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Effect of Lime andWaste Stone PowderVariation On the pH Values, Moisture Content and Dry Density of Clayey Soil

Armin Roohbakhshan[1], Behzad Kalantari[2]
[1] Department of Civil Engineering, University of Hormozgan, Iran
[2] Assistant Professor, Department of Civil Engineering,University of Hormozgan, Iran

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ABSTRACT

This paper reports an investigation of the influence of waste stone powder and limeon the geotechnical properties of clayey soil. The compaction and changes in the chemical properties of the soil with pH test when mixed with varying proportions of waste stone powder and limewere investigated. Thus, the effectiveness of using Waste Stone Powder (WSP) and lime for preliminary laboratory tests including grain size analysis, PH test and standard Proctor compaction tests for stabilizing fine-grained clayey soil (CL) was investigated in the laboratory. The percentage of lime and WSPused on the samples varied from 0 to 11%,which treatment of the samples with lime and WSPcontent show that the optimal moisture and maximum dry density values of the samples were changed. The results show increasing in the pH value of clayey soil with increasing amount of waste stone powder and lime. And the optimal moisture content increased with increasing lime and WSPcontent for all the samples. Also the maximum dry density decreased with increasing lime, whereas the maximum dry density increased with increasingWSP content. The behavior of the geotechnical properties of the clayey soil when blended with waste stone powder and lime indicates that these materials are a good modifier for this soil.

Corresponding Author:

Armin Roohbakhshan,
Department of Civil Engineering,
University of Hormozgan, Iran.
Email: arminroohbakhshan@yahoo.com

1. INTRODUCTION

Lime stabilization is achieved by adding measured quantities of hydrated lime or calcium hydroxide, and quick lime or calcium oxide, to the fine-grained soils. The interaction of the lime and soil is immensely complex with the reaction occurring rapidly when they are mixed [1].

When lime and water are added to a clay soil, chemical reactions begin to occur almost immediately. If quicklime is used, it immediately hydrates (i.e. chemically combines with water) and releases heat. Soils are dried, because water present in the soil participates in this reaction, and because the heat generated can evaporate additional moisture. The hydrated lime produced by these initial reactions will subsequently react with clay particles. These subsequent reactions will slowly produce additional drying because they reduce the soils moisture holding capacity. If hydrated lime or hydrated lime slurry is used instead of quicklime, drying occurs only through the chemical changes in the soil that reduce its capacity to hold water and increase its stability.

These reactions can be divided and explained as follows. Cation exchange and flocculation-agglomeration practically all fine-grained soils display cation exchange and flocculation- agglomeration reactions when treated with lime. The general order of replaceability of the common cations associated with soil is given by the series $Na^{+} < Ca^{2+} < Mg^{+}$ [2].

Cations tend to replace cations to their left in the series and monovalent cations are usually replaceable by multivalent cations. The addition of lime to a soil in sufficient quantities supplies an excess of Ca^{2+}, and cation exchange will occur with Ca^{2+} replacing dissimilar cations from the exchange complex of the soil, thus acting to change the electric charge density around the clay particles. These clay particles then become electrically attracted to one another, causing flocculation and agglomeration which produce an apparent change in texture with the clay particles 'clumping' together to form larger-sized 'aggregates'. Carbonation Lime carbonation is an undesirable reaction which may occur in soil-lime interaction. Lime reacts with CO_2 from the air to form calcium and magnesium carbonates which are relatively weak cementing agents. Carbonation is more pronounced in industrial areas, where the CO_2 content in air may be twice that in rural areas, and thus the CO_2 content of rainwater is sometimes increased several hundred per cent. Because of the undesirable effects of carbonation it is now widely considered that uncarbonated lime can be used in a more beneficial way if it is combined with silicates and aluminates, i.e. through a pozzolanic reaction [3].

