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Investigational Study on the Influence of Sisal Fiber and Rice Husk Ash in the Stabilisation of Clayey Soil

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Abstract - The process of improving and enhancing the engineering qualities of soil so that it can support large loads without failing is known as "soil stabilization" in the realm of civil engineering. The behavior of the soil was examined in the current work at various proportions following the addition of Rice Husk Ash (fixed at 15%) and sisal fiber (varying at 1.5%, 2.0%, and 2.5%; length 40 mm). Various soil properties, such as OMC, MDD, CBR value, and UCS values, were then quantified. Utilizing Sisal Fiber and Rice Husk Ash together can enhance the diverse engineering features of soil, according to the conclusion of this experimental research project. Laboratory tests such Atterberg's Limits, Specific Gravity, Particle Size Distribution, Standard Proctor test, Unconfined Compressive Strength (UCS), and California Bearing Ratio (CBR) were carried out to examine the engineering qualities of the soil and its mixtures. The results showed that the engineering qualities of clayey soil were significantly enhanced by the addition of Sisal Fiber and Rice Husk Ash. As a result, Sisal Fiber and Rice Husk Ash may act as soil stabilizing agents, making clayey soil a better choice for building foundations. All testing were carried out in accordance with Indian standards regulations.

***Key Words*:** Compaction test, CBR, UCS, Rice Husk Ash, Sisal Fiber

INTRODUCTION

When exposed to water, expansive soils exhibit a significant inclination to inflate and shrink and lose strength. These soils show significant volume fluctuations, great compressibility, and acute sensitivity to variations in water content. This type of exceptionally flexible soil might develop fractures that could harm construction work done on top of it. About 20% of India's land area, or the entire Deccan Plateau, is covered by expansive soil. Their major colors are reddish brown and black, and their layer thicknesses range from 0.5 to 10 meters below the surface. The expansive soil may expand and cause the buildings built on top of it to elevate because of its inclination to undergo volume changes when exposed to water through rainfall or the activity of the water table's capillaries. Therefore, before these soils can be used for construction projects, they must first be fully stabilized in order to increase their low bearing capacity.

Approximately 46% of India's total geographical area is covered by alluvial soil, which is the most significant type of soil in our country. These soils have swelling tendencies and high water absorption due to the cohesive nature of clay, which can produce problems such soil bulging, low bearing strength, and the possibility of foundation fractures.

2. Literature Review

Kumar et al. (2023)

This study aims to determine how the mixture of sa wdust ash and rice husk ash affects the electrical pr operties of black cotton. For all mixed models, diffe rent concentrations of rice husk ash of 0, 3, 6, 9, 12 and 15% (based on the weight of black soil) were a dded to the soil compared to sawdust ash at 6% by weight of the soil. cotton soil. To evaluate the electr ical properties of soils and their mixtures, tests such as Attenberg Limit, Specific Gravity, Particle Size Distribution, Standard Proctor Test, Unconstrained Compressive Strength (UCS) and California Bearin g Ratio (CBR) are performed. The results showed th at the addition of 9% wheat hull and 6% wood ash g reatly improved the electrical properties of black cot ton.

Vishal Kumar et al., (2022) In the field of civil engineering, stabilization of soil is a procedure to improve and enhance the engineering properties of soil in such a manner that it can withstand heavy loads without any failure. In current work, the behaviour of soil after adding the rice husk ash (fixed proportion 10%) and sisal fibre (varying proportion 0.5%, 0.75% and 1%; varying length 20 mm and 40mm) was studied at different proportions and then different soil properties like, OMC, MDD, CBR value and UCS values were determined.

Chandrakaran et al. (2021) The studies used soil that had only been treated with fly ash and nylon fiber. First, the methods used to determine the ideal fly ash that may be employed in untreated soil. In addition, different amounts of nylon fiber (0.25 and 0.5) were applied at different fly ash percentages (10, 20, 30 and 40), and the ideal was discovered. To determine the optimal percentage, a supervised test was performed and strength was measured usin g a compressive strength test. The optimum nylon f iber and fly ash (from heavy soil) are 0.25 percent and 20 percent, respectively. The effect of positive percentage on the compressive strength and plastic properties of cultivated soil was tested at applicatio n periods of 1 day, 7 days and 28 days. This study shows that the strength of the soil stabilized with n ylon fibers and fly ash increases, and the soil tillag e strength also increases in the case of the combina tion of fly ash and nylon fibers.

