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MATERIAL MANAGEMENT AND COST-EFFECTIVE PROJECT: TREATMENT OF EXPENSIVE SOIL BY UTILIZATION OF LIME IN PAKISTAN

Hafiz Rana Muazzam Ali[1], Ibrahim Khan[2] & Shahan Mehmood Cheema[3]

[1]M.Phil. Scholar, Business & Management Sciences Department, The Superior University, Lahore
[2]Instructor Civil PS-17, Government College of Technology Sangla Hill (TEVTA), Pakistan
[3]Assistant Professor, Business & Management Sciences Department, Superior University, Lahore

KEYWORDS

Project Management Lime, Cost, Unified Compressive Strength, Rice Husk Ash, Soil Utilization

ABSTRACT

The study is conducted to evaluate the material management with respect to cost effectiveness regarding soil utilization of lime project, and the potential applicability of the materials as Pozzallans in Pakistan. Lime (L) was applied to soil at concentrations of 5%, 10%, and 15% based on the soil's dry weight. The study focused on analyzing physical properties & behaviors of untreated and treated soil, specifically emphasizing volume change. After conducting experimental program, we have obtained results for specific gravity, moisture to dry the density ratio, unconfined compressive strength (UCS), and swelling potential. The study's results offer important information wherein the most significant result is that behaviors of swelling & decreasing were significantly improved. Ultimately, it was concluded that using 10% lime solution yielded most significant outcomes. To achieve effectiveness, combining it with porous soils & compact it under light loads is necessary to take under consideration. Finally, it is concluded that the cost may reduce and quality of the project may be enhanced of the project by implementing the project management in pure essence.

Correspondence	Ibrahim Khan
Email:	ibrahimkhan7839@gmail.com
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INTRODUCTION

There are several factors of the failure of construction project but adverse management of material during site activity is the most common factor which becomes the reason of failure. So, it is necessary to manage the material to avoid any over cost of the project that is valuable for stock of the firms (Hussain, Hamid, Imdad & Khan, 2011). Management of material and alternative use of material may reduce cost of the project. The material management system ensures the use of right material in right quantity at right time, and enhance working capital of firms (Khan, Akash, Hamid & Hussain, 2011). Expanded soil, also known as collapsing soil, is prevalent factor that can lead to foundational problems, and cause and effect relation can be enhanced of these factors (Akash, Khan & Shear, 2023). Various structures, such as the pavements, railroads, highway embankments, roads, building foundations, slabs, canals and tanks linings, irrigation systems, water pipes, and the sewage systems, experienced cracking and failure due to significant soil problem, and volatility of the stock (Khan, Akhter & Bhutta, 2020). Therefore, to stabilize the moisture content of these soils, a diverse range of stabilizers are used to address this issue, and cover the distortion of the markets (Khan, Akhter & Bhutta, 2020). Thus, the financial system of the firms can be enhanced by this phenomenon (Khan, Bashir & Amir, 2023). The rice husk ash (RHA) is a substance that can be effectively utilized as a biological waste stabilizer.

RHA is derived from rice husks, which comprise rice kernels' outermost layer. Biogas is commonly used as the fuel in boiler furnaces responsible for steam production. Soil expansion is considered the most financially damaging natural hazard in specific regions due to its potential to cause structural damage (Anwar, 2011). Mudslides in the United States cause more destruction annually than floods, hurricanes, earthquakes, and tornadoes combined. India, Bangladesh, Malaysia, and Iran are the most notable developing nations that produce RHA. The work in Pakistan is limited but expanded in the field of brand awareness in the markets (Khan, Hussain & Akash, 2023). RHA is a highly effective. Chemical stabilization has become increasingly popular for treating a wide range of soils, with the three most frequently used stabilizers being fly ash, gypsum, and cement. Lime (L) has been used to treat clay soils to improve their properties and behaviors for centuries. In this connection, hydrated lime, lime slurry, or quicklime (CAO) can be applied to soil to achieve soil consolidation. Thus, calcium oxide, also known as CAO, is formed through a chemical transformation of calcium carbonate, denoted as CACO3. This investigation aimed to analyze the impact of curing upon the stabilization of expansive soils treated with silica fume and improve volume change characteristics of these mentioned soils.

