the effects of WR on the compaction characteristics and engineering properties of cement-treated soil. As expected, similar benefits of water reduction and improved properties could be achieved by adding WR in cement-treated soil. The improved mechanical and durability properties of cement-treated soil were due to the fact that WR could improve the compaction behavior of cement-treated soil through reduced optimum moisture content and increased maximum dry density. Further studies are recommended for the interaction among WR, soil particles, and cement particles to achieve an optimal effect for engineering applications.

1. Introduction

Water reducers (WR) have long been used in the production of Portland cement concrete (PCC). When WR is added into PCC, WR molecules are adsorbed around cement particles, preventing the formation of cement clusters and thus releasing the water otherwise entrapped in these clusters. Use of WR can reduce the water demand for concrete to achieve the same workability or increase the workability of concrete if the same amount of water is used in making concrete [1,2]. In the case of water reduction, WR can significantly increase the strength and durability of PCC [1,2].

Cement-treated soil is a product of Portland cement blended with soil and/or aggregate, water and compacted for use as a pavement base layer material. Cement-treated soil has been widely used in pavement construction to treat and stabilize a variety of soils, including granular materials, silts, and clays since its first use in 1935 [3,4]. Due to the similarity in raw materials and chemical compositions between PCC and cement-treated soil, it would

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be natural to use WR to help disperse the soil particles and to improve the compaction of cement-treated soil, thus improving the engineering properties of cement-treated soil. However, little research has been conducted to explore the possibility of using WR in cement-treated soil to enhance its mechanical and durability properties [5].

Water plays a significant role in the compaction of soils and cement-treated soils. At an appropriate content called optimum moisture content, water can serve as a lubricating agent among soil particles to reduce the friction resistance between soil particles, thus improving the compaction quality to achieve the maximum dry density and the potentially best properties of soils after compaction [6]. Too much or too little water makes the compaction difficult, resulting in a poorly-compacted soil unless the compaction effort is adjusted accordingly. As Fig. 1 shows, with the increase in compaction effort, usually the optimum moisture content decreases and the maximum dry density increases.

When cement is added into a soil, a series of complex physiochemical interactions and chemical reactions take place among soil particles, cement particles, and water, resulting in the changes in the optimum mixture content and maximum dry density of cement-treated soil for compaction [7,8]. Christensen [9] found that the optimum moisture increased slightly and the maximum dry density decreased slightly in his study of 11 clay soils stabilized with stabilized with 3 and 5 percent cement. However, Baghdadi et al. [10] found that cement kiln dust (CKD) can significantly decrease the optimum moisture content and significantly increase the maximum dry density of pure kaolinite when the CKD content is less than 50%. Miller and Azad [11] observed an increase in the optimum moisture content and a decrease in the maximum dry density when CKD was added into three types of soil with different high, medium, and low plasticity and concluded that the effect of CKD on optimum moisture content and maximum dry density is obviously a function of soil and CKD type as well as compaction method.

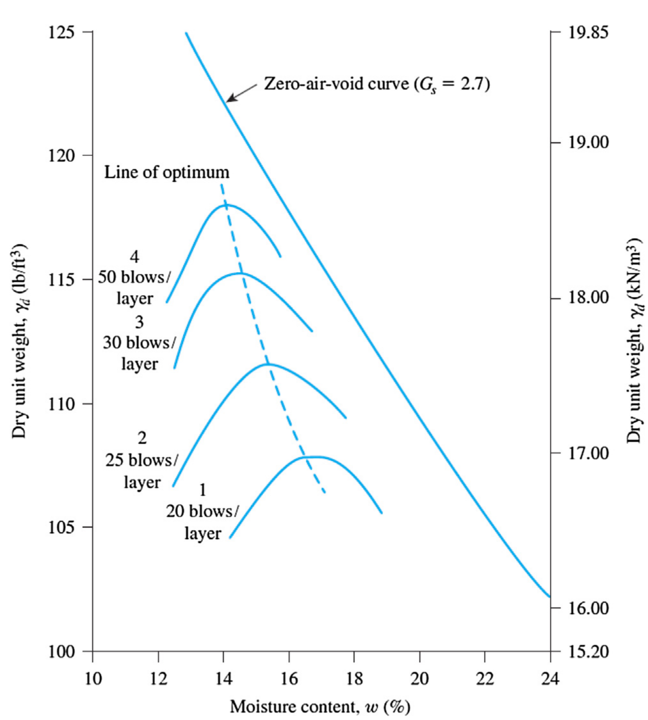

Fig. 1. Typical Compaction Curves of Soil [6].

2. Objective and scope

The objective of the study was to evaluate the effect of water reducer on the compaction of cement-treated soil and the thus to explore the potential of using water reducer to facilitate the compaction of cement-treated soil and to enhance the mechanical and durability properties of cement-treated soil. One type of water reducer widely used in the United State was selected in the study. Two types of soil from the state of Tennessee and two water reducer dosages were used. The laboratory tests used for the evaluation included the compaction, unconfined compressive strength, durability, and permeability tests.

3. Laboratory tests

3.1. Materials

Three types of soil from Tennessee, U.S. were used in the study and they are named Shelby, Frontage and Silty gravel, respectively. They were classified as A-4, A-7-6 and A-2-6 according to the American Association of State Highway and Transportation Officials (AASHTO) soil classification system; and CL and CL according to the Unified Soil Classification System (USCS). Table 1 presents the physical properties of the soils.

Type I Portland cement was used to make the cement-treated soil in the study. The amount of cement was 9 percent of the total dry weight of soil.

One type of water reducer widely used in the United States to produce Portland cement concrete was employed in the study. It is classified as Type A according to ASTM C 494. Based on the dosages recommended by the producer, two WR contents were used: 0.15% and 0.3% of the cement weight. For comparison purpose, the properties of cement-treated soil with WR were compared to those of cement-treated soil without WR and soil itself.

3.2. Sample preparation

The soil samples were first dried and mixed with cement using a mechanical mixer. Then water reduced was added into water and together they were added into the dry blend of soil and cement. The cement-treated soil was mixed using a mechanical mixer to achieve a uniform consistency. The mixes were left to stand for several minutes to allow the dispersion of WR and its interaction with cement and soil particles before two specimens 101.6 mm (4″) in diameter were made for each laboratory test.

For the laboratory compaction test, the specimens were immediately used for compaction. For the other three tests, the specimens were compacted at their optimum moisture contents and extracted from the molds two hours after compaction. Then the specimens were cured at an air temperature 20 ± 2 °C and at a relative humidity of 95% for 28 days. After the curing, the other three tests were performed.

3.3. Test methods

Four laboratory tests were performed to investigate the effects of WR on the behavior and performance of cement-treated soil, including compaction test, unconfined compressive strength test, durability test, and permeability test. The laboratory compaction test was conducted in accordance with ASTM D 698. The goal of this test was to develop the relationship between the dry density and moisture content and to determine the maximum dry density and the optimum moisture content, thus allowing us to examine the effect of WR on the maximum dry density and the optimum

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