Field and laboratory resistance assessment for deep mixing of clay-cement and clay-lime

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ABSTRACT

Evaluation of the strength of deep mixing columns as a soil improvement method is the main subject of this study. In this research, cylindrical laboratory samples with a length of 20cm and a diameter of 10cm have been constructed. The result of mixing soil-cement and soil-lime have taken into account that cured in the temperature and humidity of both laboratory environments and field conditions, and then were subjected to unconfined uniaxial loading tests. Different weight mixtures of soil-adhesive materials with a minimum of 6% and a maximum of 14% by weight of adhesive materials have been used for this purpose. Also, in this study, the deep mixing of the soil in real and field scale has been implemented in a layer of thin clayey soil, CL, with low plasticity properties of CL type clay. Mixing of deep field soil has been carried out by the designed digging-mixing machine. In addition to laboratory cylindrical samples, cylindrical samples were taken from bulk mixing columns in two linear (single) and clock-type (group) arrangements and were subjected to uniaxial loading in the laboratory until the moment of failure. The general result of this study is the proposal of conversion coefficients of strength of laboratory samples to field samples and vice versa, in the same conditions of construction geometry and the type of selected materials and different environmental conditions of samples curing.

KEYWORDS

Deep mixing, soil-cement, soil-lime, field sample, laboratory sample.

Introduction

Deep mixing is one of the widely used and cost-effective methods to improve weak and problematic soils. Mixing materials include soil and various binders such as cement and lime, which are fortunately abundant. Various soils such as cohesive clayey soils or granular soils are well improved by this method. In order to better advance the work steps, there is a need to investigate and recognize the effective factors on the deep mixing process, which requires the study of articles and researches of various researchers regarding this issue. Therefore, using the results of laboratory and experimental studies and software [1] is very important and can be the basic policy of conducting the present research. Based on this, the following is a description of the related research findings in previous studies. For example, the results of the study by Benen Shu et al. (2022) showed that using a curved blade has a complete and good effect on deep mixing piles. That is, the angle

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of 30 degrees of the curved blade has a great effect on homogeneity, and 4 repetitions of mixing is also the best number of rotations [2]. The stress-strain behavior of cement-stabilized marine soil deposits in Hong Kong has been studied by Ho et al. (2021) [3] by conducting 38 uniaxial UCS and triaxial consolidated-undrained, CU, shear strength tests [3]. Also, Quang et al. (2020) performed a study to determine the mechanical behavior of Vinh Long soils by increasing the amount of cement and curing time [4]. It was found that the elastic modulus increases with the increase of uniaxial compressive strength [4]. Suganya et al. (2020) tested the compressive behavior of modified and disturbed Kuttanad organic clay as well as its 1D consolidation behavior [5].

In this article, it was found that the ratio of water to cement is the most important parameter for modified clay. The results proved that the addition of cement increases the yield stress and the post-yield stress decreases with a decrease in the water-cement ratio. Also, changes in the amount of initial water have no effect on the yield stress [5]. Zakaria et al. (2020) [6] have done the stabilization of local Egyptian soft clays by deep mixing method using ordinary Portland cement or lime. The results of the tests confirmed that the settlement is more in the floating columns (non-end bearing) and the settlement is less in the columns with end-bearing conditions [6]. Yao et al. (2019) evaluated the strength of marine clay modified with cement with mixing ratio, amount of cement, amount of total water and different curing period by uniaxial test [7]. According to their findings, compressive strength increased with increasing curing time and decreased with increasing water content [7]. However, according to detailed studies, the real effects of simultaneous preparation of specimens in the laboratory and in the field on the behavior of soil-cement and soil-lime samples have not been addressed so far.

Methodology

In this study, the cylindrical samples prepared in the laboratory and the field environments have been subjected to unconfined uniaxial compressive strength (UCS) tests. To make the samples, in-situ soil of thin clay, CL, with a ratio of water to binder equal to the liquid limit of the soil, LL, was used. Two types of laboratory and field cylindrical specimens have been subjected to UCS tests. Unconfined compressive strength, UCS, tests have been performed with a displacement speed of 1 mm/min. For this purpose, in Figure 1, the test of the field sample under UCS loading and data recording by the data logger is shown. The dimensions of cylindrical samples in all stages of this study include length 20cm and diameter 10cm. Therefore, the ratio of length to diameter (that is, L/D=2) of the sample meets at least 2 standard requirements of UCS tests.

Figure 1. Field sample test under unconfined compressive strength loading and data recording by data logger.

