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Stabilization of soft soil with rice husk and coconut fibre

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Abstract. This study focuses on the stabilization of soft soil, which has a low bearing capacity and is prone to significant deformations and high moisture content. Soft soil is one type of soil with a poor bearing capacity, and when loaded, it significantly reduces the likelihood of a nonuniform decline. The aim of this study is to determine the physical properties of soft soil and to determine the mechanical properties of soft soil mixture with rice husk and coconut fibre with curing days of 14, and 21 days. The significance of this study lies in its contribution to establish a strong foundation and stabilizing soil, which plays a crucial role in constructing solid and durable structures, ensuring their stability and longevity. By utilizing rice husk and coconut fiber as soil stabilizers, the study also addresses environmental concerns by substituting natural resources with unwanted or discarded materials. Furthermore, this approach offers an economically viable solution for soft soil stabilization. The study involved two types of soil samples. The first type served as a control sample without any rice husk or coconut fiber, while the second type included rice husk and coconut fiber. The second type of sample was further divided into two ratios, with curing durations of 14 days and 21 days. A soil sample was collected from a paddy field in Sg Balang, Muar, Johor. The rice husk was burned at temperatures below 800 °C, resulting in silica-rich ash. The physical and mechanical properties of the soft soil mixture with rice husk and coconut fiber were determined through various tests. The preliminary tests were conducted to assess the physical qualities of the soil, including the Atterberg Limit Method, Compaction Test, and Direct Shear Test. The results showed that the Liquid Limit (LL) was 20.1%, with moisture content ranging from 15.56% to 27.38%. The compaction test indicated that a ratio of 2 with a 21-day curing duration achieved a maximum dry density of 0.56 and an optimum moisture content of 47.8%. The Direct Shear Test demonstrated that a ratio of 1 with a 21-day curing period exhibited the highest shear strength and shear stress at 3.25 kg and 10.45 kPa, respectively. Moreover, the cohesive and friction angle increased with longer curing days, with the mixture of ratio 1 and 21 days showing the highest values at 4.7 kPa and 35.03°, respectively. In summary, the presence of rice hush and coconut fibre significantly improve the soft soil stabilization. The study suggests that further research should explore longer curing periods of 30 days and 60 days to enhance shear strength.

1. Introduction

Soil is useful as a construction material in various Civil Engineering projects, and additionally, soil acts as a support for the building's foundation. Soil is a material that significantly affects the stability of building structures, highway pavements, tunnels, and dams. However, not all soils can be used directly in Civil Engineering projects. Some soils have a low bearing capacity, exhibit significant deformations or changes, and have a high moisture content, which affects the soil's consistency. Soft soil is one type of soil with a poor bearing capacity, and when loaded, it significantly reduces the likelihood of a non-uniform decline. To alleviate or mitigate the issue of construction on soft soil, soil treatment is necessary. Stabilisation is the most often used way of improving soft soil. Soil stabilisation is the process of altering or improving the technical features of the soil to satisfy specific technical criteria.

This study aimed to determine soft soil stabilisation with rice husk ash and coconut fibre, focusing on the soil's physical and mechanical properties. Therefore, the aim of this study is to determine the physical and mechanical properties of the soil with curing days of 14 and 21 days. Rice husk ash is a good medium for soft soil stabilisation [2]. It is also an economic way for soft soil stabilisation. The stabilised soil materials have a higher strength, lower permeability, and lower compressibility than the native soil. In this study, an experiment was conducted on lateritic soils stabilized with lime and rice husk ash. According to the AASHTO soil classification scheme, the index property tests classed the soils as (A-7-6) based on their index properties. Index and geotechnical property tests conducted on the soil having a combination of lime and rice husk ash revealed a considerable enhancement in attributes. The shear strength of soil is assessed and measured through an experimental relation between cohesion and friction angle. The understanding of the physical relationship between the soil and shear strength is essential for engineering judgment and it should be exercised in interpreting the test results. The liquid limit test is conducted to determine the moisture content of the undisturbed soil sample. Then, the compaction test is used to find the optimum moisture content of the soil and it is related to the direct shear test which the moisture content can affect the result of the cohesion and friction angle of the soil.

