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Effect of Geotextile on Lime Stabilized Lateritic Soils under Unsoaked Condition

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Statement of Compliance with Ethical Standards

This research paper adheres to the highest ethical standards in conducting and reporting the study. The following statement outlines compliance with ethical considerations:

1. Informed Consent: All participants involved in the study provided informed consent before their inclusion in the research. The purpose, procedures, and potential risks and benefits of the study were clearly explained, and participants had the freedom to withdraw their participation at any time.
2. Animal Subjects: No animal subjects were involved in this research study.
3. Human Subject: No human subjects were involved in this research study.
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5. Conflict of Interest: The authors declare that there are no conflicts of interest that could influence the objectivity or integrity of the research. Any potential conflicts of interest, financial or otherwise, have been fully disclosed.
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The author is committed to upholding ethical practices in research and ensuring the integrity and validity of the findings presented in this paper.

ABSTRACT

In this study, the basic engineering and geotechnical qualities of poor subgrade soils were evaluated. Woven geotextile was used to stabilize the soil and to address the lime problem, enhancing its strength and mechanical properties. This is considered of significant importance in civil engineering works. Subgrade soils, its properties like plasticity and strength are essential to the design of pavement structures and any road construction. Experiments were conducted to investigate the application of geotextile on lime stabilized lateritic soils under unsoaked conditions. Geotechnical experiments were conducted to determine Grain size analysis, Atterberg, compaction and California bearing ratio test. CBR tests were done by placing the geotextile at varying depths under unsoaked conditions to determine the soil's bearing capacity. The result shows that the strength of lateritic soil is visibly increased by introducing geotextiles at different layers in the soil. It is found that geotextile placed at one-half the distance from the base showed higher CBR

value by comparison with layers one-fourth and 1/4&3/4 distances from the base. The strength of the laterites was improved to thereabout 50% of its original strength without any stabilizer. Geotextile requires minimal maintenance, corrosion resistance, no threat to human health and increases the service life of road pavement. Geotextiles should be considered when dealing with the problems with lime and as a modernized form of improving road construction on poor laterites.
Keywords: Soil Stabilization, Geotextile, Lime, Laterite, Road Construction, Civil Engineering, California Bearing Ratio (CBR).

1. INTRODUCTION

Soft soils pose significant challenges in construction projects, as their low bearing capacity and high compressibility can lead to excessive settlement and instability [1]. The kind of soil, the amount of water in it, and the degree of compaction all have an impact on their strength. To overcome these issues, various soil improvement techniques have been explored. Implementing soil enhancement techniques may increase bearing capacity, minimize settlement, and ultimately lower the thickness of surface layers while improving performance [2]. To improve the overall performance of soils, a variety of ground improvement techniques are used in infrastructure projects like highways, railways, airports, and embankments. These techniques include vertical drains, complete soil replacement, grouting, geosynthetic reinforcement, and lime stabilization [3].

The use of Quick lime (CaO) or Hydrated lime ($Ca(OH)_2$) as agents for soil improvement has recorded tremendous success, especially with specific clay soils. For example, clays with more silica have been reported to be more reactive with lime addition [4]. The mechanism of lime stabilization usually takes place in a series of processes starting with the exchange of ions between water, clay, and lime minerals. The exchange of ions is dependent on factors such as soil pH and clay mineralogy. Thereafter, flocculation, carbonation, and some pozzolanic reactions take place lasting for a few days. At this stage, the plasticity of the soils is typically altered. The long-term reaction usually takes about 2years [5]. Lime treatment is often accompanied by a reduction in the liquid limit (LL) and an increase in the plastic limit (PL) [6]. Nonetheless, several researchers have given other opinions on the relationship between clay, water, and these atterberg limits. For example, the increase in LL has been reported to be due to the reduction in the thickness of the diffuse double layer and the effect of water and hydroxyl ions on the clay surfaces [7]. Bell [8] reported that the plastic limit increase was more for soils with montmorillonite minerals. Nonetheless, the effect of lime on the engineering properties of soils is dependent on the amount of lime quality and quantity, temperature, moisture, and power of hydrogen (pH). The addition of lime is typically associated with an increase in Ph of up to 12.4 which causes the dissolution of silica and alumina minerals [9].

The UCS and CBR are common tests for assessing the strength of lime-stabilized soils. In general, the addition of lime to clay soils leads to significant improvements in strength by promoting the development of pozzolanic products that exhibit a cementitious effect on soil particles [10, 11]. According to Thompson et al. [12], the unconfined compressive strength (UCS) of lime-treated clays can increase by approximately 60% after 28 days of curing, attributed to pozzolanic reactions. Soils with a high clay fraction require a higher lime dosage to achieve strength gain compared to soils with a lower clay content, as the latter requires less lime for plasticity improvement and has more lime available for pozzolanic reactions [7]. The relationship between strength and lime content does not exhibit continuous improvement. Instead, beyond an optimal lime content, strength tends to decrease [13]. This decline can be attributed to the excessive presence of Ca^{2+} ions, which causes deflocculation and the separation of clay particles, resulting in the formation of cracks even under low loads. Consequently, this leads to a reduction in the unconfined compressive strength (UCS) value of soils [14]. Observable compressibility behavior of soils after lime addition also indicates significant effect on performance. The influence of pozzolanic reactions on the reduction in compressibility seen in lime-treated soil is largely related to short-term reactions [15]. When compaction is conducted on the drier side of the optimum moisture content, the compressibility of lime soil is decreased. The durability considerations of soils have also been assessed by several authors [16, 17]. Notably, lime-stabilized soils have increased fatigue strength and have the potential to reduce frost penetration [18].

Geotextile has gained significant popularity as a soil improvement method due to its advantages of cost-effectiveness, ease of application, and swift construction. The high-strength geotextile can prevent plastic deformation in the

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underlying foundation soil, raise the collapsed height of the embankment on soft ground, and provide a two-step failure mechanism when used to strengthen embankments on soft grounds [19]. When compared to other geotextile options, the woven material is designed with a higher tensile strength that can support heavier loads and increased weight [20]. This has made geotextiles more reliable for any application, in handling strength, aggregate separation or large stabilization requirements.

The behavior of construction materials has been investigated scientifically from prehistoric times, understandings has significantly improved there have advances and theoretical treatment has become more realistic and précised. It is no gainsaying that many of the tasks of civil engineers require taking prompt decisions and exercising judgment. It is also evident that this may relate well to the choice of materials or to the selection of the appropriate numerical expression of their properties. The endeavor must always achieve the highest level of competence, and this implies that the decision and selection must be made based on the best available information. Moreover, it is evident that soil is the basis of all civil engineering construction works. It could therefore be used alone or with other construction materials to improve its properties or cater for its deficiency, and it depends on whatever construction is intended. Lime as a stabilizer may pose some health threat to humans; the amount of lime to consider in treating soils is also limited to about 2-10 percent which may not be enough to stabilize extremely poor lateritic soils [10]. There is therefore the need to look for a way to deal with the problem of lime stabilization for effective road construction. While a previous study [21] on soaked conditions has been completed, the objective of this paper is to investigate the application of geotextile on lime stabilized lateritic soils under unsoaked conditions.

The findings of this study would be useful for immediate use in many civil engineering applications, especially those involving soil improvement, road construction in extreme regions, and applications involving challenges with unsatisfactory properties of lime stabilized soils. Additionally, the findings in this paper will be useful in improving the body of knowledge involving areas of soil improvement, material science in construction, and material standardization. It will also benefit policy makers and designers to explore options when dealing with complex civil engineering projects.

2. MATERIALS AND METHOD

Three sets of samples were used in this study and collected at three separate locations in Ogbomosho. To preserve their natural state, they were stored in polythene bags. Two of the samples were collected at pakiotan and one at a place close to the sawmill area labeled, samples A, B, and C, respectively. Each laterite sample was stabilized with 4%, 5%, and 6% lime, respectively. Geotextiles were then applied at three different layers for each sample at layers 2, 3, and 1&3, respectively. Compaction and corresponding CBR results were determined.