Discussion and Results

Figure 2 shows the 7-days stress-strain curve for cylindrical samples with 8% to 10% cement. In this figure, the effect of curing on the samples has been compared. According to this figure, with the curing of soil-cement samples, for 8% cement, the values of failure load of the samples have increased with curing time. But the values of deformation at the moment of failure of the sample have not changed by using curing and the deformations are almost the same. For the specimens with 10% cement, there is no noticeable change in the load values at the moment of failure of the samples with curing.

Also, the values of deformation at the failure of the sample have not changed with the use of curing, and the deformations are almost the same. Therefore, for the 7-days curing, it can be concluded that curing does not change the deformations. It should be noted that uncured samples were also prepared for 28 days of age, but the degree of brittleness of the samples has increased to such an extent that it is not possible to test the samples in a uniaxial test. Therefore, it is possible to distinguish the effects of curing for samples older than 7 days, so that the samples without curing have experienced more brittle behavior and without obtaining higher compressive strength results.

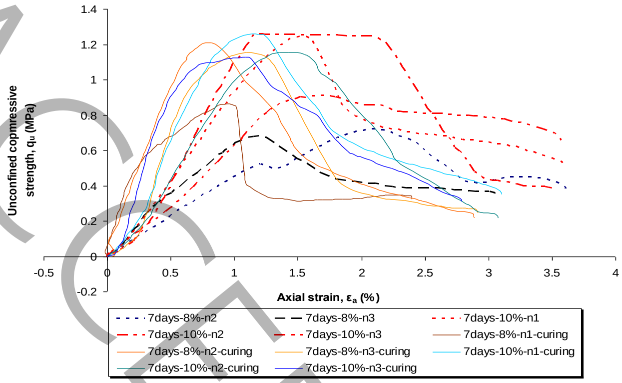

Figure 2. Stress-strain curve for 7-days samples with and without curing with 8% to 10% cement.

Conclusions

In this study, numerous samples of single and group deep mixing columns of soil-cement and soil-lime materials in thin clayey soil have been investigated and evaluated by UCS test. Based on the comprehensive results of this research, obtaining the same and uniform mixing plan in the field scale is a very difficult task, and the samples that are produced in laboratory conditions can include more detailed controls. In general, control of mixing design in field scale and large volume operations is almost impossible in some cases, especially when specific percentages of mixing materials are used in a weight ratio.

It can never be ensured that the deep mixing materials are well mixed together and that the mixture has the same binder distribution at all points. All relative and environmental conditions, including the amount of injection pressure, time duration of injection pressure, amount of mixing water, temperature, fluidity of grout, efficiency and reliability of grout, flow rate of grout, grading and particle size distribution of in-situ soil materials and the skill level of executive persons [1]. In this study, the issue of deep mixing has been researched in two areas of laboratory element modeling, large-scale field operations and evaluation of soil-cement and soil-lime laboratory samples.

The current conditions are relative and dependent on issues such as the amount of injection pressure, time duration of injection pressure, amount of mixing water, temperature, fluidity, efficiency and reliability of slurry, flow rate of slurry, granulation and particle size distribution of in-situ soil materials and the level of skill of executive personnel. In general, some of the most important findings of this study are as follows:

1. With the increase of lime percentage, the amount of deformation corresponding to the failure point has increased. The occurrence of this issue is opposite to the state of mixing soil with cement binder. That is, the stress-strain behavior of the mixing samples with a higher weight percentage of lime tends to the behavior with more ductility.
2. Deformation values at the moment of failure of the specimen have decreased with the increase in weight percentage of cement in the mixing plan. This means that the addition of more than 6% cement to the mixture caused the brittleness of the soil-cement mixture samples after 28 days of curing. The increase in curing time has caused the unconfined uniaxial (compressive) ultimate strength of samples with different weight percentages of cement to approach.
3. In general, increasing the curing time from 7 to 28 days causes two different changes to occur: firstly, increasing the uniaxial strength of samples with a lower adhesive weight percentage to the extent of samples with a higher amount of adhesive, and secondly, reducing the range of failure strain (brittle, hardening) in samples with higher adhesive percentage. According to the findings of this study, both cement and lime play a significant role in connecting clay particles together, with the difference that in calcareous calcium hydroxide samples, Ca $(OH)_2$ plays an essential role in creating bonds between clay particles.
4. In this research, the conversion coefficients of laboratory strength to field strength of the samples, numbers between 1.11 and 2.47 have been obtained. These values are dependent on the weight percentage of the cement binder, the number of days of sample curing, the type of arrangement of the samples (single or group) in the field mixing site, and so on.

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