The Application of Rice Husk Ash and Lime as a Stabilizer for Constriction Purposes

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ABSTRACT: The objective of this study is to improve the engineering properties, strength, and CBR value of sandy, fine-grained soil. All types of earthen structures rest directly on the soil. The CBR value refers to the strength of the subgrade soil, which greatly affects the durability and cost of pavement. By properly treating the subgrade soil, its properties and strength can be improved to protect it from post-construction damage. Stabilization of soil is an effective technique for improving soil properties and the performance of the pavement system. With the same intention, an attempt was made to modify the engineering properties of soils collected from Mirpur-12, Dhaka, Bangladesh, by using rice husk ash and lime. The soil samples were mixed with rice husk ash in varying proportions of 4%, 8%, 12%, 16%, 20%, 24%, and 28% by weight, as well as 2%, 4%, 6%, 8%, 10%, 12%, 14%, and 16% lime content. Increases in stabilizer contents directly increase liquid and plastic limits. However, as the proportion of rice husk ash and lime increases, the plasticity index gradually decreases. The reduction in dry density was from 1.61 gm/cc to 1.38 gm/cc, and the increase in optimum moisture content was from 16% to 20.9% for the addition of 28% rice husk ash with the soils. In addition, the same reduction and increase were also observed for the lime stabilizer. Based on both the California bearing ratio and the unconfined compressive strength test, it is recommended to use 8% lime and 20% rice husk ash to stabilize this soil for sub-base materials.

KEYWORDS: Stabilizer, CBR, Unconfined compressive strength, Lime, Rice husk ash.

1. INTRODUCTION

Soil is an essential element of this nature, and the road development industry understands its importance for pavement work. Soil is defined as the accumulation of mineral particles formed by the physical or chemical disintegration of rocks, as well as the air, water, organic matter, and other substances that may be present. Soil is a non-homogeneous, porous earthen material whose engineering behaviors are affected by moisture content and density changes [1] As a subgrade; soil rests beneath the road pavement. The subgrade is a weak soil that causes road damage. Expansive soil expands when wet and contracts when dry. When the level of groundwater rises during the rainy season, the road begins to heave. By combining various additives with soil samples, the soil properties are improved [2] Soil stabilization is the process of modifying soil to improve its physical properties. Stabilization can improve the load-bearing capacity of a sub-grade to support pavements and foundations by increasing shear strength and controlling shrink-swell properties. To stabilize the soil, various additives such as cement, lime, ashes, chemicals, and so on are used [3] Stabilization has been found to be the best technique for reducing the swelling and shrinkage behaviour of soil over the last few decades. Several researchers attempted to stabilize soil with lime, cement, fly ash, rice husk ash, brick dust, and other materials. Several researchers use lime, fly ash, brick dust, and cement, as soil stabilizers with different types of soil [4-7]. One of these techniques, lime stabilization, has been employed for decades to stabilize black cotton soil. The use of lime reduces the high plasticity of black cotton and makes it workable. Furthermore, the interaction between lime and soil strengthens the soil-lime mixture and provide suitability for construction purpose [4] Mesida [8] established that soil types in Okitipupa areas of Ondo State require only 10-12 percent cement for stabilization in order to be reliable for building purposes. Researchers Lazaro and Moh (9) have given the chemical composition of rice husk ash presented in Table 1. It can be distinguished that silicon dioxide ($SiO2$) is somewhat more than 88% of the fully burnt rice hush ask.

Researcher Por [10] investigated the effects of cement accumulation on expansive clay on its characteristics of deformation and stress responses during swelling. The effects were assessed by focusing on the unconfined compressive strength, swelling shrinkage strains under different situations, and the lateral coefficient of earth pressure throughout one-dimensional compression for artificial blends of two separate clays in three different ratios.

The goal of Chompoorat [11] was to enhance the engineering and physical characteristics of sedimentary soil for potential use in road construction. The soil samples were mixed with cement in a 3 - 10% proportion by weight. Chompoorat [12] investigated the macro-mechanical and micro-structural behaviour of dredged natural expansive clay from coal mining treated with ordinary Portland cement or hydrated lime addition. The stabilized expansive soil aims for possible reuse as pavement materials. Researcher Chompoorat [13] attempted to improve the shrinkage and swelling potentials of cement-stabilized dredged sediments by the addition of fly ash (FA). Chompoorat [14] explored the stabilization of dredged lakebed sediments with ordinary Portland cement and fly ash to repurpose the sediment as road pavement construction material. Data are obtained from previous studies on sediments collected from Phayao Lake and Huai Mae Phong Reservoir in Phayao province and Mae Sab Reservoir in Chiang Mai province in Thailand.

