IJNRD.ORG ISSN : 2456-4184

INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG

An International Open Access, Peer-reviewed, Refereed Journal

Experimental Investigation on Strength Properties of Black Cotton Soil Stabilized with GGBFS.

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***Abstract**: Black cotton soils are normally very stiff when they are dry and become soft when they are saturated. Soft clays are associated with low compressive strength and excessive settlement. This low strength due to moisture leads to severe damages to buildings and foundations. The soil behavior can hence be a challenge to the design engineer to build and plan the structure on clay deposits The damages caused by the expansive soils are not because of the lack of inadequate engineering solutions but due to the failure to identify the behavior of these soils with respect to strength characteristics. For improvement in the problematic soil it has to be either replaced by suitable soil or has to be stabilized. The high cost involved in the replacement of soil led researchers to go for soil stabilization with different additives. Adding cementing agents or industrial byproducts like fly ash, GGBFS, RHA, Silica fume etc with soil results in improved geotechnical properties. This research paper addressed the utilization of GGBFS for increasing the strength properties of BC soil for structural applications.*

***Index Terms** – BC soil, GGBFS, Stabilization.*

I INTRODUCTION

Stabilization is a method where the GGBFS acts as a stabilizing agent that alters the properties of a soil chemically to meet the specified engineering requirements based on its field application. Soft clay is always susceptible for settlement and consolidation. Stabilization of soft clay with GGBFS results in increased strength, reduced compressibility and shrinkage. Clay soils provide a challenge to the geotechnical engineer due to their considerable variety in terms of composition and properties and in particular their variation in properties with time and loading.

Soil stabilization is used in many areas of the construction industry such as roads, parking lots, airport runways, building sites, landfills etc. The use of soil stabilization for slope protection, dam cores, impervious liners are feasible based on both economical & service life considerations. A the water infiltrate and weaken the underlying soil layer and due to the wheel loads moving on the surface layer will damage the pavement structure, the use of stabilization method in road construction proved to be the one of the best method.to increase the life of the pavement.

II LITERATURE REVIEW

With the addition of GGBS (5%, 10%, 15%, 20%, and 25% by weight of soil) to the mixture of soil, OMC goes on decreasing and simultaneously MDD goes on increasing which shows that compactness of the soil increases with the rise of GGBS and makes the soil denser. (Ashish Kumar Pathak .et.al 2014) [1], (Anil Kumar Sharma .et.al 2016) [2]. The optimized stabilized proportions obtained are 30% for GGBFS. (Gyanen Takhelmayum .et.al 2013) [29] Addition of GGBFS to expansive soil shows the utmost dry density of expansive soil amplified. (S. Durga Prasad .et.al 2019) [33]. Use of slag as an admixture for improving engineering properties of the soils is a cost-effective solution to use the locally available poor soil.(K.V. Manjunath .et.al 2012) [32] It is observed that with increase of slag, more stability of soil is achieved as compared to using lime alone. It is often observed that with the utilization of GGBFS, the black cotton soils are often stabilized efficiently. (Anil Kumar Sharma .et.al 2011) [22]. GGBFS gives less dry density than cement and ash at any varied percentage but increases compared to normal black cotton soil.(B. Rajendra.et.al 2017) [35]. With the increase of GGBFS percentage optimum moisture content goes on decreasing while maximum dry density goes on increasing, hence compatibility of soil increases making the soil denser. (Pingili Sravanthi .et.al 2017) [28], (Tirtha Sathi Bandyopadhyay.et.al 2016) [21], (Anil Kumar Sharma .et.al 2016) [19].

The unconfined compressive strength of soil was found to increase with increase in binder content further more as long as curing period. (Anil Kumar Sharma .et.al 2016) [19] The compressive strength of stabilized mixes increases with curing period.

