Research Corridor Journal of Engineering Science
ISSN Online: 3078-3054, ISSN Print: 3078-3046
Volume No: 02 Issue No: 02 (2025)

International Conference on Innovating for a Sustainable Future: Global Challenges and Solutions
April 24-25, 2025

Shear Strength Improvement of Fine-Grained Soils Using Lime Stabilization

Sawera Samuel[1], Bilal Tanveer[2], and Usman Pervaiz[3]*
[1] Department of Civil Engineering, Lahore Leads University, Lahore 54000, Pakistan; sawerasamuel2000@gmail.com
[2] Department of Civil Engineering, Lahore Leads University, Lahore 54000, Pakistan; bilalmughal1020@gmail.com
[3] Department of Civil Engineering, Lahore Leads University, Lahore 54000, Pakistan; usman.dpk2@gmail.com
*corresponding author

Abstract
An essential component of any civil engineering building is soil. Buildings, bridges, highways, tunnels, dams, towers, and other civil engineering structures are constructed on or below the earth's surface. Proper foundation soil is necessary for their stability. Fine-grained soils often exhibit weak shear strength, posing challenges in construction projects. This study focuses on enhancing the shear strength of such soils through chemical stabilization using lime, a cost-effective and widely available material. In this experimental investigation, lime was mixed with fine-grained soil at varying dosages of 2%, 4%, 6%, 8%, and 10% by weight. The prepared samples were subjected to curing periods of 7, 14, and 28 days. The unconfined compressive strength (UCS) test was conducted to evaluate the shear strength development over time. The results revealed a significant increase in shear strength with both lime content and curing duration. The maximum shear strength of 1007.7 kPa was observed at 8% lime content after 28 days of curing, which is approximately five times greater than that of the untreated (in-situ) soil. The study concludes that lime stabilization is an effective technique for improving the shear strength of fine-grained soils, with optimal performance achieved at 8% lime content after sufficient curing. These findings contribute to the development of sustainable ground improvement strategies in civil engineering.

Index Terms
Enhancing Shear Strength, Lime stabilization, Soil Strength Improvement, Unconfined Compressive Strength (UCS).

I. INTRODUCTION

Silty soil is one type of soil that can be problematic in construction projects because of its low bearing capacity and shear strength [1]. Fine-grained soil has a larger surface area, and it creates more voids relative to the coarse grain soil due to their extremely small particle size [2]. Due to these properties, fine-grained soils with high plasticity have the ability to expand when moisture levels in the soil fluctuate. To improve the soil's engineering qualities and control its impact on shear strength, chemical stabilization with lime is applied [3]. Additives improve the performance and ability of fine-grained soils as compared to their in-situ conditions [3].

Our study aims to address the significant issue of weak soil preventing infrastructure construction due to its low bearing capacity and shear strength by comparing and evaluating the effectiveness of different amounts of lime as a soil stabilizer. We examine how using lime as a stabilizing agent can eventually increase the stability of the soil. The goal of our research is to determine the ideal lime proportion.

STABILIZATION TECHNIQUES

The various methods of stability include

i. Mechanical stabilization
ii. Stabilization using different types of admixtures
   a. Lime stabilization
   b. Cement stabilization
   c. Fly Ash stabilization
   d. Rice Husk Ash stabilization

LIME STABILIZATION

Several chemical processes that significantly affect the soil's structure are involved in the stabilization of soil with lime. Lime interacts with soil to alter its characteristics through cation exchange mechanisms, hydration, flocculation, and pozzolanic reactions [4]. Lime, especially nano-lime, can be added to clayey soils to improve their strength, durability, and compressibility while also adjusting their Atterberg limits [5]. Due to intricate chemical interactions, soil may not react well to lime stabilization, which could result in unfavorable effects such excessive swelling or weakening [6].

A study is performed in 2016 in which the Unconfined compression test (UCS) is performed at maximum dry density and moisture content; with 4 lime contents (2% to 8%) and curing times of 7 days,14 days and 28 days. Stabilization of fine-grained soils with the addition of 8 % lime and gains higher UCS strengths achieved at 28 days [7].