The research will consider the following factors: 1) the stabilizer affects physicochemical properties of the soil as it grows, 2) the impact of varying hardening time on the properties of stabilized soil, and 3) the engineering properties of the soil were analyzed to understand the effects of adding lime and the reasons behind those changes, and asymmetric effect, international flow on markets (Khan et al., 2023; Akash et al., 2023). Moreover, the corporate value of the firms can also be enhanced (Akash et al., 2023). The investment can be attracted by this concept, and economic value as well as cash flow of the firms (Amir, Bilal & Khan, 2023). This would lead to produce the cause and effect relation of stocks, and value creation of firms (Khan, Hussain & Akash, 2023). Soil stabilization is a crucial process that aims to reduce amount of volume change in soil while simultaneously refining its strength and cohesion. The study employed a methodology that includes the soil classification, establishment of Atterberg limit, determination of the unconfined compressive limit, compaction properties of expansive soil, as well as the determination of the swelling potential. The engineering properties of the soil were analyzed to understand the effects of adding lime and the reasons behind those changes. Extensive research was carried out to examine the chemical's effects and determine the appropriate dosage.

LITERATURE REVIEW

The clay soils with low water content and high ductility exhibit a strong sensitivity to changes in moisture levels, leading to substantial variations in the volume. Expansive soils are types of soils that have the tendency to expand in volume as their water content increases. Soils with high plasticity causes cracks in diverse infrastructure types, includes pavements, railways, highways, foundations, and structures. The soils' significant swelling and shrinking properties frequently pose challenges in civil engineering projects (Khan, Akhter & Bhutta, 2020). Expansive soils tend to swell when they come into contact with moisture; conversely, they tend to shrink when they are no longer in contact with moisture. This volume change is primary cause of natural disasters and can cause substantial damage to structures and infrastructure (Akash, Khan & Shear, 2023). Volumetric changes in soil are responsible for numerous issues in structures and substructures. The expansive soils are common worldwide and cause weighty damage to roads, pavements, and lightweight buildings. Movement of edifices in wide soils during wet & dry seasons. Expansive soils exhibit famous changes in volume as their water content fluctuates, mainly in arid regions. The types of soil are influenced by three factors: the geological properties of the soil, the engineering characteristics of the soil, and the local environmental conditions.

The expansion of clay particles is influenced by three factors: the amount of moisture in the soil, the flexibility of the soil, and dry density of the soil. It is crucial to stabilize expansive soils with specific additives since of their significant volume change. This volume change is primary cause of natural disasters and can cause substantial damage to structures and infrastructure. It is crucial to ensure the stabilization of these soil varieties (Akash, Khan & Shear, 2023). This is because the estimated annual global cost of damage to civil engineering structures built on the expansive soils amounts to billions of pounds. The objective of this investigation is to improve the geotechnical properties of expansive soils by incorporating different elements, such as industrial residues like silica fume (SF). Soil stabilization is a crucial process that aims to reduce the amount of volume change in soil while concurrently refining its strength and cohesion. Sonebi, (2010) explained Stabilizers, like limestone, fly ash, cement, and other similar minerals, have been used for significant period of time in past. Use of stabilizers has gained popularity as a result of significant waste generated by economic growth and industrialization. Seco, Ramírez, Miqueleiz, and Ramírez (2011) documented that Stabilized soils are widely utilized in the global construction industry, particularly in countries that possess ample natural or industrial resources.

Dehghanpour, Yilmaz and Ipek (2019) explained various additive mixtures, such as lime combined with rice husk ash/fly ash mixed with rice husk ash have confirmed their effectiveness in stabilizing expansive soils and mitigating issues related to volume changes. Anwar (2011) conducted the study Pozzolan stabilizers have ability to bond soil particles together and reduce water absorption size of clay particles. Basha, Hashim, Mahmud and Muntohar (2005) have explored the use of the various industrial byproducts, including blast furnace slag, fly ash, rice shell ash, foundry sand, foundry slag, and cement kiln dust, as potential stabilizers for the clayey soils. RHA is a highly versatile material that possesses favorable chemical composition and physical properties, making it suitable for soil stabilization drives. Wansom, Janjaturap & Sinthupin (2009) explored that due to its affordability and high activity, it is excellent choice to use as pozzolan. When RHA is mixed with cementations materials and water, it exhibits properties similar to cement. Saha and Sarkar (2012) elaborated that this mixture helps in bonding the individual soil particles together and enhances geotechnical properties of expansive soils. Faramawy, Zaki and Sakr (2016); and Kalkan, Nadaroğlu, Celebi and Tozsin (2014) show that SF is finely grained particulate that is produced as byproduct in facilities for silicon metal production.

