STABILIZATION OF CLAYEY SOIL USING MILLET HUSK ASH AND COCONUT COIR FIBRE

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***Abstract*: This study examines the geotechnical behavior of soil that is locally obtained and treated using Millet Husk Ash(MHA) and coir fiber(CF). Using four concentrations (5%, 10%, 15% and 20%) of MHA and (.5%, 1.0%, 1.5% and 2.0%)coir fiber, a number of laboratory experiments were carried out to assess the impact of these additives. These tests included the Standard Proctor, California Bearing Ratio (CBR), and Unconfined Compressive Strength (UCS) tests. To evaluate the effect of these changes on the soil's engineering qualities, the treated soil's compaction, strength, and stiffness were examined. According to the findings, adding coir fiber and Millet Husk ash significantly improves the strength, load-bearing capacity, and compaction behavior of the soil. The results demonstrate how well these materials work to enhance soil performance, offering a viable, affordable, and sustainable substitute for ground improvement—particularly in regions where soil stabilization is essential for building and infrastructure development.**

Keywords: Stabilization of soil, Millet Husk Ash, Coir Fibre, Agriculture waste, Geotechnical Properties of soil and Ecofriendly.

1. INTRODUCTION

Urban land scarcity is a recurring problem that frequently necessitates using locations with less than ideal soil conditions [1, 2]. The need for land reclamation and the usage of unstable, environmentally impaired terrain is made worse by the rapid growth of industry and urbanization. Because poor soil frequently cannot offer adequate support, these situations pose serious issues during the design, construction, and maintenance of civil engineering projects [3, 4]. The stability of the structures above is put at risk as a result of problems such excessive settlement or insufficient subgrade bearing capacity [5, 6]. Improving the soil's engineering qualities becomes essential when it is not possible to remove inappropriate dirt. When soils are not sufficiently treated, structural collapses are frequent, especially as a result of inadequate foundation design and excessive settlement. To improve soil behavior and ensure that it can sustain applied loads without experiencing significant shear failure or settlement, a variety of ground enhancement techniques have been investigated and recorded. These techniques play a critical role in safeguarding modern structures against potential failures. The main techniques for improving weak soil conditions are discussed in this text.

In soil stabilization, Millet Husk Ash demonstrates significant potential by forming cohesive matrices that reduce erosion, enhance strength, and improve load-bearing capacity. Various soil stabilization methods are employed to improve soil properties, categorized into mechanical, chemical, biological, and physical techniques. Mechanical stabilization relies on compaction and particle size alteration, while chemical stabilization uses agents like lime, cement, and polymers to enhance soil properties. Biological stabilization involves natural methods such as vegetation or microbial techniques, including Microbially Induced Calcite Precipitation (MICP), to bind soil particles and improve stability. Physical and thermal methods, like freezing or heating, are also used to alter soil properties for temporary or permanent stabilization.

Agriculture wastes such as rice husk ash, coffe husk, saw dust, wheat straw, sugarcane baggasse, and coir fibre offer sustainable alternatives to conventional stabilizers. Among these, millet husk ash stands out due to high amounts of silica and alumina, which react with calcium hydroxide in the presence of water to form calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A-H). The fine particles of MHA fill the voids between soil grains, making the soil matrix denser. As a biodegradable, renewable, and non-toxic material, millet husk ash aligns with sustainable construction practices. Its application in soil stabilization not only improves soil performance but also significantly reduces environmental impacts, establishing it as a promising solution for modern geotechnical challenges.

2. NEED AND SCOPE OF THE STUDY

2.1 NEED OF THE STUDY:

India, as one of the world's fastest-developing economies, is witnessing a rapid surge in infrastructure development. By December 31, 2022, the country had built an extensive road network exceeding 6.3 million kilometres, with steady expansion continuing across various construction domains. Despite this progress, a major challenge persists: many native soils across India exhibit poor mechanical strength, making them unsuitable for supporting long-term structural loads without treatment. While conventional stabilizers like cement and lime have been widely used to enhance soil performance, their environmental drawbacks—particularly high carbon emissions—pose sustainability concerns. This has led to a growing demand for greener alternatives. Among these, agriculture wastes have emerged as a compelling option, capable of enhancing soil stability while significantly reducing ecological footprints. Their use not only addresses the technical shortcomings of weak soils but also aligns with India’s commitment to sustainable infrastructure and environmental stewardship.