Another study is performed that was on Unconfined compression test (UCS), at maximum dry density and optimum moisture content; with three different lime contents (4%,6% and 8%) and curing times of 14 days and 28 days. It has been concluded that the optimum moisture content decreased and UCS strength increased with different percentages of lime in fine grained soil [3].

II. METHODOLOGY

To perform this study, a structured methodology was adopted. The process involved soil sample collection, sample preparation and experimental analysis. The methodology followed in this study is presented in figure 01.

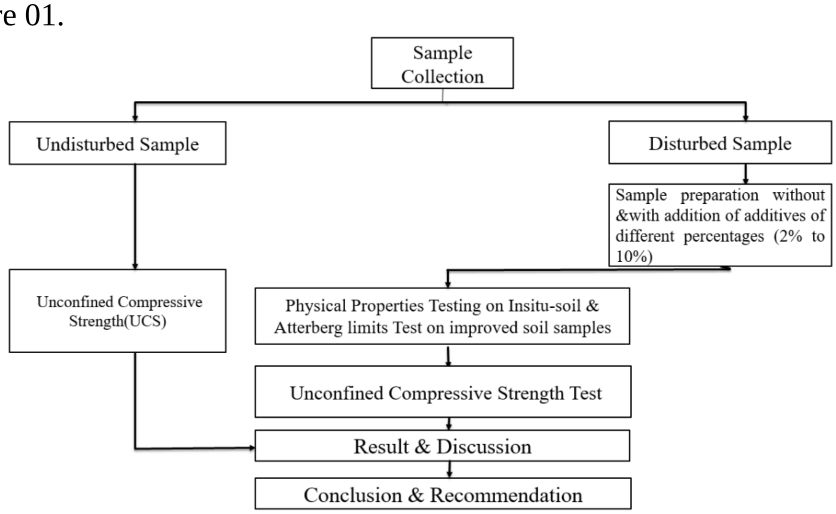

Figure 1: Methodology Flow Chat

Experimental Testing Plan

To evaluate particle size distribution and differentiate between coarse and fine fractions, sieve analysis will be performed initially in accordance with ASTM D6913. To determine the distribution of fine-grained particles less than 0.075mm, a hydrometer analysis is conducted according to ASTM D7928. The next is to compare the mass of soil solids to an equivalent volume of distilled water to determine the soil's specific gravity using ASTM D854. Atterberg Limits (L.L & P.L) will be calculated according to ASTM D4318 to evaluate the soil's plasticity properties. The MDD and OMC are determined using the Modified Proctor Test (ASTM D1557). The compressive strength of the in-situ soil and modified samples are determined by using the UCS test in accordance with ASTM D2166.

SAMPLE PREPARATION

The fine-grained soil used in this study was first air-dried and then pulverized to pass through a 4.75 mm sieve to ensure uniformity. Lime was added to the soil in varying proportions of 2%, 4%, 6%, 8%, and 10% by dry weight of soil. The lime and soil were thoroughly mixed in dry form to ensure homogeneity, followed by the addition of a calculated amount of water to reach the optimum moisture content. The moist mixture was then compacted into cylindrical molds for unconfined compressive strength (UCS) testing. Prepared samples were carefully sealed in plastic wraps and stored in a controlled environment for curing periods of 7, 14, and 28 days.

Figure 2: Sample Preparation

Figure 3: Prepared Samples

Figure 4: Curing of Samples

III. RESULTS AND DISCUSSIONS

a) Results of grain size analysis of in-situ soil by using standard sieves and hydrometer.

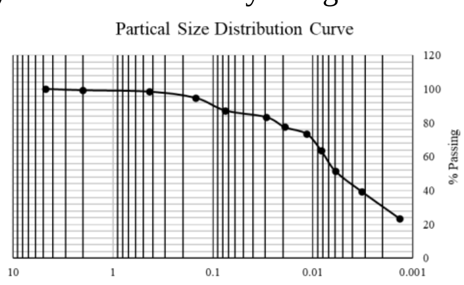

Figure 5: Particles size distribution

By performing the Sieve analysis and Hydrometer analysis test, According to AASHTO classification system the soil is classify as A-4 (silty soil).

b) Results of grain size analysis of in-situ soil by using standard sieves and hydrometer.

