SSRG International Journal of Civil Engineering
ISSN: 2348-8352/ https://doi.org/10.14445/23488352/IJCE-V11I5P110

Volume 11 Issue 5, 96-107, May 2024
© 2024 Seventh Sense Research Group®

*Original Article*

# Experimental Analysis and Assessment of Lime-Stabilized Peat Soil Performance Admixed with Sodium Bentonite

Vasu Krishnan[1], Kesavan Govindaraj[2]

[1,2]*Department of Civil and Structural Engineering, Sri Chandrasekharendra Saraswathi Viswa Mahavidyalaya (SCSVMV), Tamil Nadu, India.*

[1]*Corresponding Author : kvasu@kanchiuniv.ac.in*

Received: 09 March 2024 Revised: 11 April 2024 Accepted: 10 May 2024 Published: 31 May 2024

***Abstract*** *- This study aims to evaluate the performance of lime-stabilized peat soil that has been enhanced with sodium bentonite. Peat soil, characterized by its rich organic content and poor load-bearing ability, poses significant challenges for construction projects. By incorporating sodium bentonite, a natural clay mineral known for its swelling and binding properties, the effectiveness of lime stabilization in improving the engineering properties of peat soil could be further enhanced. This study assesses the influence of varying levels of sodium bentonite on the mechanical and durability characteristics of lime-stabilized peat soil. Multiple laboratory tests were conducted on samples of lime-stabilized peat soil containing different proportions of sodium bentonite, including pH, Atterberg limits, unconfined compression tests, and microstructural assessments. The findings reveal the combined impact of adding 4% lime and 1% sodium bentonite to peat soil, such as increased strength, reduced compressibility, improved hydraulic conductivity, and enhanced durability. The results of this study contribute to the developments of sustainable and cost-effective methods for stabilizing problematic peat soil. This provides critical information for engineers working on infrastructure development and environmental conservation projects.*

***Keywords*** *- Soil stabilization, Peat soil, Lime, Sodium Bentonite, Atterberg limits, UCC.*

## 1. Introduction

The construction of structures on peat soil presents numerous challenges for engineers and architects due to its complex characteristics, including high organic content, instability, poor bearing capacity, high compressibility, and low shear strength. As a result, the soil is more susceptible to excessive settlement during or after construction [1]. Despite these challenges, rapid urbanization and land scarcity often make it necessary to build on peat soil. Recent research has focused on finding effective methods to modify and stabilize the properties of peat soil to address these challenges. Peat soil is formed through the degradation of a high level of organic matter present in the soil at a constant rate over a specific period, and factors such as percentage of mineral content, moisture, air, organic content, climate, ageing, and water level are vital to determining its engineering behaviour [2]. The geotechnical behaviour of peat soil depends on its type and level of moisture and organic content. Its nature and level of decomposition influence the chemical properties of peat and its components, leading to variations in chemical composition, carbon exchange capacity, and acidity. Due to its unique characteristics, such as high compressibility, sudden creep, and low shear strength, peat soil particles rearrange during construction, leading to the distribution of pore water pressure. This can result in different levels of settlement as the soil particles rearrange and the water flow modifies during loading [3]. During the rise of the groundwater table, the wood matters present in the untreated peat soil get damp, leading to a decrease in bearing strength. Peat soil often oxidizes and shrinks during the fall of groundwater level, which increases permeability, compressibility, and the rate of humification.

Compared to clay soil, peat soil exhibits inconsistent compression behaviour during its initial and later stages of consolidation, influenced by the rate of fibre decomposition within the soil. This decomposition affects the soil's consolidation, permeability, and shear strength. Studies have indicated that peat soil falls within the medium permeability zone [4]. To secure structures constructed on this type of soil, engineers and designers must adopt appropriate methods to enhance the soil's engineering behaviour. Research has demonstrated that peat soil has low strength and extreme compressibility, which can be addressed through techniques such as blending peat soil with normal soil, installing stone and sand columns, utilizing fabricated vertical drains, preloading, applying surface reinforcement, stabilizing with

This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

mechanical and chemical additives, and implementing pile foundations [5]. Recent research on stabilizing peat soil using admixtures and binding agents has improved and helps to understand its geotechnical properties. Alternative materials such as fly ash, rice husk ash, and sodium bentonite, as well as traditional stabilizers, have been shown to enhance soil strength and durability in construction applications [3]. The study examines the effect of fly ash and quick lime on peat soil, revealing significant improvements in Unconfined Compressive Strength (UCC) with varying amounts and curing periods. The optimal mixture was found to be 15-20% fly ash and 6% quick lime, with initial decreases after 28 days and increases after 120 days [6]. The study demonstrates that oil shale ash and pozzolanic agents can stabilize peat soils, improve load-bearing capacity, reduce road construction costs, and have a lower environmental impact compared to traditional methods [7]. Additionally, the use of Mg-rich synthetic gypsum and concrete waste aggregate in Malaysia has been shown to significantly enhance peat soil strength and compressibility, highlighting the potential of recycling waste [8]. Sustainable methods, such as using industrial byproducts in geopolymer concrete and alkali-activated materials, highlight the importance of understanding the behaviour of peat soils under different conditions and the need for adapting traditional and novel materials. For instance, industrial byproducts like POFA and fly ash emphasize the need for sustainable materials in stabilization techniques to improve peat engineering behaviour, resulting in environmental conservation and economic benefits [9]. Soil-mixing with cement can significantly carbonate stabilized peat, making it a net carbon sink despite its reputation as a carbon source. This carbonation behaviour should be taken into account when assessing a construction project's environmental impact and sustainability [10]. The effectiveness of cement stabilization varies with peat moisture content, suggesting optimal W/A ratios for different moisture levels [11]. The study found that using Effective Microorganisms (EM) stabilized peat soils led to a significant improvement in compressive strength after 21 days of curing [12]. Controlled moisture content improved the strength, demonstrating enhanced engineering properties. Fly ash and polypropylene fibre can significantly reduce the environmental impact and cost of cement usage in peat soil stabilization. The combination of 30% fly ash and 0.15% PPF with cement offers superior mechanical properties and increased hydration products [5]. From the review of various literature, it was observed that Stabilization and consolidation can considerably improve the shear strength of peat soil. In the current scenario, a promising treatment method wherein the peat soil matrix is strengthened through fibre encapsulation by developing a silicate coating over the fibres in the soil, modifying the soil's chemical and mechanical properties while preserving its natural porosity [13]. Additionally, reinforcing the peat soil with a mixture of fly ash and gypsum at different ratios and curing periods to enhance its matrix strength. During the construction of the deep foundation, strengthening the peat soil by constructing a deep column with a mixture of lime or cement has proven to be a cost-effective and effective method for pile foundation [14]. This research proposes a novel technique to enhance the performance of peat soil by stabilizing it with lime and adding sodium bentonite, addressing problems like high organic content and low bearing capacity. The study aims to create novel blends of lime and sodium bentonite to improve the physical and mechanical properties of peat soil, benefiting construction projects. The study compares the performance of new blends with plain lime-stabilized peat soils, emphasizing the improvement's magnitude. A research gap is the need for more cost-effective stabilization methods for peat soils compared to conventional stabilizers. The study also aims to improve the engineering and index behaviour of peat soil stabilized with lime and bentonite, examining its compressibility, shear strength, pH, and moisture content. The primary objective is to provide a practical solution, improve peat soil's performance under various loads, and offer insights for engineering applications. The study also addresses safety and stability-related concerns in construction projects involving peat soil by examining the impact of different proportions of lime and sodium bentonite during stabilization.