2.2 SCOPE OF THE STUDY:

This research investigates the potential of using millet husk ash (MHA) and coir fibre (CF)—both eco-friendly agricultural byproducts—as sustainable alternatives to conventional soil stabilizers such as cement and lime. Given their low environmental impact and small required dosages, MHA and CF present a promising solution for enhancing the strength, cohesion, and resilience of weak soils. The study focuses on identifying the optimum mix proportions of these materials for different types of problematic soils through a series of controlled laboratory experiments. It also examines the economic viability of this approach for real-world applications. Furthermore, the research evaluates the long-term durability and performance of soils stabilized with MHA and CF under varying environmental conditions. A detailed comparative assessment with traditional stabilization techniques is conducted to measure the relative effectiveness of these natural additives. Ultimately, this study seeks to establish MHA and CF as reliable, sustainable, and cost-efficient solutions for improving geotechnical properties in contemporary infrastructure development.

2.3 OBJECTIVES OF THE STUDY

The key objectives established for the present study are as follows:

1. To find out Atterberg’s limits of the soil and then classifying the soil as per IS code.
2. To determine the various engineering properties of soil like Optimum Moisture Content (OMC), corresponding Maximum Dry Density (MDD) and Unconfined Compressive Strength (UCS) Test and CBR test of the soil for comparing it with modified soil with Millet Husk Ash.
3. To determine the OMC, MDD, UCS & CBR on the millet husk ash treated soil with varying percentage of 5%, 10%, 15% and 20% by weight of soil.
4. To determine the OMC, MDD, UCS & CBR on the coir fibre(10mm) treated soil with varying percentage of .5%, 1%, 1.5% and 2% by weight of soil.
5. To determine the OMC, MDD, UCS & CBR on the millet husk ash (5%, 10%, 15% and 20%) + coir fibre treated soil with percentage of 1.5%by weight of soil.
6. To determine the UCS & CBR on the millet husk ash (15%) + coir fibre (20mm & 30mm) treated soil with percentage of 1.5%by weight of soil.
7. To compare the results of the tests on treated soil with virgin soil and finding out the optimum dosage of millet husk ash and coir fibre needed for the particular type of soil.

3. RESEARCH METHODOLOGY

1. To evaluate the fundamental index properties of the parent soil by conducting tests such as Atterberg limits, specific gravity determination to gain insights into its classification and behavior.

2. The Modified Proctor Test will be conducted to establish the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of the native soil, providing essential data for compaction and stability analysis.
3. Compacted specimens prepared at the Optimum Moisture Content (OMC) from the parent soil will be tested to evaluate their Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR) under both soaked and unsoaked conditions, assessing the soil's load-bearing capacity and strength characteristics.
4. The soil will be dry-mixed with 5%, 10%, 15%, and 20% millet husk ash, followed by compaction testing to determine the MDD and OMC. UCS and CBR tests (soaked and unsoaked) will then be performed at the respective OMC values.
5. The soil will be dry-mixed with .5%, 1%, 1.5%, and 2% coir fibre of length 10mm, followed by compaction testing to determine the MDD and OMC. UCS and CBR tests (soaked and unsoaked) will then be performed at the respective OMC values.
6. The soil will be dry-mixed with 5%, 10%, 15%, and 20% millet husk ash 1.5%, coir fibre of length 10mm, followed by UCS and CBR tests (soaked and unsoaked) will then be performed at the respective OMC values.
7. The soil will be dry-mixed with 15% millet husk ash 1.5%, coir fibre of length 20mm and 30mm, followed by UCS and CBR tests (soaked and unsoaked) will then be performed at the respective OMC values.
8. The optimum dosage of millet husk ash and coir fibre required for this specific type of soil will subsequently be determined by comparing the results.

4. EXPERIMENTAL DESCRIPTION

1. Soil sample and additives**:** Soil is collected from Sheikhpura district of Bihar. Millet Husk Ash is procured from local farmers.

