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Stabilization of Black Cotton Soil by Ground Granulated Blast Furnace Slag (GGBS)

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Abstract - *Black cotton soil is considered as a problematic soil because it has less stability, less shear strength, large expansion and shrinkage in volume caused by their alternate swelling and shrinkage with changing season.*

On the other hand, Ground Granulated Blast Furnace Slag (GGBS), which is a by-product of pig iron and steel industry industrial waste, causes land pollution. In India over 10 million tons of ground granulated blast furnace slag is produced every year. [15]

In this paper, experimental study is conducted on the stabilization of black cotton soil by Ground Granulated Blast Furnace Slag.

Key Words**: Black Cotton Soil, Swelling, Shrinkage, Stability, Shear Strength, Ground Granulated Blast Furnace Slag, Stabilization.**

1. INTRODUCTION

The black cotton soil occurs in major parts of Kalaburagi district and it is derived from Deccan Traps. The demerits of black cotton soil obstructs constructional works like big infrastructure, road pavements, etc. on this soil. Hence, Stabilization of this soil is required. Apart from various conventional methods of soil stabilization, stabilization by GGBS could not only solve the problem of proper stabilization of black cotton soil, but also solve the issue of disposal of an industrial waste i.e. GGBS.

1.1. SIGNIFICANCE OF THE PROJECT

Soil properties vary a great deal and construction of structures depends a lot on the bearing capacity of the soil, hence, we need to stabilize the soil, which makes it easier to predict the load bearing capacity of the soil and even improve the load bearing capacity.

The gradation of the soil is also a very important property to keep in mind while working with soils. The soils may be well graded which is desirable as it has less number of voids or uniformly graded which though sounds stable but has more voids. Thus, it is better to mix different types of soils together to improve the soil strength properties. It is very expensive to replace the inferior soil entirely and hence, soil stabilization is the thing to look for in these cases.

- It improves the strength of the soil, thus, increasing the soil bearing capacity.
- It is more economical in terms of both cost and energy to increase the bearing Capacity of the soil rather than going for deep foundation or raft foundation.
- It is also used to provide more stability to the soil in slopes or other such places.
- Sometimes soil stabilization is also used to prevent soil erosion or formation of dust, which is very useful especially in dry and arid weather.
- Stabilization is also done for soil waterproofing; this prevents water from entering into the soil and hence helps the soil from losing its strength.
- It helps in reducing the soil volume change due to change in temperature or moisture content.
- Stabilization improves the workability and the durability of the soil.

2. LITERATURE REVIEW

1. The studies of **Rehana Rasool et al. (2017)** proves that the primary benefits of using GGBS for soil stabilization are Cost Savings: because slag is typically cheaper than cement and lime; and Availability: because slag sources are easily available across the country from nearby steel plants. Waste management of one of the industrial wastes can be done economically. Use of slag as an admixture for improving engineering properties of the soils is an economical solution to use the locally available poor soil. [1]

2. **Rajesh Jain et al. (2017)** states that -The lowest dry density was observed to be about 1.84g/cc for 90% soil and 10% GBFS mixture and maximum density was about 2.05 g/cc for 50% soil and 50% GBFS mixture. The lowest CBR value was observed to be about 3.26% for 90% soil and 10% GBFS mixture and maximum CBR value was about 8.74% for 50% soil and 50% GBFS mixture. [3]

3. **Faisal I. Shalabi et al. (2017)** from Saudi Arabia says that- Unconfined compressive strength of the treated clay soils with GGBS depends on the initial compaction conditions of the soil. While the zero GGBS compacted soil, shows a decrease in UCS with the increase in GGBS content, the compacted soil at different GGBS content shows almost a slight change in UCS with GGBS content. In addition, CBR value of the treated clay soil was found to increase with the increase in GGBS content, and it is in a reverse relation with the free swell value. [2]

4. The works of **Mukul Dhake et al. (2017)** suggests that from UCS test results the addition of GGBS up to 40%, it increases the strength of the test specimen. However, after 30% there is very little increase in UCS strength. The UCS strength increased from 230.1KPa for 100% black cotton soil (0% GGBS) to 443.3 for 70% black cotton soil (30%GGBS). Therefore, they have concluded that 30% is the optimum dosage of GGBS in soil. [4]

5. **Ashutosh Rawat et al. (2016)** states in their paper that using GGBS as stabilizer gives the following advantages cost savings, availability, waste management. It was also observed that with increase of slag, more stability of soil is achieved as compared to using lime alone [5]

2.1. FINDINGS FROM LITERATURE REVIEW

- Most researchers found that the application of GGBS on the soil improves the CBR largely.
- Improves the soil structure sufficiently which results in cost savings
- Improves load capacity, and reduces the occurrence of serious defects such as potholes and rut formation, resulting in fewer maintenance needs.
- Application of GGBS offer good results on expansive soils.
- Improves Unconfined Compressive Strength
- Decrease of plasticity index
- Reduces swell index

2.2. PROPERTIES OF MATERIALS REQUIRED

2.2.1. Black cotton soil

Black cotton soil was obtained from agricultural fields on Rajapur road of Kalaburagi region, the soil was pulverized and then it was oven dried for 24 hours at 105°c to 110°c.