It is used in stabilization process. Silica fume is highly sought after as a byproduct among pozzolan stabilizers because of its strong pozzolan properties. Due to its small particles, extensive surface area, and high silica content, it exhibits reactive pozzolan properties. Fly ash is the waste substance that is utilized as an ingredient in production of hydraulic cement (Akash, Khan & Shear, 2023). Its use has a significant impact on expansion of highly plastic expansive clays, as well as compressibility of other highly plastic clays that are not expansive. Phani, Kumar and Sharma (2004) led the study, increasing the ash content to 20% resulted in a decrease of around 50% in swelling potential and pressure for both types of clay. There was a 40% decrease in the compression index and secondary consolidation coefficient. Copper slag, that is non-reactive material produced during metallurgical processes in river beratory furnaces, can be efficiently stabilized by adding copper dross gradually. This should be done in increments of five percent until reaching a maximum of 30%. Lime, which is mineral containing calcium, reacts with the alumina and silica present in soil to produce calcium aluminates silicates. This cementations material possesses both high strength and a low capacity for the volume change.

Research has demonstrated that the addition of fine lime in concentrations ranging from 0.2 to 8% can effectively reduce maximum dry density (MDD), plasticity index (PI), and swelling potential. In a study conducted by Barasa (2017), a combination of lime and lime fly ash was successfully utilized for remediation of clay soil. Expansive soils exhibit notable changes in volume as water content fluctuates, particularly in arid regions. Soil stabilization is a crucial process that aims to reduce the amount of size change in soil while simultaneously improving its strength and cohesion. Wansom, Janjaturaphan and Sinthupinyo (2009) explored that due to its affordability, high activity level, it is an excellent choice to use as a pozzolan. Particle size distribution was determined over discharge tests. Different doses of lime (0.4%, 0.50%, & 0.6%) were used for treating clay soil. The plasticity index and California Bearing Ratio value were calculated and analyzed. Its use has a significant impact on the expansion of highly plastic expansive clays, as well as compressibility of other highly plastic clays that are not expansive. Quicklime is usually regarded as efficient than hydrated lime because it has a higher concentration and lower cost. The type of lime used in a specific region, like Europe, depends on its availability. Adding suitable amount of lime to the soil improves its stability by enhancing its structure.

RESEARCH METHODOLOGY

Soil preparation is an important step in gardening or farming. It involves getting the soil ready for planting by improving its quality and structure. Preparing the soil involves several steps in the process. This study focuses on the expansive soils found in the Nandipur region of Punjab, Pakistan. Various locations throughout Pakistan have expansive soils. The research has discovered that this particular soil can lead to a range of issues for lightweight structures, such as single-story homes, highways, and similar constructions. Comprehensive soil identification has been conducted in the Nandipur region, revealing the various issues associated with these soils. Later on, the scope of this project was expanded to include the stabilization as well as enhancement of the extensive soils in the Nandipur region.

Lime

Dowling, O'Dwyer and Adley (2015) demonstrated that Quicklime, called calcium oxide (CaO), is frequently utilized for soil stabilization. The calcium oxide is produced by chemically converting calcium carbonate (limestone, CaCO3). This type of lime is commonly used for soil treatment due to its higher concentration and cost-effectiveness than hydrated lime. Furthermore, when combined with soil, it also generates extra heat for the hydration. In this study, the locally available quicklime (CaO) is utilized.

Specific Gravity

This test is used to determine soil density, which is ratio of material's density to the density of water. ASTM standard number D854 conducts tests to measure the Gs (specific gravity) of clay soil and its mixture with additives, also known as stabilized soil.10. For this test, we used 50 g of soil that had not been disturbed and had been dried in an oven. We used a standard pycnometer with volume of 500 mL. First, weight of empty pycnometer was measured, and then it was weighed again. Measurement of 50 grams of soil has been taken. Next, proceed to soak soil in distilled water for 24 hours. This will effectively saturate soil and ensure that all empty spaces within soil are filled. Next day, pycnometer was vacuumed to remove air bubbles in solution. Pycnometer is left for some time to allow particles to settle. Next, pycnometer is filled with purified water, and its volume is measured. Containers are filled with distilled water and weighed again. The test was conducted multiple times using varying percentages of lime.