Karim et al. (2018)

The main purpose of this study is to stabilize clay sa mples by mixing sawdust ash (SDA) at different co ncentrations (0%, 2%, 4%, 6%, 8% and 10% of dry soil weight). Studies have shown that the presence o f clay causes the liquid limit and plasticity index of the soil affecting the soil. The addition of sawdust t o fine clay improves the bulk and strength of the soi l, as demonstrated by a decrease in specific and max imum dry density (MDD) as well as a decrease in c ompressibility (Ccan and Cr) and an increase in SD A. contents. Both the observed moisture content (O MC) and the undrained shear strength (cu) increase d with increasing SDA concentration.

Sharanakumar et al., (2018) The sisal fiber was collected from Tokyo Engineering Corporation Private Limited, Coimbatore (Tamilnadu).Soil stabilization is done with the addition of sisal fiber with varying percentages of sisal fiber are 0.2%, 0.5%, 0.9% and 1.2% with varying lengths of sisal fiber are 3cm, 3.2cm and 3.4cm length at the interval of 0.2cm.For knowing the properties of soil laboratory tests are to be done. They are Atterberg’s limits, Light compaction test, unconfined compressive strength test, Specific gravity test, California bearing ratio test, Moisture content test and Sieve analysis test.

Okonta et al. (2018)

At dry mass concentrations of 0%, 0.25%, 0.5%, 0.75%, and 1%, sisal fibers measuring 25 mm were added to stabilized soil. By applying pre-compression forces to soil specimens made of fiber composite and without reinforcement, the strength mobilized by the unprecompressed specimens was increased to 10% and 20%, respectively. The conditioned specimens were then given permission to continue curing under the same conditions after 4 hours, 8 hours, and 24 hours of accelerated curing at 40 °C. Through a series of unconfined compression tests, the fully cured composites' 7-day strength was assessed. The findings revealed that specimens with a 0.75% unprecompressed fiber content mobilized an optimum strength of 3.5 MPa. Pre-compression with 20% UCS produced the strongest material with a strength of 3.04 MPa, whereas pre-compression with 10% UCS produced the strongest material at a strength of 2.8 MPa at 0.25% fiber content.

Shawl et al. (2017)

The major purpose of the article was to investigate the stability of clayey soil utilizing lime, sawdust ash, and other components. The Atterberg Limits, the compaction features, the UCC of the parent soil, and the soil treated with sawdust, ash, and lime were all discovered. Every exam was passed, at least by Indian standards. In order to stabilize soil for a range of building purposes, industrial wastes, such as sawdust ash, can be used. But this study demonstrates categorically that when an activator, such as lime, is added to the sawdust ash, the results are rather positive.

Rokade et al. (2017)

Three sets of testing were used to establish the soil's CBR. Tests were done on BC soil that had different amounts of fly ash mixed in, ranging from 10% to 40%, with 20% turning out to be the optimum amount. Then, nylon fiber was used with aspect ratios (length/diameter) of 20, 40, 60, and 80. Fiber concentrations ranged from 0.25 to 1.5 percent with a 0.25 percent interval, with 0.7 percent of fiber content being deemed optimal based on MDD and maximum CBR value.

Mahesh et al. (2016)

Soil stabilization is employed in earthen buildings to raise the shear strength of the soil mass and decrease its permeability and compressibility. To increase the bearing capacity of foundation soils, stability of the soil is necessary. Stabilization's primary objective is to enhance the existing soils, allowing for the construction of new roads and airports. In comparison to the other proportions, the CBR value is high at 10% lime + 1.5% fiber. The CBR value for soil with 10% lime and soil with 40% lime is same. CBR steadily rises as fiber content rises by up to 2% (soil + 5% lime).

Tiwari et al. (2016)

They looked at how fly ash and nylon fiber stabilized black cotton soil. They employed various percentages of fly ash in their investigation, including 10%, 20%, 30%, and 40%. Their ideal value was 20%. Then, using various values such as 0.25%, 0.50%, 0.75%, 1%, and 1.5%, they computed the nylon fiber's optimal value. From which it follows that 0.75 percent nylon fiber is ideal. The soil with 20% fly ash + 0.75 percent fiber had the greatest CBR value of all the measurements. The largest mix fraction was also seen in the MDD.

