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Laboratory study on the effects of stone factory waste on the strength of cement or lime stabilized soil against freeze-thaw cycles

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Abstract

Despite many efforts by industry and environmental organizations to reduce industrial waste production and improve productivity over the past few decades, reducing industrial waste is still complex and costly. One of the appropriate methods with the aim of reducing costs and replacing this type of waste is to use different types of it as additives in the construction industry in construction projects. In this paper, the maximum dry density, Optimum moisture content and CBR value of stabilized soil specimens mixed with crushed stone obtained from rock factory waste have been investigated. The effects of the crushed stone waste, cement or lime contents, curing time and number of freeze-thaw cycles have been investigated. The results of standard Proctor compaction tests show that the maximum dry density has an increasing trend due to the increase in crushed stone, cement or lime content, and also the optimum moisture decreased significantly with the increase of the crushed stone content. The results of the CBR test show that the increase in processing time caused a significant increase in CBR values. Increasing the crushed stone waste in lime or cement-stabilized specimens results in an increase of CBR value. Increasing the cement or lime content increases the strength of the specimens for a given crushed stone content and curing time. Comparing the results between cement and lime-stabilized specimens shows that cement-stabilized specimens have more resistant than lime-stabilized specimens under the same condition. The results of freezing-thawing tests show that increasing the number of freeze-thaw cycles decreases the CBR value of lime or cement-stabilized specimens. The effect of the number of freeze-thaw cycles on reducing the resistance of the specimens is more significant with increasing the crushed stone content.

Key words: *CBR, Silty sand, Crushed stone, Stabilization, Cement, Lime*

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Extended Abstract

1. Introduction

In situ soil stabilization using stabilizer materials such as cement and lime to stabilize a construction site is a method of meeting land shortages. Many studies have been done on the geotechnical characteristics of cement or lime-stabilized soil (Yoon and Abu-Farsakh 2009, Bayat et al. 2013, Saeed et al. 2015, Saadat and Bayat 2019, Wang et al. 2019, Yin et al. 2019). The addition of cement or lime will enhance the geotechnical behaviour of the soil over the curing period by occupying the intra-aggregate pore spaces and development of cementation bonding (Horpibulsuk et al. 2010). Natural pozzolan, fly ash, and rice husk ash have been added to conventional stabilizer as environmentally friendly approaches (Vakili et al. 2013, Cheng et al. 2018). On the other hand, researchers have attempted to convert industrial waste to alternative materials for the civil engineering projects which are cost-effective and environmental-friendly which includes soil stabilization (Al-Bared et al. 2018, Panfilova et al. 2020), concrete additives (Al-Bared et al. 2018, Kim et al. 2020), construction blocks (Carvalho et al. 2014) and road pavement (Fırat et al. 2012, Jafar 2016, Li et al. 2019).

2. Materials and methods

In the current study, the effects of crushed stone waste content, cement content, soaked and unsoaked soil conditions and freeze-thaw cycles on the mechanical characteristics of silty sand have been studied. Tests for pH measurement, modified Proctor compaction, California bearing ratio (CBR) and unconfined compression (UCS) were conducted. Scanning Electron Microscopy (SEM) was also used to investigate interactions between the materials to obtain an insight into the reaction mechanisms.

3. Results and Discussion

The results of modified Proctor compaction tests indicate that an increase in MDD and a decrease in OMC with an increase in the crushed stone waste content. Increasing the cement content from 0% to 7% increased the OMC, but had a negligible effect on the MDD at a given stone waste content. The increase of OMC with increasing cement content may be due to the more added fine materials and/or to the hydration of the cement. The pH measurement results indicate that the natural soil had a pH of 8.80 and the pH of the stabilized soil was 9.10–10.40, which was primarily independent of the crushed stone waste content.
The CBR test results indicated that the CBR value increased gradually with an increase in the crushed stone waste or cement content. However, the CBR values of the stabilized specimens with a crushed stone waste content of 10% decreased as the cement content increased from 3% to 5% and continued to increase up to a cement content of 7%. The UCS results show that an increase in the cement content resulted in an increase in the UCS. An increase in the stone waste content from 0% to 10% increased the UCS and after it the UCS decreased slightly with crushed stone waste contents above 10%. The freeze-thaw test results show that the CBR and UCS value decreased with an increase in the number of freeze-thaw cycles. The effect of the freeze-thaw cycles on the CBR and UCS values of the stabilized specimens was greater for the cement-stabilized specimens with high cement contents. The SEM results show that during the freezing process, ice crystals, ice lenses and ice layers of various sizes and shapes tended to segregate the soil, resulting in an increase in volume and creation of cracks and fissures.

4. Conclusion

Based on the tests results the following conclusions were reached:
The addition of crushed stone waste to soil specimens increased the MDD and decreased the OMC. However, as the cement content in the soil specimens increased, the OMC increased, but the MDD did not change significantly. The pH values of the specimens increased due to increasing cement content. An increase in the crushed stone waste or cement content result in an increase in the CBR values. The crushed stone waste content results in a significant increase in the CBR value. Generally, the UCS increased with an increase in the crushed stone waste content from 0% to 10% and then decreased with a further increase in the crushed stone waste content. Comparison of the results of tests under soaked and unsoaked conditions indicated that the unsoaked UCS and CBR values were greater than those for the corresponding soaked values. The results of freeze-thaw tests showed a decrease in the UCS and CBR values with an increase in the number of freeze-thaw cycles.

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