

Effect of Sisal Fibers and GGBS on Strength Properties of Black Cotton Soil

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ABSTRACT: An experimental study is conducted to find the effect of ground granulated blast furnace slag (GGBS) and Sisal fibers on mechanical properties of black cotton soil. In the initial the basic properties of black cotton soil and sisal fiber were found out. The first phase of the work includes effect of GGBS on compaction characteristics of black cotton soil. The next phase focuses on the unconfined compressive strength and CBR values of mixture of black cotton soil and optimum dosage of GGBS randomly reinforced with varying percentage of sisal fibers. The work also focuses on change in unconfined compressive strength and CBR value with curing period. The results indicated that with addition of GGBS to black cotton soil the maximum dry density increased and optimum moisture content decreased. The unconfined compressive strength and CBR values increased addition of sisal fiber to mixture of black cotton soil and optimum dosage of GGBS. The highest result was obtained for mixture of black cotton soil and optimum dosage of GGBS with 0.75% of sisal fibers. The Unconfined compressive strength and CBR values increased with curing period.

KEYWORDS: Black cotton soil, GGBS, Sisal fibers, Strength properties.

I. INTRODUCTION

In today's world due to rapid growth of urbanization and modernization leads to scarcity of land for construction. The increasing value of land and due to limited availability of site for construction of structures and roads are done on land having expansive clays. The stability of structure or road depends on soil properties on which it has built. The constructions can be economical if the soil is good at shallow depth below the ground surface. In this case shallow foundations such as raft foundations or footings can be used. However if the soil available on top surface is weak and strong stratum is available at greater depth foundations such as pile foundation, deep foundation, caisson and well foundation can be used. Such foundations are not economical for small structures. In some cases soil condition are so poor even at greater depths.

Around 20% area of India is covered with these expansive soils. These are also called as "Black Cotton Soil". These soils undergo swell shrink behaviour due to presence of a mineral called montmorillonite. Expansive soils have very low shear strength when saturated and exhibit high volumetric change during wetting and drying. These soils are very weak so as not fit to construct any structure or pavement above it. The property of the soil has to be increased before any structure or pavement has to be built over it.

In modern history the concept of reinforced soil was discovered by Henry Vidal. Reinforcement is a procedure where different types of additives are used to improve the soil properties. The reinforcement in soil improves its bearing capacity and reduces settlement it also takes a main part in reducing the liquefaction behaviour of soil. Reinforced soil acts as a composite material in which reinforcing element have higher tensile strength. The shear strength present in soil and tensile strength present in reinforcing element imparts greater strength to soil. Blast furnace slag is by-product which is produced during the production of pig iron. It is not a cementitious material but with addition of lime or alkaline material it can be used as cementitious material. Blast furnace slag can be divided in to three types; they are air cooled slag, granulated slag and expanded slag. Ground granulated blast furnace slag (GGBS) is obtained by quenching molten iron slag in water or steam, which produces a glassy, granular material which is then dried and grounded in to powder. If the molten slag is cooled by rapid water quenching to a glassy state, no

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crystallization occurs to form a sand sized fragments. The gradation and physical structure of granulated slag depends on its temperature at the time of quenching, the chemical composition and method of production. When granulated blast furnace slag grounded in to cement sized particles, it provides a cementations property. The GGBS contents around 95% of silica, alumina, calcium oxide, magnesia and the remaining will be occupied by manganese, iron, sculpture etc. when water is added to the GGBS, the water reacts with GGBS to form calcium silicate hydrates (CSH) it depends on availability of calcium oxide and silica. A puzzolanic reaction takes place with SiO present in slag, Ca(OH) is produced by hydration of silicates and water produces more CSH which helps in soil stabilization.