2. Compaction Test: The purpose of this test is to determine the amount of water needed to mix with soil to achieve the maximum dry density, thereby identifying the Optimum Moisture Content (OMC) for maximum compaction. In this study, the mould used had a weight of 2250 grams and a volume of 1000 cubic centimetres. The rammer used weighed 4.90 kg and had a free-fall height of 450 mm. The soil was compacted in 5 layers of approximately equal mass, with each layer receiving 25 blows. After the compaction, a sample of soil was extracted from the mould to measure its moisture content. Using this value, the bulk density and dry density of the soil and its mixtures were calculated.

3. *California Bearing Ratio (CBR) Test*: This test, developed in 1929 by the California Division of Highways (US), calculates the ratio (expressed as a percentage) of the force required to penetrate a soil mass with a standard circular plunger (50 mm in diameter) at a rate of 1.25 mm/min, compared to the force needed for the same penetration in a standard material. The ratio is typically measured for penetrations of 2.5 mm and 5 mm. If the ratio at 5 mm is consistently higher than at 2.5 mm, the 5 mm ratio is used instead.

4. *Unconfined Compressive Strength (UCS) Test*: Unconfined Compressive Strength is the load per unit area at which a cylindrical soil specimen, without confinement, fails during an axial compression test. In this test, the specimens had a diameter of 38 mm and a height of 76 mm. Three specimens were prepared for each parental soil and its mixtures. They were loaded at a rate of 1.25 mm/min until failure or until an axial strain of 20 percent was reached. A graph of compressive stress versus strain was then plotted to determine the soil's maximum unconfined compressive strength.

5. RESULT AND DISCUSSION

5.1 ENGINEERING PROPERTIES OF SOIL:

Sl. No	Test Name	Value
1	Specific Gravity	2.51
2	Liquid Limit	42
3	Plastic Limit	24
4	Max. Dry Density	1.75
5	Optimum Moisture Content	11.4

Table 1 Engineering Properties of Soil

5.2 OPTIMUM MOISTURE AND MAXIMUM DRY DENSITY

Sl. No	OMC	MDD
1	4.8	1.56
2	5.5	1.61
3	7.0	1.70
4	9.4	1.68
5	11.4	1.75
6	13.5	1.73
7	17.6	1.65
8	21.0	1.59

Table 2 OMC and MDD of soil

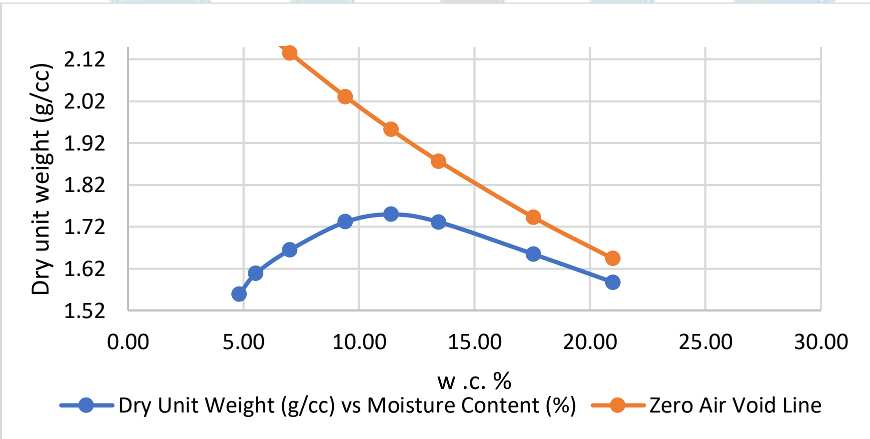

Fig 1 Compaction Behaviour of Parent Soil

5.3 Comparison of the OMC and MDD Parental Soil and Mixes

Sl. No	Soil Mix	OMC	MDD
1	Soil	11.4	1.75
2	Soil + 5%MHA	18.00	1.66
3	Soil + 10%MHA	19.48	1.61
4	Soil + 15%MHA	21.82	1.60
5	Soil + 20%MHA	24.19	1.57