Samples were air-dried and subjected to a comprehensive laboratory program to establish the classification, compaction strength, California Bearing Ratio (CBR) test (See **Fig. 1b**), and unconfined compressive strength test to characterize the engineering properties of the soil. Grain size distribution, Atterberg limits, British standard, and West African standard compaction as well as CBR tests were conducted on the representative samples.

a)

b)

Fig. 1. a) Oven for drying samples b) CBR testing machine

3. Results and Discussion
4.

The result of the laboratory tests (grain size analysis, compaction, and Atterberg's limit) and the engineering property test (compaction, California bearing ratio (CBR)) are presented in the tables and figures below.

3.1 Grain size analysis

Grain size analysis or gradation test was a procedure used in the experiment to assess the particle size distribution of samples A, B, and C of a granular material (See **Fig. 2.).** Sieve analysis of samples using sieve sizes of 20mm (about 0.79 in), 8mm (about 0.31 in), 4mm (about 0.16 in), 2mm (about 0.08 in), 1mm (about 0.04 in), 710µm, 425µm, 355µm, 250µm, 125µm, 75µm was used to determine the particle size distribution of the samples. The particle passing for sample A was 100%, 94.52%, 77.62%, 65.58%, 55.70%, 50.26%, 31.44%, 27.48%, 21.40%, 12.68%, 10.06% respectively which indicates that soil Sample A has a lower clay content of intermediate moderately graded soil sample. The soil sample contains about 34.42% gravel and 65.58% sand which shows a predominantly sand with some percentage soils unaccounted for of finer silt content passing through the 75µmicrons.

Sample B gives 100%, 96.2%, 83.68%, 69.52%, 61.50%, 55.08%, 38.78%, 35.74%, 31.30%, 24.38%, 21.64%, respectively which further shows that soil Sample A has a lower clay content of intermediate moderately graded soil sample, the soil sample contains about 34.42% gravel and 65.58% sand which shows a predominantly sand with some percentage soils unaccounted for of finer silt content passing through the 75µmicrons. The result shows that sample B has more clay content than sample A by comparison. Sample C using the same set of sieves gave results of, 100%, 96.76%, 91.76%, 83.56%, 75.52%, 70.94%, 56.56%, 54.20%, 50.80%, 46.02%, 44.32% respectively which further shows that soil Sample A has a lower clay content of intermediate moderately graded soil sample, The soil sample contains about 34.42% gravel and 65.58% sand which shows a predominantly sand with some percentage soils unaccounted for of finer silt content passing through the 75µmicrons. The result shows that sample C has more clay content than sample A and B by comparison.

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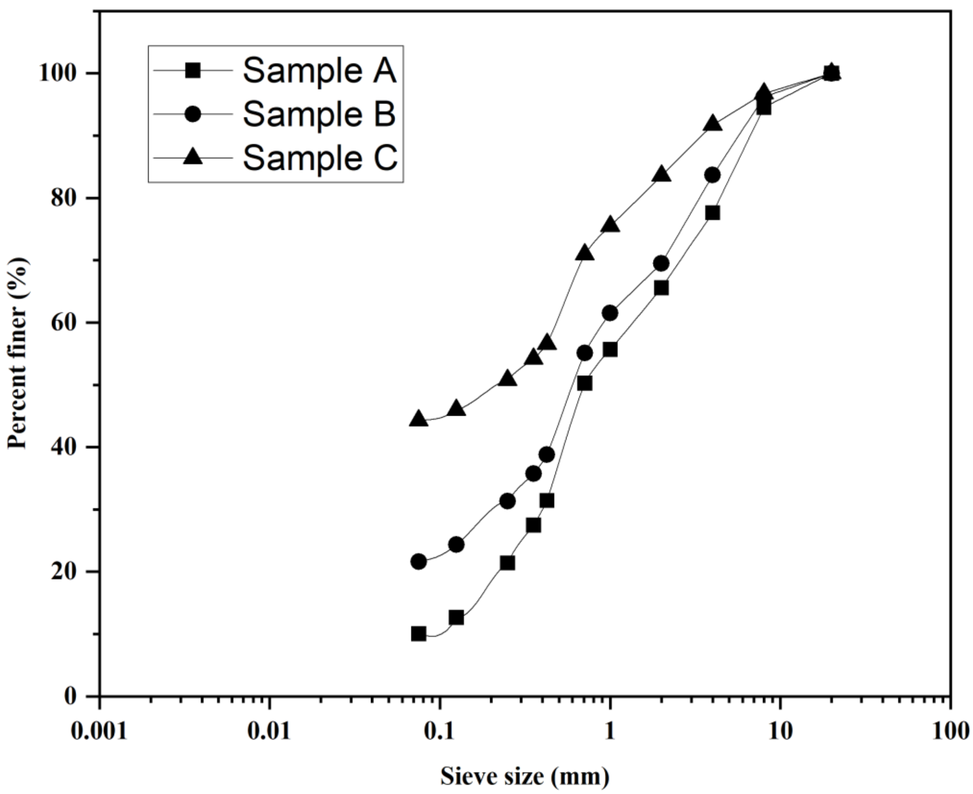

Fig. 2. Sieve analysis of soil of samples

The grain size analysis of the soil samples gives useful information about the particle size distribution of the soils. It is important to note that the proportion of sand, silt, clay present in the soil samples have a direct effect on the engineering properties of each soil sample. The high proportion of sand in the samples indicates that the samples are predominantly coarse-grained, which can have significant impact on the soils' permeability and compressibility.

3.2 Atterberg limit test

120 grammes (about 4.23 oz) of soil sample was soaked (moisturized) for 24 hours and four trials of dry to wet or vice-versa Atterberg limits were conducted to establish the soil's liquidity. Four trials were done on each sample for control and lime at 4, 5, and 6 percent of the soil mass. The soils' plastic limits were also determined; this was done by rolling the samples until it breaks at some point and the mass of the samples was determined. The range of plasticity (i.e., the plasticity index) is determined by subtracting the values for the plastic limits from the values of the liquid limits. The average liquid limit was determined at the value of the liquid limit at the twenty-five blows on the moisture content as presented in the graphs below.

Table 1. Atterberg Limits for Sample A

Soil	LL%	PL%	PI%
Control	23	9.5	13.5
Sample A + 4% Lime	12	10.1	1.9
Sample A +5% Lime	20.8	18.2	2.6
Sample A +6% Lime	21.5	12.9	8.6

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Table 1 provides insights into the effects of lime additions on the soil's plasticity characteristics. The control mix exhibited a relatively high liquid limit (LL%) of 23%, indicating a high degree of plasticity and potential liquidity. The addition of 4% lime resulted in a decrease in the liquid limit to 12%, indicating a reduction in the soil's plasticity. This suggests that lime can effectively decrease the water-holding capacity of clay minerals, resulting in less plastic soil.

