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Impact of Lime Stabilization on the Dry Density, Specific Gravity, and Moisture Content of Clayey Soil

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Abstract
Globally, there are a lot of clayey soils. The areas where relatively little energy is deposited, like huge marine basins, river deltas and lakes, are typically associated with clayey soil deposits. It is thought that soils with more clay content are more vulnerable to changes in moisture. Furthermore, a number of challenges are presented by these soils, such as high compressibility, water softening, low bearing capacity, and expansive characteristics. The aim of this study is to determine the specific gravity, optimum moisture content and maximum dry density on the clayey soil with the effect of lime content. The previous studies mainly focused on the chemical properties shear strength characteristics and biological properties of clayey soil with the adding of natural fibers content.it is little focused on the influence of lime on the average specific gravity and compaction characteristics of clayey soil. In present investigation the lime content is incorporated in a clayey soil sample at the dosages of 0% (standard sample), 2%, 4%, 6%, 8% and 10% by weight and applied the modified proctor test on the samples and the standard equation method used to calculate the average specific gravity of the modified soil samples. The test findings show that with addition of lime contents it has been noticed decrease in maximum dry density, an increase in optimal moisture content and specific gravity.

Keywords
Lime, Specific Gravity, Maximum Dry Density, Optimum moisture content

1. Introduction
The process of changing the characteristics of the soil to make them sufficient for meeting the prerequisite for design is known as "ground improvement." The idea of modifying soil through the use of soil stabilizing chemicals dates back thousands of years. (Mitchell 1981). Even now, many regions of the world are beginning to accept soil stabilization using bituminous materials, fibers, lime, fly ash, Portland cement, and geogrids [1]. The many mechanical and physical properties of the soil, such as shear strength, conductivity properties, Atterberg limits, shrinkage and swelling, can be altered by using a soil stabilizing agent. Increased Shear strength, deformability resistance, and stability in the face of volume change, decreased permeability, decreased erodibility, improved durability, and variability control are the goals of soil modification [1]. To achieve the desired result, the procedure for improving the ground may entail mixing soils or adding soil stabilizing agents, which might alter the soil's flexible nature, gradation, texture, or function as a binder.[2]. Therefore, adding stabilizing chemicals can significantly improve the qualities of the soil. Soil stabilization and soil reinforcement are two ways to modify the qualities of the soil. There are numerous methods for improving the ground, including chemical, mechanical, and alteration methods. Better physical property adjustment is known as soil stabilization. The mechanical qualities of soil stabilization can be increased, enhancing the supporting foundations' capacity to support loads [3]. There are other techniques, such soil mixing, to stabilize the soils. [4] Three types of

stabilization: chemical, biological, and mechanical [5].or combined stabilization [6-9]. In civil engineering, lime stabilization is used extensively in a variety of applications, including piles, roadbeds, embankments, and foundations. It is often known that clay soils typically exhibit low resistance and bearing capacity, which are linked to inflationary issues [10]. Thus, the necessity for their reinforcement results from comparatively long-term sustainability, which prioritizes lime for the cost-effective change of soil properties. Consequently, lime stabilization offers a number of benefits [10]. Hence, lime can be utilized as a stabilizing agent to improve and enhance the various qualities of soil. Because it is inexpensive, readily available, and has long-lasting benefits, lime is commonly employed in cohesive soils, however it is also utilized in other types of soil [11]. When lime is added to soil, it interacts chemically with the soil particles, improving several of the geotechnical characteristics[12]. According to certain research, applying lime to soils can significantly increase their strength behavior [13-15]. The clay's flocculation and cation exchange in high plastic soils provide the instant strength benefits brought about by lime stabilization [16]. Some researchers suggest that treating with lime may cause a reduction in ductile behavior, which could cause a failure to occur more quickly and cause a greater loss of strength [17, 18]. When lime is mixed with damp soil, two distinct processes occur: stabilization and modification, according to research on lime behavior [19-21]. A clayey soil's maximum dry density (MDD) is contingent upon several parameters, such as the kind of clay, its mineral content, and the degree of compaction. Laboratory tests like the Proctor compaction test and the Modified Proctor compaction test are frequently used to determine the MDD. The soil's composition, compaction effort, and moisture content are some of the variables affecting the MDD. It should be remembered that the highest level of dry density and ideal moisture content vary throughout clayey soils. The maximum dry density of a particular clayey soil needs to be ascertained by compaction testing representative samples in a lab. In these tests, the soil is compacted at different moisture contents, and the dry densities that result are measured. The moisture content at which the maximum dry density is obtained is known as the optimum moisture content.

