Analysis of Clayey Soil Improvement as Subgrade Using Wheat Husk Ash and Basalt Fiber

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Abstract - Transportation provides a basic need for humankind. Throughout the dawn of time, people have traveled for food or pleasure. People have high expectations for transportation infrastructure since there is a strong correlation between a country's degree of development and the quality of its infrastructure. The creation of transportation systems that are analytically sound, economically sound, environmentally benign, socially credible, sustainable, and workable presents major challenges for today's civil engineers. Ground improvement technologies are becoming more and more popular as a result of traditional construction methods' shortcomings in the modern world. Access to an affordable road network is critical to the economic development of emerging countries such as India. In highway applications, a poor subgrade layer of the pavement requires a thicker pavement, which drives up pavement construction costs. Organic soils are not suitable for building work due to their low bearing capacity, high potential for swelling, and weak shear strength. These kinds of soils can be treated with compaction and stabilizing techniques. The main objective of this study is to enhance the geotechnical properties of soil by the efficient use of stabilization employing Wheat Husk Ash (WHA) and Basalt Fiber in varying amounts. The research employed three different amounts of Wheat Husk Ash (5%, 10%, and 15%) and Basalt Fiber (2%, 3%, and 4%). For the reinforced soil, compaction and an unconfined compressive test (UCS) were carried out. The trial's results showed that the soil had significantly increased in both shear and compressive strength.

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

INTRODUCTION

The term "complex material" refers to soil. It possesses physical and chemical properties that are crucial for coping with loads and other outside influences. The design of sub-structures such as foundations, piles, and other soil-based structures such as the sub-grade for pavements, embankments, etc. involves taking safety into consideration, making soil engineering and soil mechanics the most challenging of all the civil engineering specializations. Compared to conventional building materials, these projects demand a substantially higher level of safety.

Therefore, the engineering qualities of the soil are assessed prior to any significant building activity to ensure that the soil will be stable under the weight of the required structures. In contrast to the soil, which is normally made up of rock particles, the voids (also known as empty spaces) are where the air and water are found. The geological features impacted by mineral abundance, grain size distribution, and particle size and size distribution must be identified. When studying the site features and constructing structures, it is common practice to take the bulk unit weight, saturated unit weight, dry unit weight, permeability, and porosity of the soil into consideration. Numerous laboratory techniques are used to look at the relative density, soil compaction characteristics, permeability, and water content.

2. Literature Review

G. R. Ashwin Kumar et al. (2015) A form of clay called marine clay is present in coastal areas all over the world. The earth shrinks and loses moisture during dry spells, leaving a space beneath the footings. The house then begins to settle, resulting in warped door and window frames, fractured masonry walls, and interior plaster cracks. Foundations that have moved during dry periods typically return to near their original placements as rainfall replenishes the soil's moisture, causing the soils to swell once more. Wider fissures may develop as a result of the foundation's rebound gradually fading after several cycles.

Dayalan et al., (2016) In this study, different amount of fly ash and GGBS are added separately i.e. 5, 10, 15 and 20% by dry weight of soil are used to study the stabilization of soil. The performance of stabilized soil are evaluated using physical and strength performance tests like specific gravity, atterberg limits, standard proctor test and California Bearing Ratio (CBR) test at optimum moisture content. From the results, it was found that optimum value of fly ash is 15% and GGBS is 20% for stabilisation of given soil based on CBR value determined.

Rashad et al., (2015) It is vital to make utilization of these wastes as building materials to secure the ecological from degradation. In this paper, the possibility of reusing calcined PG (CPG) as an incomplete substitution of FA in alkali-activated FA (AAFA) glue was considered. FA was halfway changed with CPG at purpose of 0%, 5%, 10% and 15%, by weight. Compressive quality at ages of 3, 7 and 28 days was figured.

The execution of the explored blends subsequent to being presented to 400, 600, 800 and 1000 °C for 2 h was order by measuring the lingering compressive quality.

