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Experimental Evaluation of Expansive Soil Stabilized with Wheat Husk Ash and Sisal Fiber

Deepak Sarngal[1], Anoop Sharma[2]

[1]PG student, Dept. of Civil Engineering, Sri Sai College of Engineering& Technology, Badhani, Punjab, India
[2]Assistant Professor, Dept. of Civil Engineering, Sri Sai College Of Engineering& Technology, Badhani, Punjab, India
anoopsharma777r@gmail.com
Deepu.sarngal@gmail.com

Abstract - Everything starts with soil. Being a civil engineer, we are aware of how essential soil is to construction, as everything is dependent on it. Before building any kind of structure on top of soil, we examine the soil's characteristics and behavior to determine its strength and ability to support the weight of the structure to be built on top of it. In this study work, we used agricultural waste materials, such as wheat husk ash (WHA), as a stabilized material in soil at different percentages of 5%, 10%, and 15% to perform various tests on the soil to determine its qualities or strength. Sisal fibers are inexpensive, readily available locally, and environmentally benign, making them an excellent choice for enhancing soil properties. The stabilizing effect of sisal fiber on soil characteristics has been experimentally investigated in this work. In light of this, an experimental study is carried out using pricey, locally accessible soil that has been blended with various percentages of sisal fiber. In the CBR mold and UCS sampler, soil samples are prepared at their maximum dry density (MDD) matching to their optimum moisture content (OMC) both with and without Sisal Fiber and WHA. In the laboratory, CBR and UCS tests are carried out in accordance with the proportion of Sisal Fiber by dry weight of soil, which is determined to be 1%, 1.5%, or 2%. According to test results, the amount of sisal fiber in the soil increases with its saturated CBR and UCS value. When wheat husk ash and sisal fiber are added, the CBR of the mix increases and the pavement thickness decreases, resulting in lower construction costs and ultimately, more economical highway building.

***Key Words*:** Compaction test, CBR, UCS, WHA, Sisal Fiber

INTRODUCTION

Soil is a significant component in the construction scenario. The longevity of a structure is directly dependent on the soil upon which it rests, therefore, it is necessary to ensure that the soil over which any structure is constructed, is firm or stable enough. Soil stabilization is a set of methods devised to improve the stability of soil. Various stabilization techniques prevail in the construction field utilizing diverse materials of varying properties. The basic construction material of the geotechnical engineer's design foundation is the soil.

In many set of circumstances, road service layers, foundation layers and construction material cannot utilize the soil directly. The rising cost of the land, and huge demand for high rise buildings makes the improvement of soil at a site unavoidable. Therefore, it is required to revamp the quality of the soil.

2. Literature Review

Mr. Santosh et al. (2012) Reported that Addition of different % of Wheat Husk Ash (WHA) the water content decrease up to a limit afterwards again it increases. This is more effective for addition of 9% (optimum) WHA. Addition of different % of WHA the dry density increases up to a limit afterwards again it decreases. This is more effective for addition of 9% (optimum) WHA. The stress against different days for varying % WHA, for varying % of WHA, as number of day's increases stress also increases. This is more effective for 7days.

Agrawal M.L. et al. (2013) performed compaction tests and CBR test on black cotton soil. They varied the percentage of flyash from 10% to 50% with increase of 10% at a time.They investigated that the MDD increases with increment in fly ash up to 20% ,

and with more addition it decreases. The increase in CBR value and dry density is maximum for 30% fly ash mixture with black cotton soil. On increasing percentage of fly ash, there is decrease in tthe liquid limit of black cotton soil, resulting in reduced swelling of soil.

Yanbin Li et al. (2014) performed compaction test and triaxial shear test on silty clay. They used 0.5%, 1%, 1.5% sisal fibre with lengths 5mm, 10mm and 15 mm. They reported that the stress increased with increase in strain when 1.0% fibre content is taken and they observed no decrease in stress when the strain exceeded 1.0%.They reported that silty clay reinforced with sisal fibre has 20% more strength than non-reinforced clay when 1.0% fibre content of length 10 mm is considered.

Kumar R. et al. (2014) studied the effect of sisal fibres 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 fibres. The highest UCS value was obtained at 8% lime, 8% phosphogypsum and 1% sisal fibres. UCS value increased with increment in fibre from 0.5 to 2% fibre.