Atterberg Limits

Atterberg limits are soils' liquid and plastic limits, used to classify the fine-grained sediments. The liquid limit is the point at which soil transitions from a plastic state to a liquid state, while the plastic limit is the amount of water required for the soil to retain its plasticity. A series of soil samples were collected after determining the Atterberg limits of single clay soil and its various L% combinations. The study aimed to understand how lime content affects behavior of combinations and the impact of time (hardening) on Atterberg limit. Limit of Liquid (LL) refers to the maximum amount of liquid a substance can hold. The evaluation was conducted using ASTM D4318-10 criteria, with 200 grams of ground and desiccated soil mixed in steel container and submerged in purified water. Experiment was repeated with a specific quantity of lime, and the number of blows needed to close the groove by 13 mm towards its center was recorded. The experiment was repeated using a larger volume of water, with each step increasing incrementally. The multipoint liquid limit method was employed to determine the liquid limit.

Plastic Limit

The test was conducted on the specimen used for liquid limit test, following the guidelines of ASTM Standard Test Number D4318-10. The samples were left to harden for 24 hours before undergoing a liquid limit test to compare and analyze any changes in soil. In this connection, the container was placed in desiccators for 24 hours to ensure evenly distributed water content. Thus, for each test, approximately 200 g of soil was collected and then rubbed on a smooth surface until small cracks, up to 3 mm in diameter, appeared. Consequently, the water content was determined by drying the sample in an oven.

Modified Proctor Compaction Test

The compaction curve was used to assess the correlation between water content and dry unit weight of samples, using a modified Proctor compaction test. The mixtures were compacted in three layers using standard metal moulds with diameter of 109 mm. Each layer was 5-8 cm thick and compacted with 25 blows. This compaction process was carried out using automatic dynamic compactor, which dropped a 5 kg hammer from height of 305 mm. The compacted samples were cut and weighed, and the water content was measured using ASTM D1557 method. This process allowed for calculating a compaction curve, in lieu of water content ratio to dry density. Optimal water content was resolute by identifying the values at highest points on compaction curves. Laboratory tests were conducted in four stages. Following phases are displayed below: Untreated soil can be described as soil that has undergone no treatment or modification. This study aims to examine properties of soil treated with lime at varying amounts of 5%, 10%, and 15%. Investigation is centered on soil properties of both original soil and alternative soil. These properties were analyzed so as to determine their suitability for pozzolanic stabilization.

The results were utilized to assess the soil's suitability for pozzolanic stabilization and its potential for improvement through stabilization. Classification of soil based on grain size was performed through the use of sieve analysis and hydrometry testing. The test results were determined in accordance with ASTM D422-00 guidelines, using fifty grams of soil that had been dried and finely powdered. The Atterberg limits were determined by employing a No. 40 (0.425 millimeter) soil permeable sieve, and the plastic limit test was conducted in accordance with the ASTM D4318-10 standards. The plasticity index (PI) is thus determined by subtracting the plastic limit from the liquid limit. The ASTM D854-00 standard and a water pycnometer were used to calculate the Substantial Gravity (GS). This calculation helps determine the percentage of soil solids that can pass through a 4.75-millimeter (No. 4) sieve. The relationship between soil moisture and density was investigated using the modified Proctor compaction test specified by ASTM D1557. This test collected data upon the moisture density relationship for various types of soil, including untreated expansive soil, expansive soil treated with different amounts of the lime and silica fume, as well as untreated expansive soil without any treatment.

Table 1 Following are Two Combinations of Variables.

	1st Combination		2nd Combination.
1.	Untreated Soil	1.	Treated Soil
2.	95% ES + 5% L	2.	95% ES + 5% L
3.	90% ES + 10% L	3.	90% ES + 10% L
4.	85% ES + 15% L	4.	85% ES + 15% L
5.	80% ES + 20% L	5.	80% ES + 20% L

Research Models

Model- I

Independent Variable (Particle Size) = Constant + Coefficients (Pure Soil) + Coefficient (Lime Treated Soil)

Model-II

Independent Variable (Aterbergs's Limit) = Constant + Coefficients (Pure Soil) + Coefficient (Lime Treated Soil)

Model-III

Independent Variable (Maximum Dry Density) = Constant + Coefficients (Pure Soil) + Coefficient (Lime Treated Soil)