2. Materials and Methods

The soil and lime which was used in this study as shown in Fig. **1**.The specific gravites (Gs) are 2.68 and 3.3 for clayey soil and lime respectively. The Fig. **2** shows the powdered form of lime and clayey soil. Fig 3 and Fig. **4** show the grading curve of used clayey soil and composition of soil. The basic chemical composition of lime is given in Table 1. The MDD and OMC of the clayey soil and soil with lime content were obtained as per ASTM D1557 – 07 methods.

Fig. 1 Stock of clayey soil and Lime

Fig. 2 Powder Form of Clayey soil and Lime

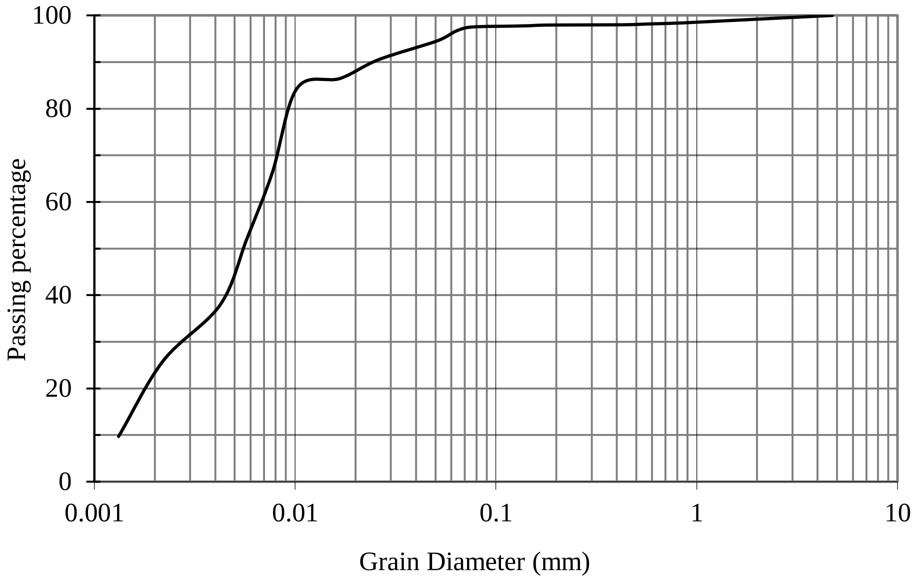

Fig 3 Soil Grading Curve

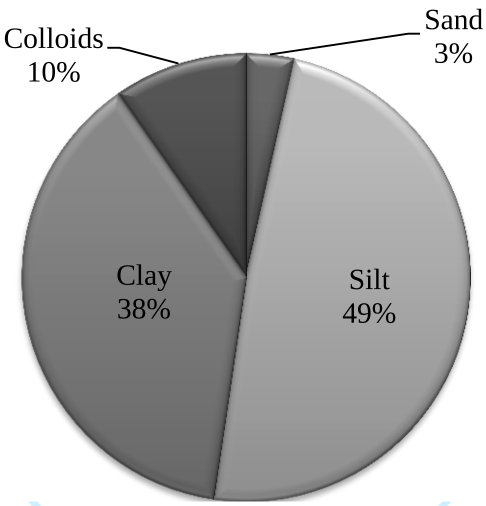

Fig. 4 Composition of Soil

Table 1 chemical Contents of Lime

Constituent	Quantity
Insoluble in hydrochloric acid	0.03%
Substitutes not precipitate by NH_4-OX(a SO4)	2.5
Chloride	50 mg/kg
Sulfate	500 mg/kg
Cu	5 mg/kg
Fe	500 mg/kg
Pb	2 mg/kg
Zn	5 mg/kg
$CaCO_3$	3%