The ratio of UCS values at 14 and 7 days of curing is found to be higher for low slag contents, indicating that the addition of slag to the fly ash– cement mixes accelerates the puzzolonic reaction. An increase within the percentage of cement within the fly ash–GBFS mix increases enormously the CBR value. Also, increase of GBFS within the fly ash sample with fixed cement content improves the CBR value of the stabilized mix. (S.P. Singh .et.al 2007) [26]. both soaked and unsoaked CBR of fly ash-GGBS mixture increases with the increase in the GGBS content. (Tirtha Sathi Bandyopadhyay.et.al 2016) [21]. Optimum amount of GGBS was 30% because it increased the maximum dry density to 1.80gm/cc from 1.59gm/cc of BC soil. In spite of the development indicated during this research, .(B. Rajendra.et.al 2017) [35] With the increase of GGBS percentage compressive strength increases which means arrangement of soil particles are very close, which reduces the voids and more suitable for pavement construction. Triaxial test result indicates that with the increases of GGBS percentage cohesion (C) decreases while angle of internal friction increases thus making the soil less cohesive and more resistant. Hence with the increase of GGBS percentage compressive strength also increases. (Ashish Kumar Pathak .et.al 2014) [24], (Tirtha Sathi Bandyopadhyay.et.al 2016) [21], (Ashish Kumar Pathak .et.al 2014) [24].

III RESEARCH METHODOLOGY

This explains about the soil which is used for investigation and also the properties of stabilizer used in the study namely ground granulated blast furnace slag.

3.1 Materials used:

3.1.1 Black cotton soil: Black cotton soil used in the study is obtained from Belagavi in the state of Karnataka. It is smooth in texture. For the purpose of tests, the soil is collected at a depth of 1mt below the ground level. It is pulverized, dried, sieved through different sieves for the required tests and stored in polythene bags in the laboratory. The chemical compositions of BC soil is as shown in table: 3.1

Fig: 3.1 BC soil used in research work.

Table: 3.1 Chemical composition of BC soil.

Chemical present	Available percentage.
Ca O	1.05
SiO_2	79.93
Al_2O_3	10.59
Fe_2O_3	5.07
MgO	2.11
Na	0.6
K	1.11

3.1.2 Ground granulated blast furnace slag: GGBFS is very fine off white colored powder which is commercially procured for the research work. The chemical compositions of ggbfs is shown in table: 3.2

Fig: 3.2 Ground granulated blast furnace slag used in research work.

Table: 3.2 Chemical composition of GGBFS

Chemical present	Available percentage.
Ca O	43.2
SiO_2	33.8
Al_2O_3	13.68
Fe_2O_3	0.4
MgO	0.46
SO_3	-----

3.1.3 Methodology.

To understand the behavior of stabilized BC soil the initial tests on BC soil, BC soil stabilized with GGBFS are conducted. Standard tests are performed in the laboratory for the physical properties.

3.1.3.1 Characterization of expansive soil (BCS): Characterization of expansive soil is done on the basis of engineering properties of BC soil. Series of laboratory tests are conducted to determine these properties. Following is the experimental programme which is planned for tests on soil.

1) Tests conducted on BC soil.
2) Tests conducted on BC soil stabilized with GGBFS.