## 2. Materials and Methods

### *2.1. Soil*

The soil sample, as shown in Figure 1, was utilized in this research and was acquired near Paiyanoor Village, Chengalpattu district, Tamil Nadu, India.

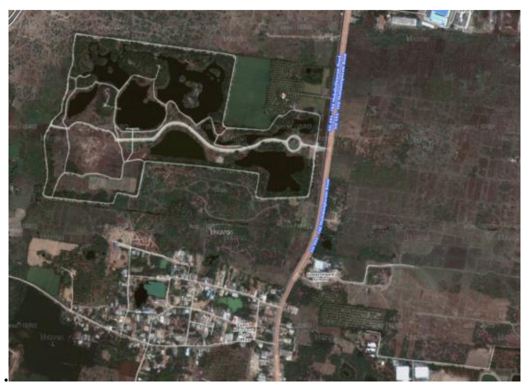


**Fig. 1 Location of peat soil sample (12°37'06"N 80°09'44" E)**

The data collected from on-site examinations was employed to evaluate the physical characteristics of the soil. An appropriate amount of peat soil samples were gathered at this location for laboratory analysis. The peat soil was collected by digging trenches and removing all plant material to a depth of two feet below the surface. The samples were carefully placed in plastic bags and sealed to maintain moisture. The material was stirred with a weed and then collected using a trowel. The peat soil samples that were collected varied in color from black to dark brown and had a pungent odor. One notable feature observed at the site was the porous and easily compressed nature of the peat soil, which distinguishes it from inorganic soils such as clay and sand, which are primarily composed of solid silicate particles. Its natural moisture content was found to be 63.2%. The soil was then dried under the sun and subjected to a controlled temperature in an oven for 24 hours. The grain size distribution was The UCC specimens were prepared using soil that had passed through a 425-micron sieve without any additives to stabilize the soil. The initial compressive strength of the untreated specimens was measured at 243.8 kN/m$^2$. The specific gravity of the organic, untreated peat soil was found to be 1.73. Additionally, the liquid limit value was 65.13%, the plastic limit was 32.56%, the plasticity index was 41.1%, and the shrinkage limit was 17.31%. The optimum moisture content was determined to be 21.07%, and the maximum density when completely dry was recorded as 1.56 g/cc using a conventional proctor compactor test determined using sieving analysis, as shown in Figure 2.

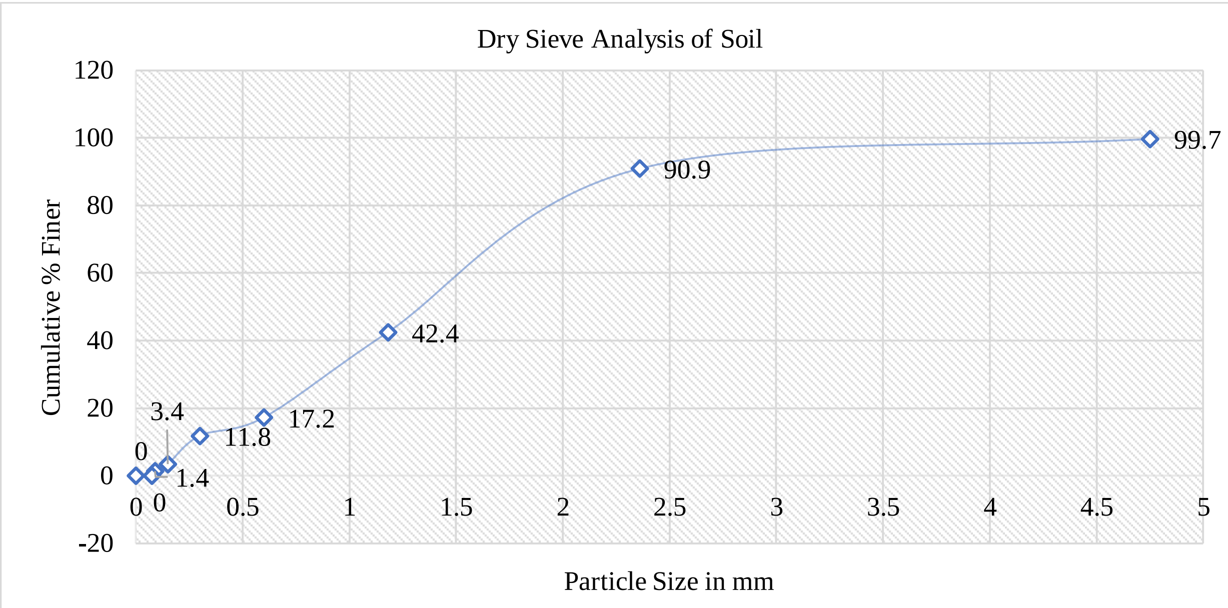



**Fig. 2 Sieve analysis of peat soil sample**

### *2.2. Sodium Bentonite*

Figure 3 illustrates Sodium bentonite, a natural sealant characterized by its creamy colour, high swelling capacity, waterproof properties, affordability, eco-friendliness, and absence of hazardous chemicals or toxic compounds [15].

**Fig. 3 Sodium Bentonite**

Sodium bentonite is commonly utilized in sewage lagoons, recreational ponds, and landfills to create a seal. When combined with water, it produces gel-like masses in the soil and forms bonds with the particles. Its chemical resistivity protects the soil from alkaline chemicals, preventing destabilization. After being exposed to a temperature of 1000°C, only a 5% ignition loss was observed [16]. The chemical formula for Sodium bentonite is Al2H2Na2O13Si4, and its molecular weight is 423 grams per mole. The composition of the Sodium bentonite material utilized in the laboratory is outlined in Table 1.

**Table 1. Sodium bentonite compounds**

| Oxide Compounds | % Concentration |
|---|---|
| Silicon Dioxide ($SiO_2$) | 67.8% |
| Aluminium Oxide ($Al_2O_3$) | 16.3% |
| Magnesium Oxide (MgO) | 1.63% |
| Sodium Oxide ($Na_2O$) | 3.68% |
| Calcium Oxide (CaO) | 0.46% |
| Potassium Oxide ($K_2O$) | 2.34% |
| Ferric Oxide ($Fe_2O_3$) | 0.87% |
| Titanium Dioxide ($TiO_2$) | 0.13% |
| Manganese (II) Oxide (MnO) | 0.05% |

### *2.3. Lime*

Lime is a crucial component in soil, enhancing load-bearing capacity and increasing stability and Impermeability. It improves cation exchange, leading to an increase in plastic limit and a reduction in plasticity. Soil stabilisation is achieved through techniques like flocculation, agglomeration, lime carbonation, cation exchange, and pozzolanic reactions [17]. These processes rapidly alter soil characteristics, such as pH, strength, and plasticity index. The pozzolanic reaction, a time-dependent process, occurs when silica/alumina in soil combines with lime, forming cementitious materials that improve soil strength [18].