Kumar R. et al. (2014) studied the effect of sisal fibers on the UCS value of bentonite. He reported that there can be an increase in the UCS value of bentonite by adding lime, phosphogypsum and sisal fibers. The highest UCS value was obtained at 8% lime, 8% phosphogypsum and 1% sisal fibers. UCS value increased with increment in fiber from 0.5 to 2% fiber.

Phanikumara et al. (2013)

This study examines how remolded expanding clay specimens reinforced with nylon fiber that has been scattered randomly swell and solidify. The nylon fiber's (l) length in this instance ranged from 15 to 20 mm. The aspect ratios of the employed fibers, which had a 1mm diameter, were 15 and 20, respectively.

Using the dry weight of the soil, the fibre content (fc) was changed to 0%, 0.05%, 0.1%, 0.15%, 0.2%, 0.25%, and 0.3%. According to the findings of their investigation, increasing the fiber content (fc) for a specific fiber length resulted in a decrease in both the vertical swelling pressure and the swell potential (S %). Aside from fiber length, secondary compression decreased.

Manjunath K.R. et al. (2013) studied the effect of sisal fiber on compaction and strength characteristics of black cotton soil treated with lime. They reported that for a particular fiber percentage, the MDD of stabilized soil increases and OMC decreases. The maximum dry density and OMC of sisal fiber reinforced soil increased with 3% lime. 3% of lime content and 0.75% sisal fiber were considered as optimum percentage for black cotton soil to increase the California bearing ratio value.

3. Materials

3.1 SOIL

Source of soil

In order to remove any moisture from the soil, it is oven dried for 24 hours before to usage. First, virgin soil devoid of any admixtures is evaluated for its qualities and strength, and then it is evaluated after the addition of different ratios of Rice Husk Ash and Sisal Fiber.

Table no. 1 Properties of soil used in the study

S.No.	Properties	Result
1.	Liquid limit (%)	46
2.	Plastic limit (%)	24
3.	Plasticity Index (%)	22
4.	Specific Gravity	2.65
5.	Maximum Dry Density (KN/m³)	17.85
6.	Optimum Moisture Content (%)	13.6
7.	Soil Classification	CI (Intermediate Compressive Clay)
8.	CBR (%) (soaked)	3.5
9.	CBR (%) (Unsoaked)	5.6
9.	UCS (kN/m²)	330

3.2 Rice Husk ASH

The husk of the rice Burning rice husk, a byproduct of paddy rice milling, results in ash. For this study endeavor, RHA was obtained from adjacent mills.

Table 2: RHA physical and chemical characteristics

S. No	Rice husk ash (RHA)	
	Index Property	**Index Value**
1	Water content (W)	83.3 %
2	Specific gravity (G)	2.0
3	SiO_3	81.2 %
4	Al_2O_3	6.01 %
5	Fe_2O_3	0.08 %
6	CaO	0.75 %
7	MgO	0.91 %
8	SO_3	0.42 %
9	Na_2O	0.13 %
10	K_2O	2.56 %
11	P_2O_3	6.1 %

3.3 SISAL FIBRE

Source of sisal fiber

The sisal fiber used in this study was obtained from Jindaram Exports, Sirsa. Sisal is a natural fiber having greater tensile strength and can be used as an effective reinforcing material in soil stabilization. Sisal Fiber length 40mm is used in this study. The properties and composition of sisal fiber are discussed in table no. 3 and 4

Table 3:- Properties of Sisal Fiber

S. No	Property	Value
1	Colour	White
2	Specific Gravity (Kg/m^3)	1370
3	Water Absorption (%)	110
4	Length of fiber (mm)	30
5	Diameter of sisal fiber (mm)	0.2
4	Tensile Strength(MPa)	347
5	Modulus of elasticity (GPa)	15

Table 4:- Chemical Composition of Sisal Fiber

S .No	Component	Percentage
1	Cellulose	71.5
2	Hemicelluloses	18.1
3	Lignin	5.9
4	Pectin	2.3
5	Waxes	0.5
6	Water Soluble Matter	1.7