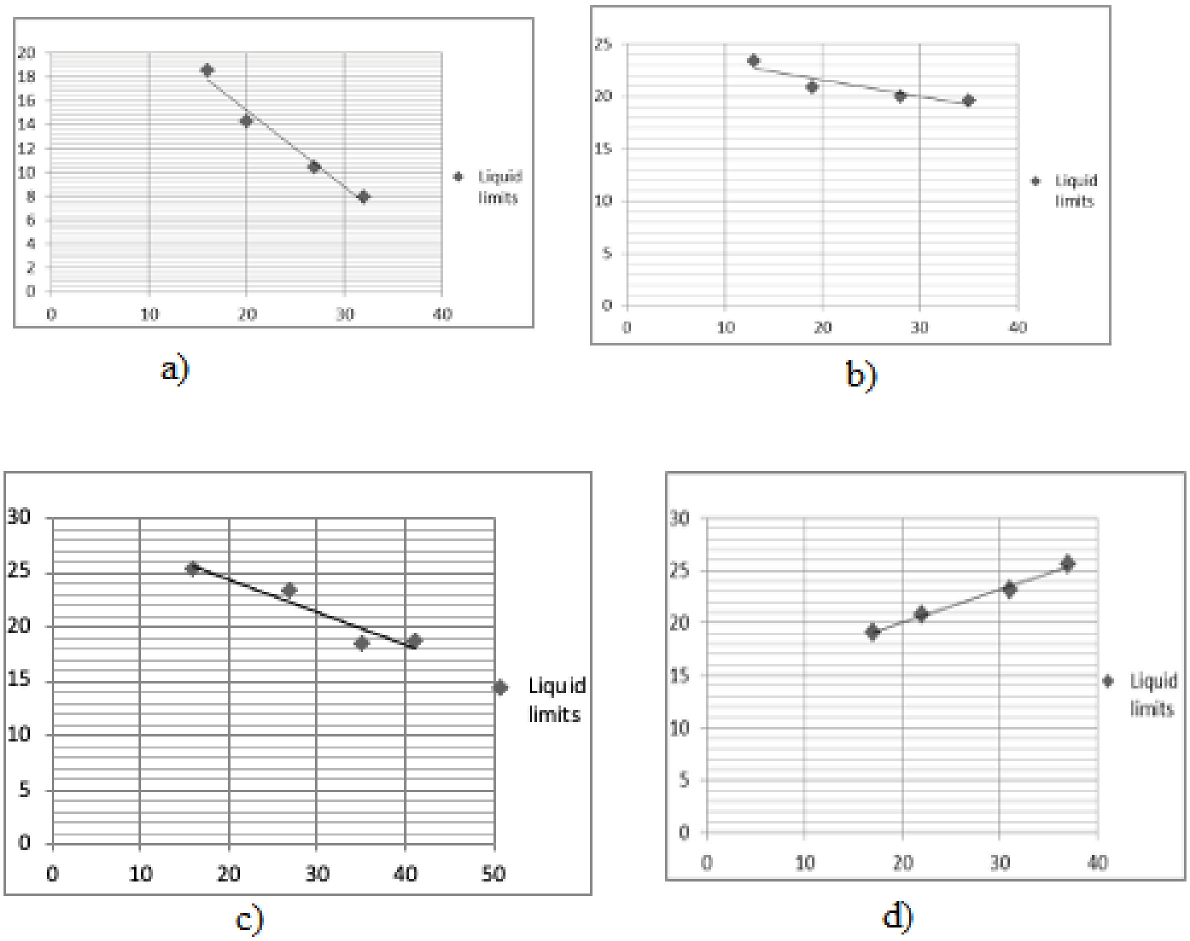

Fig. 3. Atterberg limit for a) control sample A b) Sample A + 4% Lime c) Sample A + 5% Lime d) Sample A + 6% Lime

However, the plastic limit (PL%) remained unchanged at 10.1%, indicating that the addition of lime did not significantly affect the soil's plastic behavior. The plasticity index (PI%) decreased to 1.9%, indicating a narrower moisture range for workability. Conversely, the addition of 5% lime led to an increase in both the liquid limit (20.8%) and plastic limit (18.2%). This suggests that lime can enhance the water-holding capacity of clay minerals, increasing the soil's plasticity and moldability. The slight increase in the plasticity index (2.6%) indicates a small expansion in the range of moisture content for plastic behavior. Lastly, the addition of 6% lime resulted in a high liquid limit (21.5%) and an increased plastic limit (12.9%). The significantly higher plasticity index (8.6%) indicates an expanded moisture range for workability, highlighting the challenges in managing soil moisture content when using higher lime percentages. The plot is indicated in Fig 3.

Table 2 presents the results of different soil mixes with varying percentages of lime additions, focusing on the Liquid Limit (LL%), Plastic Limit (PL%), and Plasticity Index (PI%). The control mix has an initial LL% of 20, indicating moderate plasticity. The PL% is 10.8, suggesting a relatively low plastic limit and indicating the soil's ability to be

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molded without excessive cracking. The resulting PI% is 9.2, representing the range of moisture content within which the soil remains plastic.

Table 2. Atterberg Limits for Sample B

Soil Type	LL%	PL%	PI%
Control	20	10.8	9.2
Sample B + 4% Lime	30	25	5
Sample B +5% Lime	20	17.5	2.5
Sample B +6% Lime	29	22.5	6.5

With the addition of 4% lime, the LL% significantly increases to 30, indicating a higher degree of plasticity. The PL% also increases to 25, suggesting an increase in the soil's plastic limit. As a result, the PI% rises to 5, reflecting a broader range of moisture content over which the soil remains plastic. These changes indicate that the addition of 4% lime has led to a more plastic and moldable soil compared to the control mix. In the case of 5% lime addition, the LL% returns to the initial value of 20, indicating a similar level of plasticity as the control mix. However, the PL% is slightly higher at 17.5, implying an increased plastic limit. The resulting PI% is 2.5, indicating a narrower range of moisture content for plastic behavior compared to the control mix. These results suggest that the addition of 5% lime has minimal influence on the plasticity characteristics of the soil. With a 6% lime addition, the LL% increases to 29, indicating a higher degree of plasticity compared to the control mix. The PL% was also observed to have increased to 22.5, indicating a higher plastic limit. As a result, the PI% rises to 6.5, indicating a wider range of moisture content within which the soil remains plastic. A reasonable explanation is that the addition of 6% lime has led to a more plastic and workable soil compared to the control mix, similar to the effect observed with 4% lime addition. The plot is shown in **Fig 4.**

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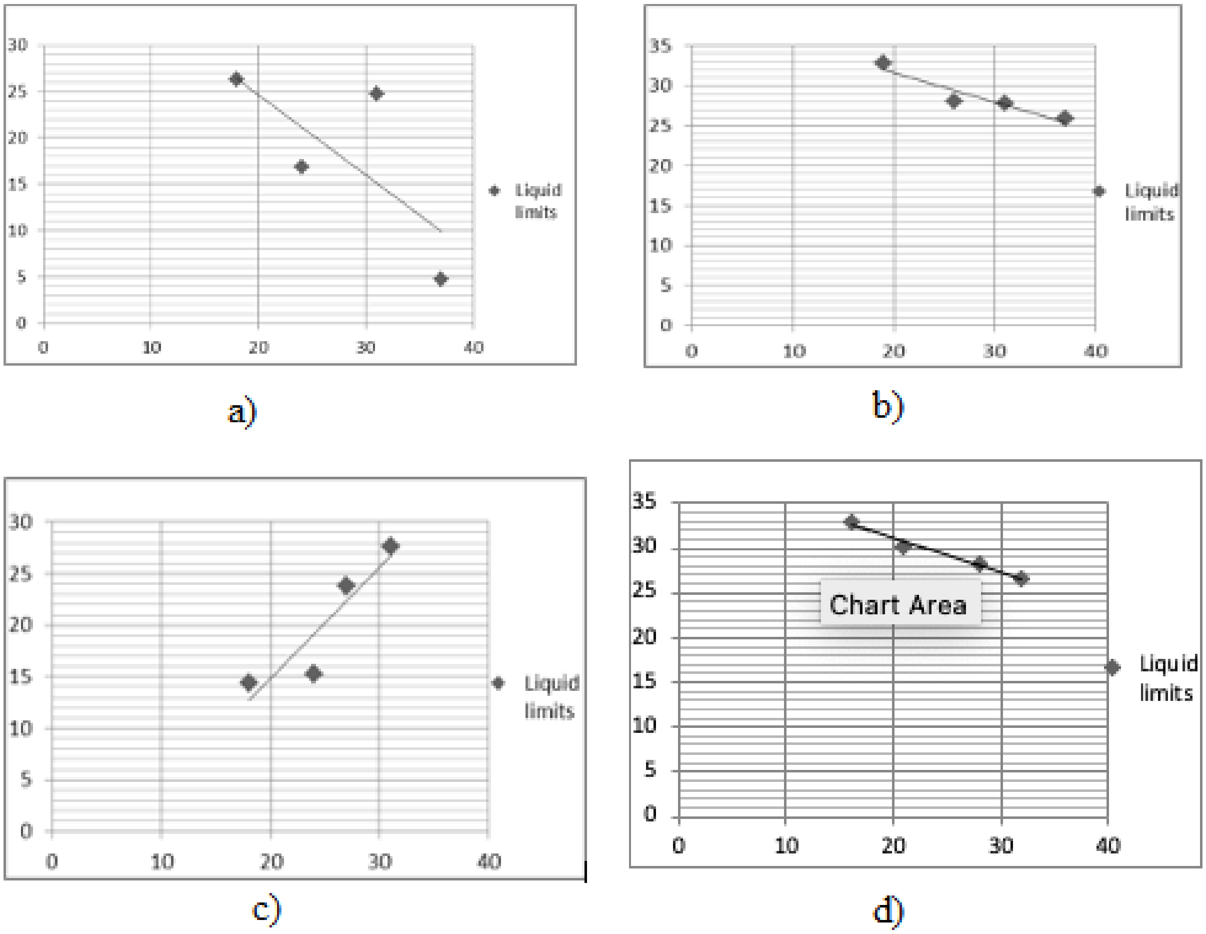

Fig. 4. Atterberg limit for a) control sample B b) Sample B + 4% Lime c) Sample B + 5% Lime d) Sample B + 6% Lime

Starting with the control mix, it exhibited a high LL% of 49, indicating a significant level of plasticity and potential for liquidity. The PL% was relatively low at 10.4, suggesting a threshold moisture content at which the soil begins to exhibit plastic behavior. As a result, the PI% was relatively high at 38.6, indicating a wide moisture range over which the soil remains in a plastic state (See **Table 3**).