Chemical interaction is essential in lime soil stabilisation, enhancing physical, chemical, and engineering properties. The carbonation process produces weaker cementing, but the enduring physio-chemical enhancements result from pozzolanic reactions. Lime's significance as a construction material and soil stabilizer is discussed in many literary works [19]. The Laboratory-grade lime, as shown in Figure 4, was used in this study in the form of a snowy crystal-like powder, with its chemical components listed in Table 2.

**Table 2. Constituents of lime**

| Oxide Compounds | % Concentration |
|---|---|
| Assay/Purity | 95.8% (Max) |
| Chloride (Cl) | 0.015% (max) |
| Sulphate ($SO_4$) | 0.23% (max) |
| Lead (Pb) | 0.0015% (max) |
| Arsenic (As) | 0.00045% (max) |
| Insoluble matter | 1% max |

### *2.4. Specimen Preparation*

In this study, the soil samples that were retained below 425 microns were used to make cylindrical UCC specimens with a diameter of 38mm and a height of 76mm, maintaining a size ratio of 1:2, as shown in Figure 4. To stabilize the soil samples, they were packed in five separate batches with varying percentages of laboratory-grade lime and sodium bentonite, ranging from 2%, 4%, 6% and 1% to 5%, respectively. After mixing, the soil samples were cast using a UCC mould under natural dry density and optimum moisture content. The Casted soil samples were then securely stored in airtight zip lock covers, indicating the percentage of material used. The samples were placed in airtight Ziplock bags, labelled with the test date, and allowed to cure for 7 days, 14 days, and 28 days, respectively.

## 3. Experimental Analysis and Discussion

### *3.1. Optimum Lime % in Soil Stabilization*

The test method suggested by Eades and Grim was used to predict the most effective and optimised lime content for stabilising peat soil. This establishes a basis for estimating the appropriate ratio of peat soil to the lime mixture and guaranteeing the presence of residual calcium and a high pH level for a sustained pozzolanic reaction. This reaction is essential for the development of strength and stiffness in peat soil.

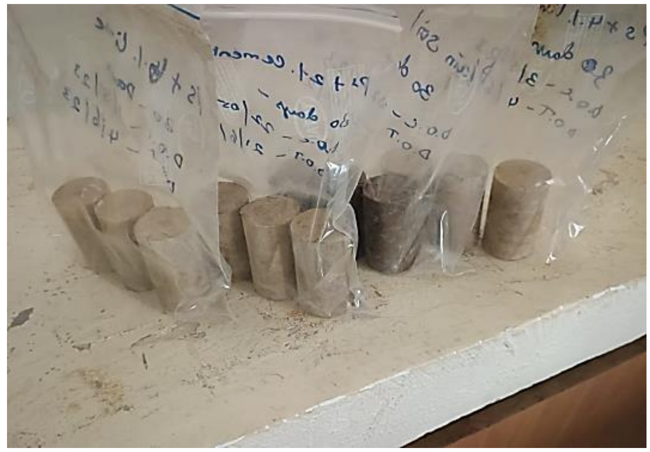


**Fig. 4 Preparation and curing of UCC specimen**

As a result, shown in Figure 5, the minimum lime content in peat soil, yielding an optimum soil-lime pH of 11.24 with lime content of 4%, is required to stabilise the soil effectively, promoting durable pozzolanic and flocculation responses that enhance soil strength and stiffness over time.

### *3.2. pH Value of Soil with Lime and Sodium Bentonite*

The research examined the alkalinity and acidic range of untreated and stabilized peat soils using a laboratory digital pH meter. By determining the optimal concentration of lime and sodium bentonite for stabilizing the soil, the study aimed to improve soil quality. The pH test assessed the pH values of the original peat soil samples and those mixed with lime and sodium bentonite at different percentages.

As shown in Figure 6, the study demonstrated that the original peat soil was acidic due to the presence of an excess of decomposed organic matter. When the soil was stabilized with different proportions of lime and Sodium Bentonite (SB), the acidic nature of the soil was changed to an alkaline state as a result of the reaction between soil particles and compounds present in the lime and sodium bentonite [20].

However, adding more than 1% bentonite with 2 and 4% lime resulted in a decrease in the alkaline nature of the soil, indicating that further addition of bentonite with this level of lime may decrease the alkaline nature and increase the acidic condition of the peat soil. In contrast, 6% lime showed an increase in the alkaline nature of the soil up to 3% addition of sodium bentonite. Therefore, it was concluded that higher doses of lime simultaneously increase the proportion of sodium bentonite in peat soil stabilization, and it is necessary to take steps to monitor and control the acidity in the soil.