3. Experimental Setup

The compaction properties of clayey soil mixed with varying amounts of lime were ascertained using a modified Proctor compaction test. The motorized modified Proctor test setups are displayed in Fig. **5**. The specific gravity of the composite materials can be ascertained using the weightage average of the specific gravity. The following equation (1) was utilized to get the average specific gravity.

$$G_{av} = \frac{100-L}{100} \times G_{soil} + \frac{L}{100} \times G_{Lime} \quad \text{\_\_\_\_\_\_\_\_\_\_} \qquad \text{Equation (1)}$$

Where, Gav is the average specific gravity of combined content and (L) is the lime content percentage-wise.

Fig. 5 Modified Proctor test apparatus

4. Sample Preparation

The clayey soil sample is taken from the District East of Karachi Division – Pakistan the soil sample for modified proctor test was prepared to add after adding many amounts of lime by the dry weight of the soil, the soil was sufficiently "dry mixed" before being combined with water and completely mixed once more, a process known as "Dry mixing." as depicted in the Fig. **6**. OMC and MDD calculations for each lime content were then done using modified Proctor compaction tests.

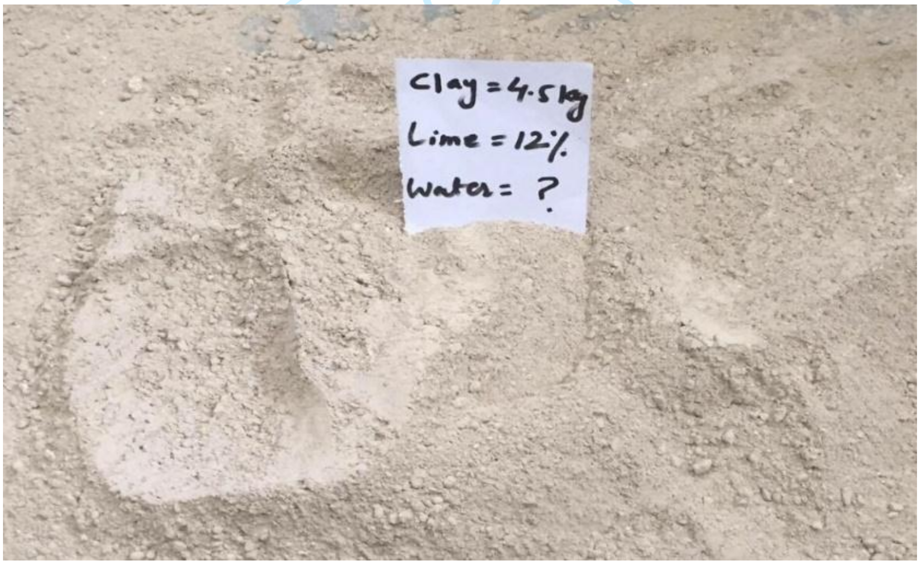

Fig. 6 Mixing of clayey soil with Lime

5. Results and Discussion

5.1 The Influence of Lime on Average Specific Gravity of Soil

It was discovered that the average specific gravity of lime is 3.3 and that of clayey soil is 2.60. Table 2 provides the average specific gravity based on the proportion of lime. Figure 7 illustrates the impact of the % addition of lime. The figure shows a progressive increase brought on by an increase in the amount of lime. This may be due to lime's comparatively high specific gravity of 3.3 compared to soil's 2.60 specific gravity. Previous research has also shown that adding lime to a mixture has an effect on its specific gravity; for example, adding lime to Kaolin soil raised its specific gravity reported by Ali Jamal Alrubaye [22].