Yoobanpot [15] conducted a survey, and the purpose of that study is to present a multiscale laboratory investigation into the mechanical properties and microstructures of dredged sediments stabilized with ordinary Portland cement type I and fly ash. The base sediment was silt with high plasticity. The results of mechanical tests were used to calculate the resilient modulus, free-free resonance, splitting tensile strength, wetting and drying cycle number, and unconfined compressive strength.

The aim of Ramaji [16] was to review on stabilization of soil using low-cost methods. In their research, they discussed different types of low-cost materials such as Portland cement, lime, fly ash, tire, etc. The advantages and disadvantages of different types of soil stabilization methods were also reflected in this research.
Researcher Yoobanpot [17] has shown the process of removing sediments from the bottom of dams generates large amounts of dredged sediments, which are considered waste.

Chompoorat [18] conducted a study that aims to present the results of testing conducted on dredged sediment stabilized with ordinary Portland cement (OPC) and fly ash (FA) for reuse as pavement materials.

This research presents experimental results of dredged lakebed sediment stabilized with ordinary Portland cement (OPC) and fly ash (FA) for use as pavement materials in road infrastructure. The work also proposed empirical correlations for the strength and stiffness parameters of chemically stabilized dredged sediments intended for pavement engineering.

The aim of this study is to improve the engineering properties, strength, and CBR value of the sandy fine-grained soil and make it suitable for constriction purposes. In this study, rice husk ash and lime were used in collected soil as a stabilizer. The soil samples used in this study were collected from Mirpur-12, Dhaka, Bangladesh, at a depth of 5m below the existing surface. The soil is mixed with prepared rice husk ash in varying proportions of 4, 8, 12, 16, 20, 24, and 28% by weight. In addition, the soil is mixed with prepared rice husk ash in varying proportions of 4, 8, 12, 16, 20, 24, and 28% by weight. A series of standard laboratory tests were carried out on soil samples with various proportions of rice husk ash and lime. The standard tests were Atterberg limits, standard Proctor compaction, unconfined compression, specific gravity, and California bearing ratio. All the tests were performed in accordance with ASTM standards. Finally, Suitable proportions of RHA and lime were selected based on unconfined compression and California bearing ratio.

Table 1 Chemical composition of rice husk ash

Chemical Name	Composition proportions (%)
Silicon dioxide (SiO_2)	88.66
Calcium oxide (CaO)	0.75
Magnesium oxide (MgO)	3.53
Ferric oxide (Fe_2Os)	0.36
Aluminum oxide ($A1_2O$)	1.48
Carbon dioxide (CO_2)	0.51
Loss on ignition	3.80

2. MATERIALS AND METHODS

The materials used in this study work are soil, rice husk ash, and lime, which are collected from different locations**.**

2.1 Soil Samples

The soil samples used in this study were collected from Mirpur-12, Dhaka, Bangladesh, at a depth of 5m below the existing surface in order to avoid and circumvent vegetable matters. The Engineering properties of soil samples were determined by different tests in the European University of Bangladesh laboratory through the ASTM standard and are shown in Table 2.

Table 2 Physical properties of collected soil sample

Properties of soil sample	Unit	Values
Initial moisture content	%	37.65
OMC	%	16
MDD	gm/cc	1.61
Specific gravity	--	2.67
LL	%	44.2
PL	%	24.9
PI	%	19.3
Shrinkage limit	%	34.11
Sand: Silt: Clay	%	4.62: 63.68: 31.70
California bearing ratio	%	6.94
Unconfined compressive strength	(kPa)	201.4