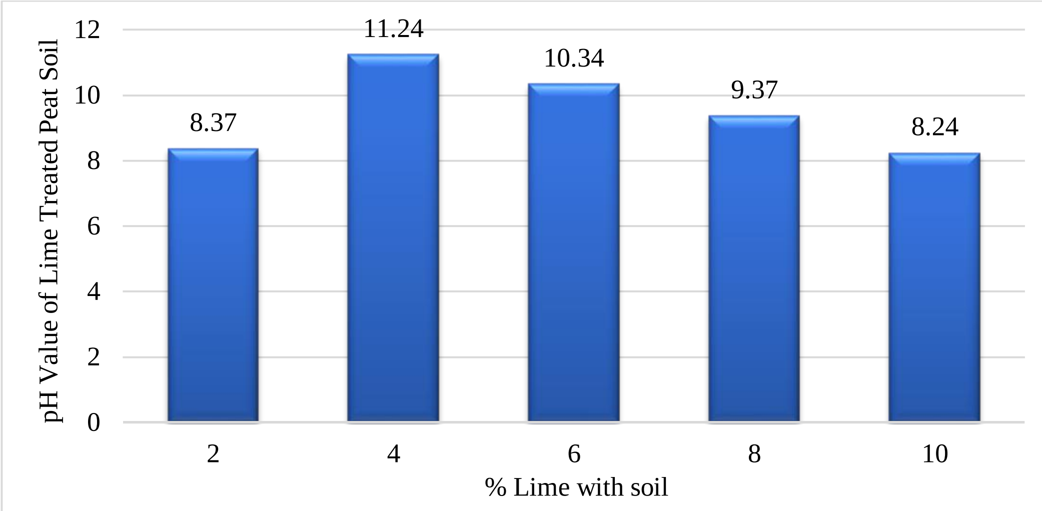



**Fig. 5 Optimum lime proportion for peat soil**

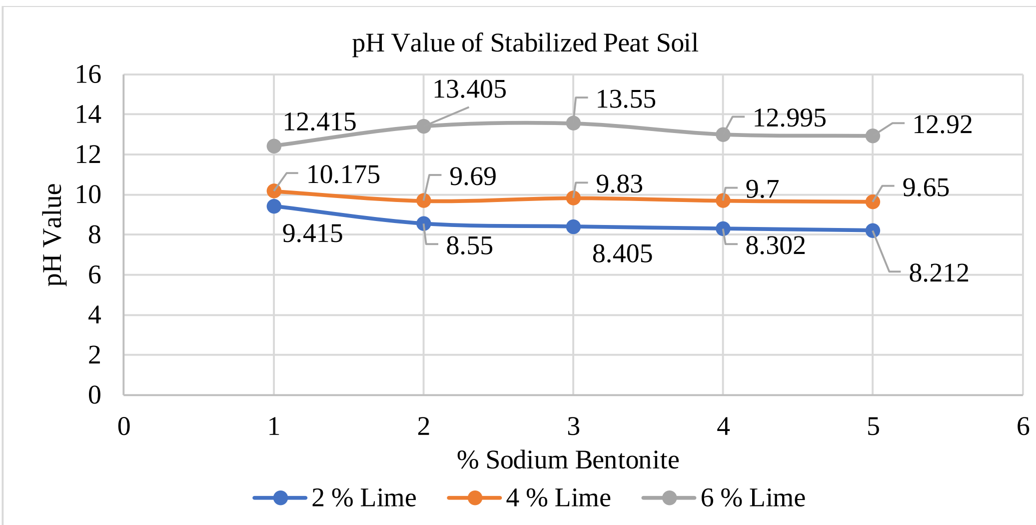



**Fig. 6 pH Value of Peat Soil**

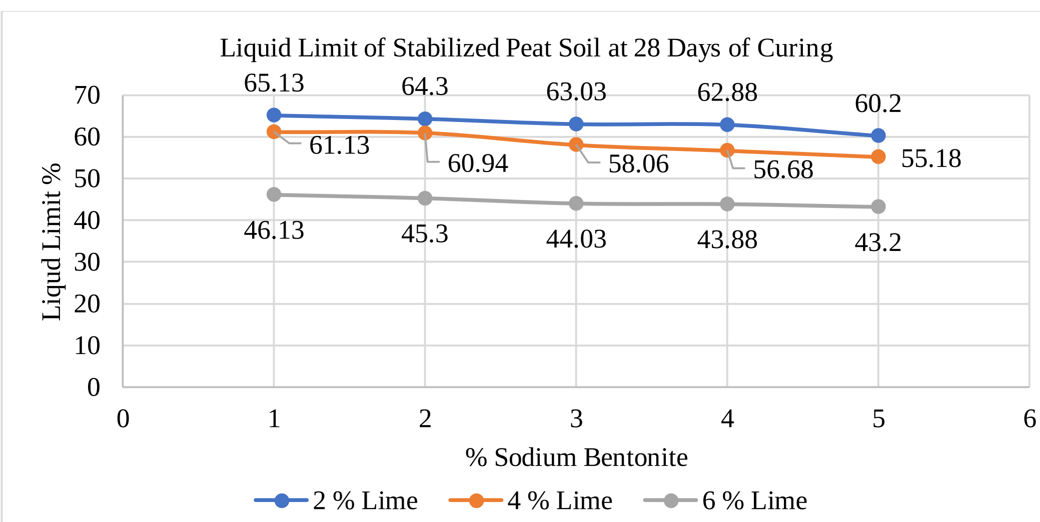



**Fig. 7 Liquid limit of stabilized peat soil**

### *3.3. Atterberg Limits*

Liquid Limit (LL), the Plastic Limit (PL), the Plasticity Index (PI), and the Shrinkage Limit (SL) are the components that make up the Atterberg or consistency limit of soils [21]. The purpose of these index tests is to validate the use of visual descriptions. These tests are carried out on soil samples to ascertain the appropriate quantity of water that is required to achieve a variety of behavioural traits as desired.

#### *3.3.1. Liquid Limit of Stabilized Peat Soil*

The graph in Figure 7 shows the fluctuation in the liquid limit of peat soil that has been stabilized with Sodium Bentonite (SB) at different proportions after a 28-day curing period. Initially, the untreated peat soil had a liquid limit value of 57.63%. When 2% Lime and 1% Sodium bentonite were added, the liquid limit value increased to 65.13%. As the percentage of SB increased, the liquid limit value decreased significantly. However, when 4% Lime was added, the liquid limit value increased considerably until 3% Sodium bentonite was added. Beyond that point, the liquid limit value began to decrease again, similar to the 2% Lime addition. With a 6% Lime addition, the highly acidic nature of the soil from the beginning caused a drastic reduction in the liquid limit of the stabilized peat soil. Generally, a reduction in the liquid limit value of soil indicates a change in plasticity and an increase in compressive behaviour simultaneously [22]. Therefore, the addition of Lime with Sodium bentonite for peat soil stabilization has shown better results than plain lime stabilization.

#### *3.3.2. Plastic Limit of Stabilized Peat Soil*

Figure 8 displays the variations in the plastic limit of stabilized soil due to the addition of Sodium bentonite at different proportions and tested after 28 days of curing. Initially, the untreated Peat soil had a plastic limit value of 32.56%. With stabilization, it is observed that the incorporation of varying percentages of SB additive in lime stabilization has shown a significant increase in the plastic limit value until the 3% addition of Sodium bentonite. Beyond this percentage, the plastic limit value starts to decrease and eventually reaches the initial stage. This increase and subsequent reduction in the plastic limit value indicate a change in the soil's plasticity property [16]. As a result, the increase in plasticity has contributed to the strength development in the soil. The plastic limit value decreases consistently after stabilization with a higher dose of SB additive. Therefore, it is recommended that the quantity of additive used is sufficient, as 3% to maintain the plasticity condition of the soil.

#### *3.3.3. Plasticity Index of Stabilized Peat Soil*

Figure 9 illustrates the plasticity index of stabilized peat soil. Typically, the plasticity index is the numerical difference between the liquid limit and the Plastic Limit (PI = LL - PL). This study found that the Liquid Limit (LL) decreases while the Plastic Limit (PL) increases in stabilized peat soil. This implies a reduction in the Plasticity Index (PI). When the liquid limit drops, it suggests that the soil requires less water to reach its plastic state, which indicates a decrease in soil plasticity. Consequently, the range between the liquid limit and the plastic limit narrows, leading to a decrease in the plasticity index. An increase in the plastic limit signifies that the peat soil has less clay content or that the clay particles are less prone to deformation. This also contributes to a decrease in the plasticity index since the difference between the liquid limit and plastic limit is reduced. As a result, when the liquid limit decreases and the plastic limit increases in stabilized peat soil, it indicates a decrease in the plasticity index. This means that the peat soil taken for this study has a reduced capacity for volume change with variations in moisture content.