Manjunath K. R, et al., (2013) The tests were conducted on influence of sisal fibers on strength properties of black cotton soil. They conducted Unconfined Compressive Test and California Bearing Ratio Test for different percentage of sisal fibers with different percentage of lime. They concluded that with addition of 3% and 0.75% sisal fiber are optimum dosage. Gyanen Takhelmayum, Savitha. A. L et al., (2013) The study was done on effect of GGBS on the Compaction and Unconfined Compressive Strength properties of black cotton soil. The compaction was conducted with different percentage of coarse and fine grained GGBS. The conclusion shows that as the percentage of GGBS goes on increasing the Maximum Dry Density increases and Optimum Moisture Content decreases up to 30% of GGBS above which Maximum Dry Density decreases. This is due to formation of C-S-H (Calcium Silica Hydrate) due to hydration of GGBS. K. V. Manjunath, Himanshu Shekar et al., (2012) Investigated the effect of GGBS and lime on the Unconfined Compressive Strength properties of Black Cotton soil with curing. Different combinations were made with varying percentages of lime and GGBS for curing days of 0,7,28. The result concluded that with addition of GGBS along with lime gives better strength than lime alone. The combination of BC + 30% GGBS along with 4% lime with 28 days curing gives 18 times more strength than BC alone. Santhi Krishna K, Sayida M. K., (2009) They evaluated the effect of sisal fiber on BC soil. The optimum moisture content and the maximum dry density decreases as the fiber content and length increases. For different length of fibers 0.5% was optimum dosage. The maximum CBR value of 14.21% was obtained for 2.5cm length and 0.5% of sisal fibers which was 2.74 times over plain soil. Similarly the unconfined compressive strength also increased 7.8 times over plain soil for 2.5cm and 0.5% fibers. They also conducted durability test, the results shown that the tensile strength decreased with time. The decrease of tensile strength was more in soil embedded sisal fiber than in water.

II. MATERIALS

A. Black Cotton Soil

The black cotton soil is collected from Begur, Chitragurga District, Karnataka State, India. The sample was collected from a depth of about 1.5m below the ground level by open excavation. The obtained soil is air dried and pulverized manually. The soil passing through 425 μ IS sieve is used for the study. All the tests are conducted as per IS-2720 standards. The properties of black cotton soil are presented in Table 1.

Table 1: Properties of black cotton soil

Properties	Values
Colour	Black
Specific Gravity	2.51
Sand (%)	26
Silt and Clay (%)	74
Liquid Limit (%)	53.5
Plastic Limit (%)	22.75
Plasticity Index (%)	30.75
Shrinkage Limit (%)	13.05
MDD (KN/m ³)	13.09
OMC (%)	22

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B. Ground Granulated Blast Furnace Slag (GGBS)

India annually produces around ten million tons of blast furnace slag as by product of steel industry. The blast furnace slag is rich source of silicates and alumino silicates. For the present work GGBS was procured from Nandi Cements Pvt. Ltd., Bengaluru. The properties of GGBS are given in Table 2. Fig. 1 shows the GGBS used in this study for stabilization of soil.

Table 2: Properties of GGBS

Properties	Values
Colour	Off-white
Specific Gravity	2.85
Liquid Limit (%)	34.5
Plastic Limit (%)	Non Plastic
Plasticity Index (%)	Non Plastic
Shrinkage Limit (%)	33
MDD (KN/m ³)	16.324
OMC (%)	20



Fig. 1: GGBS used in present study

C. Sisal Fibers

For the present study, sisal fibers were obtained from Parbeer Industries, Nittur, Tumkur District, Karnataka State. The obtained fibers were cut in to 10mm-15mm length. The properties of sisal fibers are given in Table 3. Fig. 2 shows the sisal fibers used in the present study.

Table 3: Properties of sisal fibers

Properties	Values
Colour	White
Average Diameter, mm	0.215
Length of Fiber, mm	10 - 20
Average Tensile Strength (N/mm ²)	138
Density (KN/m ³)	14.22

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Fig. 2: Sisal fibers used in present study

III.METHODOLOGY

The standard Proctor compaction test was conducted to obtain the optimum dosage of GGBS. The test specimens for unconfined compressive strength test were prepared. The black cotton soil and optimum dosage of GGBS are mixed with different percentages (0.25%, 0.5%, 0.75%, 1.0%, 1.25% and 1.5%) of sisal fibers to prepare unconfined compressive strength test specimen. The prepared unconfined compressive strength test specimens were kept for curing in desiccators. The CBR mould were prepared with black cotton soil and optimum dosage of GGBS are mixed with different percentages (0.25%, 0.5%, 0.75%, 1.0%, 1.25%, 1.5%) of sisal fiber, kept for saturation and then were tested. The three tests were conducted which are Compaction test, UCS test and CBR test.