2.2 Collection of Rice Husk Ash

Rice milling produces husk as a by-product, which encircles the paddy grain. Roughly 78% of the weight of milled paddy is received as rice, broken rice, and bran. The remaining 22% of the weight of the paddy is collected as a husk. In rice mills, this husk is used as fuel to produce steam for the boiling process. The husk contains about 75% organic volatile matter, and the remaining 25% of its weight is transformed into ash during combustion, which is known as Rice Husk Ash (RHA). The rice husks were gathered from the local market, and their natural moisture content was 9.43%. To burn the rice husks, researchers Williams and Sompong (1971) created a simple combustion chamber, which included a drum, a circular pipe, and gauze. The drum measured 0.6 m in diameter and 0.8 m in height. Compressed air was routed through a circular pipe with 3-mm-diameter holes installed in the drum's lower section. The rice husks were placed on the gauze, which was located 50 mm above the circular pipe. A match was used to light the rice husks, and compressed air was provided until the combustion was complete. The specific gravity of rice husk ash was determined to be 2.02. The soil was mixed with prepared rice husk ash in varying proportions of 4%, 8%, 12%, 16%, 20%, 24%, and 28% by weight.

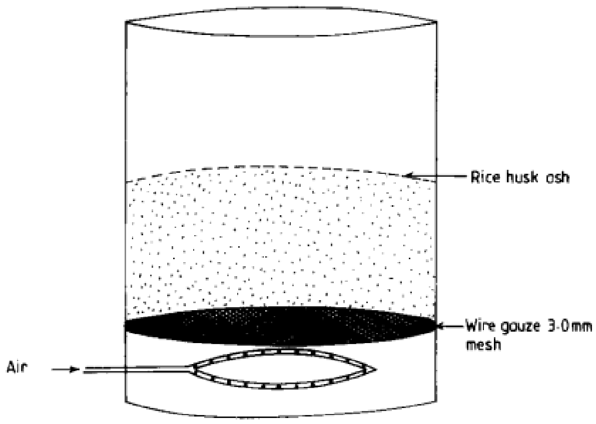

Figure 1 Chamber for rice husk ash preparation

2.3 Collection of Lime

The goal of our current research is to enhance the various properties of soil by combining locally available materials, such as lime, which was chosen to mix with soil in various proportions. Lime used in this study was obtained from the local market in Dhaka, Bangladesh. The Specific gravity of lime was determined as 2.16. The soil is mixed with collected lime in varying proportions of 2, 4, 6, 8, 10, 12, 14, and 16% by weight.

2.4 Experimental Procedures

A series of standard laboratory tests were carried out on soil samples with various proportions of rice husk ash and lime. The standard tests were Atterberg limits, standard Proctor compaction, unconfined compression, specific gravity, and California bearing ratio. All the tests were performed in accordance with ASTM standards. In a large tray, each stabilizer was mixed thoroughly with the soil. The mixing was done by hand. All soil-stabilizer samples compacted in unconfined compression and California bearing ratio tests were at optimum moisture content. The standard Proctor compaction test was used to determine various optimum moisture content for different proportions of stabilizers. The larger specimens for the unconfined compression test were moulded using the same compaction effort and mould as the compaction test. A wire saw and soil lathe were used to cut smaller cylindrical specimens from the moulded sample. In compression tests, all test specimens had a length-diameter ratio of 2.0. The dimensions of each specimen were 78 mm long and 39 mm in diameter. Before loading in compression, specimens were air-cured at room temperature for one day and seven days.

The composite soil specimens for the California bearing ratio test were formed in the CBR mould using the same compaction energy per volume as in the standard Proctor compaction test. Penetration testing was performed in the California bearing ratio test using a plunger with a cross-sectional area of 19.35 cm^2.

3. RESULTS AND DISCUSSION

3.1 Atterberg Limits

Figure 2 and Figure 3 show the results of Atterberg's Limits for the composite soil with rice husk ash (RHA) and lime, specifically in terms of liquid limit, plastic limit, and plasticity index. The Atterberg limits define the consistency and engineering properties of fine-grained soils and are used by geo-engineers to differentiate between silt and clayey soils and further classify different types of silt and clay.