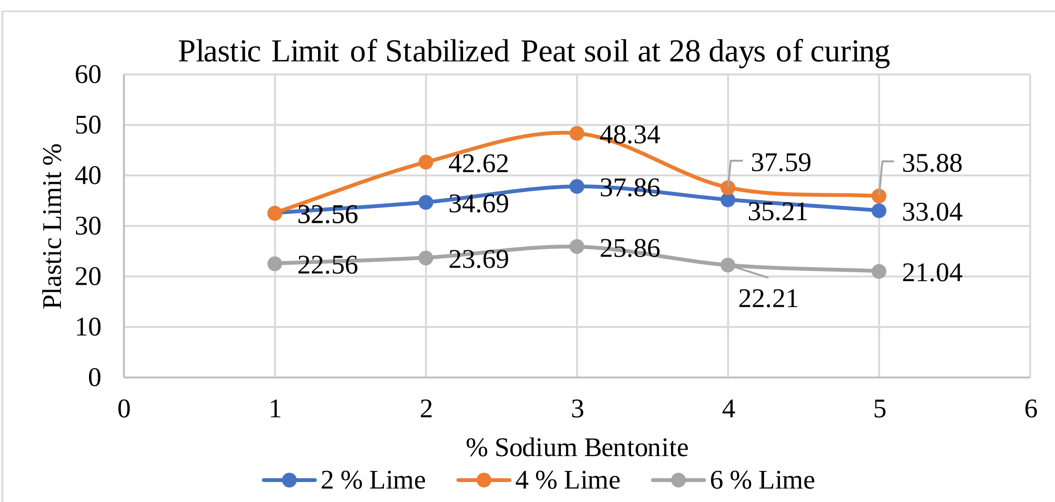



**Fig. 8 Plastic limit of stabilized peat soil**

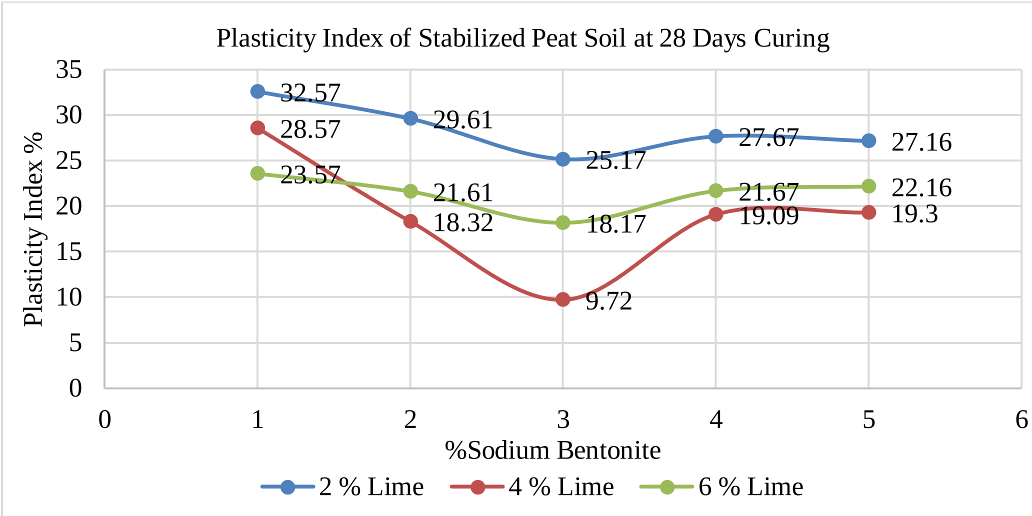



**Fig. 9 Plasticity index of stabilized peat soil**

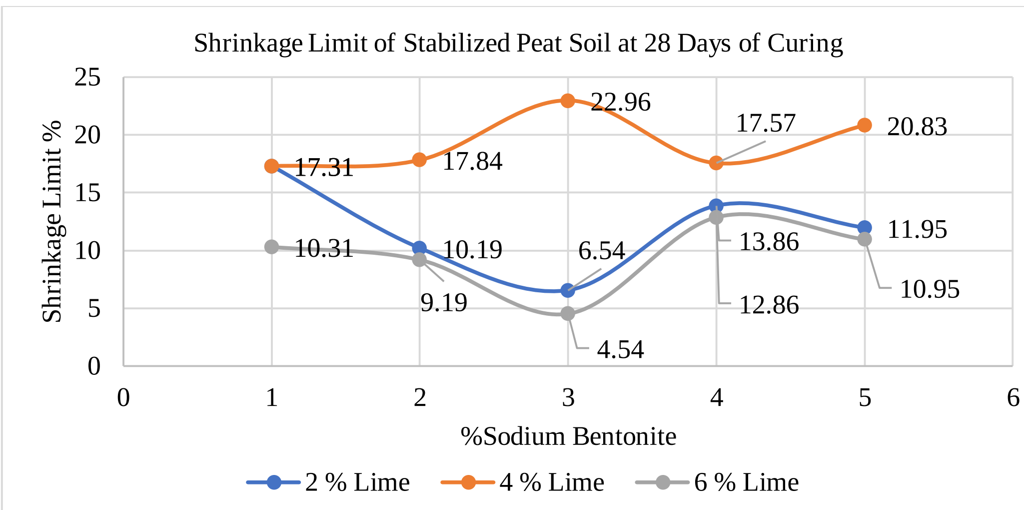



**Fig. 10 Shrinkage limit of stabilized peat soil**

*3.3.4. Shrinkage Limit of Stabilized Peat Soil*

Figure 10 illustrates the shrinkage limit of peat soil that has been stabilized after 28 days of curing. This shrinkage limit is the moisture content that corresponds to the loss of volume and moisture reduction in the soil. The alteration of the liquid limit and plastic limit determines the shrinkage properties of the soil. In this study, it was observed that an increase in the liquid limit value and a decrease in the plastic limit value due to the addition of sodium bentonite with lime at varying percentages led to a corresponding decrease in the plasticity index.

The shrinkage limit of stabilized soil is directly related to the plasticity index of the soil, and as the plasticity index increases, so does the shrinkage behaviour of the soil also increase. In this case, based on the dosage of lime and sodium bentonite and their combined reaction and observed both higher and lower shrinkage values [23, 24]. Therefore, based on the study, it was found and recommended that the average quantity of additive at 4% lime with 3% sodium bentonite was sufficient to preserve the shrinkage characteristics of the soil.

### *3.4. Unconfined Compressive Strength of Peat Soil*

*3.4.1. Curing Vs UCC Strength of Stabilized Peat Soil with 2% Lime*

Figures 11 and 12 illustrate the Unconfined Compression Strength (UCC) of stabilized peat soil using 2% lime and 1%-5% Sodium Bentonite (SB). The prepared UCC specimens were tested after a curing period of 0, 7, 14, and 28 days. When the specimens were tested after 2 hours of casting, those containing 1% SB showed immediate strength increments compared to pre-stabilization peat soil samples.