Srikanth et al. (2017) A crucial factor in the realm of construction is soil stability. Various stabilization techniques can be used on soil that is not sufficiently stable. Stabilizing the soil can increase its shear strength and control its shrink-swell properties, which will improve the subgrade's ability to hold pavements and foundations under stress. There are a wide range of stabilization techniques. The objective of this paper is to examine the practicality of stabilizing soil using rice husk ash and coir fiber in order to repurpose waste materials and give a reasonably priced and ecologically friendly method of doing so.

Pooja et al. (2017) Testing the behavior of soil reinforced with Coir fiber in percentages ranging from 0.5% to 1.5% by mass revealed that the UCS test results for soil samples with fiber contents of 0.5%, 1.0%, and 1.5% increased from the value starting from 11.68%, 1.26%, and 0.62% respectively. Researchers came to the conclusion as a result of this that adding fibers to the soil might be regarded as a beneficial ground improvement strategy, particularly for engineering projects requiring more support in weak soils.

P. Bharath Goud et al. (2018) The purpose of the current study was to evaluate the effectiveness of different mixtures of copper slag and rice husk ash as soil stabilizers. The combination of copper slag and rice husk ash to stabilize soil has only been the subject of a small number of studies. It was discovered that the optimal mixture was 64%BC+30%CS+6%RHA. The FSI of soil that has received RHA+CS treatment reduced dramatically from 100% to 20.4%. The maximum dry density of the treated soil changed little. The unsoaked CBR test revealed that the optimal mix had strength of 12.7%.

Sharana Kumar et al. (2018) The study's goal is to determine the impact of short polypropylene filaments that have been randomly distributed on the CBR test and the UCS of black cotton soil on strengthening. The stabilization process used in this study aims to ascertain the impact of Slag and fiber on the engineering characteristics of black cotton soil. The amounts of fiber used are 0.5%, 1%, 1.5%, and 2% relative to the dry weight of the soil, and the amounts of copper slag utilized are (6%, 12%, 14%, and 24%). Next, combine copper slag and As a percentage of the dry weight of the soil, polypropylene fiber should be added in the following amounts: 0.5%, 1%, 1.5%, 2%, and 3.6%, 9%, and 12%, respectively.

G. Ramachandran et al. (2019) The major goal of this study is to improve the geotechnical qualities of soil, which is why basalt fiber and GGBS in varied quantities are used in this work to examine effective stabilization. The study used 1%, 2%, and 3% of basalt fiber and 3%, 6%, and 9% of powdered granulated blast furnace slag in three different amounts. Compaction and UCS test were performed on the reinforced soil. The findings of the trial indicated that the soil's compressive strength and shear strength had been effectively improved.

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.

Adla Prathyusha et al. (2020) The purpose of this study is to evaluate the suitability of red soil from a nearby source with the addition of basalt fiber for highway building. Basalt fibers are added to the conventional red soil in varying proportions (by weight of the raw soil, 0%, 0.2%, 0.4%, 0.6%, 0.8%, 1%, 1.2%, and 1.4%). Proctor compaction tests and California bearing ratio (CBR) testing were performed on stabilized soil in addition to the preliminary tests. The experiment's results show that strengthening the soil by adding basalt fiber was greatly enhanced. By adding basalt fiber to subgrade soil at a rate of 0.8% (by soil weight), it is possible to dramatically boost the strength of the soil, which also has a positive impact on the design of highway pavement structures.

Kumar et al. (2023) The major goal of the study in this work is to improve the geotechnical qualities of soil by the effective usage of stabilization utilizing basalt fiber and ground granulated blast furnace slag (GGBS) in varied quantities. The study used 2%, 3%, and 4% of basalt fiber and 5%, 10%, and 15% of powdered granulated blast furnace slag in three different amounts. Compaction and an unconfined compressive test (UCS) were performed on the reinforced soil. The findings of the trial indicated that the soil's compressive strength and shear strength had been effectively improved.