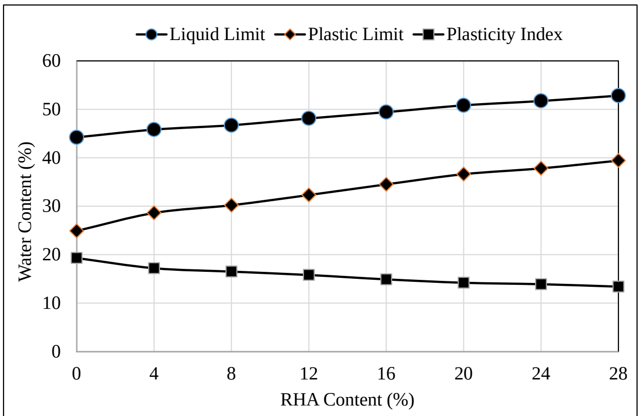

Figure 2 Variation of Atterberg limits with RHA contents

When the stabilizer content of both RHA and lime is increased, the Atterberg limits change incrementally, resulting in an increase in liquid and plastic limits. However, as the proportion of RHA and lime increases, the plasticity index decreases gradually. The author suggests that the addition of rice husk ash and lime to fine-grained cohesive soils causes flocculation, leading to a decrease in the plasticity index.

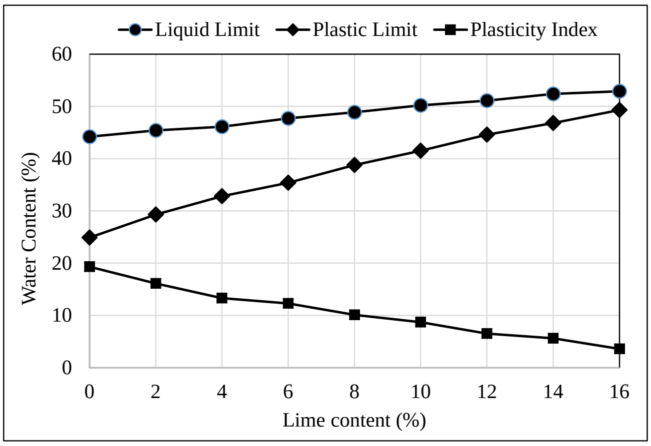

Figure 3 Variation of Atterberg limits with lime contents

The results reveal that LL for control soil was 44.2%, then it dropped to 45.8, 46.7, 48.1, 49.4, 50.8, 51.7, and 52.8% for other composite soil with 4, 8, 12, 16, 20, 24, and 28% RHA content respectively, (Figure 2). Furthermore, LL was found 45.4, 46.1, 47.7, 48.9, 50.2, 51.1, 52.4, and 52.9 for liners with 2, 4, 6, 8, 10, 12, 14, 16, and 18% lime content, respectively (Figure 3). The same increment is also observed in PL. The flocculation of rice husk ash and lime with sail causes a decrease in the plasticity index. Therefore, it was found 17.2, 16.5, 15.8, 14.9, 14.2, 13.9, and 13.4% plasticity index for the composite soil with 4, 8, 12, 16, 20, 24, and 28% RHA, respectively. On the other hand, the plasticity index was observed at 16.1, 13.3, 12.3, 10.1, 8.7, 6.5, 5.6, and 3.6% for the soil with 2, 4, 6, 8, 10, 12, 14, and 16% lime, respectively.

3.2 Compaction Test

Table 3 summarizes the results of compaction tests on soil stabilized with various proportions of RHA and lime. Over the range of contents tested, the dry density of lime-stabilized soil decreases at a slower rate. On the other hand, the maximum dry density of RHA-stabilized lateritic soil decreases steeply up to 16 percent RHA and then remains nearly constant (Table 3). These compaction characteristics are caused by the grain size distribution and the specific gravities of the soil mass and stabilizer. The stabilizers initially coat the soils, forming large aggregates that occupy larger spaces. As a result, fine-grained soils have a tendency to initially reduce dry density until the stabilizer, which tends to increase dry density, compensates for the larger spaces. Rice husk ash and lime are properties of low specific gravity and are not able to produce this effect. The reduction of maximum dry density for rice husk ash and lime is displayed in Table 3.

With the addition of RHA, the optimal moisture content rises. After reaching 16 percent RHA, the increase in water content becomes constant. The addition of lime to the soil increases the optimum moisture content in a linear fashion. The reaction of RHA and lime with soil constituents increases the optimum moisture content. Results show it was found 17.2, 18.5, 19.9, 20.2, 20.4, 20.7, and 20.9gm/cc OMC for the stabilized soil with 4, 8, 12, 16, 20, 24, and 28% rice husk ash, respectively. In addition, OMC was measured at 17.4, 18.2, 18.9, 19.5, 20.0, 20.7, 21.3, and 21.8gm/cc for the soil with 2, 4, 6, 8, 10, 12, 14, and 16% lime, respectively.