**Fig. 11 UCC testing of soil specimen**

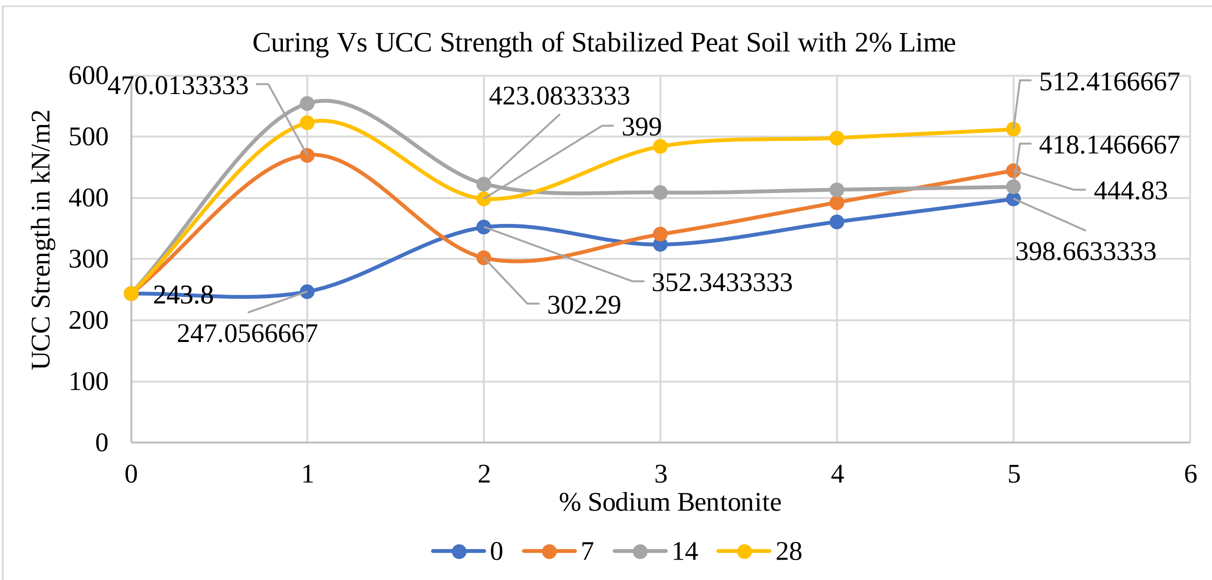



**Fig. 12 UCC strength of stabilized peat soil with 2% lime**

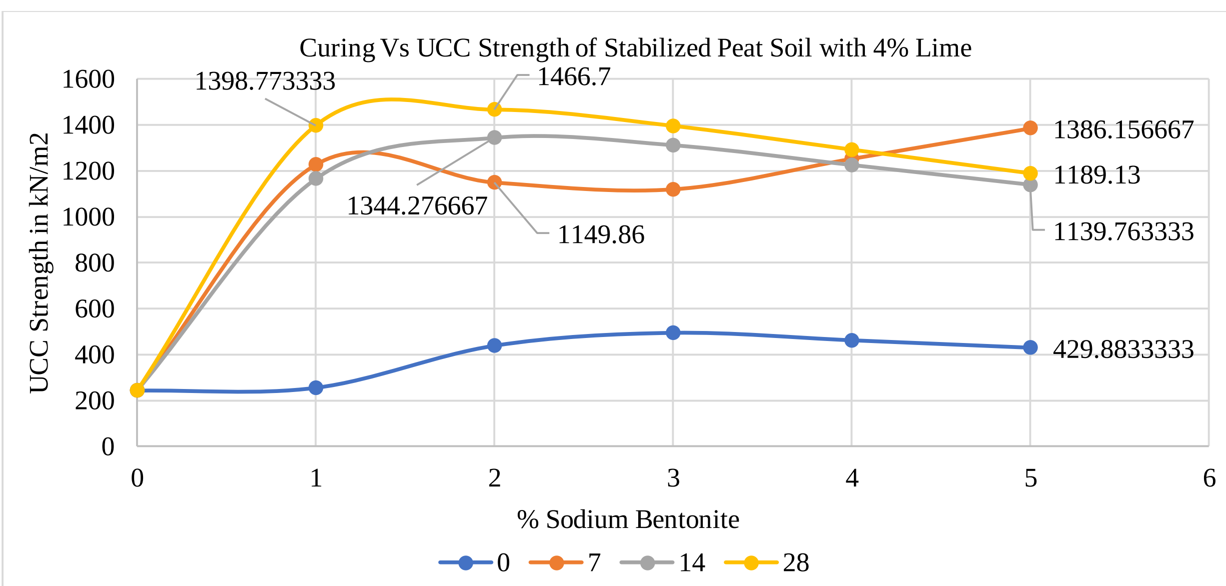



**Fig. 13 UCC strength of stabilized peat soil with 4% lime**

However, the percentage increment of SB from 2% to 5% did not show any significant improvement in compressive strength for 7 and 14 days of curing. However, during the 28-day curing period, 5% SB admixed soils displayed significant improvements in peat soil strength. Additionally, it was observed that the 2% proportion of lime with 2% SB was not found to be an effective combination due to their equal volumes, which resulted in a drastic decline in soil strength.

*3.4.2. Curing Vs UCC Strength of Stabilized Peat Soil with 4% Lime*

Figure 13 illustrates the Unconfined Compressive Strength (UCC) of soil that has been stabilized with 4% lime and 1% to 5% SB. When 1% SB was added to 4% lime, the strength of the peat soil increased significantly.

However, as the amount of SB increased from 2% to 5%, the strength of the soil samples also increased, even when the curing period was extended. Unlike the previous case, there was no significant increase in strength during the 28-day curing period.

This finding is consistent with the previous case, where the 4% lime and 4% SB in equal volumes resulted in a decrease in the strength of stabilized soil due to an unfavourable combination of additives and admixtures.

*3.4.3. Curing Vs UCC Strength of Stabilized Peat Soil with 6% Lime*

Figure 14 illustrates the Unconfined Compressive Strength (UCC) of stabilized peat soil using 6% Lime with 1% to 5% Sodium Bentonite (SB). Similar to previous cases, the addition of 1% SB with 6% lime revealed improved performance in all curing periods. However, as the percentage of SB increased, the strength of the stabilized soil decreased inversely. In this case, it was also found that the increase of lime proportion by 6% makes the soil stiffer and more vulnerable to failure easily and turns the soil again from alkaline to acidic. Also, it suggests that higher proportions of SB do not provide any positive contribution to lime soil stabilization and may even drastically reduce the strength of the soil, resulting in a strength level equal to the pre-stabilization stage.