Table 3. Atterberg Limits for Sample C

Soil Type	LL%	PL%	PI%
Control	49	10.4	38.6
Sample C + 4% Lime	45	35	10
Sample C +5% Lime	48.4	14.6	33.8
Sample C +6% Lime	52	22.65	29.35

Upon the addition of 4% lime, there was a slight decrease in the LL% to 45, indicating a minor reduction in plasticity. Meanwhile, the PL% increased to 35, suggesting an expanded range of moisture content at which the soil exhibits plastic behavior. Consequently, the PI% increased to 10, signifying a broader but relatively lower moisture range for plasticity compared to the control mix. When 5% lime was added, the LL% slightly decreased to 48.4, indicating a

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subtle reduction in plasticity compared to the control mix. The PL% increased to 14.6, suggesting an expanded plastic limit. Consequently, the PI% decreased to 33.8, indicating a narrower moisture range within which the soil remains in a plastic state. Lastly, with the addition of 6% lime, there was an increase in the LL% to 52, indicating an enhancement in the soil's plasticity compared to the control mix. The PL% also increased to 22.65, pointing to a higher plastic limit. Consequently, the PI% decreased to 29.35, indicating a narrower moisture range for plastic behavior compared to the control mix (See **Fig. 5.)**

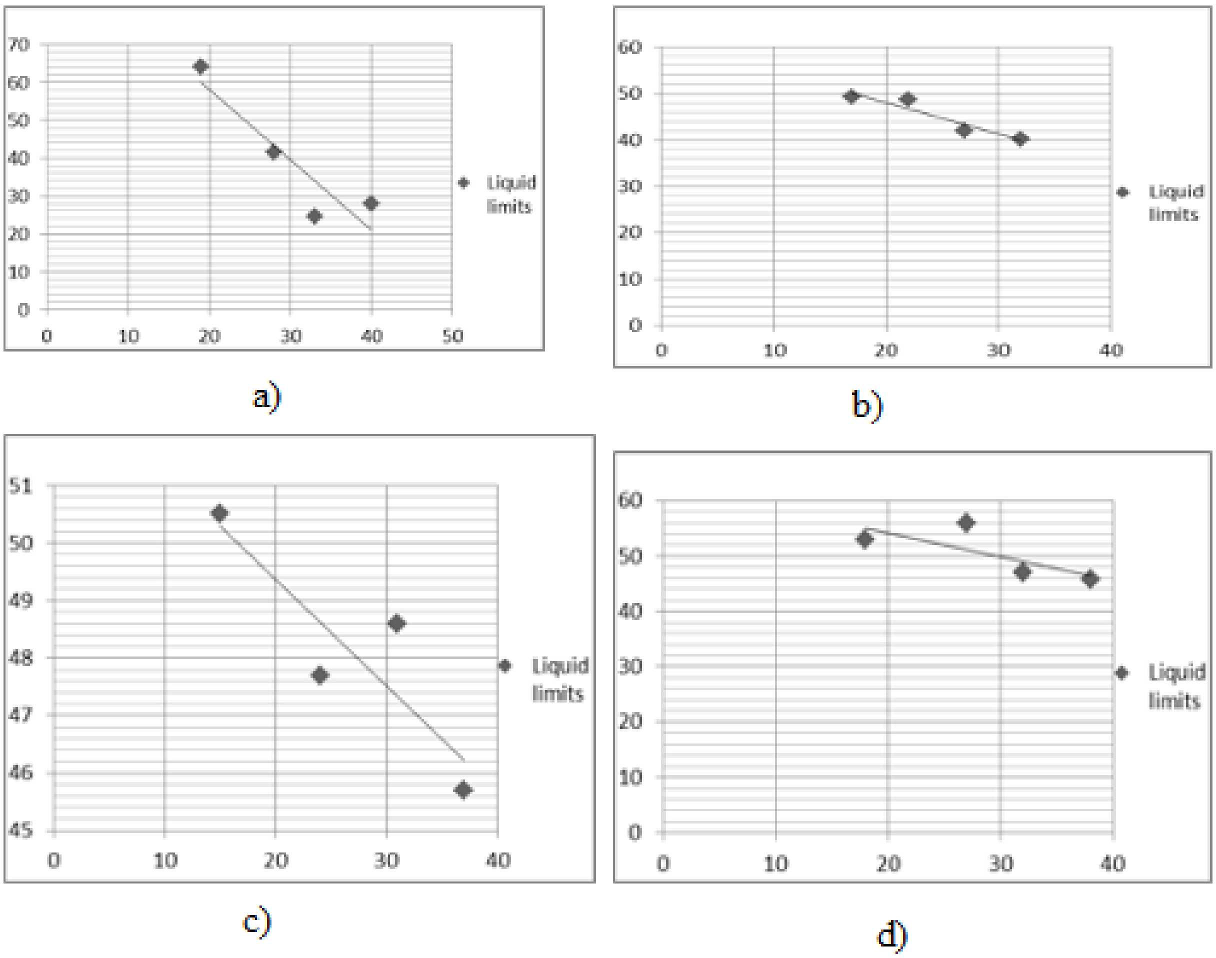

Fig. 5. Atterberg limit for a) control sample C b) Sample C + 4% Lime c) Sample C + 5% Lime d) Sample C + 6% Lime.

The findings reveal that the impact of lime on the plasticity of the soil samples is dependent on the amount of lime added. The result shows that different soil samples exhibit different plasticity properties. In sample A, the optimal lime replacement for reducing plasticity appears to be 4% and 5%, as 6% lime replacement led to increased plasticity. However, in samples B and C, 4% lime appears to be the optimal amount in reducing the plasticity of the soil. In addition, from the results of the Atterberg limits, it was found that the lime-stabilized samples exhibit different plasticity from the samples without lime. It is also noteworthy that the addition of lime to soil samples can either increase or reduce plasticity, which may have effects on major engineering characteristics of different soil samples including permeability, strength, and compaction properties.

3.3 Dynamic compaction

The West African Standard and the British standard compaction molds were used with 27 blows at each layer. The result for the control values was obtained as well as for the addition of 4, 5, and 6 percent lime to the bulk mass of soil samples. The optimum moisture contents (OMC) and maximum dry densities (MDD) were obtained for each specimen

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tested. The addition of lime to each sample gave a corresponding increase in the dry density of the soil as moisture content increased before reaching its optimum moisture content.