Table 3 Stabilizer effects on the compaction characteristics of soil

RHA (%)	OMC (%)	MDD (gm/cc)	Lime (%)	OMC (%)	MDD (gm/cc)
0	16	1.61	0	16	1.61
4	17.2	1.54	2	17.4	1.58
8	18.5	1.51	4	18.2	1.57
12	19.9	1.47	6	18.9	1.56
16	20.2	1.42	8	19.5	1.57
20	20.4	1.41	10	20.0	1.56
24	20.7	1.39	12	20.7	1.55
28	20.9	1.38	14	21.3	1.54
--	--	--	16	21.8	1.53

3.3 Specific Gravity

Figure 4 and Figure 5 depict the changes in specific gravity as stabilizer content increases, such as rice husk ash and lime, respectively. The term "Specific Gravity" (SG) refers to a liquid's weight or density in comparison to the density of an equal volume of water at a given temperature. The temperature used mostly for measurement is typically 39.20F (40C), which allows water to surmise its maximum density. Understanding the specific gravity of the fluids being merged is important when configuring a mixer because it affects the torque and horsepower required to properly mix your fluid. More torque would be required to achieve the desired result in applications with higher specific gravity. If specific gravity was not taken into account and a mixer was not optimized accordingly, the results would be unexpected, and motor damage and failure would be likely. From the Results, it was found 2.61, 2.57, 2.54, 2.51, 2.49, 2.47, and 2.45 specific gravity for the stabilized soil with 4, 8, 12, 16, 20, 24, and 28% rice husk ash, respectively. In addition, specific gravity was measured at 2.64, 2.62, 2.60, 2.58, 2.57, 2.56, 2.55, and 2.54 for the soil with 2, 4, 6, 8, 10, 12, 14, and 16% lime, respectively.