2. Assessment of soft soil stabilisation

Soil stabilisation is the process of altering soils in order to improve their physical qualities [1]. Stabilisation can improve the shear strength of a soil and regulate the shrink-swell qualities of a soil, hence enhancing the subgrade's load-bearing capacity to sustain pavements and foundations [3]. Soil stabilisation can be used on roads, parking lots, site development projects, airports, and many other places where the subsoil is unsuitable for construction. From expansive clays to granular solids, stabilisation can be utilized to treat a vast array of subgrade materials. This method employs a wide range of additives, including lime, fly ash, and Portland cement. Soil stabilisation serves a particular purpose.

The initial is strength enhancement. This strengthens the existing soil, so increasing its load-bearing ability. The second function is dust suppression. This is done to minimize or reduce dust caused by the operation of equipment and aircraft in dry weather or desert environments. The third function of waterproofing is to retain the natural or manufactured strength of soil by limiting the infiltration of surface water. Cement, lime, bituminous products, calcium chloride, Palm Oil Fuel Ash, Shredded Rubber Tires, and others are utilized as soil stability additives. This research highlights the use of rice husk ash and coconut fibre as additives mixture to the soil to enhance the mechanical properties of the oil with curing days of 14 and 21 days.

3. Materials and methods

Every laboratory test was completed in accordance with the British Standard (BS) specification. The suitability tests were performed in the laboratory on the mixture of soil, rice husk, and coconut fiber to ensure that the soil could be used for stabilization with the appropriate amount of rice husk and coconut fiber.

3.1. Materials

An experiment on soil-lime-RHA (rice husk ash) stabilization reveals the effect of RHA and lime on the soil's engineering qualities [6]. A significant reduction in pliability and effect on strength and CBR of clayey soil with a strong expansive nature will be discovered (PI = 41.25 percent). Then, previous research has demonstrated that fibre reinforcement can boost peak shear strength, minimize post-peak decreases in shear resistance, and reduce soil stiffness. Most of the experimental research utilized granular soils. Powdered rice husk ash with finer particles than OPC improves concrete qualities because higher replacement amounts result in lower water absorption values, and the inclusion of RHA increases compressive strength [10]. The selection of the materials is according to the past literature review. and the materials are listed below:

- Soil
- Rice Husk
- Coconut Fibre

3.2. Sample preparation

The test was divided into two sample which is Ratio 1 and Ratio 2 for compaction and direct shear box test. Each of the sample also was divided into different curing days which are 14 days and 21 days. The samples of the study are shown in Figure 1. The sample ratio preparation for the experiment is displayed in Table 1 and Table 2.