Pozzolanic reaction the most important reaction in lime soil stabilization is that termed pozzolanic. This interaction between the lime and the silica and alumina present in the soil-water system forms cementitious gels which bind the particles together, thus stabilizing the mixture. This interaction of the lime and soil is affected by the soil pH, organic carbon content, presence of quantities of exchangeable sodium ions, and clay mineralogy. When a significant quantity of lime is added to a soil, the pH of the soil-lime mixture is elevated to approximately 12.4.This is a substantial pH increase of natural soils, resulting in an increased solubility of silica and alumina.

The interaction of the lime and the soil described above has an effect on the engineering properties of the soil mixture. While the investigation described in this paper has examined the effect of lime on the pH and Atterberg limits of the soil mixture, it must be recognized that other engineering properties, such as permeability [4], are also altered and, depending on the engineering application, suitable investigations would have to be carried out.

In an early study of soil-lime reaction, Eades [5] suggested that the high pH causes silica to be dissolved out of the structure of the clay mineral that makes it available to react with the Ca^{2+} to form calcium silicates.

Also in tests carried out by Faluyi and Amu [6], three selected burrow pit lateritic soil materials used for road rehabilitation in Ado-Ekiti and its environments were used and the effects of the lime stabilizer on the pH values were determined in the laboratory.

Ajayi [7] examined the effect of the using lime on the moisture content and dry density of lateritic soil in Ilorin, Nigeria. Ajayi shows thatthe results of analysis of variance showed that there is significant variation in moisture contents and dry densities with lime concentration. Furthermore, the increase in the moisture content due to the addition of lime results into lower amount of compaction or less compactive effort and this could be achieved by addition of small amounts of lime to laterite.

2. MATERIALS USED

Three different materials were used in this research:clayey soil, lime and Waste stone powder.

2.1 Clayey Soil

Clay soils have a wide range of mineralogicalcomposition. They may consist of various proportionsof different types of clay minerals, notably kaolinite, illite, mixed-layer clays and montmorillonite,of non-clay minerals, notably quartz, and/ororganic matter and colloidal matter. Very small amounts of certain clay minerals may exert a largeinfluence on the physical properties of a claydeposit. In addition, the degree of crystallinity is important; clay minerals with poorly-ordered crystallinityhave different properties from those withwell-ordered crystallinity. The different propertiesof the various families of clay minerals can be explained partly by the different levels of activityon the surface of the clay particle.

In this research the mineralogy of the clay soil was kaolinite. The chemical compositions of the kaolinite and lime that were used in this testing programme are given in Table 1. Also the clay soil used in this study is classified as (CL) by Unified Soil Classification System (USCS). The grain size distribution for the tested soil, relevant the ASTMD422 Standard Test Method is shown in Figure. 1.

Table 1- Average content of the lime and clayey soil of minerals of interest for the investigation

Chemical composition	Kaolinite (%)	(%)Lime
SiO_2	55.7	2.23
Al_2O_3	26.6	0.71
Fe_2O_3	0.54	0.26
Alkali(K_20, Na_2O)	0.75	0.08
CaO	0.5	79.8
TiO_2	0.09	-
MgO	-	0.66
etc.	15.82	16.26