Table 3 OMC and MDD of soil + MHAC

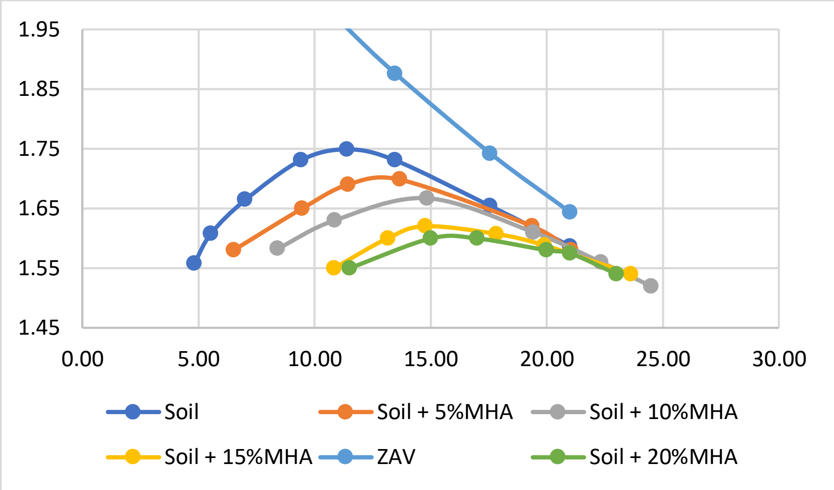

Fig 2 Compaction Behaviour of Soil+MHAC

5.4 Liquid Limit and Plastic Limit at different value of MHAC

Sl. No	Atterberg Value	Virgin soil	Soil + 5%MHA	Soil + 10%MHA	Soil + 15%MHA	Soil + 20%MHA
1	LL(%)	42	41	39	37	35
2	PL(%)	24	25	27	29	30
3	PI(%)	18	16	12	8	5

Table 4 Variation of Liquid Limit and Plastic Limit at different value of MHAC

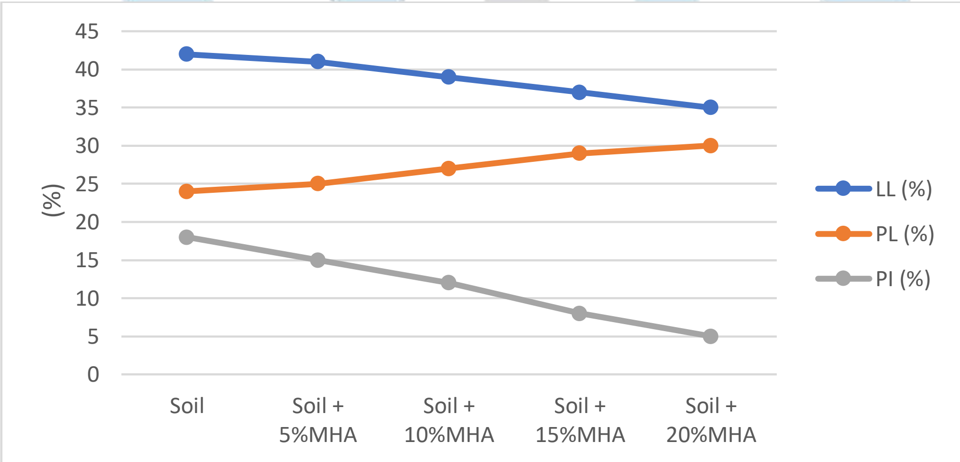

Fig 3 Variation of Liquid Limit and Plastic Limit at different value of MHAC

5.5 Performance of Soil+MHA and Soil +CF mix under CBR Test Result

Sl. No.	Soil + MHAC	CBR (Soaked)	CBR (Unsoaked)	Soil + CFC	CBR (Soaked)	CBR (Unsoaked)
1	Soil	4.53	5.84	Soil	4.53	5.84
2	Soil + 5%MHA	5.79	7.46	Soil + .5%CFC	5.84	6.74
3	Soil + 10%MHA	7.34	9.17	Soil + 1%CF	7.88	8.26
4	Soil + 15%MHA	8.56	11.73	Soil + 1.5%CFC	8.95	10.15
5	Soil + 20%MHA	8.43	11.56	Soil + 2%CFC	8.52	9.84