Table 2 The typical specific gravity of soil varying in lime content

Lime Content (%)	Soil-specific gravity G_{soil}	Lime specific gravity G_{lime}	G_{av} with the lime content
0	2.60	3.3	2.60
2	2.60	3.3	2.61
4	2.60	3.3	2.63
6	2.60	3.3	2.64
8	2.60	3.3	2.66
10	2.60	3.3	2.67

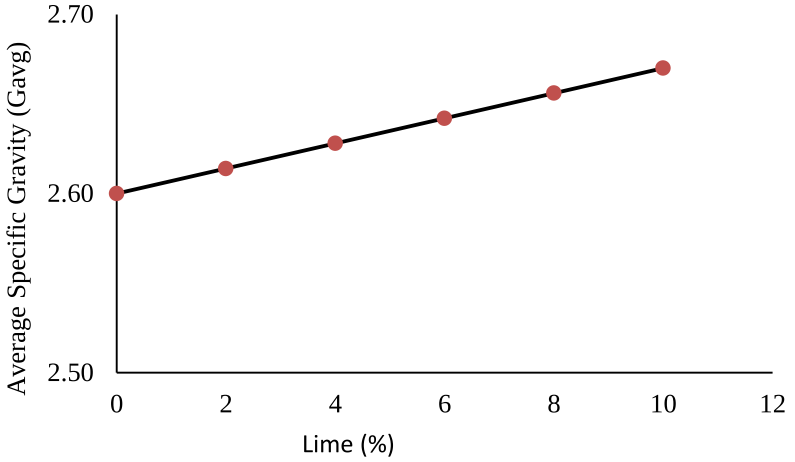

Fig. 7 Effect of percentage of lime on the gravity (Gavg) of soil

5.2 The Influence of Lime on Optimum Moisture Content (OMC)

The effects of lime content on OMC are displayed in Table 3 and Figure 8, and it is clear from the pattern that the percentage of lime increases with time, causing the OMC to gradually raise. The consumption of water during the heat of hydration of lime, which has a specific heat of hydration of 0.29 Btu/lb at 100° F, may be the cause of the increase in the ideal moisture content. Parallel outcomes about lime were also reported in the literature by Kavak and Akyarlı [23], Rahman [24], al-Swaidani, Hammoud [25], Choobbasti, Ghodrat [26], Alhassan [27], and Harichane, Ghrici [28].

Table 3 OMC values at different content of lime

Lime content (%)	Optimum Moisture Content (OMC)
0	16
2	18
4	20
6	22
8	24
10	26

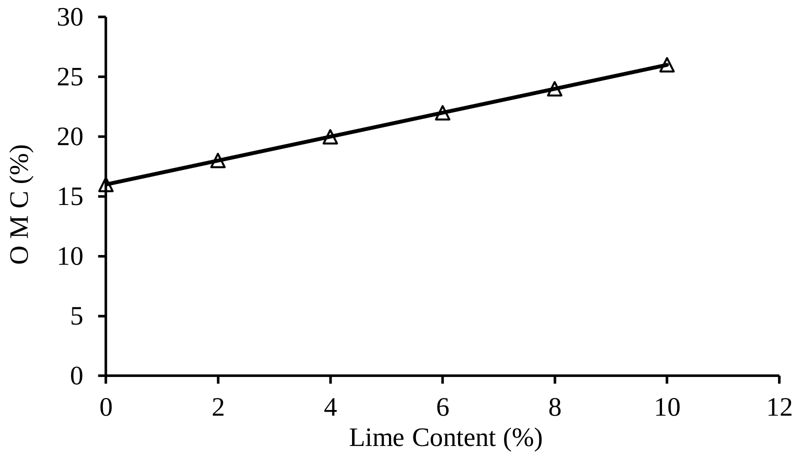

Fig. 8 Influence of lime on the optimum moisture content

5.3 The Influence of Lime on Maximum Dry Density

The maximum dry density of the soil was determined by varying the percentage of lime applied to the soil based on its dry weight. The corresponding values of wet unit weight and dry unit weight with addition of lime contents given in Table 4. The Proctor compaction curves are shown in Fig. **9** which illustrates that as the concentration of lime increases, the maximum dry density (MDD) decreases. The same results were also obtained in the literature. [22, 29].