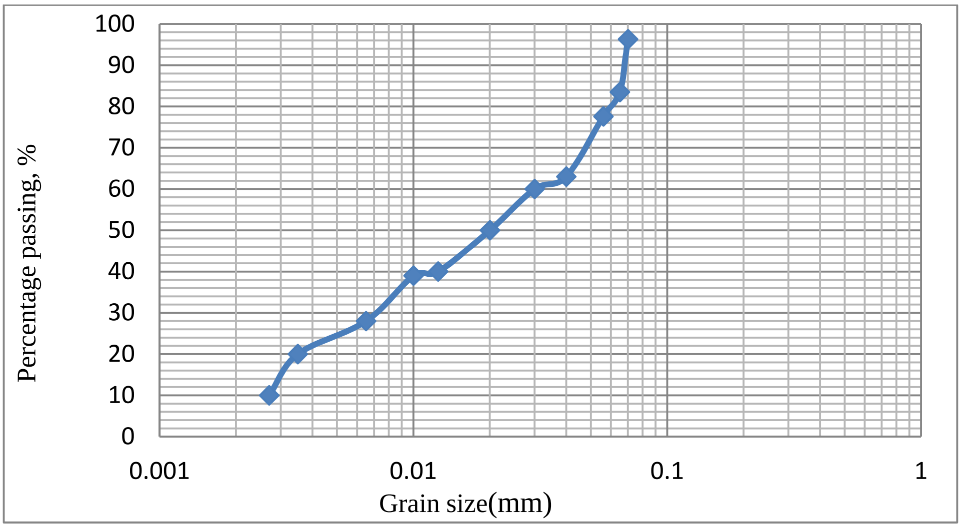

Figure 1. The grain-size distributions of clayey soil

2.2 Lime And Waste Stone Powder

In this research, quick lime was used as the stabilizing agent. The major chemical constituent of the lime is calcium oxide [CaO]. The other stabilizing material is Waste Stone Powder (WSP). For this research Waste stone powder are derived from waste slab marble as sludge. Waste stone powder cause great amount of environmental pollution that By reusing and recycling of these waste materials as an additive in the geotechnical properties of soils have great contribution to the economy and to the environment by minimizing polluting effects coming from stone quarries and stone plants. Recycled stone powder used in this research was produced in slab stone processing and plant in broujerd, Iran.

3. SAMPLE PREPARATION AND EXPERIMENTAL PROCEDURES

The clayey soil were initially mixed with the predetermined quantity of lime and WSP in a dry state and subsequently mixed with the water so that the mix acquired the intended moisture content. Initial mixing was carried out in a laboratory with hand for at least 2 min and the mix was subsequently put into plastic bags, where the mixing was continued by shaking and overturning the bag for 2 min. Finally, the air was squeezed out by hand and the bags according to figure1 were sealed and stored in the room for 24 hours. Before use the material was remixed again in the plastic bag by hand shaking, overturning and squeezing the bag. The quantities of lime and waste stone powder were 0%, 3%, 6%, 9% and 11% by weight of the dry soil. The following tests; pH test and standard Proctor compaction tests were carried out on the natural (0% waste stone powder and 0% lime content) and treated soil samples.

Figure 2. The treat soil in plastic bags

3.1 PHTEST

Tests were carried out on samples to determine the pH values of the clay soil with multimeter apparatus that are shown in Fig.3. The clay soil mixed with lime and waste stone powder. Lime and waste stone powderwas added in varying proportions of 0, 3, 6, 9 and 11%. The treatment of the samples with lime and waste stone powder content changed the pH values of the samples from acidic to alkaline and the value increased with increasing lime and waste stone powder content for all the samples. The procedures used in carrying out these tests were the ASTM D4972 - 01(2007) Standard Test Method for pH of Soils.The results of the pH test are given in table 2. Also the pH value for lime alone was 12.94 and for waste stone powderalonewas 8.47.

Figure 4. Multimeter TWT apparatus

Table 2-pH values of the clay mixed with varying percentages of lime and waste stone powder

	(+0% wsp)	(+3% wsp)	(+6% wsp)	(+9% wsp)	(+11% wsp)
C+0%L	6.82	7.88	7.93	8	8.04
C+3%L	9.1	9.25	9.31	9.45	9.52
C+6%L	10.23	10.32	10.4	10.44	10.49
C+9%L	11.08	11.16	11.24	11.31	11.52
C+11%L	12.34	12.37	12.42	12.49	12.54

The pH value for samples with increasing materials used content changed from 6.82 at 0% lime and 0% waste stone powder content to 12.54 at 11% lime and 11% waste stone powder content. These changes were as a result of the changes in the chemical properties and composition of the samples due to their chemical reactions with the lime and waste stone powder additive.