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(SiO_2)	43.22
02.	Potassium Oxide(K_2O)	11.30
03.	Magnesium Oxide(MgO)	0.99
04.	Iron Oxide (Fe_2O_3)	0.84
05.	Sodium Oxide(Na_2O)	0.16
06.	Calcium oxide (Cao)	5.46

SOIL:WHA:BF	MDD (kN/m³)	OMC (%)
100:00:00	16.75	13.40
89.0:10:1.0	17.45	12.70
88.5:10:1.5	18.30	11.90
88.0:10:2.0	17.90	12.40

3.3 BASALT FIBRE

Source of Basalt Fiber

In the test, 6mm Basalt Fiber of various lengths will be used. The basalt fiber is equally distributed throughout the clay soil sample prior to dispersion. The filamentous Basalt Fiber is bought online from Delhi.

Table 3:- Properties of Basalt Fiber

Density	2.65g/cm3
Elastic modulus	85.9Gpa
Elongation at break	3.12%
Tensile at strength	2611Mpa
Length	6mm

4. EXPERIMENTAL RESULTS

4.1 STANDARD PROCTOR TEST

Table no. 4: MDD and OMC for soil– Wheat Husk Ash–Basalt Fiber mix

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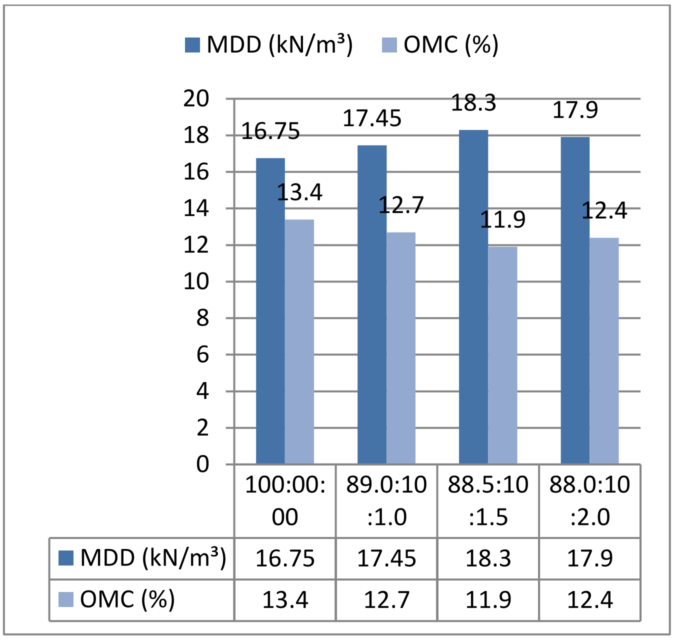

Fig:-1 Variations b/w MDD and OMC of Wheat Husk Ash, Basalt Fiber & soil with different proportions

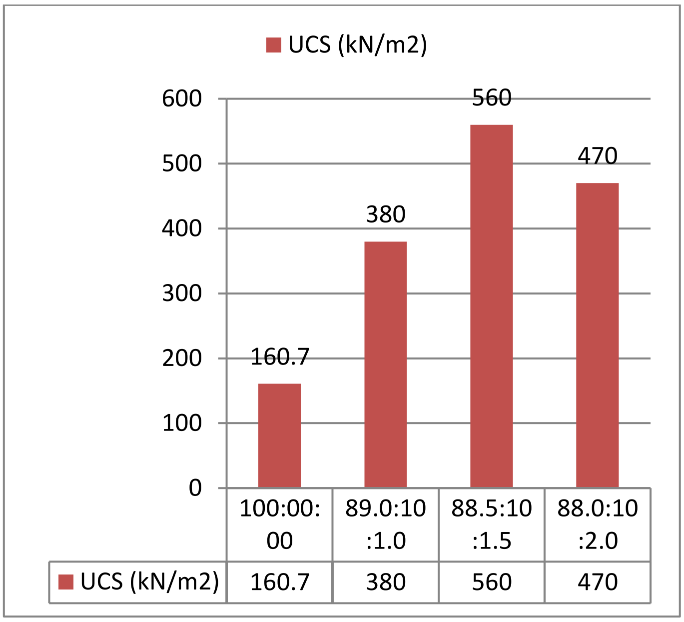

Fig:-2 Variations b/w UCS Values of Clayey soil, Wheat Husk Ash and Basalt Fiber with different proportions