Swarup J. et al.(2015) performed compaction tests and CBR tests on the black cotton soil. They used sisal fibre (0.25%, 0.5%, 0.75%, 1%, 2%, 3%), NaOH (3%, 6%, 9%, 12%,15%) and flyash 20% by weight of dry soil. They concluded that optimum value of NaOH is 9%, 12N. Normal soil matrix gives the maximum CBR values at nearly 11% of fibre content but due to this stabilization technique,the maximum amount of CBR value can be attained at less amount of fibre content i.e. at 0.2%.

Arunav Chakraborty (2016) examines the soil very closely which poses threat to the civil engineers. Here, cost effective method sugarcane straw ash is used to stabilize the expansive soil. Stress is more given on to enhance the geotechnical properties by varying curing periods and percentages of admixtures. Already, enough work is done by using cane ash but here different proportions of straw ash are taken by testing on different days. Thus, various tests are investigated such as CBR, UCS, Atterberg limits, sieve analysis, proctor and CBR value. The Unconfined compressive strength test was conducted on 3, 5 and 7 day curing period. The results represent that the increase in curing period surges the UCS value. However,10% addition of admixture gives the maximum CBR value .

Himanshu Gupta et al. (2017) They used Wheat Husk Ash and Polypropylene material to enhance the properties of natural soil used for subgrade material in pavement. The soil was stabilized different percentages of WH and after getting optimum percentage of WH, PP with percentage of 0.25%, 0.50%, 0.75%, 1.00%, is added along with WH individually, for the construction of sub grade soil and test like Liquid Limit, Plastic Limit, Plasticity Index, Specific Gravity, Optimum Moisture Content, Maximum Dry Density, Swelling Pressure and CBR is performed.

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.

Ahmed et al., (2019) In this research paper we performed various test on soil to know its properties or strength by using agricultural waste material such as wheat husk ash (WHA) as a stabilized material in soil with varying percentages 10%, 20%, 30%,40%. Soil samples for California bearing ratio (CBR) tests and UCS are prepared at its maximum 8dry density (MDD) corresponding to its optimum moisture content (OMC) in the CBR mould and UCS sampler without and with Polypropylene Fiber. The percentage of Polypropylene Fiber by dry weight of soil is taken as 0.5%, 1%, 1.5% and 2% and corresponding to each Polypropylene Fiber content soaked CBR tests and UCS tests are conducted in the laboratory.

S.M Kavitha et al., (2019) Geotechnical engineers face various problems while designing foundation because of clayey soil due to poor bearing capacity and excessive settlement. So, we rectify that with various engineering works but in this project we

choose fibers for improving soil parameters, this method is cost-effective and eco-friendly one. The clay sample was collected from Devakottai, Tamil Nadu, and India. Sisal, polypropylene, and hybrid of these two fibers were used for soil stabilization. The sisal fiber was mixed 0 .1%, 0.2%, 0.3% and 0.4% by weight of the soil samples. Similarly, polypropylene fiber was mixed 0.5%, 1%, 1.5% and 2% by weight of the soil samples and hybrid fiber mixed soil samples randomly distributed.

Khan et al., (2019) In this study an extensive lab work have been done to investigate the utilization of agricultural, industrial waste and natural fibers for enhancing the engineering properties of the moderately compressible clay obtained from Mohali Airport Road, Punjab (India). This study aimed to access the appropriateness of Bagasse Ash and Sisal Fiber for stabilization of clayey soil. Consistency limits, Maximum Dry Density, Optimum Moisture Content, UCS and (soaked) CBR tests have determined by using Bagasse Ash (2%, 4%, 6% and 8%) and Sisal Fibers in different lengths (2mm, 4mm, 6mm) with percentages (1%, 1.5%, 2%) by weight of dry soil.

S. Mathada et al., (2020) In this project a brief research is done in which industrial waste such as sugarcane straw ash (SCSA) and agricultural waste such as wheat husk ash (WHA) both used as soil stabilizers in expansive soil to improve the strength of soil by defusing various percentage of WHA & SCSA such as 3%, 5%, 7%, 9% and 11% and conducting tests such as Atterberg's limit, Standard proctor test, CBR test, UCS test. The main objective of soil stabilization is to increase shear strength and decrease the compressibility of the expansive soil. These tests are experimented and proved by the standard tests IS 2720 and finally concluded that test results improve the geotechnical properties of the soil.

