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Stabilization of Clayey Soil with Lime and Waste Stone Powder

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ABSTRACT

In this research, waste stone sludge obtained from slab stone processing from stone washing plants were recycled to stabilization of clayey soil with lime. Fine-powdered stone sludge was mixed with clay soil and lime. Thus, the effectiveness of using waste stone powder and lime in stabilizing fine-grained clayey soil (CL) was investigated in the laboratory. The soil samples in natural state and when mixed with varying percentages of lime and waste stone powder were used to laboratory tests that included atterberg limits tests, grain size analysis, standard proctor compaction tests, unconfined compression tests and California bearing ratio tests. The results showed significant reduction in plasticity and changed the optimal moisture and maximum dry density of clayey soil with increasing amount of waste stone powder and lime. The results of the unconfined compressive strength tests and California bearing ratio tests showed that in the different curing time, the addition of waste stone powder and lime caused an increase in the value of UCS up to 6% waste stone powder content and 7% lime content, and increase in the value of CBR until 6% waste stone powder content and 9% lime content, for further percentages, the value of UCS and CBR decreased.

KEYWORDS:

Waste Stone Powder, Lime, Clayey Soil, Stabilization of Soil, Environmental Pollution

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1- Introduction

Soil stabilization is a technique introduced a long time ago with the main aim to increase civil engineering physical and mechanical properties of weak soils. Based on geotechnical information, clay soil deposits are among the problematic soils. Because of land scarce, this type of soil may have to be used in various types of construction projects as foundation subsoil. Therefore, at a particular location, a clay soil deposit may not be wholly suitable for the desired engineering purpose. In such a case this type of weak soil properties may be improved by the addition of a small amount of a cementing material as a chemical additive such as lime or Portland cement. The amenability of clay soil to such treatment depends not only on the type and amount of cementing material added but also on the chemical and mineralogical composition of the soil as well.

Lime stabilization refers to the stabilization of soil by the addition of burned limestone products, either calcium oxide (CaO) or calcium hydroxide ($Ca(OH)_2$). Among quicklime and hydrated lime, hydrated lime is preferred and has been the most frequently used lime product for lime stabilization in several countries. This is because of hydrated lime higher degree of safety compared with quick lime during its application at field. Quick lime, on the hand, will give higher shear strength value for treated soil.

In general, addition of lime to clay soils produces an improved construction material. Hence soil stabilization with lime has been used in highway, railroad and airport construction to improve bases and sub-bases. It also has been used in the construction of embankments, in soil exchange in sliding slopes, as backfill for bridge abutments and retaining walls, for soil improvement beneath foundation slabs and for lime piles [1]. For coarse materials the most suitable material is Portland cement while for cohesive soil, the proper cementing material is lime.

Many laboratory studies have been carried out by many researchers to improve civil engineering properties of various types of materials (soils) using waste stone products. The materials used for this purpose include; bricks, asphalt and concrete (Bilgin et al. 2012; Karakus 2011; Ahmed, Ugai 2011; Kamei et al. 2007; Ahmed et al. 2010 and 2011; Demirel 2010) [2-8].

In general, the use of waste materials in ground improvement has several environmental benefits, apart from reducing the cost of ground improvement. In this laboratory research, waste stone sludge obtained from slab stone, processed from stone washing plants were mixed with lime using preliminary laboratory soil mechanics tests to strengthen clayey soil samples.

2- Materials and methods

Materials used in this laboratory study were: clay soil (as problematic soil and as a main base material), lime (as a chemical cementing additive), and also waste stone powder (as a non-chemical additive). The mineralogy of the clay soil used was kaolinite, the lime used was calcium oxide (CaO) and in quick condition and the waste stone powder (WSP) derived from waste stone marble.

The main soil mechanic tests used throughout the research project include: Atterberg limits, compaction, California bearing ratio (CBR) and unconfined compressive strength (UCS). Various types of mixtures with different amount of materials mixed well by their specified weight and were examined for their liquid limits, plastic limits, maximum dry densities, optimum moisture contents, CBR, as well as their UCS values. All types of tests were conducted on untreated as well as treated or stabilized soil samples.

Each type of tests was carried out based on related ASTM soil tests.

For treated samples, each clay soil test sample was mixed with lime and WSP using specified amount. Waste stone powder was added in varying proportions of 3, 6 and 9 *wt*.%. Also, lime was used in the mixtures in varying proportions of 3, 6, 9 and 11 *wt*.%. The stabilized samples were cured with water (complete submergence in water) during curing process. The samples were tested immediately after mixture, 96 hours, 7 and also after 28 days period.

For each set of tests, corresponding curves based on the obtained laboratory tests data were prepared and each curve was evaluated for the presented final results.

3- Concluding remarks

Clayey type of soil is considered a problematic soil for civil engineers. This type of soil, when is dried, has an acceptable load bearing capacity. But when its moisture content is increased, it loses its original shear strength at dried condition. Various types of tests were carried out to evaluate treated clayey soil for its physical and mechanical properties

before and after treatment (mixture of soil, lime and WSP) process.

Results obtained for the laboratory study include the followings:

1) As the amount of lime and waste stone powder are increased in tested (treated) soil samples, the value of liquid limits decreases.

2) As the amount of lime and waste stone powder are increased in tested (treated) soil samples, the value of plastic limits tends to increase.

3) The plasticity index show decreasing trends with increasing waste stone powder and lime content.

4) The treatment of the samples with lime and waste stone powder changed the optimum moisture content and maximum dry density.

5) The optimum moisture content obtained from compaction tests for various types of tests increased with increasing lime and waste stone powder contents.

6) The maximum dry density obtained from compaction tests for tested soil samples decreased with increasing lime content.

7) The maximum dry density increased with increasing waste stone powder content.

8) The unconfined compressive strength of treated soil specimen with lime and waste stone powder was affected mostly by the amount of lime and waste stone powder mixed in soil mixtures. The unconfined compressive strength increased in association with increasing lime and waste stone powder content.

9) The CBR value of the clayey soil increased by 2.44 folds with addition of 9% lime + 6% waste stone powder when cured for 28 days.

10) The highest unconfined compressive strength value of over 1 *MPa* obtained for treated clayey soil samples with 7% lime and 6% waste stone powder when cured for 28 days.

11) The highest California bearing ratio value of over 160% obtained for treated clayey soil samples with 9% lime and 6% waste stone powder.

12) Waste stone powder is considered a waste material and its existence on ground is detrimental to the environment as far as air and land pollutions are concerned. Using these waste materials as non-chemically additive to improve weak ground is an optimum alternative for geotechnical purposes to increase civil engineering properties of problematic soils such as clayey soil deposits. Also using waste stone powder as a mixing material with stabilized clay–lime soils will contribute a definite effect on the cost of the project as well.

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