RESULTS & DISCUSSIONS

The initial phase of experimental program involved testing the reactivity of PFs to evaluate both their activity and the physical properties of specific expansive soils. The second phase of the study focused on the volume change experiments. These experiments included tests on natural soil and its mixtures, which contained varying amounts of the silica (5%, 10%, and 15%). The tests specifically examined swelling, shrinkage, and compression behaviors. The following pages provide a detailed discussion of the results from soil tests, both for untreated and treated samples. Particle size analysis was conducted using two ASTM standard tests: sieve analysis (ASTM D6913) & hydrometric analysis (ASTM D422). The gravel, sand, and fines gradation analysis were conducted using the ASTM D6913 sieve analysis method. Similarly, the gradation analysis of fine soil, specifically clay and silt, was performed using the ASTM D422 hydrometric analysis method. Clean soil was analyzed for particle size, revealing that it consists of 8% sand, 26% silt, and 59% clay. In the case of the expansive soil, lime was partially replaced with 5%, 10%, and 15% in an experimental analysis. This resulted in a decrease in the Percentage of clay-sized particles from 63% to 53% and an increase in silt-sized particles from 28% to 40%. Table 4.2 displays Percentage of particles found in both clean soil and soil treated with silica fume.

Table 2 Results of Model-I of 1st Combinations

Samples	Sand (%)	Silt size particles (%)	Clay size particles (%)
Untreated Soil	9	28	63
Combination 1	11	29	60
Combination 2	10	35	55
Combination 3	8	38	54
Combination 4	7	40	53

Specific Gravity (GS)

The specific gravities of soil solids were determined for untreated and treated soil samples using a water pycnometer, following standard test method outlined in ASTM D854. The specific gravity test result for the untreated soil was 2.710. The specific gravity decreased continuously from 2.710 to 2.610 when the soil was treated with lime through partial soil replacement. This process involved replacing a portion of untreated soil. Silica fume content varies by 5%, 10%, 15%, and 20%. Table

4.3 displays relationship between increase in the Percentage of additives and the corresponding change in specific gravity.

Atterberg Limits

The liquid limit of the untreated soil was estimated using a Casagrande apparatus, while the plastic limit of soil was determined by making 1/8-inch threads. The tests were thus conducted following the guidelines outlined in ASTM D4318-05. The untreated soil test results indicate a liquid limit value of 56.40%, a plastic limit value of 26.35%, as well as a plasticity index value of 25.05%.

Table 3 Results of Model-II

Samples	LL (%)	PL (%)	PI (%)
Untreated Soil	56.40	26.35	30.05
Combination 1	53.31	29.13	24.18
Combination 2	51.11	31.33	19.78
Combination 3	50.22	31.56	18.66
Combination 4	48.76	32.11	16.65

Soil Classification

Based on the USCS classification system (ASTM D2487) and AASHTO classification system (ASTM D3282), soil classification involves conducting particle size analysis and Atterberg limit tests. After these two tests, untreated or black cotton soil can be classified as CH-oily clay (USCS), A. - 7-6 (AASHTO). When lime is added to soil in varying percentages, soil classification transitions from CH to ML (Silt). Similarly, in the AASHTO classification system, soil classification changes from (A-7-6 to A-7-5. 4.1.4) Cable strength in excessively dry and exposed soil is unlimited. Untreated soil's unconfined compressive strength (UCS) was tested by preparing and conducting a specimen by ASTM D2216. The calculated strength for untreated expansive soil is 152 kPa. The unconfined compressive strength of soil was measured after treat it with varying amounts of lime, specifically at 5%, 10%, 15%, 20%. When lime partially replaced in expansive soils, uncompacted compressive strength increased to 175 kPa at a 10% replacement rate. However, it decreased to 168 kPa at 20% replacement rate. Test results of unconfined compressive strength with increasing percentages of additives.

Swell Test

Expansive soils exhibit swelling properties under various conditions. To control these properties, stabilizers were employed and effects were subsequently analyzed. Lime was one such stabilizer used in the study. The study demonstrates positive outcomes in reducing the swelling potential of the soil in the Nandipur area. The virgin soil underwent a swelling test following the guidelines of ASTM D4546. The purpose of the test was to determine soil's swelling potential. The calculations revealed a swelling value of 6.3%. A decrease in swelling percentage was calculated when lime was used to replace soil partially. Relationship between swelling percentage & lime percentage. Data reveals decrease in swelling % from 6.3% to 1.5% as lime % increases. Study displays test results for all half-replaceable mixtures on black cotton soil, which were used to calculate soil's swelling potential.