Table 5 Variation of CBR at different value of MHAC+CFC

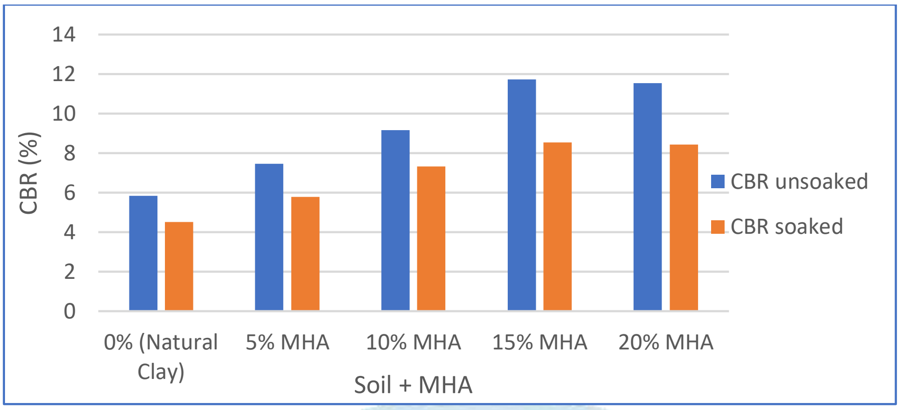

Fig 4 Variation of CBR with MHAC for Soaked and unsoaked condition

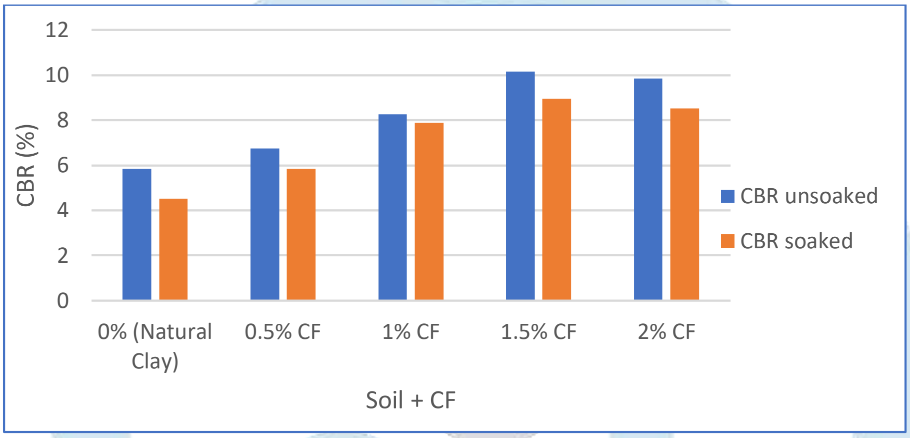

Fig 5 Variation of CBR with CFC for Soaked and Unsoaked condition

5.6 Performance of Soil+MHA, Soil +CF mix under UCS test

Sl. No.	Soil + MHAC	UCS	Soil + CFC	UCS
1	Soil	125	Soil	125
2	Soil + 5%MHA	150	Soil + .5%CF	144
3	Soil + 10%MHA	156	Soil + 1%CF	163
4	Soil + 15%MHA	169	Soil + 1.5%CF	175
5	Soil + 20%MHA	138	Soil + 2%CF	156