Table 5: Results of UCS of Wheat Husk Ash and Basalt Fiber Mix with Soil

Clayey Soil :WHA:BF	**Curing Period (Days)**	**UCS (kN/m^2)**
100:00:00	7	160.7
89.0:10:1.0	7	380
88.5:10:1.5	7	560
88.0:10:2.0	7	470

Table 6: Results of CBR of Wheat Husk Ash and Basalt Fiber Mix with Soil

Clayey Soil :WHA:BF	**CBR (%) (Soaked)**	**CBR (%) (Unsoaked)**
100:00:00	2.8	4.5
89.0:10:1.0	5.1	7.14
88.5:10:1.5	6.7	9.38
88.0:10:2.0	5.9	8.23

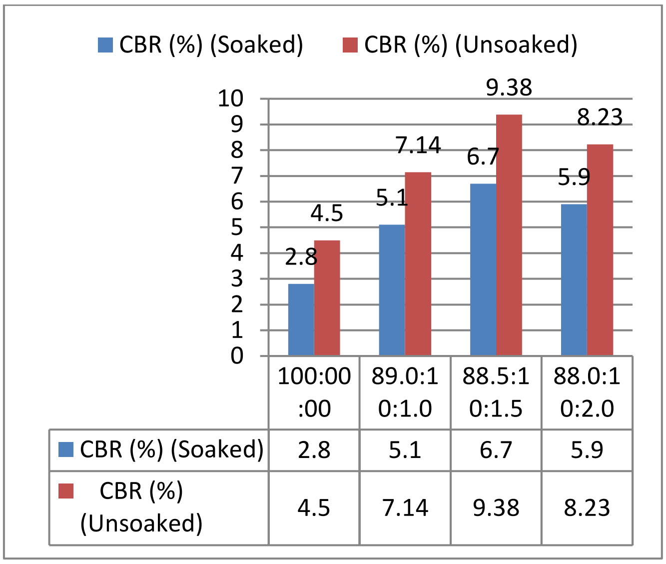

Fig:-3 Variations b/w CBR Values of Clayey soil, Wheat Husk Ash and Basalt Fiber with different proportions

5. DISCUSSIONS

5.1 COMPACTION TEST

In this investigation, different amounts of WHA were used to analyze the soil's compaction characteristics. As the amount of WHA increased, MDD was seen to decline. This might occur because soil and WHA have different specific gravities. However, as the amount of WHA is increased, the optimum moisture content rises. This might occur as a result of the pozzolanic reaction of WHA with soil, which needs additional water to complete the cation exchange process. Figures 4 and 5 below demonstrate the variance in MDD with WHA and the variation in OMC with WHA.