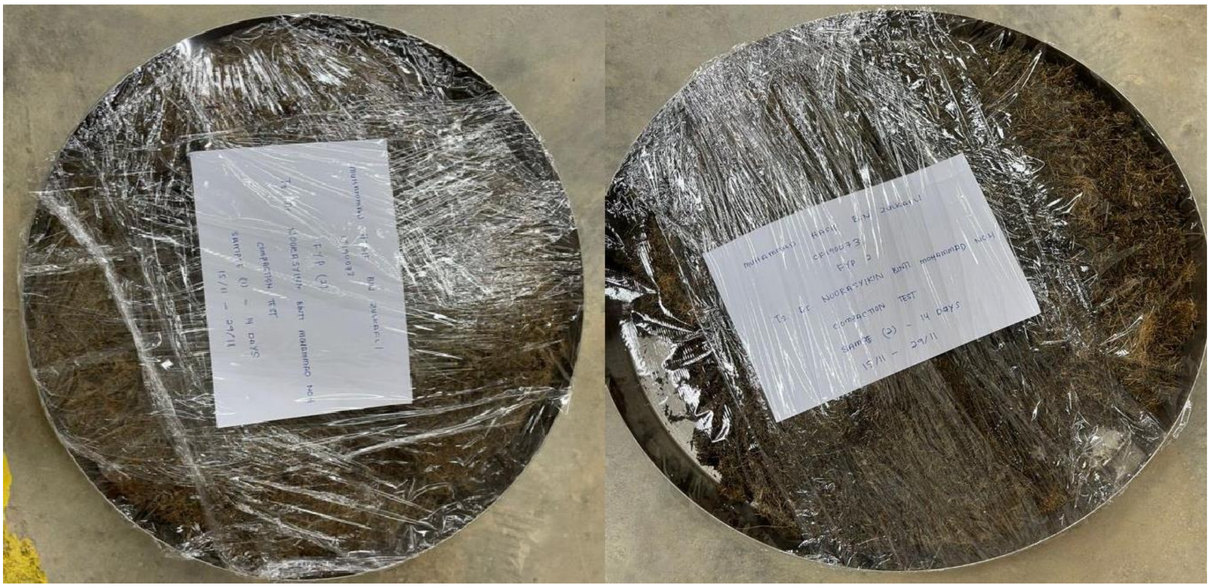

Figure 1. Sample of study.

Table 1. Sample preparation for a compaction test.

Sample 1			
Soil (gram)	Rice Husk (gram)	Coconut Fibre (gram)	Water Content (gram)
800	600	400	100
Sample 2			
Soil (gram)	Rice Husk (gram)	Coconut Fibre (gram)	Water Content (gram)
1000	600	200	200

Table 2. Sample preparation for a direct shear box test.

Soil (gram)	Rice Husk (gram)	Coconut Fibre (gram)	Water Content (gram)
Sample 1			
20	20	5	5
20	20	5	5
20	20	5	5
Sample 2			
27.5	15	2.5	5
27.5	15	2.5	5
27.5	15	2.5	5

3.3 Physical and mechanical properties test

The physical and mechanical properties test has been carried out such as Atterberg limit, compaction and direct shear box. All tests were conducted based on BS and ASTM at Geotechnics Laboratory.

4. Result and discussion

The results and discussion section presents data and analysis of the study. This research aimed to determine the physical and mechanical properties of the soil with the additives of rice husk and coconut fibre. All results and data were presented in the form of a table and graph.