Table 6 Variation of UCS at different value of MHAC and CFC

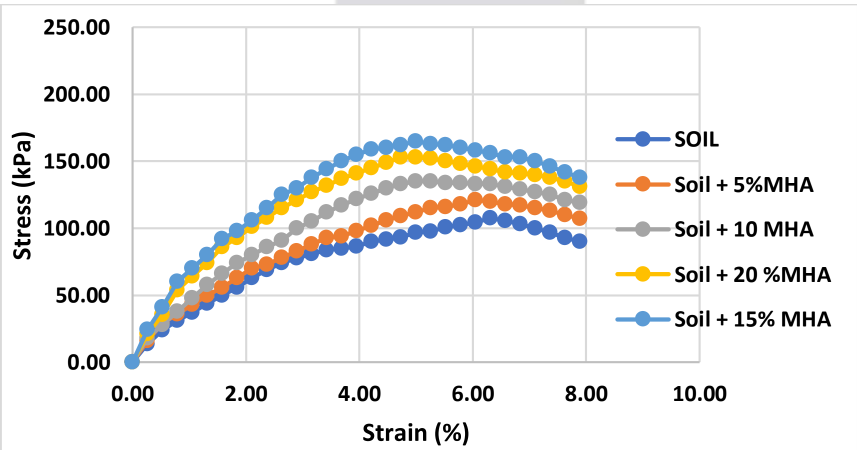

Fig 6 Variation of UCS with MHAC

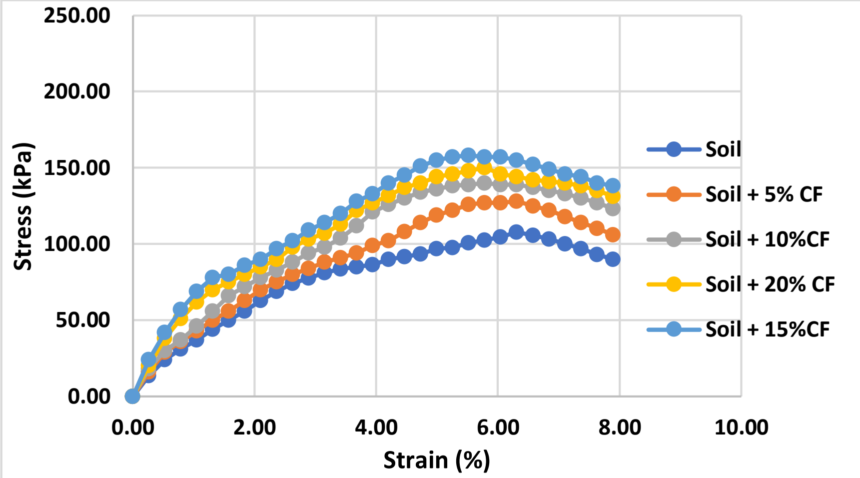

Fig 7 Variation of UCS with CFC

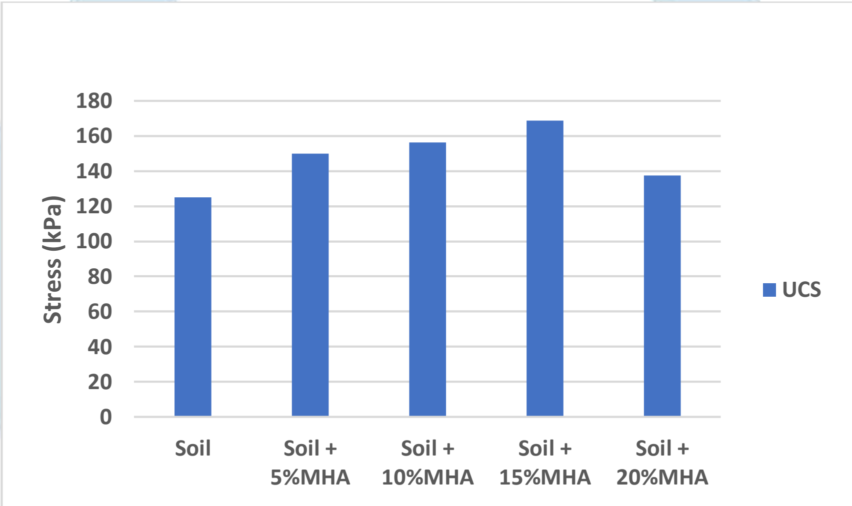

Fig 8 Variation of UCS with Soil+MHAC

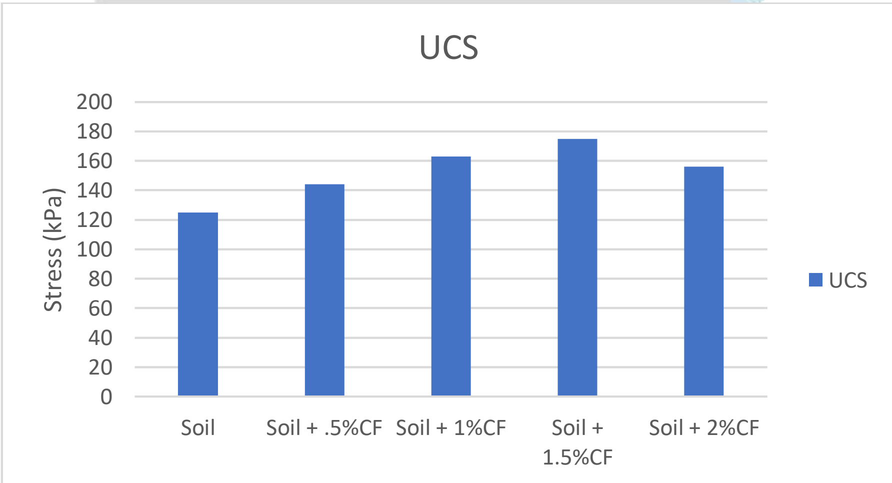

Fig 9 Variation of UCS with Soil+CFC

5.7 Performance of Soil +MHA+CF mix under CBR Test Result

Sl. No.	Soil + MHAC + 1.5%CF(10,20,30mm)	CBR (Soaked)	CBR (Unsoaked)
1	Soil	4.53	5.84
2	Soil + 5%MHA +1.5%CF(10mm)	6.12	8.32