TABLE -2.2.1: ENGINEERING PROPERTIES OF BLACK COTTON SOIL

PARTICULARS	TEST RESULT
Liquid limit (%)	71%
Plastic Limit (%)	32.7%
Plasticity index (%)	38.3%
Free Swell Index (%)	53.3 %
Compaction characteristics OMC (%) MDD(g/cc)	 31.06% 1.4
CBR (soaked)	1.38%
UCS (kg/cm^2)	1.34
Classification	Fine Graded soil(CH)

2.2.2. Ground Granulated Blast Furnace Slag

Ground Granulated Blast Furnace Slag was obtained from JINDAL STEEL WORKS, located at Bellary region of Karnataka. It is available at a rate of ₹200/- per ton. Its engineering properties are mentioned in the following table.

TABLE -2.2.2: ENGINEERING PROPERTIES OF GGBS

Specific Gravity	2.74
Grain size analysis	
D_{10}	0.28
D_{30}	0.45
D_{60}	0.99
Plasticity index	NP
Free swell	0
Weight/volume (g/cm^3)	1.39

2.3. METHODOLGY

The collected sample of black cotton soil was tested in lab for the investigation of various engineering properties and the following tests were conducted in two stages.

In the first stage, the plastic limit and liquid test were performed, in order to classify the soil sample (i.e. by Indian

soil classification system). Later all the remaining tests, mentioned below are conducted on this selected sample of black cotton soil without the addition of GGBS and the outcomes are noted.

In the second stage standard proctor compaction test was used to ascertain the optimum amount of GGBS. In addition, from previous studies it was found that the optimum value of GGBS lies in the range of 9%- 40%. Therefore, based on this range, even in this study the test conducted on soil was mixed with varying percentages of GGBS ranging from 5% to 40% (i.e. 5% 10%, 15%, 20%, 25%, 30%, 35%, 40%) by dry weight of soil. After analysing the result of these tests, the optimum value of GGBS was found to be 30%, at which the MDD is highest and OMC is relatively low compared to the other values.
Lastly, the remaining tests apart from standard proctor test are conducted on black cotton soil mixed with optimum percentage of GGBS and the results are well noted. [5, 9, 3, 8] The remaining tests performed on the soil sample are as follows:

1. Specific gravity
2. Test for free Swell Index
3. Test for Shear strength of soil
    I. California bearing ratio test
    II. Unconfined Compressive Strength

3. RESULTS

3.1.1. SEIVE ANALYSIS FOR BC SOIL

The soil was classified as "**FINE GRAINED SOIL**" of the type "**CH**".

3.1.2. SEIVE ANALYSIS FOR GGBS

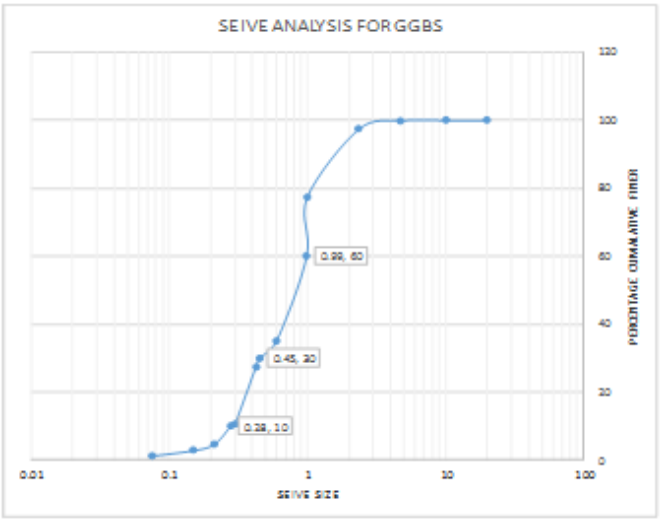

CHART -3.1.2: SIEVE SIZE VS PERCENTAGE CUMULATIVE FINER FOR GGBS

From graph

D10 = 0.28

D30= 0.45

D60=0.9

3.2. Specific Gravity

The Specific Gravity of BC soil was found to be **2.65**

The Specific Gravity of GGBS was found to be **2.74**

3.3. Atterberg's Limits

Liquid Limit of BC SOIL with 0% of GGBS:

Liquid limit (WL) = 71%

Plastic limit of BC SOIL:

Plastic limit (Wp) = 32.7%
Hence,
Plasticity index (Ip): IP = 38.3%.