4.1. Liquid limit test

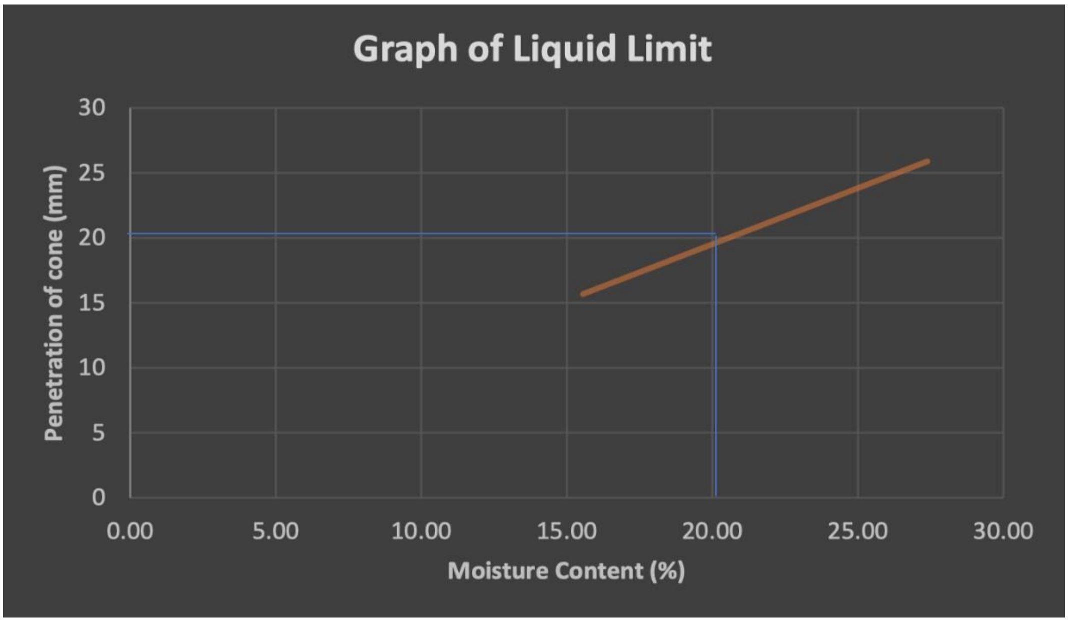

Figure 2. Graph of liquid limit.

This graph in Figure 2 illustrates the Liquid Limit (LL) result which is 20.1% at a penetration of 20mm at the greatest moisture content is 27.38% and the lowest is 15.56%. There is also prior research where the liquid limit of sand must be less than 20%. In addition, the growing Liquid Limit value is determined by the organic content and moisture content of the mixture [5].

4.2. Compaction test

The standard Proctor compaction test was conducted to determine the maximum dry density (pd,max) and optimum moisture content (OMC) of the control sample and the mixture sample. The technique employed is a conventional proctor compaction test with rammer 2.5 kg as defined in BS 1377: Part 4. Tables 3,4,5,6 and 7 show the data and the result of the maximum dry density (pd,max) and optimum moisture content (OMC) for the control sample, ratio 1 and ratio 2 mixtures with curing days of 14 and 21 days.

Table 3. Compaction test of control sample.

Mass of Mould (gram)	W1	4400
Mass of Mould + Compacted Soil (gram)	W2	5600
Volume of Mould	V	2124
Weight of wet compacted soil (gram)	W3 = W2 - W1	1200
Wet Unit Weight (g/cm3)	Y	0.56
Dry Unit Weight (g/cm3)	Yd = y/(1+w/100)	0.36
Weight of can (gram)	W4	58.3
Weight of can + Wet Soil (gram)	W5	77.0
Weight of can + Dry Soil (gram)	W6	70.3
Weight of water (gram)	Ww	6.7
Weight of soil solids (gram)	Ws	12.0
Moisture Content (%)	w = (Ww/Ws) x 100	55.8
Dry Density (g/cm³)		**0.36**

The table indicates that the dry density of the soil sample is 0.36 g/cm 3 , and the moisture content of the soil sample without any mixes is 55.8%

Table 4. Compaction test ratio 1 (14 days).

Mass of Mould (gram)	W1	4400
Mass of Mould + Compacted Soil (gram)	W2	5500
Volume of Mould	V	2124
Weight of wet compacted soil (gram)	W3 = W2 - W1	1100
Wet Unit Weight (g/cm3)	Y	0.52
Dry Unit Weight (g/cm3)	Yd = y/(1+w/100)	0.40
Weight of can (gram)	W4	58.3
Weight of can + Wet Soil (gram)	W5	78.4
Weight of can + Dry Soil (gram)	W6	71.9
Weight of water (gram)	Ww	6.5
Weight of soil solids (gram)	Ws	13.6
Moisture Content (%)	w = (Ww/Ws) x 100	47.8
Dry Density (g/cm³)		**0.40**

The table shows that the moisture content of the ratio with 14 days of curing is 47.8% and the dry density of the soil sample is 0.40 g/cm^3.

Table 5. Compaction test ratio 2 (14 days).