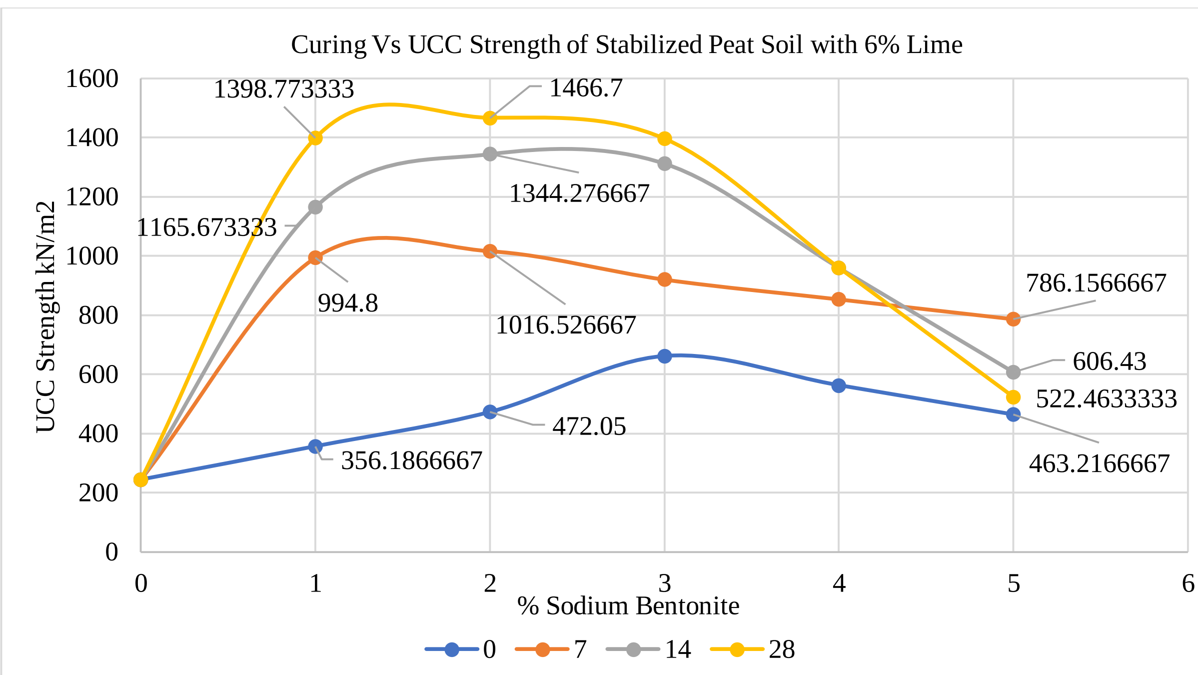



**Fig. 14 UCC strength of stabilized peat soil with 6% lime**

*3.4.4. Average 28 Days UCC Strength of Stabilized Peat Soil with Lime and SB*

Figure 15 represents the average 28 days curing strength of peat soil stabilized under different proportions of lime (2,4 and 6%) with different percentages of sodium bentonite (1%, 2%, 3%, 4% and 5%), respectively. Based on this UCC comparison study, it was easy to understand the optimum dosage of lime, and SB required to stabilize and increase the engineering behaviour of peat soil taken for this study.

As studied in previous section 3.1, the optimum percentage of 4% of lime was found as sufficient and effective for stabilizing the peat soil used in this study without any admixture. In this comparison, along with additives, the performance of lime and soil was investigated.

As per the investigation, the addition of a limited quantity of 1% SB with 4% lime has shown a promotable increase in compressive strength of peat soil as 1399kN/m2 at 28 days of curing when compared to other proportions of SB. This is due to factors such as the chemical interaction between the lime hydration process and sodium bentonite compounds, which are shown in Table 1 above. Hence, it was revealed that the usage of 1% SB with 4% Lime has promoted the compressive strength and behaviour of peat soil and it helps to maintain its alkaline nature.

### *3.5. Microstructural Improvement of Stabilized Peat Soil with 4% Lime and 1% Bentonite*

Based on the above UCC study, the Peat soil stabilized using the optimum value of 1% Sodium bentonite with 4% lime was further investigated under a Scanning Electron Microscope (SEM) to analyse and address its microstructural modification of the 28 days cured UCC tested specimen. Figure 16 depicts the SEM image of untreated soil, and 17b depicts the stabilized UCC failed soil sample with 4% lime + 1% SB.

The use of 1% Sodium bentonite additive in lime stabilization involves analysing the failed Unconfined Compressive Strength (UCC) specimen for basic electronic microscopic examination. This is because it achieves a maximum strength that surpasses that of virgin soil, and the intimate proximity of soil particles solely determines the strength of the soil. The SEM analysis employs failed UCC specimens with particle dimensions of less than 10mm.

The microstructure size of untreated Peat soil texture was characterized by a flaky nature with some organic impurities and has a minimal strength of 2µm. After stabilization, the proximity of soil particles significantly increases, resulting in a microstructural value of 15µm. This is attributed to the interaction between 4% lime and 1% SB, which leads to the continuous development of calcium presence within the gaps between soil particles.

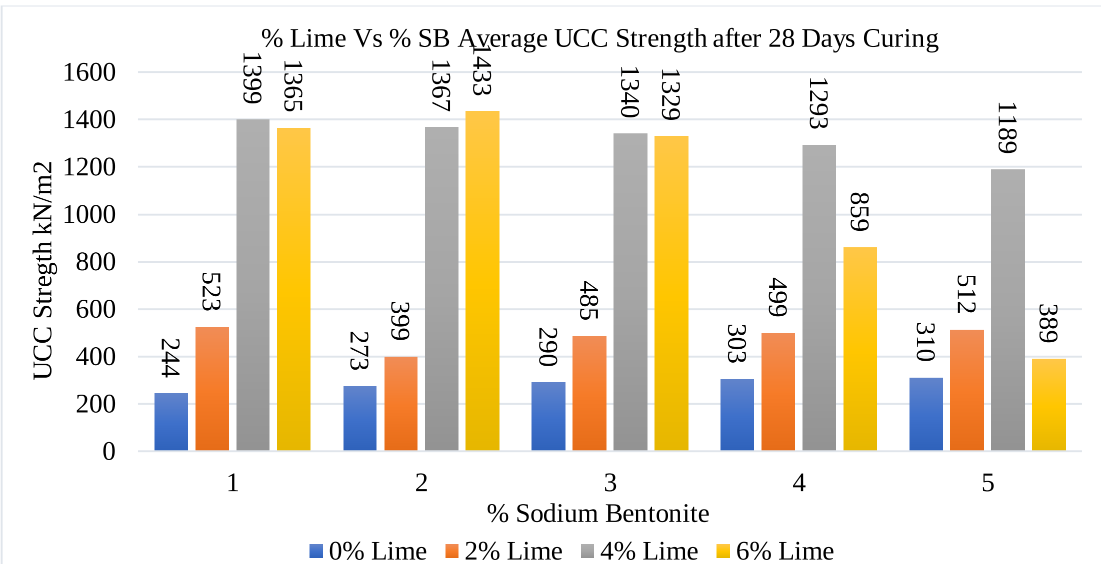
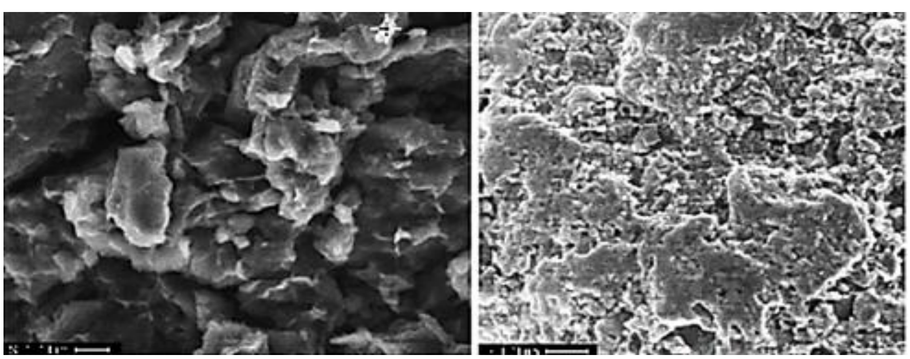



**Fig. 15 Average 28 days UCC strength of stabilized peat soil with varied % of lime and % SB**



**(a)** **(b)**

**Fig. 16 UCC strength of stabilized peat soil with 4% lime+1% sodium bentonite**

## 4. Result and Conclusion

Based on the experimental analysis conducted over the peat soil taken for this study, the following conclusion and recommendations were drawn. The findings of this study and recommendations may be helpful to future researchers who will investigate the engineering parameters of the peat soil for construction.