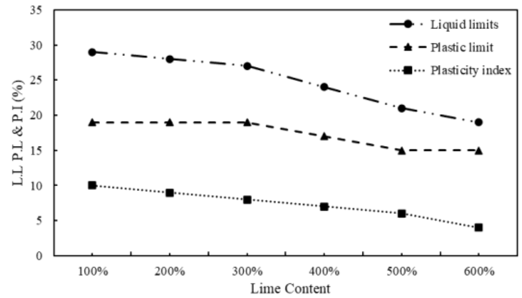

Figure 6: Liquid Limit, Plastic Limit & Plasticity Index

The Atterberg limits show a decreasing trend by increasing the amount of lime.

b) Results of maximum dry density and optimum moisture content of in-situ and modified samples by using AASHTO Modified Proctor test.

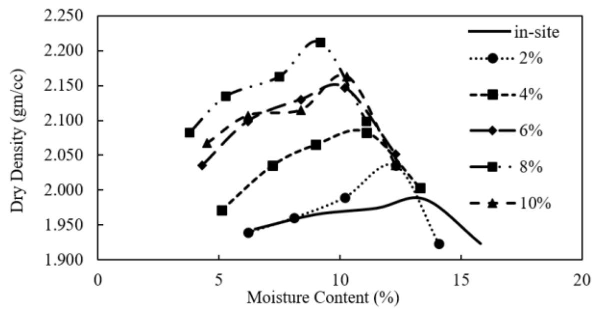

Figure 7: Maximum Dry Density and Optimum Moisture Content

The maximum dry density (MDD) is achieved at 8% of Lime content and this is 2.185 gm/cc with optimum moisture content of 8.2%.

c) Results of Unconfined Compression Strength Test of in-situ and modified samples after 7 days of curing by using UCS testing machine.

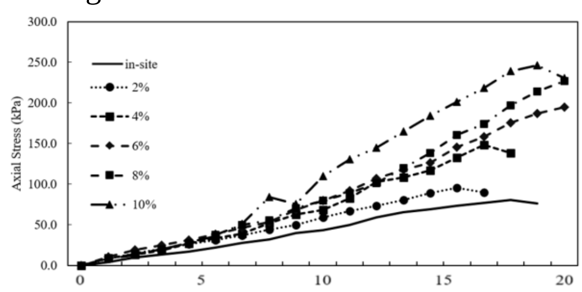

Figure 8: Unconfined Compression Strength at 7 days

The maximum shear strength after 7 days of curing is 242.7 kPa with 10% of lime additive has been noted.

d) Results of Unconfined Compression Strength Test of in-situ and modified samples after 14 days of curing by using UCS testing machine.

Research Corridor Journal of Engineering Science
ISSN Online: 3078-3054, ISSN Print: 3078-3046
Volume No: 02 Issue No: 02 (2025)

International Conference on Innovating for a Sustainable Future: Global Challenges and Solutions
April 24-25, 2025

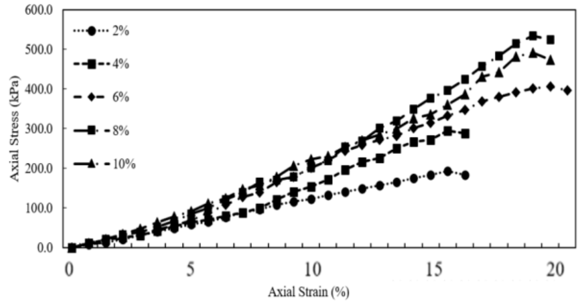

Figure 9: Unconfined Compression Strength at 14 days

The maximum shear strength after 14 days of curing is 564.5 kPa with 8% of lime additive has been noted.

e) Results of Unconfined Compression Strength Test of in-situ and modified samples after 28 days of curing by using UCS testing machine.