Table 4 Dry and wet unit weight values at different percentages of lime content

Lime content (%)	Wet Unit weight (kN/m^3)	Dry unit weight (kN/m^3)
0	20.91	18.03
2	20.44	17.62
4	20.23	16.86
6	19.96	16.36
8	19.17	16.0
10	18.89	15.46

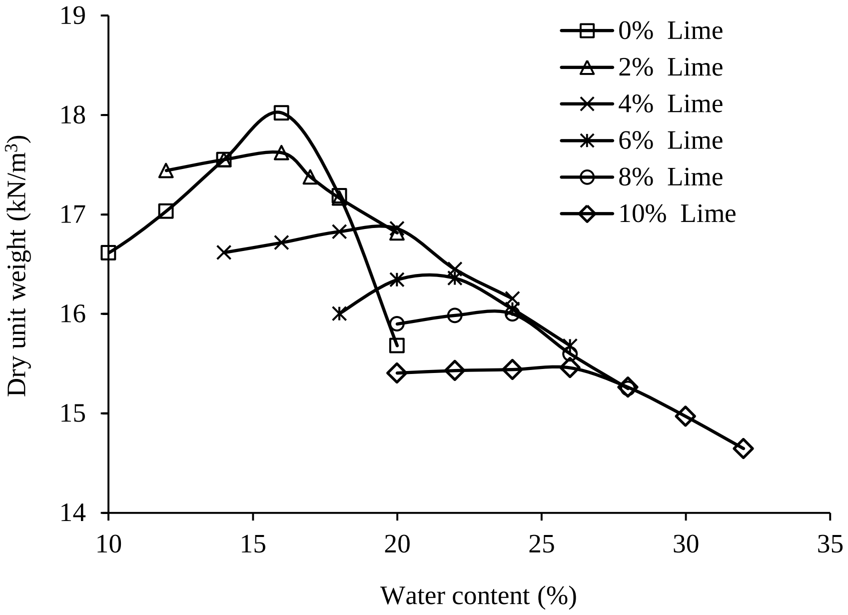

Fig. 9 Impact of the amount of lime on the MDD

6. Conclusion

It is possible to conclude from the compaction characteristic data that lime was applied to the clayey soil at a concentration of 0% to 10% and that its effects on the OMC and MDD were investigated. The test results show that when the amount of lime increases, the OMC increases and the MDD decreases. The maximum dry unit weight of clayey soil is decreased by 18.03 to 15.46 kN/m3 upon addition of lime content at 10%. Lime reduces the dry density of soil by causing flocculation and agglomeration of soil particles, which creates huge pore spaces. While the Optimum moisture content, is increased by 16 to 26%. Matching outcomes were also stated by other researchers for addition of lime in the soil.

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Declaration of Conflict

There are no conflicts between the authors of this research paper.

References

1. Baghdadi, Z., M. Fatani, and N. Sabban, *Soil modification by cement kiln dust.* Journal of Materials in Civil Engineering, 1995. 7(4): p. 218-222.
2. Ogundipe, O.M., *An investigation into the use of lime-stabilized clay as subgrade material.* Int J Sci Technol Res, 2013. 2(10): p. 82-86.
3. Ingles, O.G. and J.B. Metcalf, *Soil stabilization principles and practice*. 1972.
4. Andromalos, K.B., Y.A. Hegazy, and B.H. Jasperse, *Stabilization of soft soils by soil mixing.* GEOTECHNICAL SPECIAL PUBLICATION, 2001: p. 194-205.
5. Oades, J., *The role of biology in the formation, stabilization and degradation of soil structure.* Geoderma, 1993. 56(1-4): p. 377-400.
6. Kamon, M. and S. Nontananandh, *Combining industrial wastes with lime for soil stabilization.* Journal of geotechnical engineering, 1991. 117(1): p. 1-17.
7. Basha, E., et al., *Stabilization of residual soil with rice husk ash and cement.* Construction and Building Materials, 2005. 19(6): p. 448-453.
8. Kaniraj, S.R. and V.G. Havanagi, *Behavior of cement-stabilized fiber-reinforced fly ash-soil mixtures.* Journal of Geotechnical and Geoenvironmental Engineering, 2001. 127(7): p. 574-584.
9. Ud-din, S., A. Marri, and D. Wanatowski, *Effect Of high confining pressure on the behaviour of fibre reinforced sand.* Geotechnical engineering journal of the SEAGS & AGSSEA, 2011. 42(4): p. 69-76.