Mughal et al., (2022) It is interpreted that there is increase in OMC and decrease in MDD with addition of Bagasse Ash. But the values of CBR and UCS are increased with 4% of BA and Sisal Fiber length 4cm at 1.5%. There is increase in the percentage of UCS, when sample were prepared with 2%, 4% by 3.02%, 4.70% and decrease in percentage of UCS,. The experiments in combined sample of BA and Sisal Fiber (2cm, 4cm, 6cm)shows that the maximum value of UCS are obtained at 4cm length with 1.5% by weight, which is found to be 3.73 kg/cm2. The percentage increase as compared to the raw soil is 25.16%. The soaked CBR value of the raw soil with 4% BA is 2.59%. The soaked CBR value of combined soil sample with 4% BA, 1.5% of Sisal Fiber of 4cm length is found to be 3.09%, the increase in CBR value as compared to raw soil is 70.16%.

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.

3. Materials

3.1 SOIL

Source of soil

The soil used in this study was obtained from village. As per IS classification of soil, the soil used is low compressibility silt. The soil properties are given in the table as under:

Table no. 1 Properties of soil used in the study

S.No.	Properties	Result
1.	Liquid limit (%)	33
2.	Plastic limit (%)	21
3.	Plasticity Index (%)	12
4.	Specific Gravity	2.65
5.	Maximum Dry Density (KN/m³)	16.75
6.	Optimum Moisture Content (%)	13.40
7.	Soil Classification	CI (Intermediate Compressive

		Clay)
8.	CBR (%) (soaked)	2.8
9.	CBR (%) (Unsoaked)	4.5
10.	UCS (kN/m$^{2)}$	160.70

3.2 WHEAT HUSK ASH

Source of Wheat Husk Ash

Wheat Husk Ash is taken from locally areaby burning locally available wheat husk in an open kiln for about twenty four hours. After complete burning, the burnt material was sieved through I.S.425 micron sieve and minus 425 -fraction was taken for the study.

Table 2: Chemical properties of WHA at 600 °C

S.No	Parameters	Value (%)
01.	Silicon Oxide(SiO2)	43.22
02.	Potassium Oxide(K2O)	11.30
03.	Magnesium Oxide(MgO)	0.99
04.	Iron Oxide (Fe2O3)	0.84
05.	Sodium Oxide(Na2O)	0.16
06.	Calcium oxide (Cao)	5.46

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: MDD and OMC for soil– Wheat Husk Ash–sisal fiber mix

Proportion Soil : W.H.A: Sisal fiber	MDD (kN/m^3)	OMC (%)
100:00:00	16.75	13.40
89.5:10:0.5	17.10	12.90

89:10:1.0	**17.80**	**12.30**
88.5:10:1.5	17.30	12.60

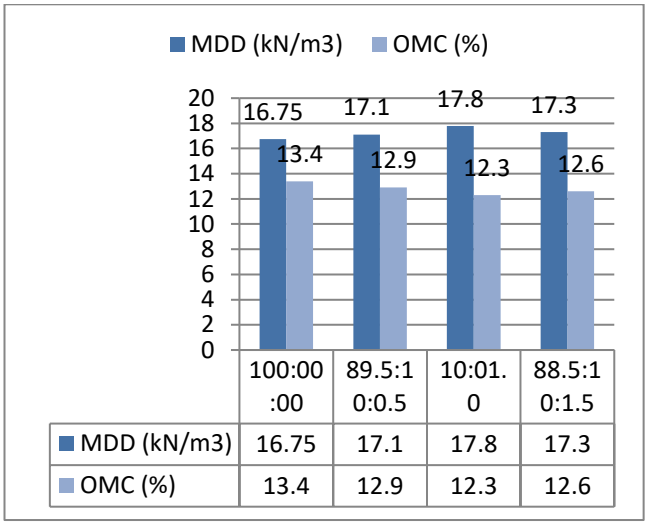

Fig:-1 Variations b/w MDD and OMC of Wheat Husk Ash, Sisal Fiber & soil with different proportions

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

Proportion Soil : W.H.A: Sisal fiber	**Curing Period (Days)**	**UCS (kN/m^2)**
100:00:00	7	160.7
89.5:10:0.5	7	320
89:10:1.0	**7**	**440**
88.5:10:1.5	7	375