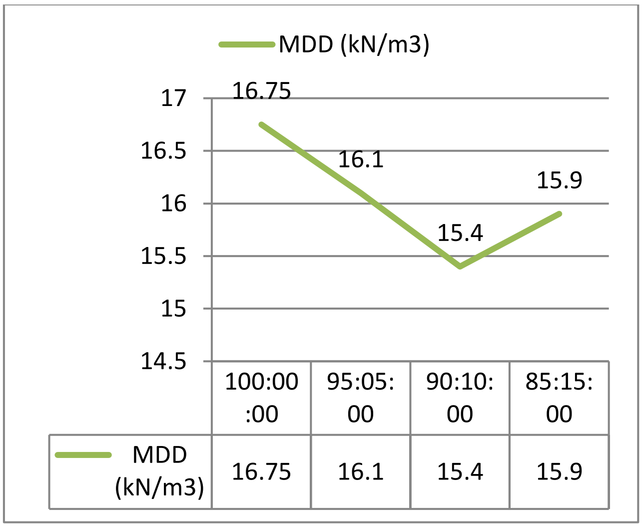

Fig. no. 4 Changes in MDD as the percentage of WHA rises

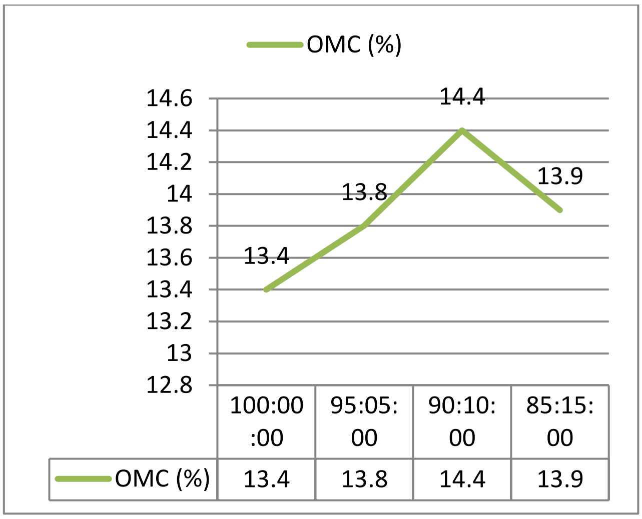

Fig. no. 5 Changes in OMC as the percentage of WHA rises

When soil and Ash are combined, MDD rises as the amount of basalt fiber grows with varying WHA ratios. Because WHA is more easily added because it is circular in shape and lighter in weight, MDD may rise as a result of this behavior. However, OMC rises as fiber content rises because fiber absorbs a lot of water.

In figures 6 and 7 below, both the variance of MDD and the variation of OMC with increasing fiber content are shown.

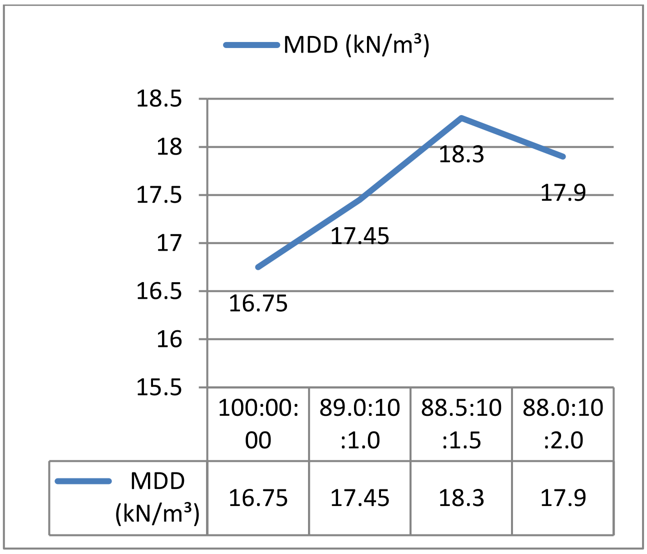

Fig no. 6 Changes in MDD as WHA and basalt fiber contents rise

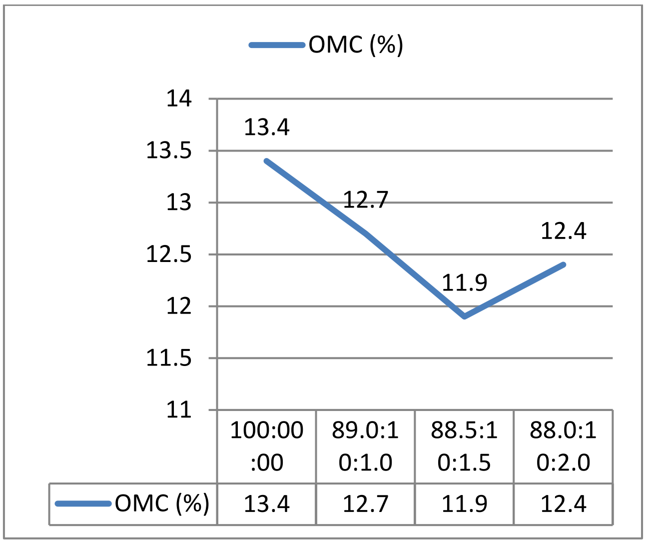

Fig no. 7 Changes in MDD as WHA and basalt fiber contents rise

5.2 CALIFORNIA BEARING RATIO TEST

Addition of WHA somewhat raises the soil sample's soaking CBR values. WHA (10%) and basalt fiber (1.5%) were added, which increased the soaked CBR value. The rise in CBR value might be brought about by the reaction between the pozzolonic compounds of soil-available CaOH and WHA, which create cementitious compounds in the soil. Basalt fiber should be used in the optimal amount. This could be the result of the fact that stabilized soil gains strength as its fiber content rises, increasing the soil's ability to withstand applied stresses. Figure 8 depicts the correlation between CBR value, WHA content, and basalt fiber content.