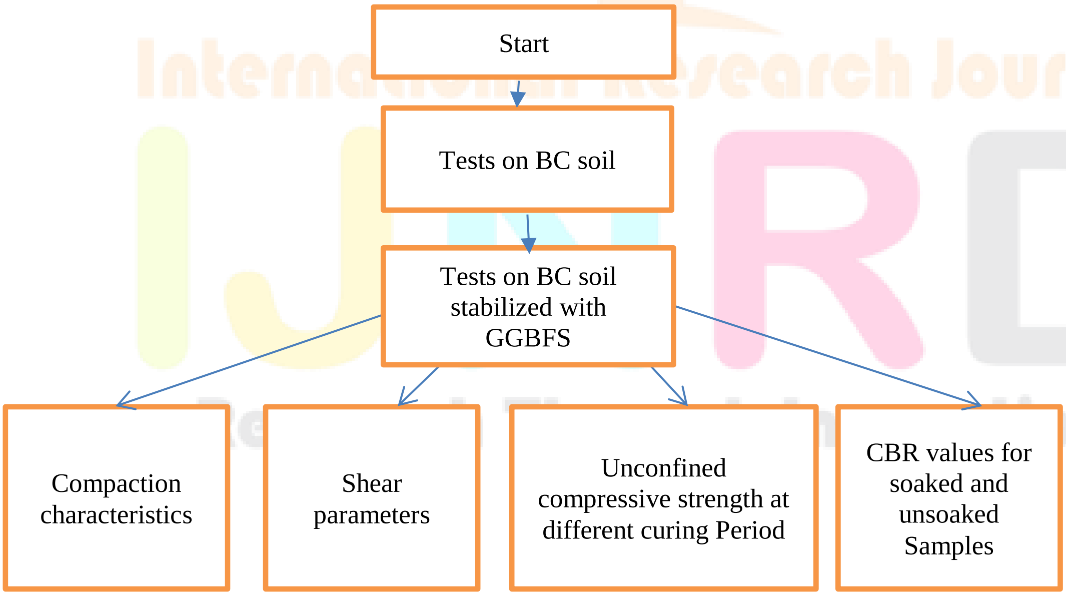

Fig: 3.3 Different set of experiments conducted on BC soil stabilized with varying percentages of GGBFS.

IV. RESULTS

Table: 4.1 Strength properties of BC soil stabilized by GGBFS.

Percentage replacement of BC soil by GGBFS	Unconfined compressive strength kg/cm^2						Cohesion (C) kg/cm^2	Percentage increase or decrease of cohesion w.r.t reference mix	Angle of internal friction (Φ)^o	Percentage increase or decrease of (Φ^o)w.r.t reference mix	CBR %			
	Day1	Percentage increase or decrease of UCS for day-1 w.r.t reference mix	7 days	Percentage increase or decrease of UCS for day-7 w.r.t reference mix	28 days	Percentage increase or decrease of UCS for day-28 w.r.t reference mix					Unsoaked	Percentage increase or decrease of unsoaked CBR w.r.t reference mix	Soaked	Percentage increase or decrease of soaked CBRw.r.t reference mix
0%	1.29		1.3		1.3		0.3		13		5.6		3.65	
5%	5.59	330.00	7.65	488.46	15.76	1112.31	0.26	-13.33	14.6	12.31	8.32	48.57	3.8	4.11
10%	6.66	412.31	12.35	850.00	22.33	1617.69	0.21	-30.00	15.3	17.69	11.56	106.43	3.94	7.95
15%	6.78	421.54	12.47	859.23	22.39	1622.31	0.16	-46.67	18	38.46	14.78	163.93	4.85	32.88
20%	6.84	426.15	12.55	865.38	22.46	1627.69	0.13	-56.67	21.2	63.08	16.34	191.79	6.4	75.34
25%	6.91	431.54	12.63	871.54	22.51	1631.54	0.1	-66.67	23	76.92	18.78	235.36	7.32	100.55
30%	7.03	440.77	12.67	874.62	22.58	1636.92	0.09	-70.00	25.7	97.69	22.53	302.32	8.9	143.84
35%	5.79	345.38	11.92	816.92	21.68	1567.69	0.15	-50.00	22.4	72.31	21.17	278.04	7.82	114.25
40%	5.53	325.38	11.87	813.08	21.53	1556.15	0.27	-10.00	19.7	51.54	19.8	253.57	7.17	96.44