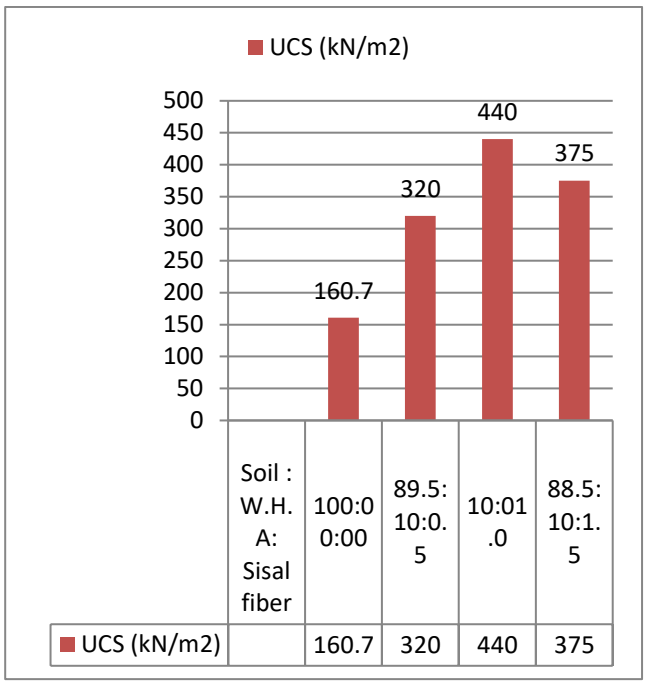

Fig:-2 Variations b/w UCS Values of Clayey soil, Wheat Husk Ash and Sisal Fiber with different proportions

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

Proportion Soil : W.H.A: Sisal fiber	**CBR (%) (Soaked)**	**CBR (%) (Unsoaked)**
100:00:00	2.8	4.5
89.5:10:0.5	4.4	7.4
89:10:1.0	5.7	8.6
88.5:10:1.5	4.9	7.5

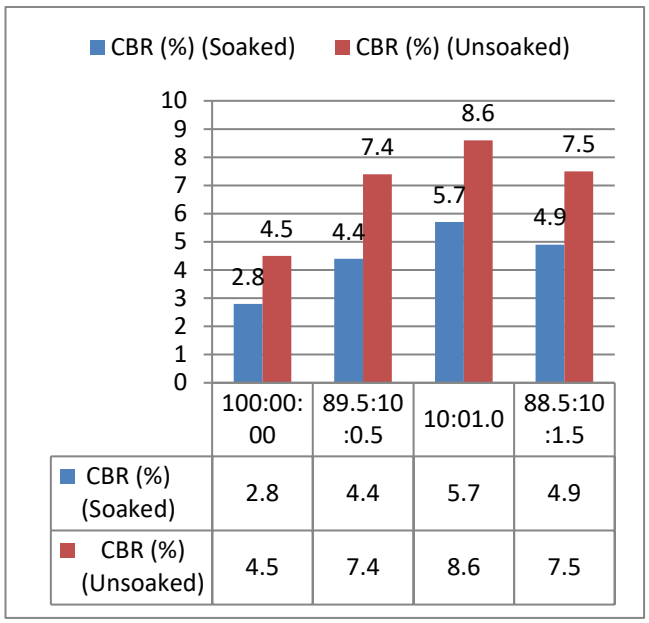

Fig:-3 Variations b/w CBR Values of Clayey soil, Wheat Husk Ash and Sisal Fiber with different proportions

5. DISCUSSIONS

STANDARD PROCTOR TEST:

- An increase of OMC from 13.40 to 14.40% and decrease of M.D.D. from 16.75 to 15.40 kN/m^3 when the percentages of Wheat husk ash are used as 5%, 10% and 15% respectively. In this value of MDD is decreased upto 10% wheat husk ash, after that it increases. Therefore, value of 10% is taken optimum
- There is decrease of OMC from 13.40 to 12.20% and increase of MDD from 16.75 to 18.90 kN/m^3 when the percentages of Sisal Fiber are used as 1.0%, 1.5% and 2.0% respectively.
- There is an also decrease of OMC from 13.40 to 12.30% and increase of MDD from 16.75 to 17.80 kN/m^3 when the percentages of Sisal Fiber vary from 0.5%, 1.0% and 2.0% and Wheat husk ash is fixed at 10%.
- Specific gravity of Wheat husk ash is lower than as compared to soil. So MDD is increased and OMC is decreased.
- With Wheat husk ash kept constant at 10% MDD increases with an addition of Sisal Fiber content in soil mix.