4. EXPERIMENTAL RESULTS

4.1 STANDARD PROCTOR TEST

Table no. 5: OMC and MDD values for the mix ratios of soil, RHA, and SF

SOIL:RHA:SF	MDD (kN/m³)	OMC (%)
100:00:00	17.85	13.6
83.5:15:1.5	18.80	13.1
83:15:2.0	19.60	12.6
82.5:15:2.5	20.40	12.2

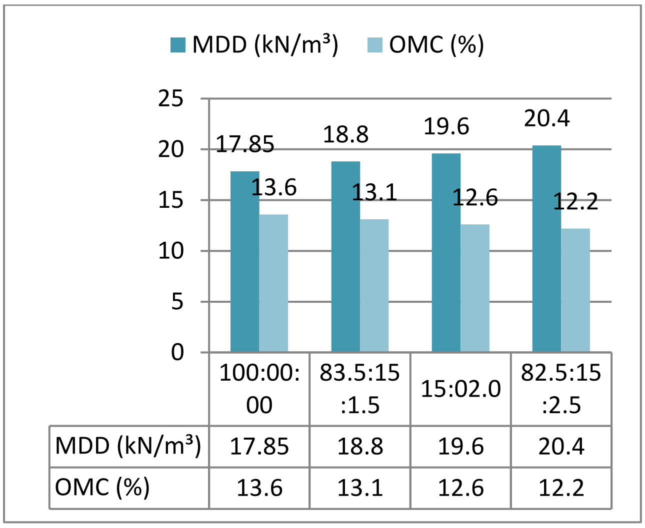

Fig:-1 Variations between MDD and OMC of RHA, SF, and soil in various amounts

Table 6: Results of UCS of Rice Husk Ash and Sisal Fiber Mix with Soil

SOIL:RHA:SF	Curing Period (Days)	UCS (kN/m^2)
100:00:00	7	330
83.5:15:1.5	7	450
83:15:2.0	7	520
82.5:15:2.5	7	580

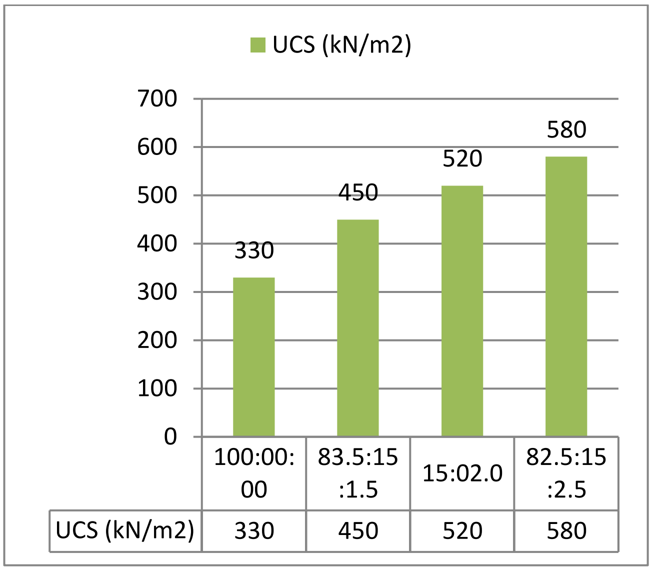

Fig:-2 Clayey soil UCS Value of Sisal Fiber and Rice Husk Ash

Table 5: Results of CBR of Rice Husk Ash and Sisal Fiber Mix with Soil

SOIL:RHA:SF	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:00:00	3.5	5.6
83.5:15:1.5	5.4	8.6
83:15:2.0	6.5	9.8
82.5:15:2.5	7.4	11.1

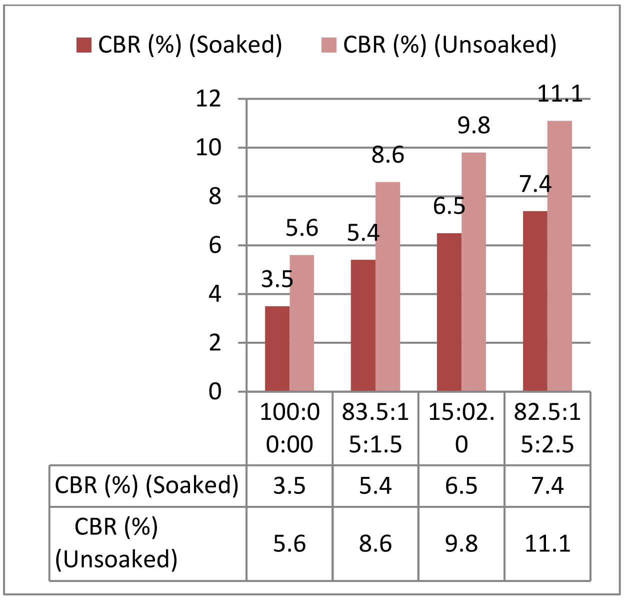

Fig:-3 CBR Percentages of Sisal Fiber, Rice Husk Ash and Clayey soil

5. DISCUSSIONS

STANDARD PROCTOR TEST:

- There is a decrease of OMC from 13.6 to 12.2% and increase of MDD from 17.85 to 20.40% when the percentages of Sisal Fiber vary from 1.5%, 2.0% and 2.5% and Rice Husk Ash is fixed at 15%.
- With Rice Husk Ash kept constant at 15% MDD increases with an addition of Sisal Fibre content in soil and Rice Husk Ash mix. The reason behind such behaviour is Rice Husk Ash is lighter in weight
- The amount of rice husk ash increases, which causes an expansion in OMC. The purpose of this pozzolanic reaction of rice husk powder with soil is to complete the cation trade response, which needs more water.
- MDD increases with an increase in the amount of Sisal Fiber in the soil and rice husk ash mixture. This action may be explained by the fact that rice husk ash is less thick and has a greater ability to absorb water since calcium oxide is present in it.

CBR TEST:

- Due to the existence of pozzolanic compounds in the soil's CaOH and RHA, the production of cementitious compounds in the soil may increase the CBR value. The earth gradually covers the gaps in the sample because there is too much rice husk ash present.
- When 20% rice husk ash is applied, the CBR value of soil, which is 3.5, increases to 1.88 times when the soil is saturated. This enhancement is brought about by the binding abilities of rice husk ash.
- The CBR value increases from 3.5 to 2.11 times when rice husk ash (15%) and Sisal Fiber (2.5%) are put to soil. The soil may gradually produce hydration compounds as a result of the interaction between the stabilizers and the fundamental soil particles, which may be what causes the increase in CBR.

UCS TEST:

- The UCS value of virgin soil greatly rises when rice husk ash content rises. After a 7-day curing period, the UCS value went from 330kN/m2 to 440kN/m2, with an increase in RHA of up to 20%. The increase in U.C.S. value due to the reaction between pozzolanic mixes in Rice Husk ash and soil-available CaOH.
- The UCS value of virgin soil is significantly raised by the addition of 15% RHA and 2.5% noticed Sisal Fiber. The figure increases from 330kN/m2 to 580kN/m2 when Sisal Fiber and RHA are included. The cause of this is the pozzolanic reactions that happen when Sisal Fiber and RHA in the curing process come into contact with water.

6. CONCLUSIONS

After conducting various laboratory tests on various samples of soil, the present study has arrived to the following conclusions:

1. The values of Optimum Moisture Content (OMC) and Maximum Dry Density obtained for the raw soil were 13.6% and 17.85kN/m^3 respectively.
2. It was concluded that the optimum moisture content increases when the rice husk ash was added however, the maximum dry density of the soil decreases after addition of RHA. Moreover, the addition of sisal fiber (4cm long) decreases the OMC value on the contrary; the MDD value keeps on increasing as the percentage of sisal fibre increases. The maximum value of MDD and OMC after addition of RHA (15%) and Sisal Fiber (2.5%) mix is 13.6% and 17.85kN/m^3 respectively.
3. It was concluded that with the addition of RHA and Sisal Fiber, the CBR value of soil mix increases when compared to the CBR value of raw soil. The CBR value increases approximately 1.88 times when 20% RHA was added when compared to the CBR value of raw soil. The maximum CBR value was attained for the soil mix (15% RHA + 2.5% sisal fiber of length 4cm) i.e. 7.4, approximately 2.11 times.
4. It was concluded that with the addition of RHA and Sisal Fiber, the UCS of soil mix increases when compared to the UCS of raw soil. The UCS increases approximately 1.33 times when 20% RHA was added when compared to the UCS of Raw soil. The experimental work on the sample having 15% RHA and 2.5% sisal fiber of length 4cm sisal fiber shows the maximum UCS i.e. 580 that is approximately 1.75 times more than the UCS of raw soil.

To conclude the present experimental research work in the gist, it is suggested to use the combination of Rice husk Ash and Sisal fiber to improve the various engineering properties of soil.

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