3	Soil + 10%MHA +1.5%CF(10mm)	6.59	10.48
4	Soil + 15%MHA +1.5%CF(10mm)	7.24	14.45
5	Soil + 20%MHA +1.5%CF(10mm)	7.03	13.57
6	Soil + 15%MHA +1.5%CF(20mm)	8.14	15.56
7	Soil + 15%MHA +1.5%CF(30mm)	7.96	14.98

Table 7 Variation of CBR at different value of MHAC +1.5%CF(10,20,30mm)

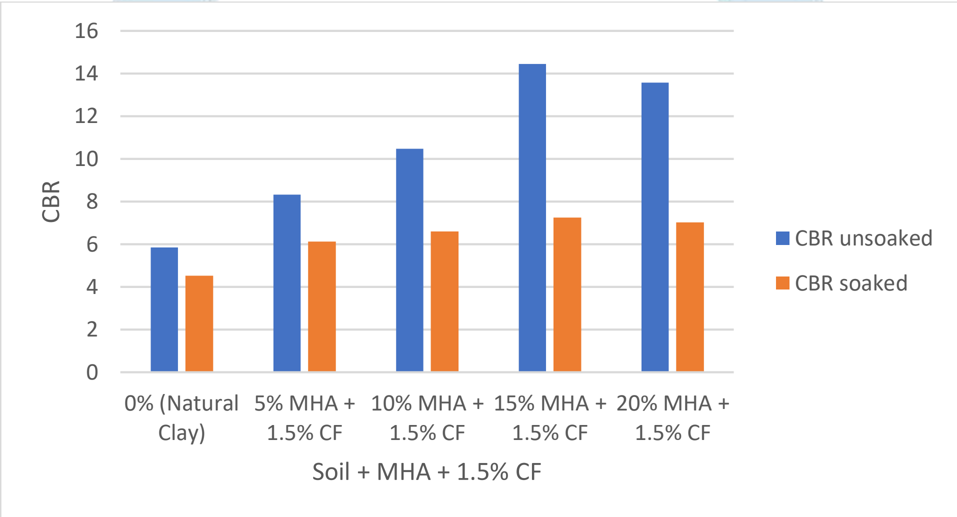

Fig 10 Variation of CBR with MHAC +1.5%CF(10mm) for Soaked and unsoaked condition

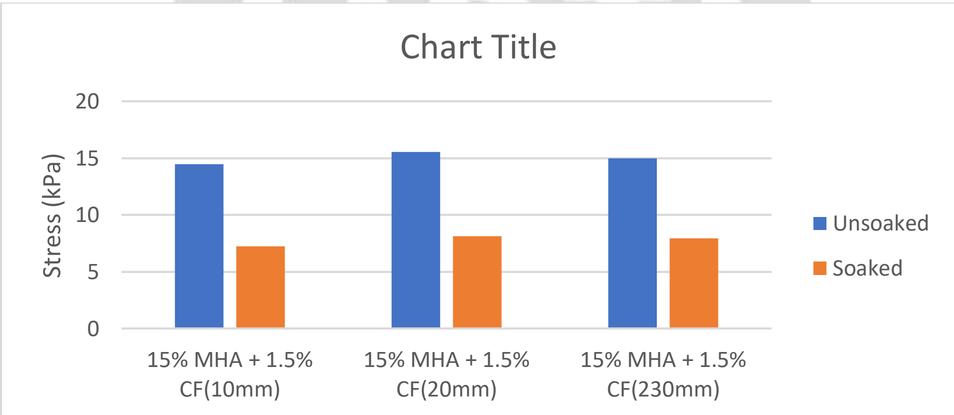

Fig 11 Variation of CBR with MHAC +1.5%CF(10,20,30mm) for Soaked and unsoaked condition