IV.RESULTS

Various tests were carried out in accordance with the standard procedure to determine the compaction characteristics, unconfined compressive strength and penetration resistance of GGBS treated sisal fiber reinforced soil. The test results as follows.

A. Compaction Characteristics Of Black Cotton Soil Mixed With GGBS

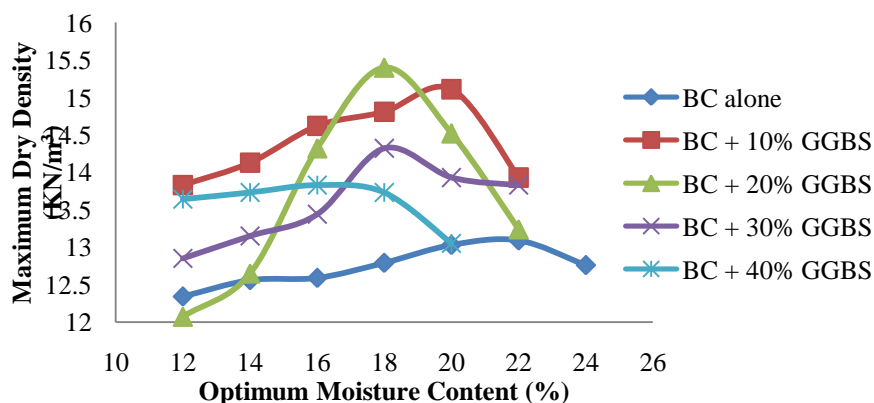


Fig. 3: Compaction characteristics of BC soil with different percentages of GGBS

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Fig. 3 shows the typical moisture density relationship curves obtained for BC soil treated with different percentage of GGBS. From the figure it can be observed MDD and OMC were obtained with addition of 20% GGBS to BC soil in present study. Hence it can be concluded that 20% GGBS is optimum dosage of BC soil used in present study.

B. Unconfined Compressive Strength Test Results

i. Effect of GGBS on UCC strength of BC soil

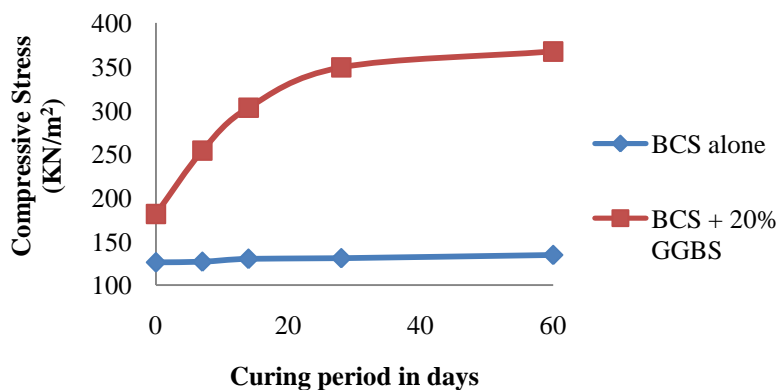


Fig. 4: Variation of UCC Strength of BC and BC + 20% GGBS

From fig. 4 it can be observed that the UCC strength of BC soil alone, mixture of BC soil and GGBS increases with curing. In starting up to 28 days strength increases in high rate after which the strength increases gradually. The curve of BC soil and 20% GGBS shows that after certain period of curing the maximum strength will be achieved above which further increase in UCC strength will not occur