3.2 Standard Proctor Compaction Test

Standard Procter compaction tests were conducted to determine the optimal moisture content and maximum dry density for soil stabilized with different contents of lime and WSP. The clay soil mixed with lime and WSP. Waste stone powder was added in varying proportions of 0, 3, 6 and 9% and Lime was added in varying proportions of 0, 3, 6, 9% and 11%. The treatment of the samples with lime and WSP content changed the optimal moisture and maximum dry density values of the samples, and the optimal moisture content increased with increasing lime and WSP content for all the samples. Also the maximum dry density decreased with increasing lime and the maximum dry density increased with increasing WSP content. The procedures used in carrying out these tests were the ASTMD698- 78 Standard Test Method for compaction of Soils. The results of the compaction test are given in figures.5,6.

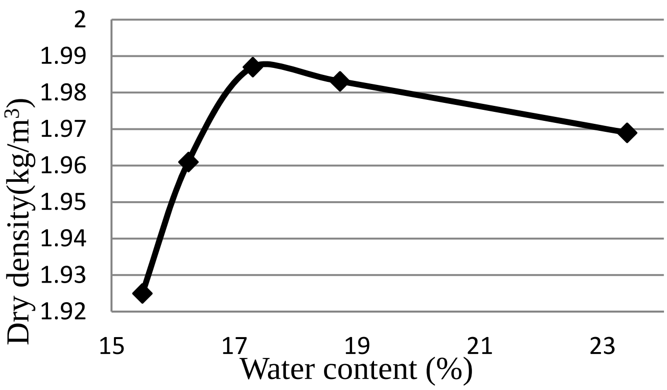

Figure 5. Proctor curves for the natural soil

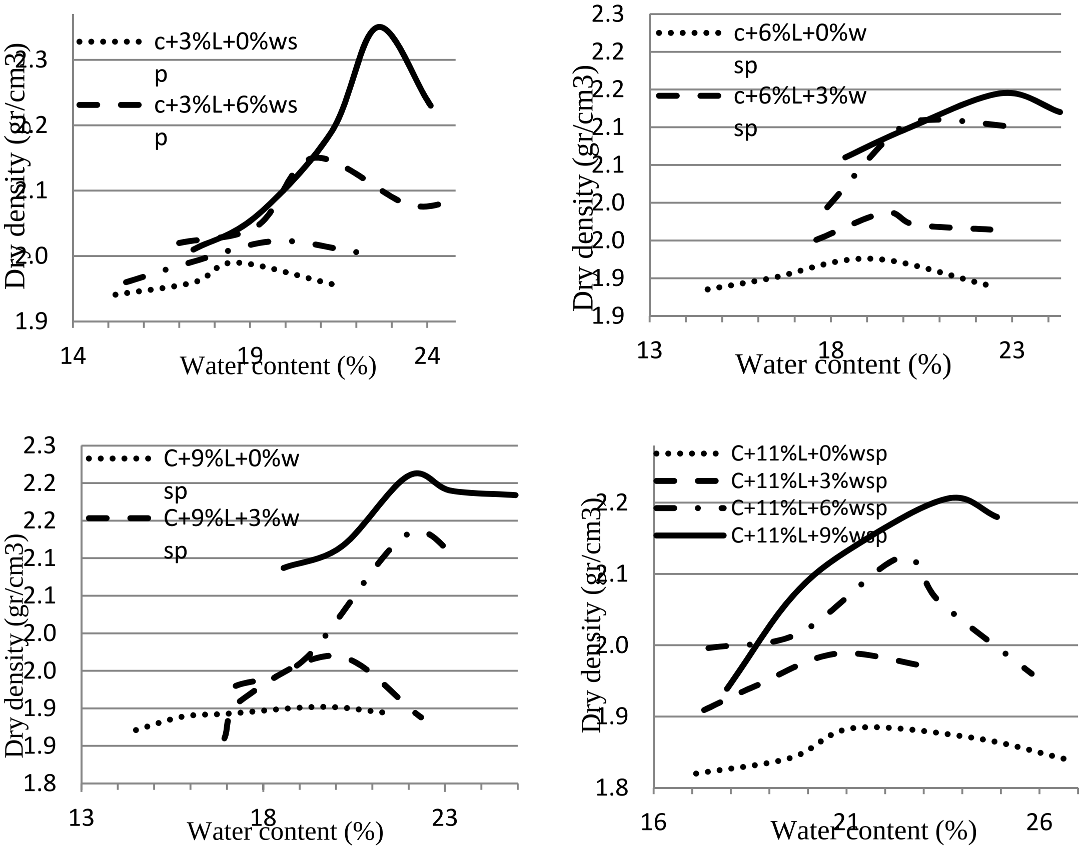

Figure 6.dry density versus water content for mixtures

It is observed that by increasing lime content, maximum dry density decreases and optimum moisture content increases. Also, when lime is added to soil, instantaneous reaction as cation exchange occurs, and clay particles flocculate together. This process leads to formation of air voids among particles and makes creation of a porous medium with lower maximum dry density. Furthermore, more water is necessary for filling voids, so optimum moisture content is increased. These mentioned effects are combined in lime–waste stone powder–soil mixture are shown in Figure.7.