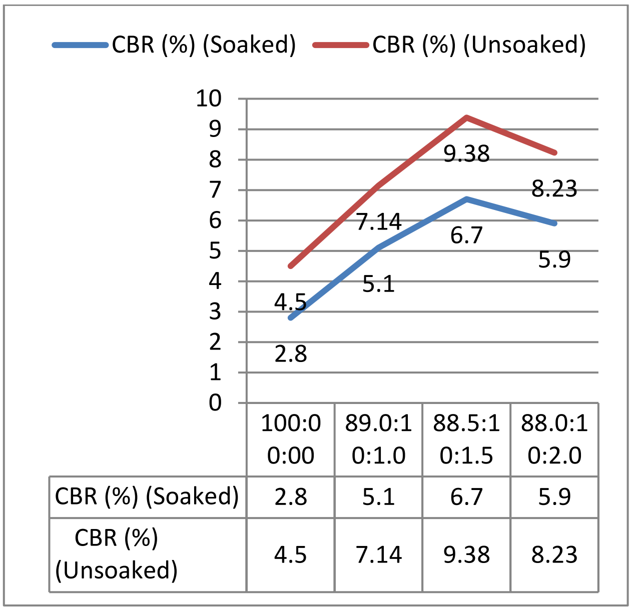

Fig. no. 8 Changes in CBR value when WHA and BF content rises

5.3 UNCONFINED COMPRESSION STRENGTH TEST

With the addition of 10% WHA and 1.5% basalt fiber, the UCS value of virgin soil also significantly increases. When WHA and basalt fiber are added, the value rises. The cause of this is that during the curing process, pozzolanic reactions occur when WHA and basalt fiber come into touch with water.

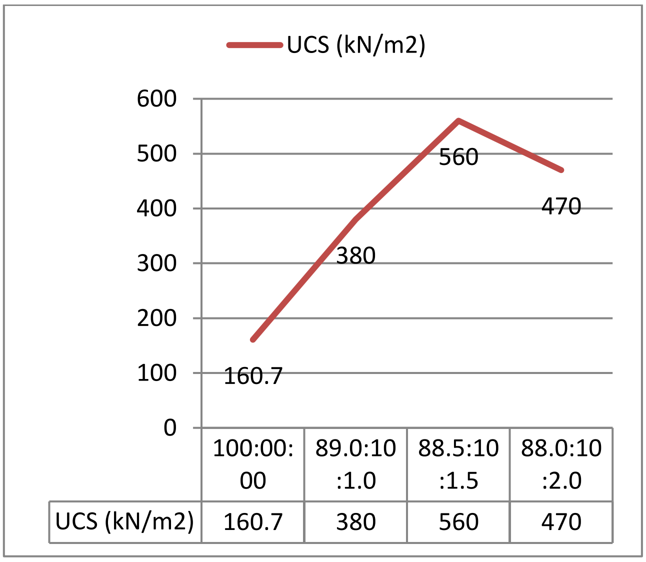

Fig. no. 9 Changes in UCS value when WHA and BF content rises

6. CONCLUSIONS

Following conclusions can be inferred on the basis of the experiments performed:

1. Due to its cementitious properties, which help to strengthen the soil, WHA is a waste product that can be used to stabilize soil.
2. In contrast, Basalt fiber is an inexpensive material that may be applied to soil in little amounts to significantly alter its strength characteristics.
3. Since adding WHA to soil is found to increase C.B.R. by 10%, WHA was utilized at a 10% value for this project.
4. When basalt fiber and a set quantity of WHA are added, the C.B.R value increases. It multiplied by 2.39 from the virgin soil.
5. The appropriate proportions of WHA and basalt fiber to the weight of the soil are 10% and 1.5%, respectively, in order to stabilize the soil.
6. Increasing the amount of basalt fiber and maintaining the same level of WHA improves unconfined compressive strength. The UCS is 3.48 times higher in treated soil than in untreated soil.

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