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The effect of adding urease enzyme on uniaxial strength of soil stabilized by cement and zeolite

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Abstract

Nowadays, modern and environmentally friendly methods have been used to stabilize soils and to improve soil engineering properties. One of these methods is formation of calcium carbonate precipitation in soil pores for increasing strength, cohesion, hardness of soil and decreasing soil permeability. Since most studies have been performed on the formation of calcium carbonate precipitation by using urea hydrolysis by bacteria. In this study, calcite precipitation was made by direct use of urease enzyme. In this method there is no limitation like using of bacteria and also there is no harmful effects on planting. This study investigated the effect of adding urease enzyme to cement and zeolite-stabilized sandy soils as well as the effect of fine aggregates. The results of the uniaxial strength tests showed that with 10% replacement of zeolite instead of cement while 10% fine grains were used, more resistance was observed to the samples without zeolite and with less fine grains. On the other hand, by adding urease enzyme with 4% cement, 10% fine grains and urease enzyme in the comparison of samples without enzyme increased the compressive strength at 14 and 28 days, 5.12 and 4.107, respectively.

Keywords: *Urease enzyme, Zeolite, Cement, Fine grained soil, UCS test*

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Extended Abstract:

1. Introduction

Ghorbani et al. (2018) studied the proper development of urban infrastructure is necessary to meet the growing needs of society, and this is directly related to access to suitable soil on which to construction. At the same time, environmental conditions are declining for living in urban areas, and this has led to an ever-increasing demand for new and environmentally friendly methods for soil improvement. One of these methods is to use bacteria in the soil to make connections and cohesion between the soil grains. Gunaratne (2006) came to the conclusion that granular soils have always been problematic due to their strength properties. The main characteristics of loose and uniform sandy soils are their low strength and non-cohesion. To stabilize this type of soil, the use of cement addition technique as one of the most widely used options is used by engineers. Fertu and Gavrilescu (2012) investigated the zeolites are crystalline aluminosilicates of alkaline or alkaline earth metals such as sodium, potassium, magnesium, strontium, barium, and calcium, which are formed from a combination of $[AlO_4]^{5-}$ and $[SiO_4]^{4-}$. Zeolites are divided into natural and artificial groups. One of the theories about the conditions and cause of the formation of zeolites in nature is that zeolites are often formed in sedimentary layers, after the formation and burial of sediments due to the reaction of aluminum silicate with water in the cavities in cracks and fractures. All the zeolite minerals that have been identified so far are secondary minerals and are formed from the degradation or alteration of primary minerals such as feldspar, clay, and finally from natural silicate gels. Equation (1) describes the general chemical formula of zeolites; Where M^+, alkali metal and M^{2+} cations are soil alkaline cations (Fertu and Gavrilescu, 2012).

$$[(M^+, M_{0.5}^{2+})AlO_2]x.[SiO_2]y.[H_2O]z \quad (1)$$

Today, biological cementation has become particularly important in geotechnics. One of the most common cementing methods that has been studied so far is the calcium carbonate (calcite) precipitation method, which has the potential to increase soil engineering properties such as soil resistance and hardness. Calcium carbonate acts as a cement to bind soil particles and increases the stability and reduces permeability by creating communication bridges between soil grains (Ozdogan, 2010 and Mortensen et al., 2011). One of the weaknesses of grain soils is low c and ultimately lack of sufficient strength. Therefore, this study investigated the effect of adding urease enzyme on washed sandy soil to investigate the role of this enzyme in improving the geotechnical properties of sandy soil in the laboratory. The use of positive urease bacteria in soil biological improvement, due to the survival of these microorganisms and the technical complexities of their use, in addition to significant effects on soil improvement, creates an heterogeneous composition of the soil and precipitation obtained from urea hydrolysis. Therefore, in this study, the effect of direct use of urease enzyme in soil biological improvement has been investigated to eliminate the weaknesses of previous research. Enzymes are protein catalysts made by a living cell that catalyze biochemical reactions inside or outside the cell. Enzymes increase the rate of reactions (the rate of equilibrium between the substrate and the product) to 10^{16} times that of the enzyme.