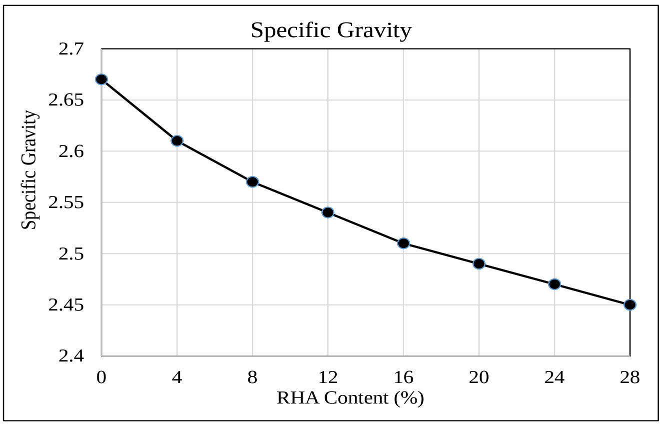

Figure 4 Variation of specific gravity with RHA contents

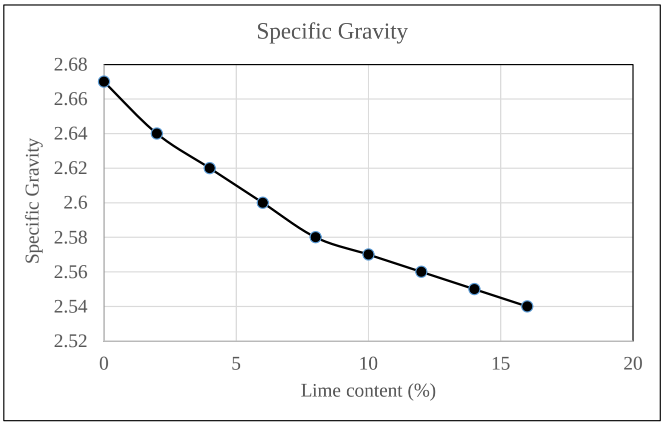

Figure 5 Variation of specific gravity with lime contents

3.4 Unconfined Compressive Strength Test

The trend of changes in unconfined compressive strength with stabilized content like RHA and lime are presented in Table 4. With increasing RHA, the unconfined compressive strength increases almost incrementally. At 20% RHA, the maximum compressive strength is 432.54 kPa, after which it begins to decrease. The addition of lime content also increases the unconfined compressive strength in stabilized specimens. At 8% lime content, the maximum compressive strength is 530.45 kPa, after which it begins to decrease. The increases in unconfined compressive strength with an escalation in stabilizer contents designate that the cohesion of the soil samples increases due to the addition of rice husk ash and lime content in stabilized soil. Stabilized soils with rice husk ash and lime have low compressive strength. The compressive strengths are underestimated here because the unconfined compression test is not appropriate for soils with larger soil particles.

Table 4 Stabilizer effects on the compaction characteristics of soil

RHA (%)	UC Strength (KPa)	Lime (%)	UC Strength (KPa)
0	201.4	0	201.4
4	254.36	2	304.11
8	311.52	4	360.23
12	380.81	6	517.82
16	428.12	8	530.45
20	432.54	10	511.37
24	421.11	12	488.35
28	401.38	14	445.22
--	--	16	440.56

The results of unconfined compressive strength tests show that all two stabilizers improved the soil significantly. This soil can be stabilized with 8% lime for sub-base materials based on the California bearing ratio. Furthermore, the soil can be stabilized with 20% RHA for sub-base materials based.

3.4 California Bearing Ratio

The nature of the changes in CBR value with different percentages of rice husk ash and lime is shown in Table 5. California bearing ratio increases gradually from 0% to 16% RHA content, with the maximum value obtained at 20% RHA. CBR values tend to decrease after 20 percent RHA. In the particular circumstance of lime, the maximum California bearing ratio is calculated at 8% lime before decreasing. The results of California bearing ratio tests show that all two stabilizers improved the soil significantly. This soil can be stabilized with 8% lime for sub-base materials based on the California bearing ratio. In addition, the soil can be stabilized with 20% RHA for sub-base materials based.

Table 5 Stabilizer effects on the compaction characteristics of soil

RHA (%)	CBR (%)	Lime (%)	CBR (%)
0	6.94	0	6.94
4	11.25	2	26.33
8	23.47	4	61.87
12	42,96	6	63.29
16	78.91	8	65.98
20	79.23	10	56.37
24	71.19	12	49.76
28	59.67	14	44.24
--	--	16	42.99

3.5. Comparison with Other Studies

Table 6 appears to show the results of a comparison between a present study and a previous study in terms of the effect of adding different percentages of lime to the soil on the unconfined compressive (UC) strength of the soil.

The data suggest that the addition of lime to the soil in the present study resulted in higher UC strength values compared to the previous study. For example, adding 6% lime to the soil in the present study resulted in a UC strength of 517.82 KPa, whereas the same percentage of lime in the previous study resulted in a lower UC strength of 251 KPa. But the previous study stated that, with the increase of Ordinary Portland Cement (OPC) in the soil sample, the UC strength also increased. In this study, the UC strength also increased due to increase of lime content in soil sample.

Table 6 Comparison with other studies

Present study		Previous study [13]	
Lime (%)	UC Strength (KPa)	OPC (%)	UC Strength (KPa)
0	201.4	0	82
2	304.11	3	103
4	360.23	5	181
6	517.82	7	251
8	530.45	--	--
10	511.37	--	--
12	488.35	--	--
14	445.22	--	--
16	440.56	--	--

4. CONCLUSIONS

The following findings can be drawn based on the results of the tests on these stabilized soils:

- Increases in stabilizer contents directly increase liquid and plastic limits. Besides, the plasticity index decreases gradually with an increase in the proportion of rice husk ash and lime.
- The reduction in maximum dry density is from 1.61 gm/cc to 1.38 gm/cc, and the increment in optimum moisture content is from 16% to 20.9% for the addition of 28% rice husk ash with the soils. In addition, the same reduction and increment are also observed for the lime stabilizer.
- The potentials of RHA in soil stabilization are considerable compared to lime.
- According to the results of both the California Bearing Ratio test and the Unconfined Compressive Strength test, it is recommended to use 8% lime and 20% rice husk ash to stabilize this soil for sub-base materials.

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