UTS UNIVERSITY OF TECHNOLOGY SYDNEY

Using eggshell powder as a supplementary additive to lime stabilization in expansive soil

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Thesis submitted in fulfilment of the requirements for the degree of

Master by Research

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Certificate

I, Reem Alqaisi declare that this thesis, is submitted in fulfilment of the requirements for the award of Master of Engineering (Research), in the Civil and Environmental Engineering School / Faculty of Engineering and Information Technology (FEIT) at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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Abstract

Expansive soils can be deemed as one of the poorest and most challenging soils frequently encountered around the world. Due to increased construction activities, particularly in underdeveloped countries, more regions of expansive soil deposits are being discovered.

Expansive soils, each with its own unique set of characteristics cause severe distress to the structures and is a major challenge for civil engineers around the world. Thus, it poses extreme difficulties in terms of its use in all construction and foundational works. One avenue for the management of such soils needs to be improved before stable and safe construction can be carried out on them. Furthermore, the suitability of expansive soils for engineering purposes involves a range of treatment processes.

This study involves the utilization of eggshell powder (ESP) as a supplementary additive to lime stabilization of the expansive soil in accordance with valuing its potential in augmenting the performance of lime mixed with expansive soil. Chicken eggshell is a waste material available from many sources such as hatcheries, fast food restaurants, poultry industry, egg product factories and domestic homes. This amount of eggshell waste material leads to an environmental issue and ends up in landfills. Challenges associated with disposals of eggshells include odour, costs, abrasiveness and availability of disposal sites. However, they can be processed into ESP and can play a role as a soil stabilizing agent. Calcium oxide is considered to be the main ingredient of the eggshell powder.

Due to some similar chemical composition of ESP to lime components, it can be used as a partial replacement of industrial lime if subjected to sufficient scrutiny. Therefore, a widespread experimental program has been carried out to quantify the properties of natural

and artificial expansive soils before and after treatment. Stage one involved an extensive analysis in determining the minimum lime required for modification of these problematic soils and it was found to be 5%. The pH values for the untreated and treated artificial expansive soil mixtures were determined after 0, 7, 14, and 28 days of curing.

The eggshell powder was used as an additive to 5% lime in four percentages of 5%, 10%, 15% and 20% by total dry weight of the soil mass in the second stage of the experimental program. In this stage, at the optimum moisture content of artificial expansive soil, which was approximately 29%, different percentages of additives were added. For each mixture, the maximum dry density of the artificial expansive soil was obtained, and it was used for performing all subsequent geotechnical tests. In the third stage of laboratory work, different percentages of ESP of 4%, 5% and 6% used as an additive to 5% of hydrated lime to investigate whether the target percentage (5%) of eggshell powder is the optimum value. In the third stage, all of the additives were added into the expansive soil at the optimum moisture content of the soil when mixed with 5% lime.

The outcomes of these experimental investigations showed that when the addition of eggshell powder into the expansive soils increased from 5% to 20%, the linear shrinkage reduced by 10% after 28 days of curing, the maximum dry density of the expansive soil decreased from 1.323 g/cm^3 to 1.293 g/cm^3 after adding eggshell powder. Similar results were obtained when the eggshell powder was added to the natural expansive soil. After conducting a series of pH and unconfined compressive strength (UCS) tests on untreated and treated expansive soil samples, it was noted that the improved geotechnical characteristics were more pronounced for 5% eggshell powder treated expansive soil. Therefore, the optimum percentage of eggshell powder believes to be around 5%. At this

optimum percentage, the compressive strength at failure and the corresponding strain increased slightly by 18% and 9%, respectively, compared to the untreated expansive soil after 28 days of curing. Meanwhile, the combination of eggshell powder and lime to stabilize soils when eggshell powder content increased up to 20% caused a further decrease in the linear shrinkage of 10.7% after 7 days of curing. Moreover, in comparison with lime (5%) only stabilized expansive soil, the combined lime (5%) and eggshell powder (5%), induced approximately 15% buildup in the compressive strength of samples.

On the other hand, the CBR value of the untreated soil increased from 2% to 56% when it was combined with the optimal values of additives. The utilization of eggshell powder for expansive soil stabilization without or with lime combination not only improved the geotechnical properties of expansive soil, but also assisted in minimizing the adverse effects of these domestic waste by-products on the environment. Finally, the effect of adding eggshell powder as a supplementary additive to lime stabilization of expansive soil has been investigated. It was observed that ESP led to a slight improvement in the geotechnical properties when it was added to the soil. However, the combined effect of eggshell powder and hydrated lime could be effective for stabilizing the expansive soil, where very high subgrade performance is neglected. Moreover, this combination could be used as a kind of fill material for road embankments to reduce energy consumption and contribute in conserving natural resources.

Keywords*:* Expansive Soils; Eggshell Powder; Hydrated Lime; Soil Stabilization; Linear Shrinkage; UCS Test.

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List of Publications

1. Alqaisi, R., Le, T.M. and Khabbaz, H., 2019, November. Applications of Recycled Sustainable Materials and By-Products in Soil Stabilization. In International Congress and Exhibition" Sustainable Civil Infrastructures" Springer, Cham, pp. 91-117.

2. Alqaisi, R.O., Le, T.M. & Khabbaz, H. 2020. Combined effect of eggshell powder and hydrated lime on the properties of expansive soils. 3rd International Conference on Environmental Geotechnology, Recycled Waste Materials and Sustainability Engineering, Izmir, Turkiye, 2020. (Submitted)

3. Alqaisi, R.O., Le, T.M. & Khabbaz, H. 2020. Eggshell powder as a supplementary additive to lime stabilization in expansive soil. Australian Journal of Civil Engineering. (In the final stage of preparation)

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