ii. Effect of curing period on UCC strength

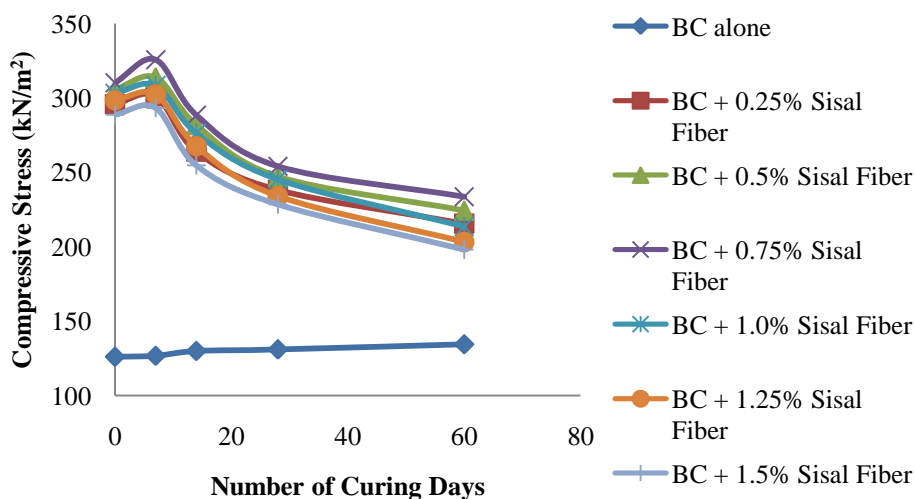


Fig. 5: Variation of UCS for BC soil with various percentages of sisal fibers

The fig. 5 shows the effect of sisal fibers on UCC strength of BC soil. It can be observed that UCC strength of soil increases up to 7 days of curing after which starts decreasing. The specimen having 0.75% fibers gives the best UCC

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strength for all curing days. The slope of the curves from 7days curing to 30 days curing is more, after which it reduces. The decrease in compressive stress occurs due to the biodegradation of sisal fibers.

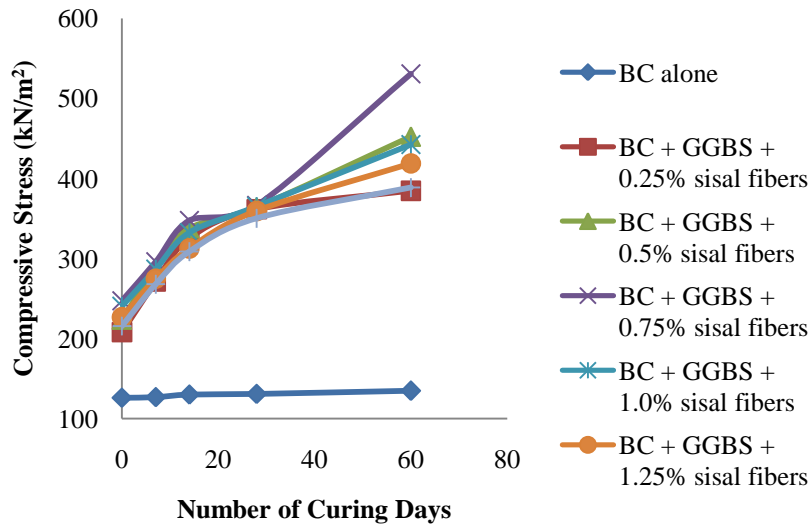


Fig. 6: Variation of UCS for mixture of BC soil and GGBS with various percentages of sisal fibers

From fig. 6 it can be observed that the compressive stress of all the specimens increases with increase in curing days. The compressive stress of all specimens increases rapidly up to 14 days curing beyond which the compressive stress increases gradually. The mixture of BC soil + 20% GGBS + 0.75% sisal fibers gives maximum strength after curing for 90 days which is 530.721 KN/m².