Liquid Limit of BCS with 30% of GGBS:

Liquid limit (WL) = 54.9%

Plastic limit of Black cotton soil+ 30% GGBS:

Plastic limit (Wp) = 28.23%
Hence,
Plasticity index (Ip): IP = 26.67%.

3.4. Standard Proctor Test

TABLE -3.4: STANDARD PROCTOR TEST RESULTS FOR DIFFERENT PERCENTAGES OF GGBS

CONTENT	MDD(g/cc)	OMC (%)
Soil + 0% GGBS	1.4	31.06
Soil + 5% GGBS	1.46	28.61
Soil + 10% GGBS	1.47	25.6
Soil + 15% GGBS	1.48	23.14
Soil + 20% GGBS	1.49	22.15
Soil + 25% GGBS	1.5	21.5
Soil + 30% GGBS	**1.545**	**19.69**
Soil + 35% GGBS	1.525	22.29
Soil + 40% GGBS	1.52	24.26

Below is a plot of OMC vs MDD at various percentages of GBBS

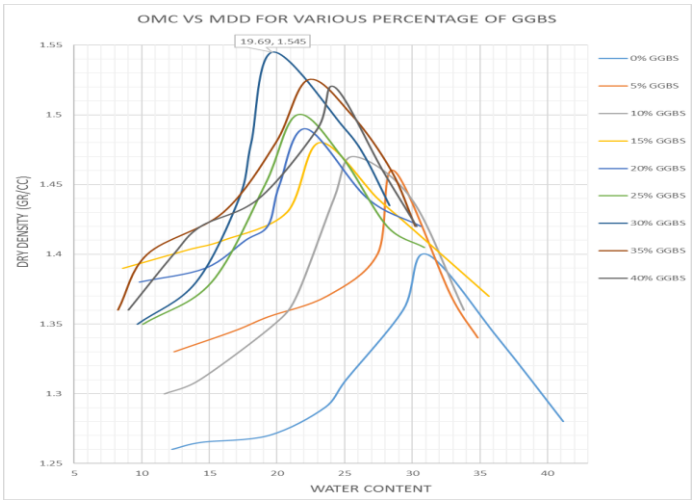

CHART -3.4: OMC VS MDD FOR VARIOUS PERCENTAGES OF GGBS

As, the OMC is lowest and MDD highest at 30% of GGBS, hence 30% is fixed as optimum percentage of GGBS.

3.5. FREE SWELL INDEX TEST OF SOIL

TABLE -3.5: SWELL INDEX VALUES AT 0% GGBS & 30% GGBS

CONTENT	FREE SWELL INDEX VALUE (%)
Soil + 0% of GGBS	53.3
Soil + 30% of GGBS	24.7