- The research proposes a method designed to enhance the engineering properties of peat soil by combining lime stabilization with the addition of sodium bentonite to address the soil's high organic content and low load-bearing capacity.
- The ideal lime content for stabilizing peat soil was determined to be 4%, with a corresponding pH value of 11.24, which helps maintain the soil in an alkaline state. When combined with 6% lime and 3% sodium bentonite, the pH value increased to 13.55. This demonstrates that adding lime with a moderate amount of sodium bentonite helps maintain the alkaline nature of the soil. However, as the content of sodium bentonite increases, it alters the soil behaviour from alkaline to acidic.
- The addition of sodium bentonite with any proportion of lime decreased the liquid limit value during testing, indicating a significant role in the strength parameter of the soil. Increasing the content of sodium bentonite beyond 1% also decreased the plastic limit value, which suggests a serious impact on the strength parameter. The rise and fall of the plasticity index of the soil with varied proportions of lime and sodium bentonite had an impact on the soil's shrinkage behaviour and complexity.
- The Unconfined Compressive Strength (UCC) of stabilized soil with 4% lime and 1% sodium bentonite showed a promotable increase in compressive strength compared to other mixtures. Microstructural investigation revealed notable increases in the soil's microstructure when stabilized with 1% sodium bentonite and 4% lime.
- This method could potentially transform construction techniques and encourage the creation of eco-friendly, efficient infrastructure in areas prone to peat formation.

### *4.1. Future Scope and Recommendation*

- Before implementing any modifications or improvements to peat soil, it is crucial to analyse its index and physical properties thoroughly. This will allow researchers to make more informed decisions when choosing the most appropriate alteration strategy.
- Lime is the ideal stabilizer if the organic content of the peat soil does not exceed 75%. On-site studies are necessary to fully comprehend the characteristics of peat soil, which will aid in validating the outcomes of laboratory tests. The accuracy of laboratory results is achieved by eliminating any individual errors that may occur during the execution of the test.

## References


[1] Ashraf E. Abdel-Salam, “Stabilization of Peat Soil Using Locally Admixture,” *HBRC Journal*, vol. 14, no. 3, pp. 294-299, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[2] Suhail Ahmad Khanday, Monowar Hussain, and Amit Kumar Das, “A Review on Chemical Stabilization of Peat,” *Geotechnical and Geological Engineering*, vol. 39, no. 8, pp. 5429-5443, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[3] Torjit Elangbam, and Ajanta Kalita, “Comparative Study of Different Stabilizers for Peat Soil Stabilization: A Review,” *Proceedings of SECON’23*, vol. 381, pp. 377-391, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[4] Ali Hauashdh et al., “Stabilization of Peat Soil Using Fly Ash, Bottom Ash and Portland Cement: Soil Improvement and Coal Ash Waste Reduction Approach,” *IOP Conference Series: Earth and Environmental Science*, Johor, Malaysia, vol. 498, pp. 1-6, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[5] Mohammed K.H. Radwan et al., “A Study of the Strength Performance of Peat Soil: A Modified Cement-Based Stabilization Agent Using Fly Ash and Polypropylene Fiber,” *Polymers*, vol. 13, no. 23, pp. 1-16, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[6] P. Kolay, and M. Aminur, “Physical and Geotechnical Characteristics of Stabilized and Unstabilized Tropical Peat Soil,” *World Journal of Engineering*, vol. 8, no. 3, pp. 223-230, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[7] Vello Pallav et al., “Stabilization of Road Embankments on Peat Soils Using Oil Shale Ash and Pozzolanic Additives,” *Applied Sciences*, vol. 13, no. 14, pp. 1-18, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[8] Siti Khairina et al., “Analysis of Strength and Compressibility on Stabilization of Peat Soil with Industrial Mg-Rich Synthetic Gypsum and Concrete Waste Aggregate,” *SSRN*, pp. 1-9, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[9] Adriana Erica Amaludin, Hidayati Asrah, and Habib M. Mohamad, “A Review of Advances in Peat Soil Stabilisation Technology: Exploring the Potential of Palm Oil Fuel Ash Geopolymer as a Soil Stabiliser Material,” *Civil Engineering Journal*, vol. 9, no. 8, pp. 2085-2104, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[10] Alan R. Duggan et al., “Stabilisation for Peat Improvement: Extent of Carbonation and Environmental Implications,” *Journal of Cleaner Production*, vol. 271, pp. 1-11, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[11] Atikah Rahmi, Siti Noor Linda Taib, and Fauzan Sahdi, “Investigation of the Application of Various Water Additive Ratios on Unconfined Compressive Strength of Cement-Stabilized Amorphous Peat at Different Natural Moisture Contents,” *Advances in Civil Engineering*, vol. 2018, pp. 1-9, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[12] N.Z. Yusof et al., “Peat Soils Stabilization Using Effective Microorganisms (EM),” *IOP Conference Series: Earth and Environmental Science*, Langkawi, Malaysia, vol. 140, pp. 1-8, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[13] Afnan Ahmad et al., “Physio-Chemical Properties, Consolidation, and Stabilization of Tropical Peat Soil Using Traditional Soil Additives-A State of the Art Literature Review,” *KSCE Journal of Civil Engineering*, vol. 25, no. 10, pp. 3662-3678, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[14] A. Raghavendar Reddy, and Kh. Lakshman Singh, “Performance of Pavement Subgrade Using Fly Ash Stabilized Peat Soil Reinforced with Nylon Fiber,” *International Journal of Pavement Research and Technology*, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[15] Suhail Ahmad Khanday, Monowar Hussain, and Amit Kumar Das, “Stabilization of Indian Peat Using Alkali-Activated Ground Granulated Blast Furnace Slag,” *Bulletin of Engineering Geology and the Environment*, vol. 80, pp. 5539-5551, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[16] D. Parthiban et al., “Performance Study on Clayey Soil Stabilized by Lime and Geopolymer with Partial Replacement of Sodium Bentonite as an Additive,” *AIP Conference Proceedings*, vol. 2271, no. 1, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[17] Sivakumar Gowthaman et al., “Biocementation Technology for Stabilization/Solidification of Organic Peat,” *Low Carbon Stabilization and Solidification of Hazardous Wastes*, pp. 49-64, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[18] Afnan Ahmad et al., “Microstructural Characterization of Fibric Peat Stabilized with Portland Cement and Silica Fume,” *Materials*, vol. 16, no. 1, pp. 1-13, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[19] Afnan Ahmad et al., “The Implementation of Industrial Byproduct in Malaysian Peat Improvement: A Sustainable Soil Stabilization Approach,” *Materials*, vol. 14, no. 23, pp. 1-22, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[20] D.S. Vijayan, and D. Parthiban, “Effect of Solid Waste Based Stabilizing Material for Strengthening of Expansive Soil-A Review,” *Environmental Technology & Innovation*, vol. 20, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[21] Devarajan Parthiban et al., “Role of Industrial Based Precursors in the Stabilization of Weak Soils with Geopolymer – A Review,” *Case Studies in Construction Materials*, vol. 16, pp. 1-17, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[22] Nadhirah Mohd Zambri, and Zuhayr Md. Ghazaly, “Peat Soil Stabilization Using Lime and Cement,” *E3S Web of Conferences*, vol. 34, pp. 1-7, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[23] Zane Vincevica-Gaile et al., “Towards Sustainable Soil Stabilization in Peatlands: Secondary Raw Materials as an Alternative,” *Sustainability*, vol. 13, no. 12, pp. 1-24, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[24] Ali A. Mahmood, T.Y. Lin, and J.K. Zhi, “Sustainable Stabilization of Peat: A Literature Study,” *Proceedings of the Canadian Society of Civil Engineering Annual Conference*, vol. 239, pp. 13–24, 2021. [CrossRef] [Google Scholar] [Publisher Link]