Moisture-Density Relationship
A compaction test was conducted using a modified force. The test results indicated a maximum dry density (MDD) of 18.8 KN/m3 and optimum moisture content (OMC) of 14.00 percent. We followed the ASTM D1557-12 standard to conduct compaction tests. Figure displays the curves depicting the relationship between moisture density and percentage increase in silica fume. The corresponding test results can be found in Table 4.9. Based on moisture density ratio results, it was estimated that there was a consistent decrease and increase in MDD value after partially replacing the admixtures. The MDD value decreases from 18.80 KN/m3 to 18.10 KN/m3, while the OMC value increases from 14.00% to 19.4% when silica fume is used as a replacement in the OMC. The study displays the dry density and optimum moisture values corresponding to each Percentage of the silica fume added to the sample.

Figure I Curves Depicting the Relationship

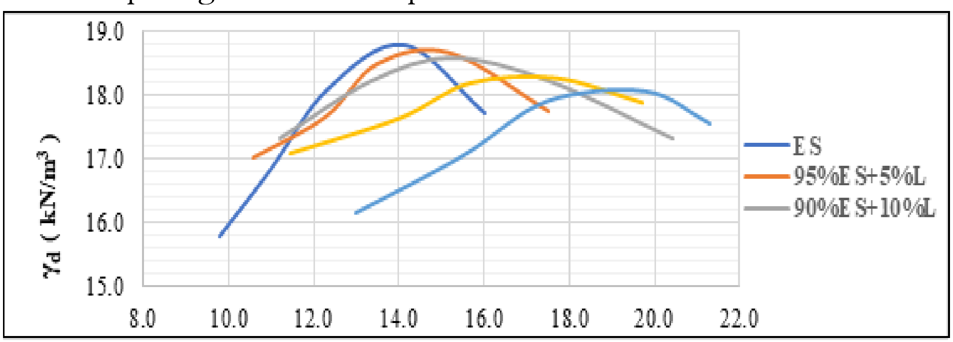

Table 4 Model-III

Samples	Maximum Dry Density (kN/m3)	Optimum Moisture Content (%)
Pure Soil	18.8	14.0
Combination 1	18.7	14.6
Combination 2	18.6	15.2
Combination 3	18.3	17.0
Combination 4	18.1	19.2

Specific Gravity
Determining the specific gravity of a specific soil type plays a key role in estimating its void ratio. The Gs value is also closely related to subsidence parameters and hydrometric analysis. Therefore, the specific gravity was carefully measured according to ASTM 854-10 (in a 100 ml pycnometer with a vacuum pump). In this connection, the specific weight of natural clay soil is 5%, 10%, 15% and 20% lime.

CONCLUSION
Based on the comprehensive research findings that have been thoroughly discussed and analyzed in the literature review, as well as the specific details of test results. There were four distinct dosages available for pozzolanic substance. Optimizing these doses was crucial in order to confirm desired impact of these concentrations on the soil engineering properties of interest, including Gs, UCS, and

swelling potential which may reduce cost of the project and enhance the quality of the project. A comprehensive investigation was conducted afterwards to analyze index characteristics of treated soil. This investigation included examining parameters like Gs (specific gravity), UCS (unconfined compressive strength) and expansion potential. Conclusions are derived from findings. The Nandipur region has soil with a high clay content, which increases the likelihood of soil swelling. However, we observed that when we partially replaced admixtures, there was a fluctuation in the number of clay particles present in soil. Based on our findings, we have concluded that the quantity of clay particles fluctuates, both decreasing and increasing. Discovery of silt-sized particles provides an additional explanation for decrease in soil expansion potential caused by reduction in clay-sized particles. The presence of lime results in reduction of the Atterberg limits, which encompass liquid limit, plastic limit, and plasticity index.

The percentage for LL decreased from 56.40% to 48.76%. The replacement procedure affects the specific gravity of the natural soil by reducing it. The soil classification results indicate that there has been a change in soil classification from CH to ML (USCS) and from A-7-6 to A-7-5 (AASHTO) as a result of adding lime proportion. During process of partial replacement, maximal dry density decreases and optimal moisture content increases by up to 10% when lime is used as a replacement material. A comprehensive investigation was conducted afterwards to analyze index characteristics of treated soil. The conclusion that can be drawn from all of the examples is as follows: Based on the results of unconfined compressive strength (UCS) test, it was observed that lime-mixed soil achieves its highest value when UCS is increased by 15% and the replacement is set at 10%. The addition of lime to soil has dual effect of reducing the swelling value and increasing value of silt-sized particles. The swelling decreased by significant 92.06 percent. In concluding remarks, study expressed that by managing the material and establishing different combinations we may improve quality of project and it affects the cost.

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