Mass of Mould (gram)	W1	4400
Mass of Mould + Compacted Soil (gram)	W2	6000
Volume of Mould	V	2124
Weight of wet compacted soil (gram)	W3 = W2 - W1	1600
Wet Unit Weight (g/cm3)	Y	0.75
Dry Unit Weight (g/cm3)	Yd = y/(1+w/100)	0.54
Weight of can (gram)	W4	58.3
Weight of can + Wet Soil (gram)	W5	88.4
Weight of can + Dry Soil (gram)	W6	79.8
Weight of water (gram)	Ww	8.6
Weight of soil solids (gram)	Ws	21.5
Moisture Content (%)	w = (Ww/Ws) x 100	40.0
Dry Density (g/cm³)		**0.54**

The data shows that the dry density of the mixture is 0.54 g/cm^3 and the moisture content of the mixture is at 40%. This mixture has higher dry density compared to the ratio 1 for 14 days of curing time.

Table 6. Compaction test ratio 1 (21 days).

Mass of Mould (gram)	W1	4400
Mass of Mould + Compacted Soil (gram)	W2	6150
Volume of Mould	V	2124
Weight of wet compacted soil (gram)	W3 = W2 - W1	1750
Wet Unit Weight (g/cm3)	Y	0.82
Dry Unit Weight (g/cm3)	Yd = y/(1+w/100)	0.56
Weight of can (gram)	W4	58.3
Weight of can + Wet Soil (gram)	W5	81.3
Weight of can + Dry Soil (gram)	W6	75.9
Weight of water (gram)	Ww	5.4
Weight of soil solids (gram)	Ws	17.6
Moisture Content (%)	w = (Ww/Ws) x 100	30.7
Dry Density (g/cm³)		**0.56**

The table shows that the moisture content of the ratio with 21 days of curing is 30.7% and the dry density of the soil sample is 0.56 g/cm^3. There is a little reduction in the dry density of the mixture during the 21 days of curing time compared to the 14 days of curing period.

Table 7. Compaction test ratio 2 (21 days).

Mass of Mould (gram)	W1	4400
Mass of Mould + Compacted Soil (gram)	W2	6000
Volume of Mould	V	2124
Weight of wet compacted soil (gram)	W3 = W2 - W1	1600
Wet Unit Weight (g/cm3)	Y	0.75
Dry Unit Weight (g/cm3)	Yd = y/(1+w/100)	0.58
Weight of can (gram)	W4	58.3
Weight of can + Wet Soil (gram)	W5	111.11
Weight of can + Dry Soil (gram)	W6	98.9
Weight of water (gram)	Ww	12.2
Weight of soil solids (gram)	Ws	40.6
Moisture Content (%)	w = (Ww/Ws) x 100	30
Dry Density (g/cm³)		**0.58**

The dry density and moisture content are 0.58 $g/cm^3$and 30% respectively. It may be deduced from the compaction test that the optimal combination is ratio 2 with 21 days of curing duration. This is because it has the highest dry density with an optimum moisture content of 30%.

4.3. Direct Shear Test

Figure 3, 4 & 5, show the graph of shear stress vs normal stress. The straight-line graph was generated to determine the angle of friction. From the findings, the shear strength was computed.