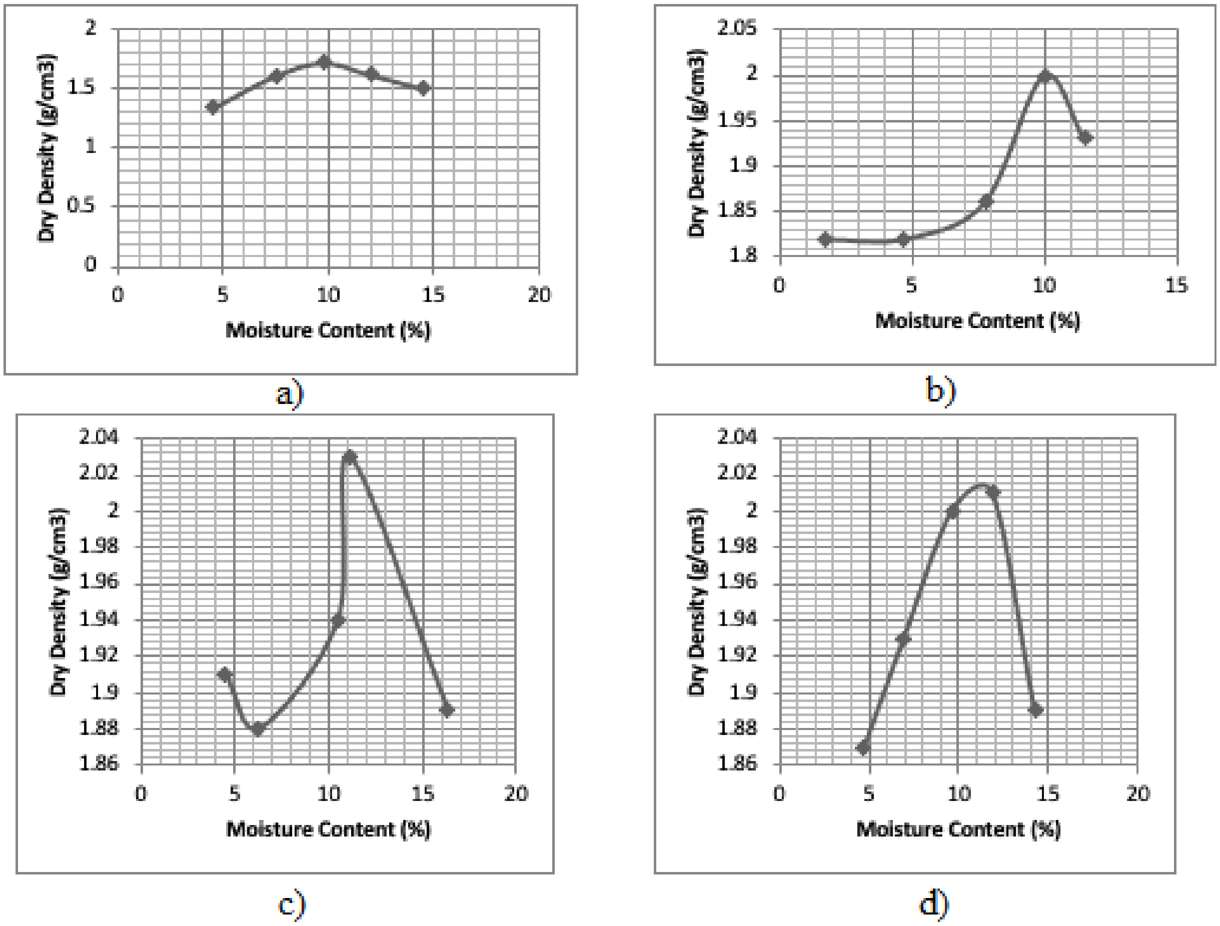

Fig. 6. Sample A compaction curve for a) 0% Lime b) 4% lime c) 5% lime d) for 6% lime.

Fig. 6. demonstrates the compaction curve for sample A at different lime additions. It was observed that the introduction of lime at various percentages resulted in increased dry densities compared to the soil sample with 0% lime. Notably, the samples with 4%, 5%, and 6% lime additions consistently show higher dry densities than the 0% lime sample. This improvement in dry density indicates that the incorporation of lime has enhanced the compaction and packing of soil particles. It is important to note that the highest dry density was achieved in the sample with 5% lime addition, reaching 2.03 g/cm^3. This suggests that 5% lime may have been the optimum lime content for improving dry density in this specific soil sample. In addition, the moisture content varies with different lime additions. Interestingly, the moisture content in the soil sample with 4% lime shows a noticeable decrease compared to the 0% lime sample, indicating that the lime addition has a drying effect on the soil. However, the samples with 5% and 6% lime additions exhibit varying moisture content values. The 5% lime sample shows an initial decrease, but the moisture content increases at later measurements, while the 6% lime sample follows a similar pattern.

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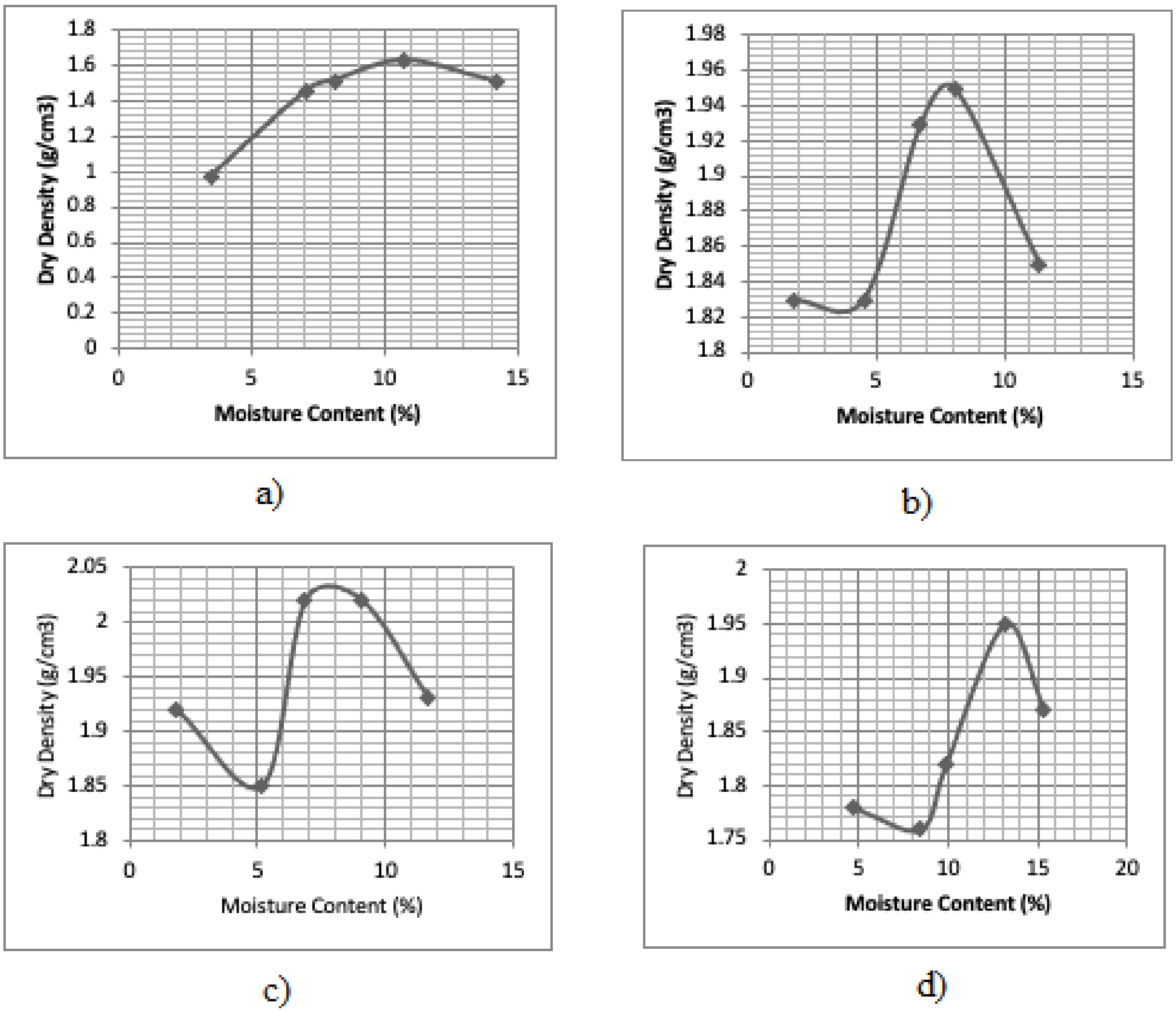

Fig. 7. Sample B Graph of DD against MC for a) 0% Lime b) 4% lime c) 5% lime d) for 6% lime

The influence of lime addition on sample B is shown in **Fig. 7.** Similarly, the incorporation of lime had a notable impact on the soil's dry densities. All samples had an initial decrease in dry densities. Remarkably, the sample with a 5% lime addition demonstrated the highest dry densities, suggesting that this particular lime percentage was optimal for achieving maximum compaction and stability. The data revealed varying trends in moisture content with different lime additions. The sample with 4% lime consistently displayed reduced moisture content compared to the 0% lime sample, indicating the lime's desiccating effect on the soil. However, the samples treated with 5% and 6% lime exhibited fluctuating moisture content values, showing no clear optimal moisture level for these lime percentages in soil sample B. It is essential to carefully consider the effect of lime on moisture content, as excessive drying or wetting could negatively impact the soil's engineering behavior. Surprisingly, the OMC for 6% lime was 13.15% which was higher than other lime additions.