5.8 Performance of Soil+MHAC+1.5%CF(10,20,30mm) mix under UCS test

Sl. No.	Soil + MHAC + 1.5%CF(10,20,30mm)	UCS
1	Soil	125
2	Soil + 5%MHA +1.5%CF(10mm)	150
3	Soil + 10%MHA +1.5%CF(10mm)	181
4	Soil + 15%MHA +1.5%CF(10mm)	200
5	Soil + 20%MHA +1.5%CF(10mm)	175
6	Soil + 15%MHA +1.5%CF(20mm)	235
7	Soil + 15%MHA +1.5%CF(30mm)	220

Table 8 Variation of UCS at different value of Soil+MHAC+1.5%CF(10,20,30mm) mix under UCS test

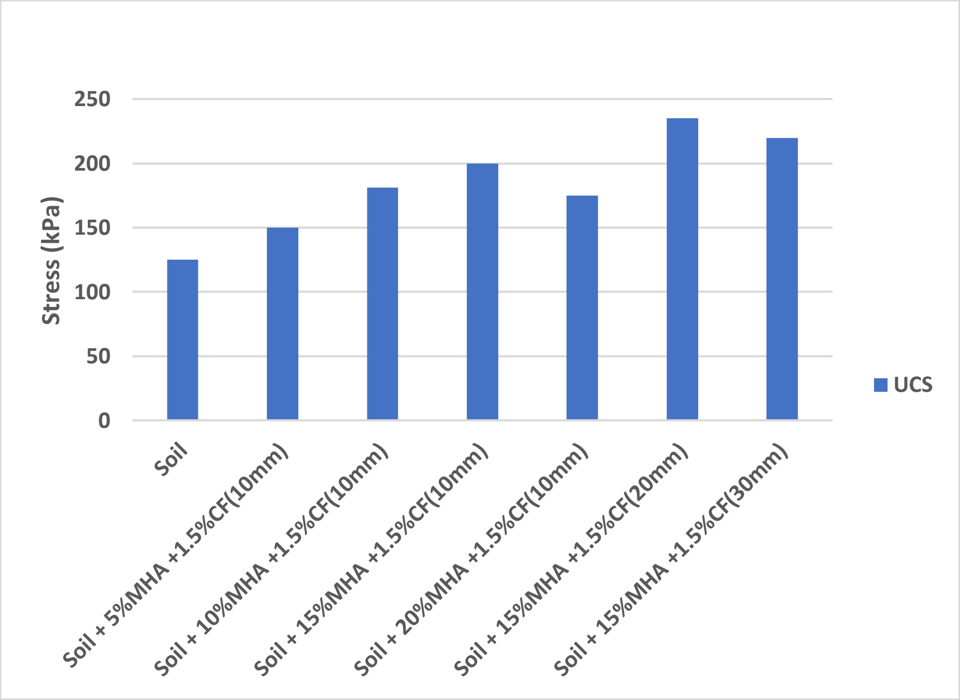

Fig 12 Variation of UCS with MHAC +1.5%CF(10,20,30mm)

6. Conclusion

1) The liquid limit of soil decreases with the addition of millet husk ash (MHA). It was around 42% for virgin soil, while at 20% MHAC, it decreased to 35%.
2) The plastic limit also increases with MHAC, rising from 24% for untreated soil to 30% at 3% SAC.
3) Adding millet husk ash shifts the compaction curve leftward and downward. The maximum dry density decreases from 1.75 g/cc for untreated clay to 1.57 g/cc at 20% MHAC, while the optimum moisture content (OMC) increases from 11.4% to 24.19%.
4) The California Bearing Ratio (CBR) and UCS improves steadily with increasing MHAC and CFC under both soaked and unsoaked conditions. Under wet conditions, the highest CBR value is achieved at 15% MHAC and 1.5% CFC for both content, indicating enhanced load-bearing capacity. Unsoaked soils exhibit even greater CBR values for the exact MHAC and CFC percentages, highlighting the effectiveness of MHA and CFC in improving soil strength, particularly in dry conditions.

5) The California Bearing Ratio (CBR) and UCS improves even further for 15% MHAC + 1.5% CFC of 20 mm length.

6) Due to pozzolanic properties of and reaction with calcium hydroxide addition of Millet husk ash reduces plasticity and improves soil structure. Coir fibre has high tensile strength and bridges micro cracks improves peak strength and resistance to deformation.

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