10. Gharib, M., H. Saba, and A. Barazesh, *Experimental investigation of impact of adding lime on Atterberg limits in Golestan province soils.* Int J Appl Basic Sci, 2012. 3(4): p. 796-800.
11. Feng, T.-W., *Effects of small cement content on consolidation behavior of a lacustrine clay.* ASTM geotechnical testing journal, 2002. 25(1): p. 53-60.
12. Neeraja, D., *Influence of lime and plastic jute on strength and CBR characteristics of soft clayey (expansive) soil.* Global Journal of Researches In Engineering, 2010. 10(1): p. 16-24.
13. Balasubramaniam, A., et al., *Strength and deformation characteristics of lime-treated soft clays.* Geotechnical Engineering, 1989. 20(1).
14. Locat, J., M.-A. Bérubé, and M. Choquette, *Laboratory investigations on the lime stabilization of sensitive clays: shear strength development.* Canadian Geotechnical Journal, 1990. 27(3): p. 294-304.
15. Rao, S.N. and G. Rajasekaran, *Reaction products formed in lime-stabilized marine clays.* Journal of geotechnical engineering, 1996. 122(5): p. 329-336.
16. Lucian, C., *Stress-Strain Behaviours Of Two Stage Lime-Cement Treated Expansive Soils.* International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering, 2015. 9(12): p. 1339-1343.
17. Sabry, M., K.I. Abdel-Ghani, and A. El Nahas. *Strength characteristics of soil-lime columns sections*. in *Proceedings of International Conference on Ground Improvement Geosystems, Tokyo*. 1996. Balkema.
18. Cai, Y., et al., *Experimental study on effect of aggregate size on strength of filled soils.* Yantu Gongcheng Xuebao(Chinese Journal of Geotechnical Engineering), 2005. 27(12): p. 1482-1486.
19. Sherwood, P., *Soil stabilization with cement and lime*. 1993.
20. Rogers, C. and S. Glendinning, *Lime requirement for stabilization.* Transportation Research Record: Journal of the Transportation Research Board, 2000(1721): p. 9-18.
21. Boardman, D., S. Glendinning, and C. Rogers, *Development of stabilisation and solidification in lime–clay mixes.* Geotechnique, 2001. 51(6): p. 533-543.
22. Alrubaye, A.J., et al., *Engineering properties of clayey soil stabilized with lime.* 2016. 11(4): p. 2434-2441.
23. Kavak, A. and A. Akyarlı, *A field application for lime stabilization.* Environmental geology, 2007. 51(6): p. 987-997.
24. Rahman, M.A., *The potentials of some stabilizers for the use of lateritic soil in construction.* Building and Environment, 1986. 21(1): p. 57-61.
25. al-Swaidani, A., I. Hammoud, and A. Meziab, *Effect of adding natural pozzolana on geotechnical properties of lime-stabilized clayey soil.* Journal of Rock Mechanics and Geotechnical Engineering, 2016. 8(5): p. 714-725.
26. Choobbasti, A., et al., *Influence of using rice husk ash in soil stabilization method with lime.* Frontiers of Earth Science in China, 2010. 4(4): p. 471-480.
27. Alhassan, M., *Permeability of lateritic soil treated with lime and rice husk ash.* Assumption University Journal of Thailand, 2008. 12(2): p. 115-120.
28. Harichane, K., et al., *Use of natural pozzolana and lime for stabilization of cohesive soils.* Geotechnical and Geological Engineering, 2011. 29(5): p. 759-769.
29. Rizal, N., et al. *Effects of lime on the compaction characteristics of lateritic soil in UTM, Johor*. in *IOP Conference Series: Earth and Environmental Science*. 2022. IOP Publishing.