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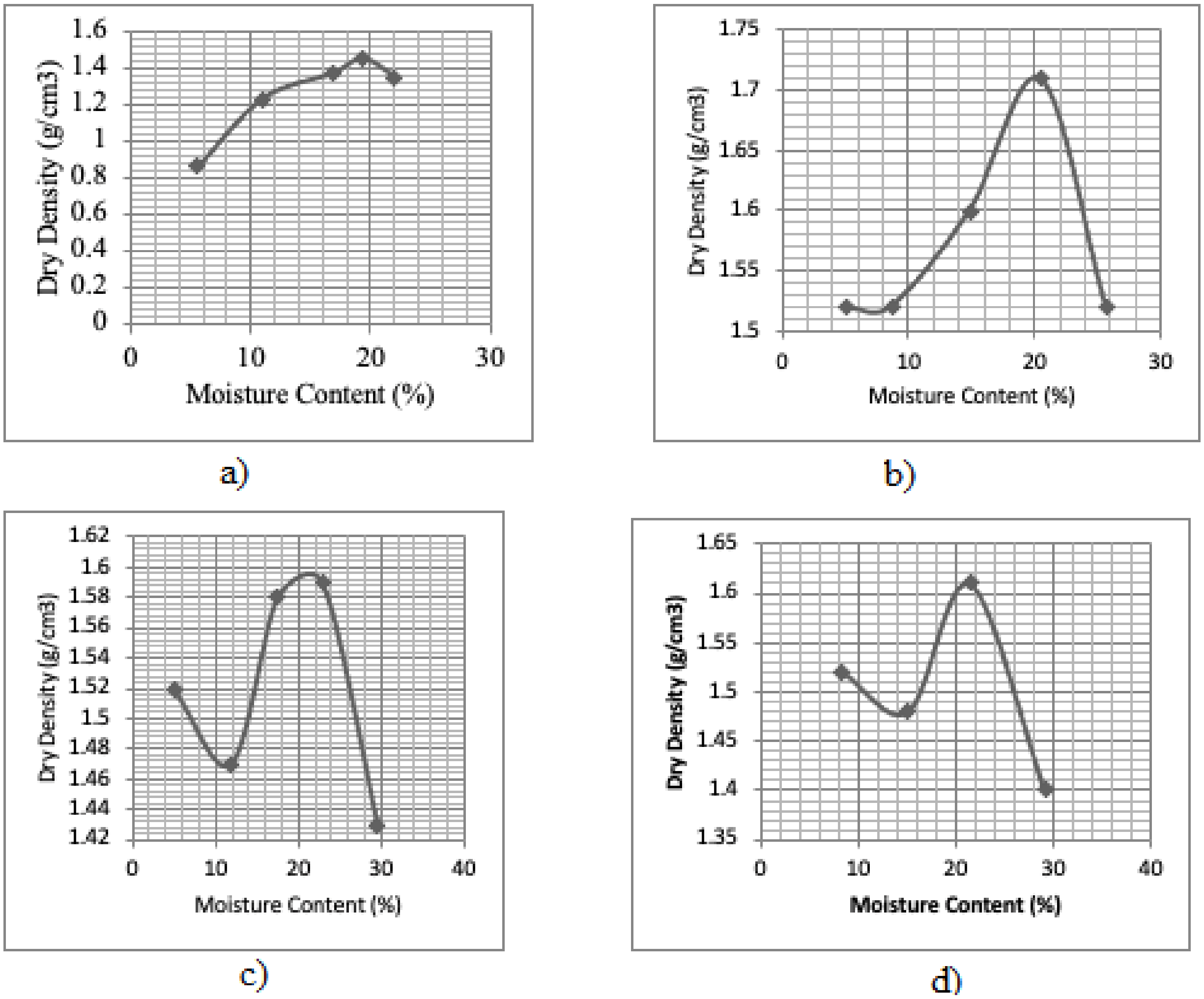

Fig. 8. Sample C Graph of DD against MC for a) 0% Lime b) 4% lime c) 5% lime d) for 6% lime.

The compaction curves for sample C at different lime additions are given in **Fig. 8.** In comparison to samples A and B with different lime additions, the OMC for sample C (with different lime additions) was about 20%, which was significantly higher. Samples with 5% and 6% also showed fluctuations in dry densities. The sample with 4% lime exhibited relatively consistent moisture content values across the measurements, indicating a stable moisture condition for this lime percentage.

The results from the dynamic compaction signify the importance of understanding the optimum moisture content (OMC) and maximum dry densities (MDD) of lime-stabilized soils. The MDD explains the maximum dry density that a soil can reach at a particular moisture content, while the OMC explains the amount of water/moisture required for a soil sample to reach its highest dry density during soil compaction. It is very crucial to understand the compaction characteristics and requirements of lime-stabilized soils, when trying to improve the soil's engineering properties. Doing compaction rightly would increase the load bearing capacity of soils and reduce the possibility of differential settlements during the service life of engineering structures. It is vital to achieve the optimal moisture content in lime-stabilization projects, as operating below or above the OMC can affect the durability and longevity of lime-stabilized structures.

4.4 Static compaction

The result from each dynamic compaction test (i.e., OMC and MDD) is used to calculate the constant mass of soil that is used in re-compaction with a constant volume of water (i.e., static compaction) and given in **Table 4**. For

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example, with a 4% addition of lime, 4% will be removed from the mass of bulk sand and replaced with lime, and then recompacted. This was also applicable to 5%, and 6% lime additions for all samples.

Table 4 Static Compaction Values.

Sample	Lime Addition	Mass of Bulk Soil for Recompaction (Mb)	Volume of Water (Wv)
A	0%	3925g (8.65 lb.)	360ml (12.17 oz)
A	4%	4564g (10.06 lb.)	426ml (14.4 oz)
A	5%	4655g (10.26 lb.)	514ml (17.38 oz)
A	6%	4632.0g (10.21 lb.)	532ml (17.99 oz)
B	0%	3736g (8.24 lb.)	361ml (12.21 oz)
B	4%	4470g (9.85 lb.)	312ml (10.55 oz)
B	5%	4584g (10.11 lb.)	294ml (9.94 oz)
B	6%	4470g (9.85 lb.)	551ml (18.63 oz)
C	0%	3353.0g (7.39 lb.)	577ml (19.51 oz)
C	4%	3816g (8.41 lb.)	657ml (22.22 oz)
C	5%	3746g (8.26 lb.)	689ml (23.3 oz)
C	6%	3699.7g (8.16 lb.)	734.9ml (24.85 oz)

It can be noted that the mass of the bulk soil for re-compaction increases as the lime addition increases. This suggests that the adding lime leads to an increase in the soil's overall weight. However, the exact values vary depending on the sample. Also, the volume of water used for the bulk soil also shows variations with different lime additions. In some cases, the volume of water decreases as lime is added, while in other cases, it increases. This indicates that the amount of water required for compaction can be influenced by the lime content in the soil.

The results from the static compaction give insight into the understanding of the relationship between the moisture content and the mass of soil in lime-stabilized soils. It can be noted that the addition of lime to soil samples would significantly increase the overall weight of the soil and as a result, affect the strength and overall density of the soil. The variation in water demand in the soil samples was also noted. In some cases, upon addition of lime, there was increased water volume demand, while there was decrease in some cases. A reasonable explanation of this can be traced to the cementitious and pozzolanic properties of lime, which may make the soil require less water for compaction. Where increased water demand was noticed, it may be traced to some chemical reactions occurring between the soil constituents and lime. Whichever the case, it would have a resulting implication on the bearing capacity and density of the lime-stabilized soil. Increased soil mass would indicate that the soil has more solid constituents, leading to higher soil density. Furthermore, reduced volume of water could indicate better compaction attribute and consequently improved soil strength.

3.5 California Bearing Ratio (CBR) (Unsoaked)

From the static compaction result, re-compaction of each percentage addition of lime to the lateritic soil sample was done. In the present study, the investigation focused on the influence of geotextile on lime-stabilized lateritic soil samples under unsoaked conditions. To assess the effects, a series of re-compaction tests were conducted on the lateritic soil samples after static compaction, wherein various percentages (4%, 5%, and 6%) lime were used to replace the soil samples.