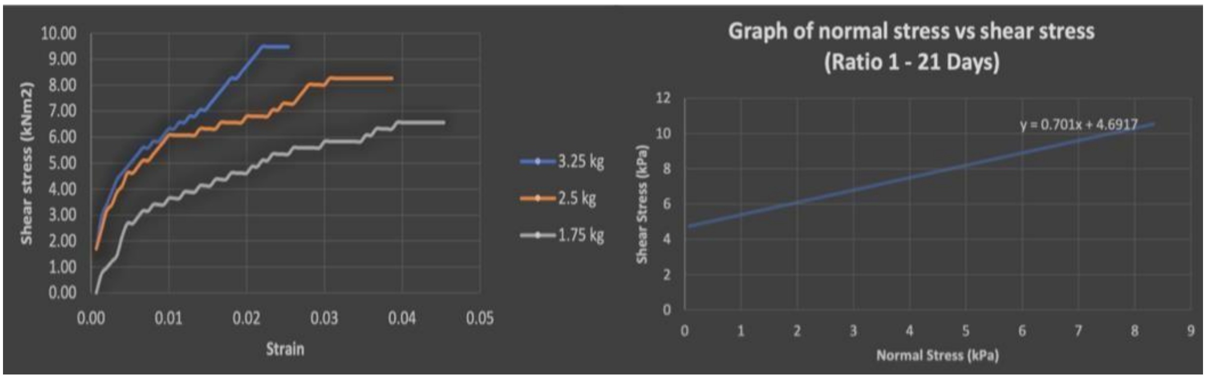

Figure 3. Graph of shear stress against normal stress ratio for controlled sample.

According to the graph, the three different loads exhibit essentially identical patterns, and the stress rises as the loads rise. Due to the gradient of the plots, the load of 3.25kg has the highest shear strength, followed by 2.50 kg and 1.75 kg. The cohesion is 4.7 kPa since the straight line's interception does not pass through zero. The sample has a friction angle of 23.3° for control sample.

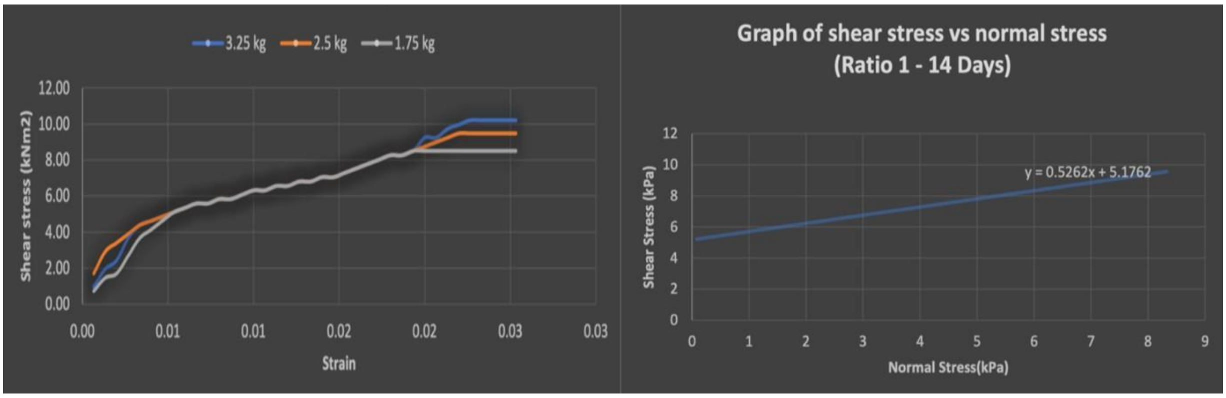

Figure 4. Graph of shear stress against normal stress ratio for ratio 1 (14 days).

Due to the gradient of the plots, the load of 3.25 kg has the highest shear strength, followed by 2.5 kg and 1.75 kg. The cohesion is 5.17 kPa since the straight line's interception does not pass through zero. The sample has a friction angle of 24.3° for a ratio of 1 after 14 days of curing.