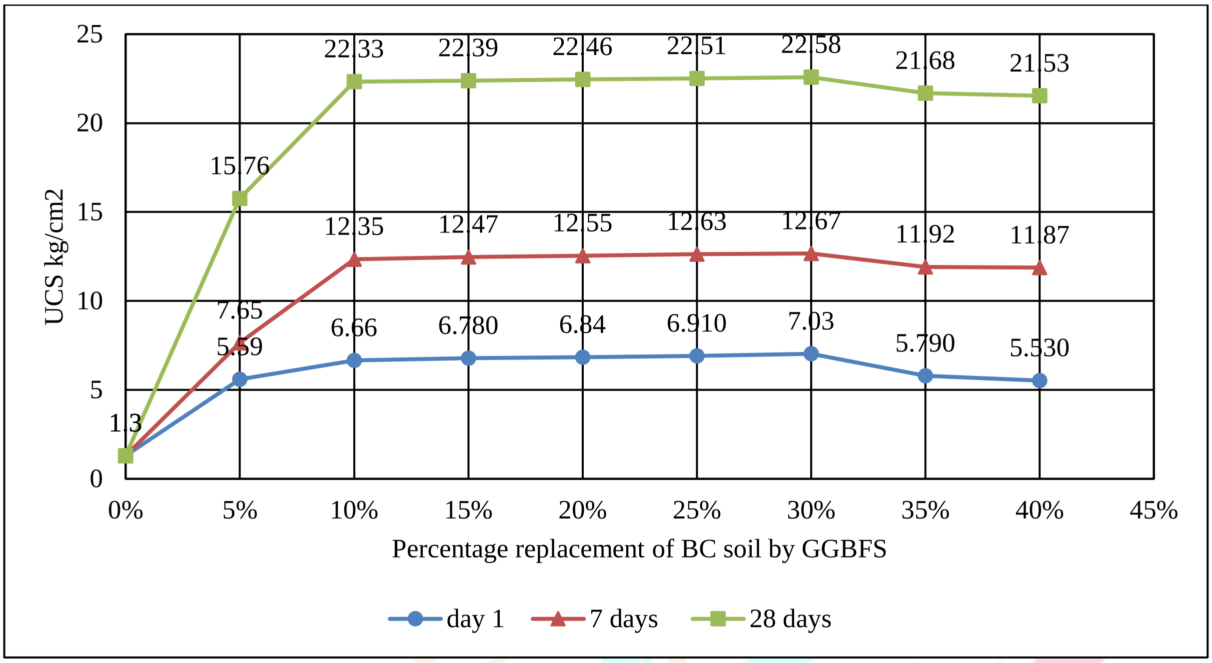

Fig: 4.1 Variation of UCS for different percentage replacement of BC soil by GGBFS for different days of curing.

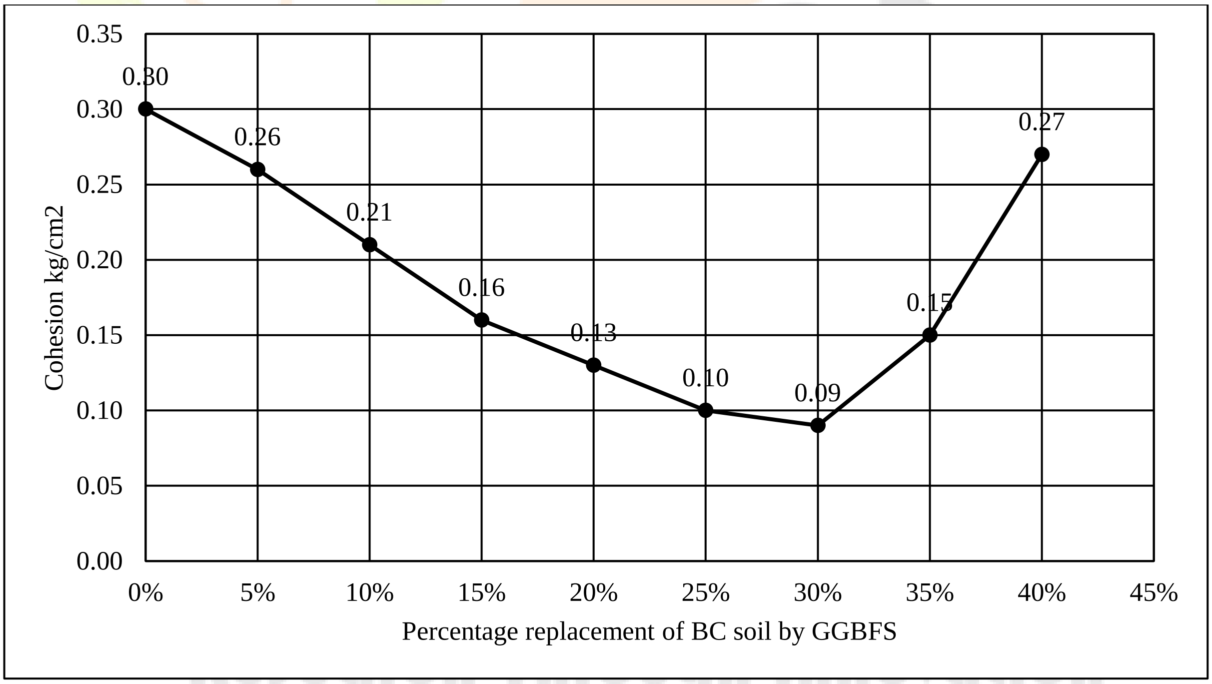

Fig: 4.2 Variation of cohesion for different percentage replacement of BC soil by GGBFS.