The subsequent re-compaction process involved the strategic placement of geotextile at three different layers within each lime-treated sample. More precisely, these layers were identified as Layer 2, Layer 3, and Layer 1&3. To illustrate this further, Layer 2 refers to the division of the mould into four equal parts, with the geotextile being positioned at the midpoint of the mould. As for Layer 3, the geotextile was introduced after the initial layer of the soil sample had been placed in the mould. The term "Layer 1&3" signifies the application of geotextile at both the one-quarter point and the three-quarter point measured from the base of the mould.

This approach aimed to systematically examine the effect of geotextile placement at different locations within the lime-stabilized lateritic soil samples. By employing this experimental design, the study sought to gain valuable insights into the geotextile's potential in enhancing the stability and strength characteristics of the lime-stabilized soils.

The recompacted sample obtained was placed in the CBR machine. Sample A gave the highest strength at 4% lime and at geotextile placed at the third layer while samples B and C recorded the maximum strength at the second layer and at geotextile placed at layer 3.

Upon replacing the soil sample with 4% lime, Sample A gave a CBR value of 39%, sample B gave a the highest CBR value of 62%, while sample C gave a CBR value of less than 5% as shown in **Fig. 9.** The CBR values when the soil samples were replaced with 5% lime are 15% for sample A, 72% for sample B, and less than 5% for sample C (**Fig. 9.**). The soil samples were also replaced with 6% lime, the CBR results are 10% for sample A, 2% for sample B, and 0.8% for sample C (**Fig. 9**.).

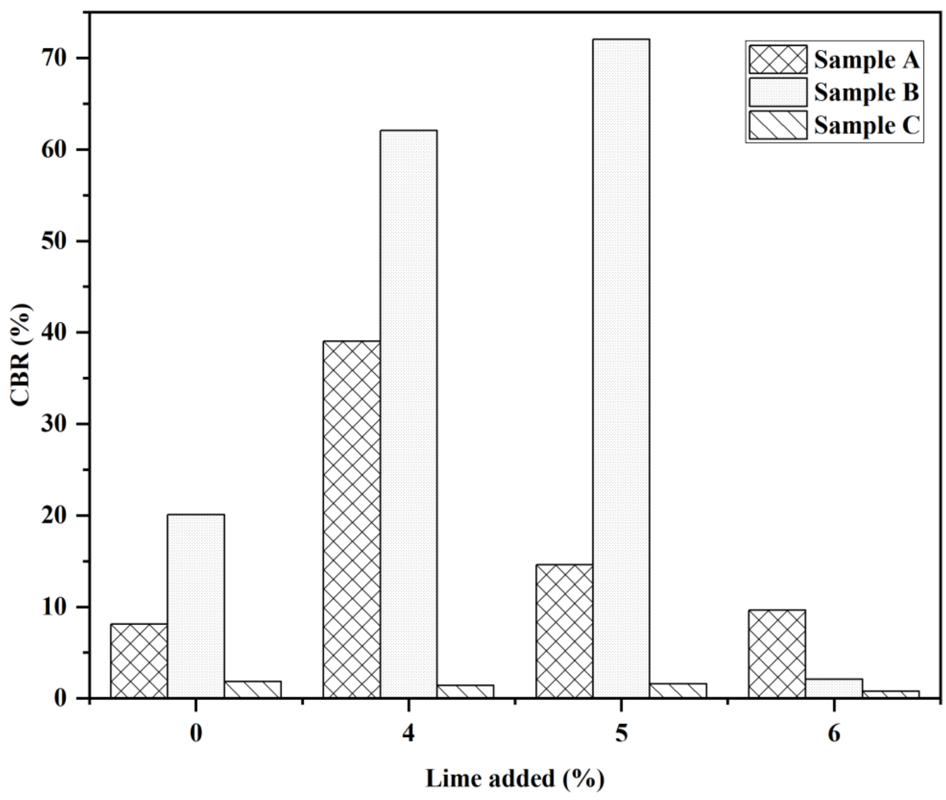

Fig. 9. CBR for samples stabilized with lime.

Since the replacement of the soil sample A with 4% lime gave the highest CBR value, indicating better mechanical properties of the soil sample, the sample was then further assessed with the addition of geotextile. Soil sample A was stabilized with geotextile at layers 2, 3 and 1&3. The CBR values were recorded as shown in **Fig. 10.**

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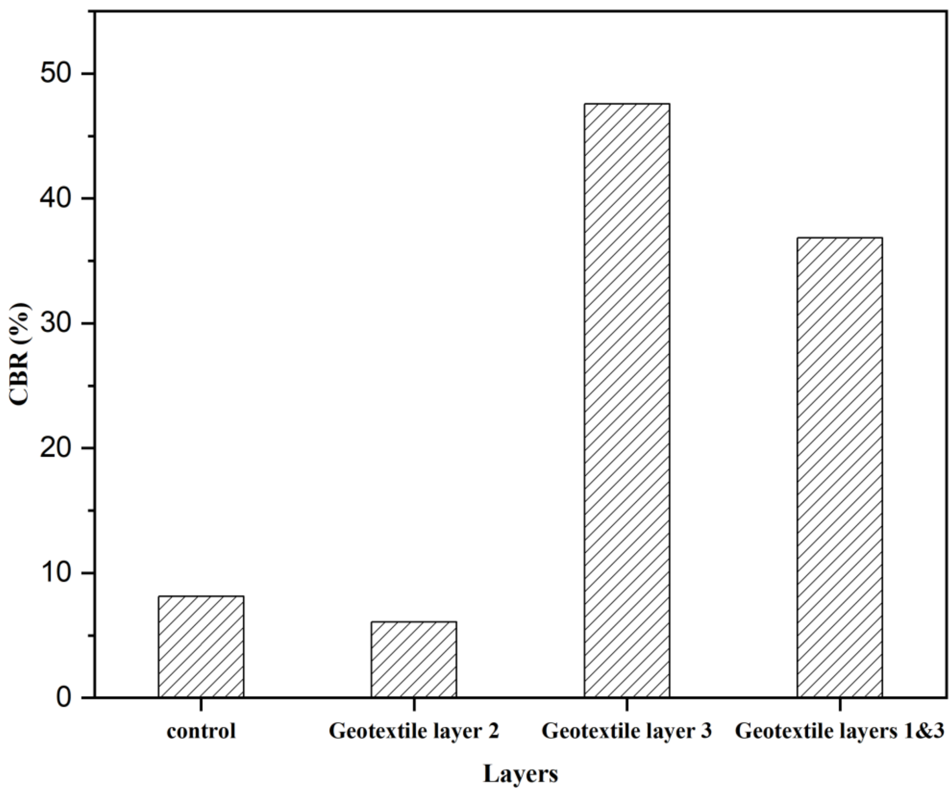

Fig. 10. 4% Lime stabilized with Geotextile for sample A.

Sample A with 4% lime replacement and geotextile at layer 3 gave the highest CBR value of 48% followed by at layer 1&3 with CBR value of 37%. The same procedure was followed for soil sample B, with 5% lime replacement and geotextile at layers 2. 3, and 1&3, since this was the best CBR recording for sample B.