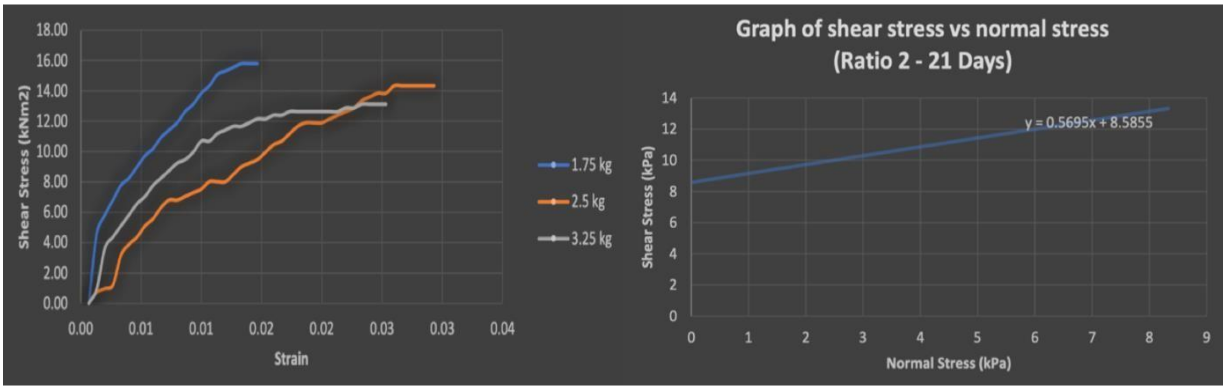

Figure 5. Graph of shear stress against normal stress ratio for ratio 2 (21 days).

Due to the gradient of the plots, the load of 3.25 kg has the highest shear strength, followed by 2.5 kg and 1.75 kg. Cohesion obtained is about 8.59 kPa, due to the straight-line intersection does not pass through zero. After 21 days of curing, the sample had a 35.05° angle of friction for the ratio 2.

4.4. Summary Result

The summarized results from the graphs obtained in subsections 4.2 and 4.3 are presented in Table 8. The table provides a concise overview of the key findings related to the mechanical properties of the soil samples with different ratios and curing durations.

Table 8. Summary result

Curing (Days)	Ratio	Compaction Test		Direct Shear Test		
		Maximum Dry Density, ρd,max (g/cm^3)	Optimum Moisture Content, OMC (%)	Shear Stress, τ (kPa)	Cohesion, c (kPa)	Friction angle, ∅ (º)
14	1	0.40	47.8	10.21	5.17	24.3
	2	0.54	40.0	10.45	7.32	27.75
21	1	0.56	30.7	13.13	7.70	29.66
	2	0.58	30.0	15.80	8.59	35.05

From the table, the compaction test results, it was observed that the mixture with ratio 2 and a 21day curing duration achieved a maximum dry density of 0.58 and an optimum moisture content of 30.0%. The findings from the Direct Shear Test indicated that the mixture with ratio 2 and a 21-day curing period exhibited the highest shear strength and shear stress values, measuring 3.25 kg and 15.80 kNm², respectively. Additionally, the mixture with ratio 2 and a 21-day curing time demonstrated the highest cohesion and friction angle values at 8.59 kPa and 35.05°, respectively. The results show that at 21 days, with the presence of coconut fibre and rice husk these two materials able improve the bonding strength and texture of the soft soil.

5. Conclusion

In conclusion, the study was able to determine the physical properties of soft soil and determine the mechanical properties of soft soil mixture with rice husk and coconut fibre with curing days of 14, and 21 days. The experimental findings indicate that the soft soil under study has a Liquid Limit (LL) of 20.1% at a penetration of 20mm, with a range of moisture content between 15.56% and 27.38%. The compaction test revealed that the mixture with ratio 2 and a 21-day curing duration achieved the maximum dry density of 0.58 and an optimum moisture content of 30.0%. The Direct Shear Test demonstrated that the mixture with ratio 2 and a 21-day curing period exhibited the highest shear strength and shear stress 15.80 kNm² and 14.43 kNm², respectively. Moreover, the mixture of ratio 2 with a 21-day curing time exhibited the highest cohesion and friction angle at 8.59 kPa and 35.05°, respectively. It is indicated with the presence of coconut fibre and rice husk these two materials able improve the bonding strength and texture of the soft soil.To further enhance this study, future research could explore longer curing periods to evaluate the mechanical properties of the treated soil. Additionally, assessing the shear strength of the stabilized samples in a soaked state could provide valuable insights.

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