2. Materials and methods

To study the effect of urease enzyme on the unconfined compressive strength (UCS) of sandy soil with uniform granulation, the parameters of cement content, zeolite, fine-grained and curing time have been considered. In order to improve this soil, 4 and 8% by weight of cement, 10, 30, 50 and 70% of zeolite substitution instead of cement and 5 and 10% by weight of basic soil, clay disinfection have been used. In another design, the previous values of urease-containing enzyme in the amount of 1 gr per 100 ml of $CaCl_2$ solution and urea in the amount of 1 mol/L were used. The curing time is 7 days, 7, 14, 28 and 45 days for samples including cement, zeolite and fine-grained, and 7, 14 and 28 days for samples including cement, zeolite, fine-grained and urease enzyme. Materials used in this study include sandy soil, cement, zeolite, fine-grained, and urease enzyme.
Because samples need time to be curing and must be stored in the mold, PVC tube is used as the mold. The molds are cut to dimensions of 40 mm outer diameter, 34 mm inner diameter and 70 mm height. Also, to facilitate the extraction of samples after processing, the molds are divided vertically into two separate parts. To add the enzymes urease, calcium chloride, and urea, the amount of water needed to make the sample is first divided into two parts according to the optimal percentage of sandy soil water. One part is mixed with urea and calcium chloride and the other part is mixed with urease enzyme. First, the sandy soil is mixed with cement, zeolite and fine-grained dry matter, and then a solution containing urea and calcium chloride is added to it; Finally, a solution containing the enzyme urease was added and after mixing, it was pounded into 3 layers inside the mold. In order to better precipitate calcium carbonate, urea solutions, calcium chloride and urease enzyme were sprayed on the samples again after 24 hours. In order to properly operate the zeolite, a wet coating with insulation has been used to prevent evaporation.

3. Tests results

As the percentage of cement increases, the corresponding strain decreases and decreases, indicating the brittle behavior of the samples. The stress-strain diagrams are almost the same, and the difference is in the maximum axial stress and strain rate. As the percentage of zeolite replacement in cement increases, the strain strain increases, indicating a decrease in the brittle behavior of zeolite specimens over cementitious specimens. On the other hand, with the increase of the fine percentage, the strain of the samples has increased and they have become softer. Also, increasing the percentage of fine-grained has led to greater integration of the sample, so that by adding 10% of fine-grained, the amount of cement can be reduced and by replacing 10% of zeolite instead of cement, more resistance can be achieved than non-zeolite samples. During the 7-day operating period, with increasing zeolite content instead of cement, the unconfined compressive strength decreases due to the incompleteness of pozzolanic reactions. On the other hand, during 28 days of operation, with the increase of zeolite percentage instead of cement, the single-axis compressive strength first increases and then decreases, and the optimal percentage of zeolite for increasing the resistance is 10%. Biological samples include 0, 5 and 10% fine-grained, urease enzyme and only 4% of cement for greater enzyme effectiveness due to soil coarseness. The results of the experiments showed that due to the formation of calcite crystals between the soil grains, the single-axis compressive strength of the samples increased, but on the other hand, the amount of strain decreased and they became brittle and fragile. According to the results of unconfined compressive strength test , adding the enzyme urease to 1 gr per 100 ml of calcium chloride and urea solution by 10% fine-grained samples increased the unconfined compressive strength at 14 and 28 days of operation by 8.93 and 9.59 times, respectively. Data show that there is a significant increase in the resistance of the specimens due to the formation of calcium carbonate precipitation in the soil grains and the creation of communication bridges between them. On the other hand, changes in the unconfined compressive strength of the stabilized samples with 4% cement, 10% fine-grained and urease-containing enzyme compared to the non-enzyme samples at the time of 14 and 28 days of operation were 4.12 and 3.1 times, respectively, and compared to the stabilized samples with 4% cement. , 10% fine and 10% replacement of zeolite instead of cement is 3.39 and 2.33 times. Also, the single-focus resistance of the stabilized samples with 4% cement, 10% fine, 10% replacement of zeolite and urease enzyme compared to the non-enzyme samples at 14 and 28 days of operation was 3.72 and 2.81, respectively.

4. Conclusion

The present study is the result of experiments conducted in the field of environmental geotechnics. The subject of the research is the use of urease enzyme in improving the geotechnical properties of loose soils, which is called for short EMCP.

Among the advantages of this design is the direct use of urease enzyme for urea hydrolysis. Much of the research on biological precipitation has been on the use of positive urease bacteria such as sporosarcina (bacillus). Therefore, the important point in this plan is to eliminate the complexities that the use of bacteria will have in biological precipitation. Because these bacteria are living organisms, they will need laboratory equipment to sterilize the culture medium and grow their colonies. Laboratory equipment such as autoclaves, incubators and spectrophotometers are among these devices. As a result, the direct use of urease enzyme not only eliminates the need for laboratory equipment, but also makes the improvement plan more practical and field-wise, which is the current need of research projects in civil engineering. Since in most fine-grained soil improvement projects, calcium carbonate precipitation are formed heterogeneously at the beginning and end of the samples, the direct use of the urease enzyme also eliminates the limitation of improvement in fine-grained soils. Another point is the use of zeolite to replace cement, which has doubled the environmental aspect of the design with the precipitation of urease enzyme. This study looked at replacing zeolite with cement in sand with poor granulation as well as adding urease enzyme to the previous design and comparing the results.

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