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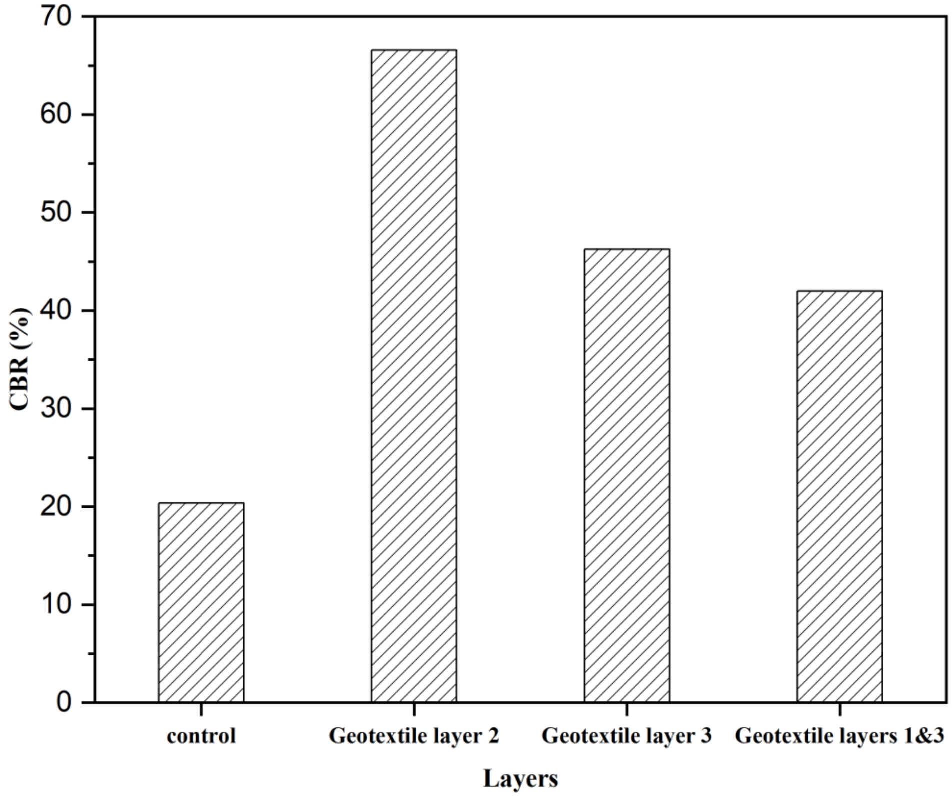

Fig. 11. 5% Lime stabilized with Geotextile for Sample B

The highest CBR value was recorded for geotextile placed at layer 2 with CBR of 67%, followed by geotextile placed at layer 3 (46%), and geotextile placed at layers 1&3 (42.3%) (see **Fig. 11.**). Sample C was replaced with 5% lime and geotextile was placed at layers 2, 3, and 1&3, as shown in **Fig. 12.** Geotextile placed at layer 2 with 5% lime addition, gave the highest CBR value of 3.3%.

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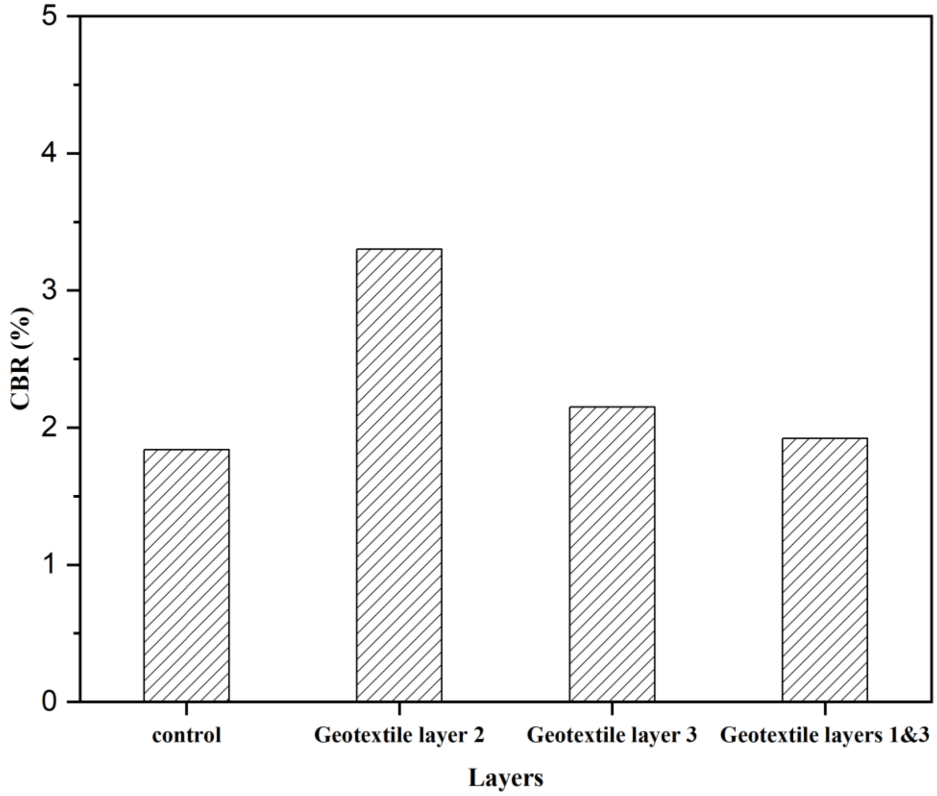

Fig. 12. 5% Lime stabilized with Geotextile for Sample C.

The results from the CBR values of the soil samples suggest important characteristics of lime-stabilized soils improved with geotextile. The higher the CBR values of soil samples, the better the resistance to deformation or failure under applied load, indicating better longevity and load-bearing characteristics of structures made from the materials. As observed, sample A with 4% lime replacement returns the highest CBR value (39%), indicating better strength properties in comparison to other samples. The CBR value is important in estimating the suitability of lime-stabilized soils for diverse engineering applications. For example, higher CBR values are required for heavy duty road constructions or in similar applications. A higher CBR value would also mean that the soil is durable, well compacted and will perform better under stress or load application. In addition, the variation in CBR values upon geotextile application gives insight into how geotextile can impact soil properties. As observed, sample A with 4% lime replacement and geotextile placed at layer 3 gave the highest recorded CBR value of 48%. The same sample gave a CBR of 37% when geotextile was placed at layers 1&3, indicating that geotextile can significantly improve the mechanical properties of soil samples, especially in areas of extreme conditions. The results observed from sample B gave the highest CBR value of 67% when geotextile was placed at layer 2, indicating how geotextile can be effective for enhancing the mechanical properties of soil at specific and strategic positions. A reasonable explanation also suggests that adding geotextile to soils influences the distribution of stresses and forces within the soil, which can lead to difference in CBR values at different points of application of load. Consequently, well-informed placement of geotextile in soil application could improve soil stability and mitigate potential weak zones within the soil, making it effective for even complex engineering designs and applications.

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5. CONCLUSIONS AND RECOMMENDATION

The research investigated the effect of geotextile on lime stabilized lateritic soils and proved to have positive effect, as geotextile showed a significant increase in the strength characteristics of the lime-stabilized soils. The CBR values gave an approximate increase of 50% by comparison to unstabilized soil. This indicates the effectiveness of geotextile application in improving weak soils. The study also evaluated the effectiveness of geotextiles placed at varying depths, and the result obtained showed that, geotextile placed at 1/2 of the depth from the base would yield enough strength for the lateritic soil; although sample A recorded maximum strength at layer 3, layer 2 still gave a considerably high strength based on the CBR values. These findings would be useful in engineering applications, enabling practitioners to strategically utilize geotextiles for soil stabilization based on unique project requirements.

While lime is a good stabilizer, the study highlighted some shortcomings in its application, including health threats, limited amount of its usage in soils, abnormal chemical reactions etc. Geotextile can be employed to address the challenges with lime stabilization and yet add some mechanical properties to the lateritic soil such as drainage, filtration, separation, and reinforcement. Geotextile can hence be recommended for poor lateritic soils or when considering dealing with the problem with lime. It has not posed any known threat to human health, and it is relatively cost effective and readily available. Geotextile is also easy to apply and is not limited by weather conditions, making it versatile and reliable choice for soil improvement.

In conclusion, the study stresses the potential of geotextile in augmenting for the strength deficits of lime-stabilized soils. By taking advantage of the numerous benefits of geotextiles, engineers and designers can heighten the performance of soil structures, especially in situations where lime stabilization poses potential environmental concerns. Field studies and more research could explore the combination of geotextile and lime for various geo-engineering applications, providing guidelines for sustainable civil engineering practices.

Declaration of Competing Interest

The authors declare that there are no competing financial interests or personal relationships that could have influenced the works or data presented in this paper.

Submission Declaration and Verification

The authors declare that the work described in this paper has not been previously published and that it is not under consideration for publication elsewhere. This publication is approved by the authors and explicitly by the responsible authorities where the work was conducted, and that, if accepted, it will not be published elsewhere in the same form, including electronically without the written consent of the copyright-holder.

Author Contribution Statement

The authors declare that we read and approved the final version of this manuscript for publication. We also confirm that we have conducted the experiment and the conception or design of the work, or the acquisition, analysis, or interpretation of data for the work. We are responsible for all the important intellectual content and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Data Availability

The datasets used and/or analyzed during the study are presented in the published article. Other raw data are available from the corresponding author on reasonable request.

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