iii. Effect of sisal fiber percentage

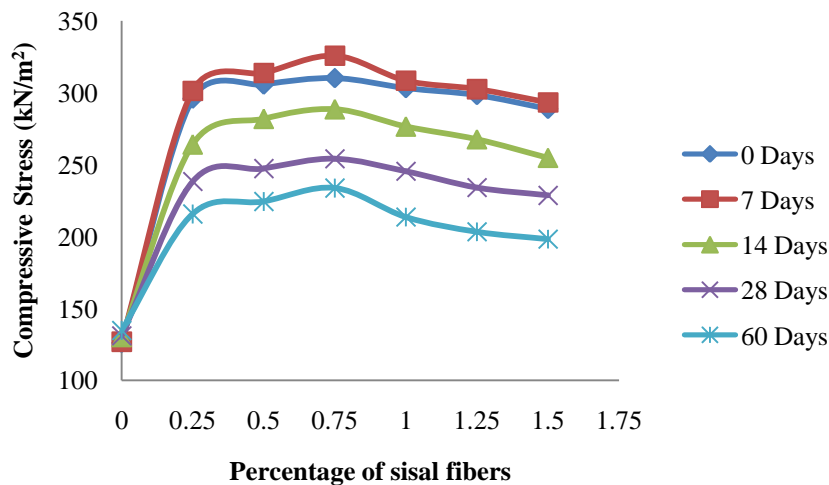


Fig. 7: Variation of UCC strength with Percentage increase of sisal fibers

The fig. 7 shows the UCC strength of BC soil with various percentages of sisal fibers. For all curing days the specimens containing 0.75% sisal fibers give maximum compressive stress. From fig, it can be observed the maximum compressive stress is obtained for 7 days of curing above which the stress starts decreasing. The very steep slope

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between 0.25% fiber and BC soil alone shows the large amount of increase in compressive stress, which is due to shear strength provided by sisal fibers.

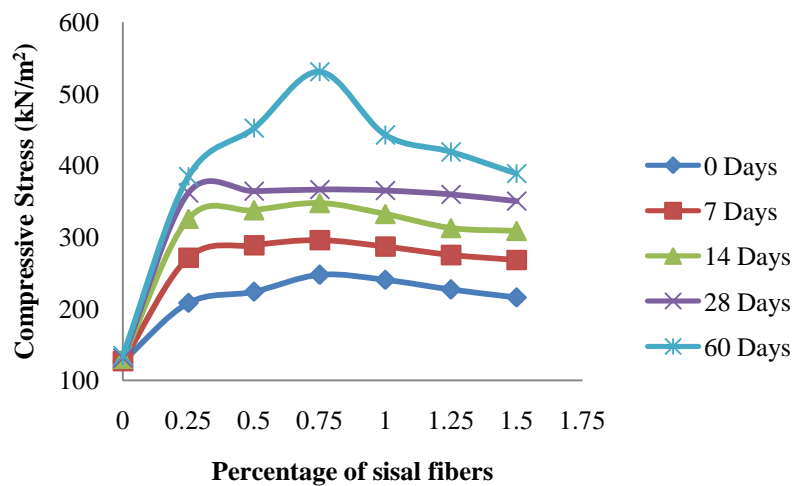


Fig. 8: Variation of UCC strength with Percentage increase of sisal fibers

From fig. 8 it can be observed that with increase in sisal fiber content the compressive stress also increases. For all different curing days the maximum Compressive stress is obtained for the mixture of 0.75% fiber. From fig, it can be observed that the compressive stress increases up to fiber content of 0.75% beyond which starts decreasing for all different curing days. The specimen containing 0.75% sisal fiber gives maximum compressive stress values for different curing days.