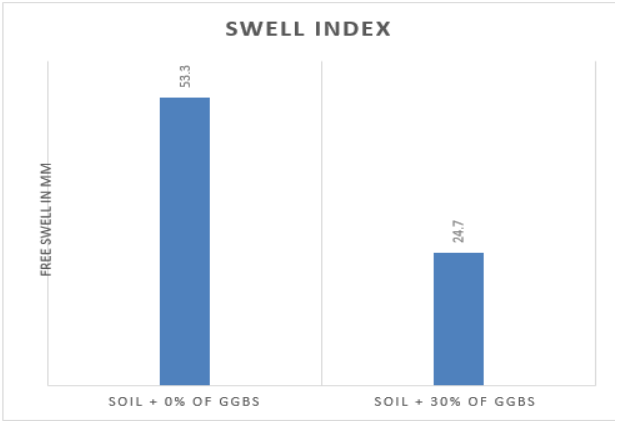

CHART -3.5: FREE SWELL INDEX @ 0% & 30% GGBS

3.6. CBR TEST

TABLE- 3.6: CBR VALUES AT 0% GGBS & 30% GGBS

CONTENT	BC SOIL +0% GGBS	BC SOIL +30% GGBS
CBR VALUE	1.38%	2.64%

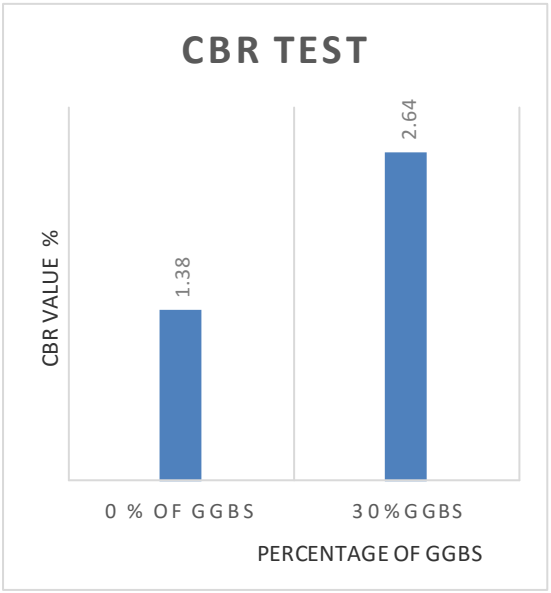

CHART -3.6: CBR @ 0% & 30% GGBS

3.7. Unconfined Compressive Strength

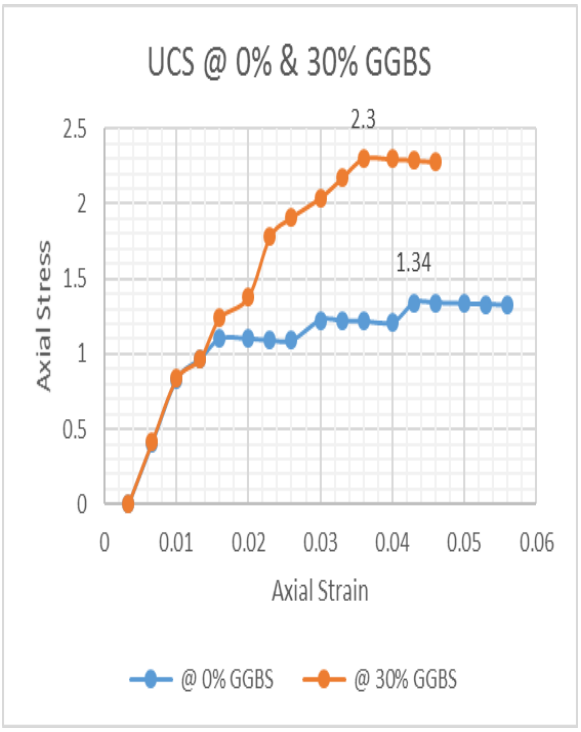

CHART -3.7: UCS AT 0% & 30% GGBS

TABLE -3.7: UCS VALUES AT 0% GGBS & 30% GGBS

CONTENT	UCS VALUE (kg/cm^2)
Soil + 0% of GGBS	1.34
Soil + 30% of GGBS	2.3

3.8. COMPARASION OF RESULTS

TABLE- 4: COMPARSION OF RESULTS AT 0% AND 30% GGBS

SL NO.	PARTICULARS	@0% GGBS	@ 30% GGBS	% DIFFERENCE
1	LIQUID LIMIT (%)	71	54.9	22.67 % Decrease
2	PLASTIC LIMIT (%)	32.7	28.23	13.6% Decrease
3	PLASTICITY INDEX (%)	38.3	26.67	30.36% Decrease
4	COMPACTION CHARACTERISTICS OMC (%) MDD (g/cc)	 31.06 1.4	 19.69 1.545	 36.6% Decrease 10.3% Increase
5	CBR (SOAKED)	1.38%	2.64%	91.3% Increase
6	UCS (KG/CM^2)	1.34	2.3	71.6% Increase

4. CONCLUSIONS

Following are the observations while using Ground Granulated Blast Furnace Slag as a stabilizer in black cotton soil of Gulbarga region:

1. The primary benefits of using these additives for soil stabilization are

a. Cost Savings: because slag is typically cheap.

b. Availability: because slag sources are easily available across the country from nearby steel plants.

2. Waste management one of the industrial wastes can be done economically.

3. Use of slag as an admixture for improving engineering properties of the soils is an economical solution to use the locally available poor black cotton soil.

4. It is observed that with increase of slag, more stability of soil is achieved

Finally, this study concluded that for the proportion of (BC soil + 30% slag)

The following results were obtained:

1. The Unconfined Compressive Strength of Black Cotton soil was increased by 71.61%

2. The MDD was increased by 10.3% and the OMC of Black Cotton Soil was decreased by 36.6%

3. The California Bearing Ratio of Black Cotton Soil was increased by 91.3%

4. The Plasticity Index of Black Cotton Soil was decreased by 30.36%

5. The Swell Index was reduced by 53.65%

Therefore, it could be concluded that GGBS is an effective stabilizer.

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