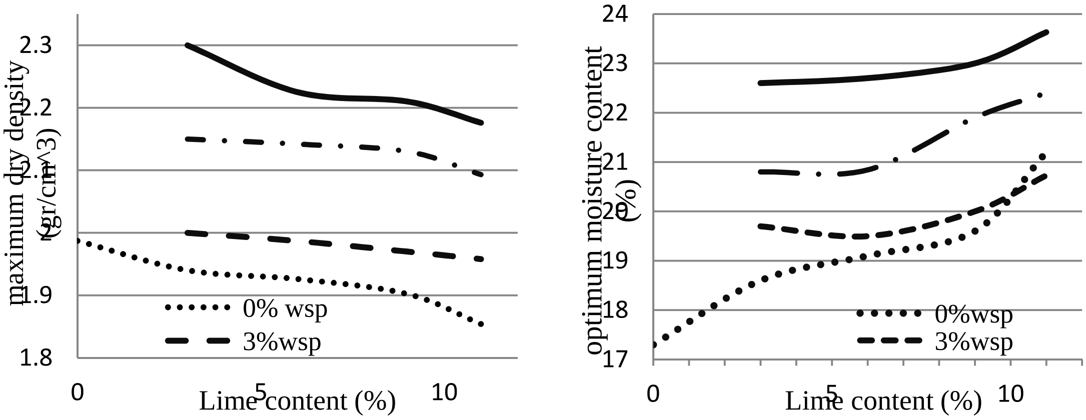

Figure 7. Variation of maximum dry density and optimum moisture content with varying percentages of lime and WSP

4. CONCLUSION

The results of geotechnical investigation on lime-treated clayey soil from Iran were investigated and discussed. Lime and waste stone powder were added in the order of 3%, 6%, 9% and 11% by weight and experiments were conducted. Relationships that correlate the geotechnical properties of lime and waste stone powder-treated soil were developed. The study has led to the following conclusions:

1- The treatment of the samples with lime and waste stone powder content changed the optimal moisture and maximum dry density.
2- The optimal moisture content increased with increasing lime and waste stone powder content.
3- The maximum dry density decreased with increasing limecontent.
4- The maximum dry density increased with increasingwaste stone powder content.
5- The treatment of the samples with lime and waste stone powder content changed the pH values of the samples from acidic to alkaline and the value increased with increasing lime and waste stone powder content.

Waste stone powder cause great amount of environmental pollution. By reusing and recycling of these waste materials as an additive in the geotechnical properties of soils have great contribution to the economy and to the environment by minimizing polluting effects coming from stone quarries and stone plants.

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