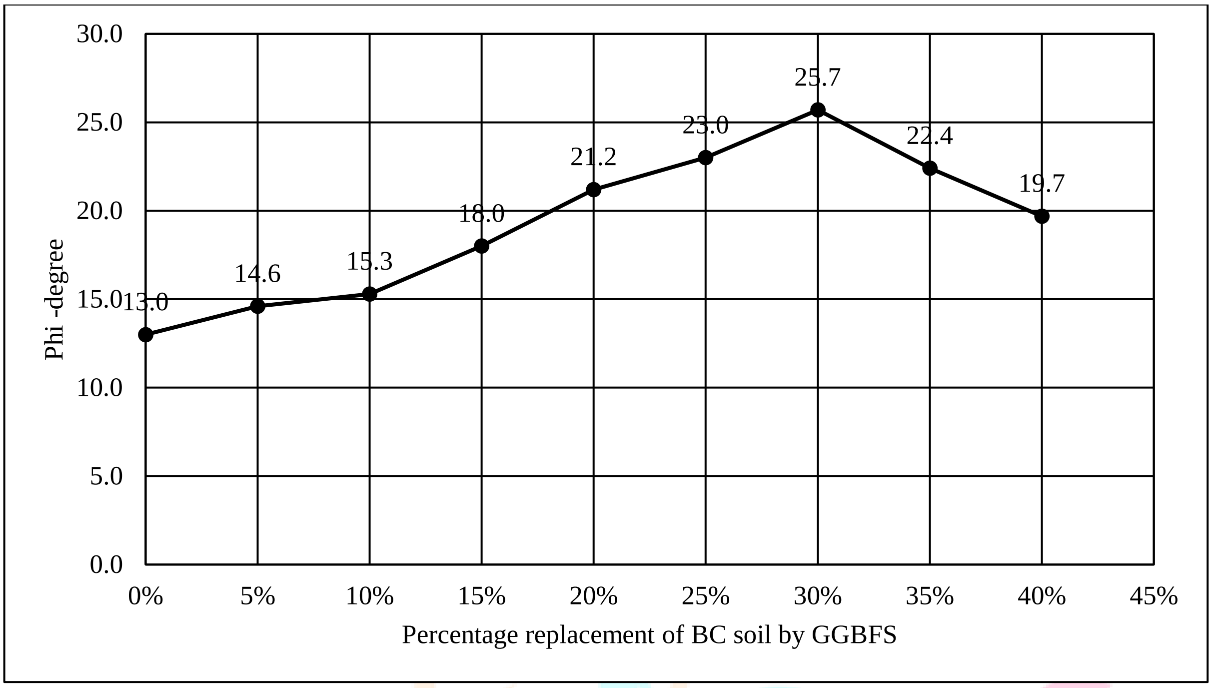

Fig: 4.3 Variation of angle of internal friction for different percentage replacement of BC soil by GGBFS