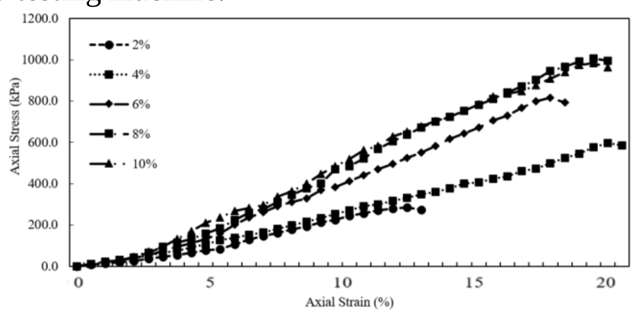

Figure 10: Unconfined Compression Strength at 28 days

The maximum shear strength after 14 days of curing is 1007.7 kPa with 8% of lime additive has been noted.

IV. DISCUSSIONS

Based on the findings of the hydrometer test and sieve analysis, the soil used in this study was categorized as A-4 (silty soil) under the AASHTO classification system. This type of soil is a good option for stabilization since it usually has low shear strength and a weak load-bearing capability. The liquid limit, plastic limit and plasticity index show the decreasing trend by increasing the amount of lime due to cementitious effect. The lime binds the soil particles together and reducing the value of Atterberg limits. Compaction and strength properties showed significant improvements after lime treatment. With a value of 2.185 g/cc and an ideal moisture content of 8.2%, the Maximum Dry Density (MDD) was attained at 8% lime concentration. Because of the chemical reaction between the lime and soil particles, this increase in MDD indicates greater compactness through improved particle bonding and a decreased void ratio. According to the Unconfined Compressive Strength (UCS) test, the shear strength increased significantly with both the amount of lime and the curing time. The maximum shear strength was measured at 242.7 kPa with 10% lime concentration after 7 days of curing, suggesting an initial pozzolanic response that aided in strength increase. The maximum strength increased to 564.5 kPa at 8% lime content after 14 days of curing, indicating that strength development works better at slightly lower lime dosages when given additional curing time. This might be explained by the persistence of pozzolanic processes, which produce cementitious substances like calcium silicate hydrates (CSH) and calcium aluminate hydrates (CAH), which greatly improve soil bonding and structure. The strength peaked at 1007.7 kPa with 8% lime after 28 days of curing, which is roughly five times higher than the strength of the untreated soil. This notable improvement demonstrates that, given enough curing time, lime stabilization is a very effective way to increase the shear strength of silty soils.

V. CONCLUSION

This study investigated the effectiveness of lime stabilization in enhancing the shear strength of fine-grained silty soil. The findings showed that lime greatly enhances the soil's shear strength and compaction properties, with strength increases occurring as curing time increases. These results demonstrate that, provided sufficient curing time is permitted, an 8% lime concentration is the ideal dosage for increasing shear strength in this kind of soil. Lime stabilization is a practical, economical, and sustainable way to improve the engineering qualities of fine-grained soil, which makes it ideal for building and infrastructure projects in areas with weak soil.

REFERENCE

S. Roy and S. Kumar Bhalla, “Role of Geotechnical Properties of Soil on Civil Engineering Structures,” Resour. Environ., vol. 7, no. 4, pp. 103 109, 2017, doi: 10.5923/j.re.20170704.03.

S. K. Laskar, A. and Pal, “Geotechnical characteristics of two different soils and their mixture and relationships between parameters,” EJGE, vol. 17, pp. 2821–2823, 2012

Ash. lime stabilization “factors affecting, advantages and disadvantages”. [online] civil engineer’s forum 2013.

M. Martinon-Torres, “Stabilization of expansive soils using chemical additives: A review,” J. Rock Mech. Geotech. Eng.

Ali Akbar Firoozi, “Stabilization Expansive Clayey with Nano-Lime to Reduce Environmental Impact,” J. Kejuruter., 2022

J. Transp. Res. Board, “Lime Stabilization of Clay Soil,” 2007

Bagherpour, Iman, and Asskar J. Choobbasti. "Stabilization of fine-grained soils by adding and lime or and cement." electronic journal of geotechnical engineering 8.b (2003)