CBR TEST:

- An increase of CBR value was observed when the wheat husk ash is added to soil. This increases at the 10% of wheat husk ash after that CBR value decreased. The optimum value of wheat husk ash was found at 10% in that case, CBR value increase 2.10 times to the CBR value of virgin soil when observed in soaked conditions.
- Presence of pozzolanic compounds in wheat husk ash and CaOH available in soil might increase the CBR value due to formation of cementitious compounds in soil.
- When Sisal Fiber is added to virgin soil the CBR value of virgin soil is 2.8 and it increases to 1.75 times with addition of Sisal Fiber when observed in soaked conditions. This enhancement is because of binding action of Sisal Fiber.
- The CBR value of virgin soil is 2.8 and it increase to 2.03 times when wheat husk ash 10% and Sisal Fiber 1.0% is added to virgin soil. This enhancement in CBR may be because of the gradual formation of hydration compounds in the soil due to the reaction between the stabilizers and the essentials particle present in the soil. The increase in CBR value from 2.8 to 5.7 when wheat husk ash is fixed at 10% and Sisal Fiber added at different ratios i.e. 0.5, 1.0, 1.5 after that it decreases.

UCS TEST:

- UCS value of virgin soil enhances fundamentally with expansion of Wheat husk ash contents. The UCS value increment from 160.7kN/m² to 310kN/m² with expansion of Wheat husk ash up to 10 % in the wake of curing time of 7 days. U.C.S. value decreases with more expansion of wheat husk ash. Therefore the mix with 10% wheat husk ash content is taken as optimum.
- The UCS value of virgin soil is 160.7kN/m² and it increases to 1.92 times with addition of 10% Wheat husk ash. This improvement is because of increases the cementation property of soil.
- The UCS value of virgin soil also improves considerably by keeping wheat husk ash value fixed at 10% and Sisal Fiber in %ages 0.5, 1.5 and 2.0. The value increases from 160.7kN/m² to 440kN/m² with the addition of wheat husk ash and Sisal Fiber upto 10% and then further addition of Sisal fiber content decreases UCS value. Therefore wheat husk ash 10% and Sisal Fiber 1.0% is taken as optimum.
- The reason behind of this when wheat husk ash and Sisal Fiber comes in contact with water, pozzolanic reactions takes place during the curing period. With further increase in the amount of Sisal

Fiber, U.C.S. value starts decreasing because of lumps are formed with extra addition of Sisal Fiber in 1.0% with 10% wheat husk ash.

6. CONCLUSIONS

Four samples containing five different contents of Sisal Fiber (1.0%, 1.5% and 2.0%) with wheat husk ash (5%, 10% and 15%) were tested at 7 cure days to verify the effectiveness and optimum ratio of Sisal Fiber and wheat husk ash in soil stabilization. Following determination of Atterberg's limits, optimum moisture content, moisture content variation depending on mix design with cure time and unconfined compression strength were determined according to ASTM method.

On the basis of above experimental results and discussions, the following conclusions can be drawn:-

- In this study, a series of Standard Proctor test, unconfined compression strength test and the CBR test was carried out to calibrate the effect of two chemical additives namely Sisal Fiber and wheat husk ash on the clayey soil sample. The results showed that Sisal Fiber and wheat husk ash could improve the UCS value, Dry density and CBR Percentage of clayey soil sample.
- The different percentages of Sisal Fiber and wheat husk ash used in this study were 1.0%, 1.5% & 2.0% and 5%, 10% and 15%. Finally, the value of wheat husk ash was fixed to 10% with variation of Sisal Fiber (0.5%, 1.0% and 1.5%) to clayey soil.
- Addition of Sisal Fiber and wheat husk ash with clayey soil increases maximum dry density and decreases the optimum moisture content of the soil sample.
- The addition of the fixed quantity of wheat husk ash 10% with changing the content of Sisal Fiber decreases the value of optimum moisture content and increases the value of maximum dry density.
- The optimum value of wheat husk ash used in this research was 10% because the maximum value of UCS was found at 10% wheat husk ash.
- The UCS value increases with an increase of Sisal Fiber content along with a fixed quantity of wheat husk ash. The maximum value of UCS was found at 1.0% Sisal Fiber and 10% wheat husk ash.
- Based on the CBR test results, the value of CBR increases from 2.8 to 5.7.
- The optimum value of California Bearing Ratio was found at 1.0% Sisal Fiber and 10% wheat husk ash.
- No more than 1% Sisal Fiber is recommended to obtain high early strength but if long-term strength is also required, then 2% Sisal Fiber with 10% wheat husk ash should be considered.

Hence, the addition of Sisal Fiber and wheat husk ash makes the soil mixes durable, economical and effective for soil stabilization process if these two materials are easily available near to the site.

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