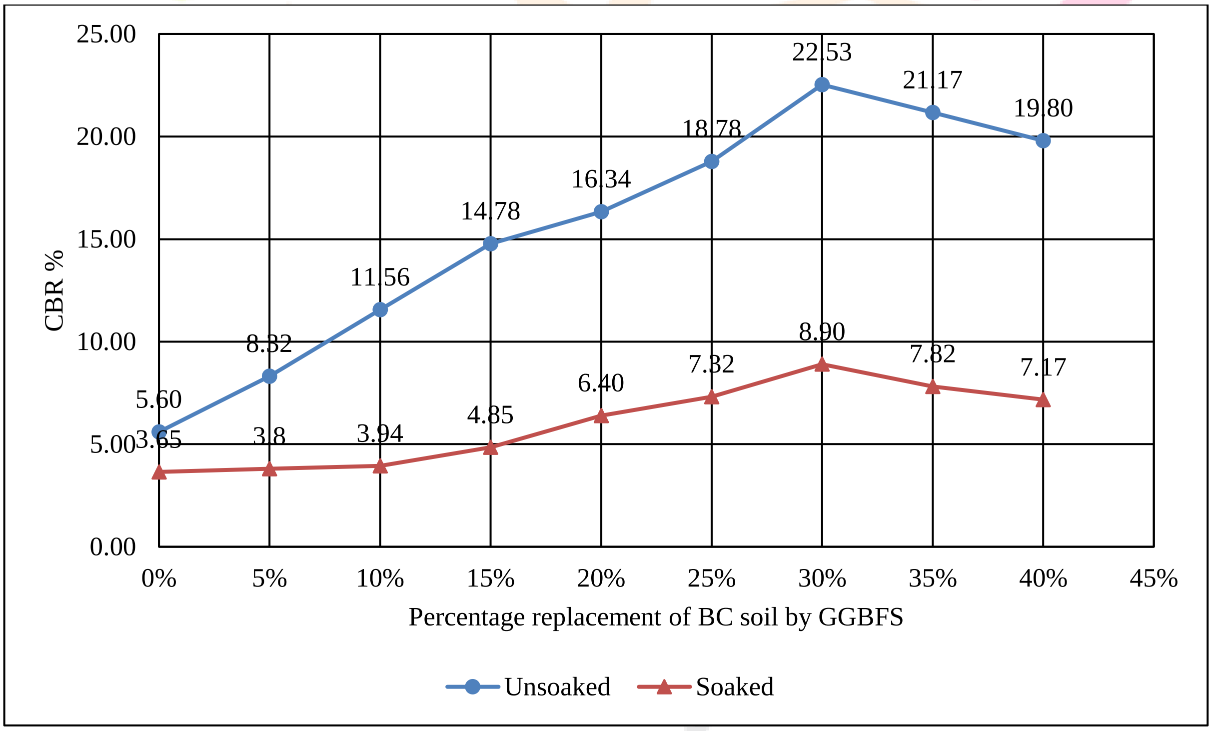

Fig: 4.4 Variation of unsoaked and soaked CBR values for different percentage replacement of BC soil by GGBFS.

V. DISCUSSIONS

Table 4.1 and figures 4.1, 4.2, 4.3 and 4.4 shows the variation of unconfined compressive strength, cohesion, angle of internal friction and CBR values for BC soil at different percentage replacement by GGBFS. Unconfined compressive strength for day 1, 7^{th} day and 28^{th} day of curing is shown in figure 4.1. There is increase of unconfined compressive strength up to 30% replacement level. After 30% level the unconfined compressive strength values start decreasing slightly. At 30% replacement level, the 28 days unconfined compressive strength is found to be 22.58 kg/cm$^{2.}$

This may be due to the fact that at 30% replacement of BC soil by GGBFS, the moisture available, in the system is such that, it reacts with the available GGBFS and produces the hydration products such as C_3S and C_2S which ultimately result in C-S-H gel and this is responsible for binding the particles more effectively.

It is observed from figures 4.2 and 4.3 that the cohesion value reaches its least value (0.09 kg/cm$^{2)}$ and angle of internal friction (Φ) reaches its higher value (25.7^{o}) when 30% of BC soil is replaced with GGBFS. There after cohesion value increases and Φ value decreases.

This may be due to the fact that GGBFS treated BC soil shows brittle behavior compared to non-treated BC soil because of the formation of sand like particles during stabilization process.

Table 4.1 and figure 4.4 illustrates the variation of CBR values. It is observed that soaked and unsoaked CBR values reach higher values when 30% BC soil is replaced by GGBFS. There after the CBR values show decreasing trend.

This may be attributed to the increase in the contact area and adhesion between GGBFS and BC soil which will create a dense network of interconnected particles. The increase in CBR value is due to the shear transfer mechanism between the soil and GGBFS and the improvement in the strength might be due to the puzzolonic action of BC soil-GGBFS mix.

VI.CONCLUSIONS

1. It may be concluded that the higher value of unconfined compressive strength may be obtained when 30% BC soil is replaced with GGBFS.
2. It may be concluded that the cohesion value reaches its least value and Φ reaches its higher value when 30% BC soil replaced by GGBFS.
3. It may be concluded that the CBR values reach their higher value when 30% BC soil is replaced by GGBFS.

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