C. California Bearing Ratio Test Results

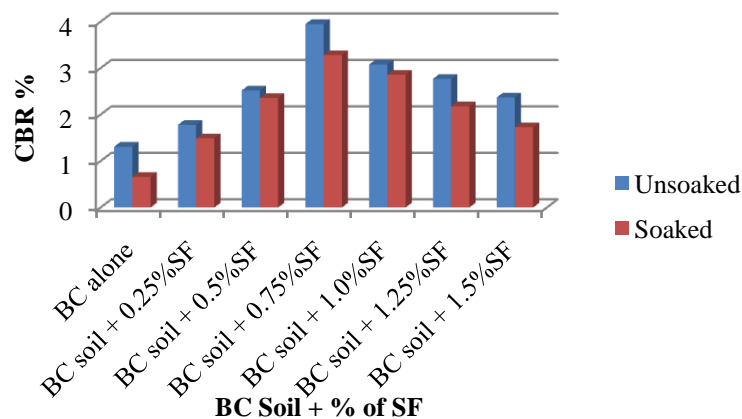


Fig. 9: Variation in CBR value with addition of sisal fiber

The fig. 9 shows the variation of CBR value with addition of sisal fiber. The unsoaked CBR values are greater than that of soaked CBR values. From the figure we can observe that as the percentage of sisal fiber increases the CBR value goes on increases u to fiber content of 0.75% beyond which it starts decreasing.

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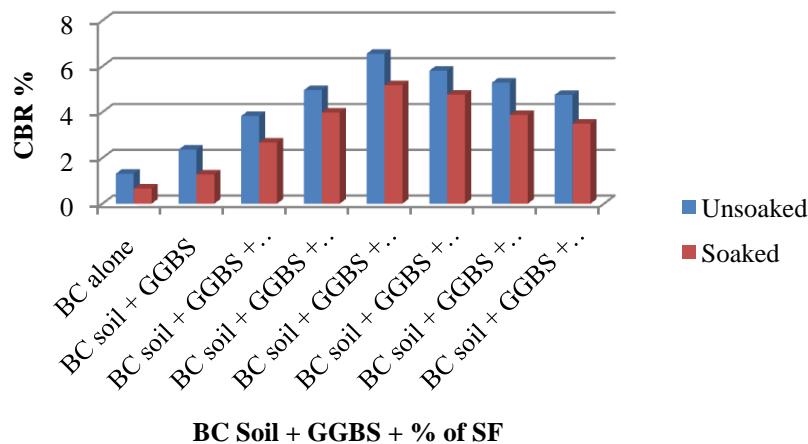


Fig. 10 Variation in CBR value with addition of Sisal fiber and 20% GGBS

From fig. 10 it can be observed a marginal increase in CBR value with addition of sisal fibers. The increase in CBR values occurs up to a fiber content of 0.75% after it starts decreasing. For both soaked and unsoaked condition the maximum CBR value is given by 0.75% sisal fibers.

V. CONCLUSION

This study evaluated the effect of GGBS and sisal fiber on compaction and strength properties of black cotton soil. A series of tests were conducted to study the effect of GGBS and Sisal fibers on strength characteristics of black cotton soil.

- GGBS is a waste product which is produced abundantly from iron factories, as it is having high specific gravity of 2.85 it is used as stabilizing material.
- The benefits of using these additives for soil stabilization are, typically cheaper than cement, lime etc. because slag sources are easily available across India.
- Up on addition of GGBS to BC soil the density of BC soil increased from 13.15KN/m^3 to 15.4KN/m^3 .
- From compaction test the optimum GGBS content was found to be 20% as the dry unit weight was maximum corresponding to 20% GGBS when compared other percentages of GGBS
- UCC strength of BC soil found to be 134.593KN/m^2 , which is increased to 530.712KN/m^2 upon addition of 20% GGBS and 0.75% SF for 60 days curing, UCC strength has increased 4 times that of BC soil alone.
- The curing period increased the UCC strength of specimens having GGBS and SF. The increment in strength was found to be 274.212KN/m^2 to 530.721KN/m^2 for specimen having optimum GGBS and 0.75% SF for 60 days curing.
- The UCC strength of specimens having 0.75% SF only increased from 310.136KN/m^2 to 325.692KN/m^2 for 7 days curing, beyond which strength reduced drastically.
- Addition of 20% GGBS with 0.75% SF give increase in CBR value from 1.31 to 6.55 for unsoaked condition and 1.31 to 5.71 for soaked condition, further increase in SF content the CBR value decreases.
- From whole study it can be concluded that 0.75% SF and 20% GGBS is optimum dosage for BC soil used in present study.

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