EFFECT OF GROUND GRANULATED BLAST FURNACE SLAG & FLY ASH ON GEOTECHNICAL PROPERTIES OF EXPANSIVE SOIL

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Abstract. Expansive soil is the most predominant geological hazard. As they get wet, the clay minerals assimilate water molecules and expand, on the other hand, as they shrink, leaving large voids in the soil which is a significant hazards for further construction Stabilization is found to be the most ideal way of reducing shrinkage & swelling nature of expansive soils. In modern days of industrialization, it is essential to utilize waste material from various industries to use for expansive soil to decrease the contaminating impact of waste material and to achieve beneficial outcomes. Likewise, use of Ground Granulated Blast Furnace Slag (GGBS) is served to be a good stabilizing agent for expansive soils and also being a by-product it fills in as an eco-friendly way of using the product without dumping it on ground. In the present study, local fly ash and GGBS is used as a mix to investigate the properties of expansive soil in various proportions. Various laboratory tests such as Standard Proctor test, Unconfined Compressive strength, California bearing ratio test are done to figure out the strength characteristics of compacted soil using GGBS and fly ash as well as tests like specific gravity to obtain the physical properties of soil.

Keywords: Expansive soil, Ground Granulated blast furnace slag (GGBS), fly ash, Unconfined Compressive Strength, California bearing ratio test.

1. Introduction

In evolving nation like India, due to the remarkable improvement in infrastructure, soil stabilization has turned the serious issue into development activity. The strength of the local soil is satisfactory for supporting the super structure over it. Soil stabilization is an unavoidable practice which improves the durability or bearing capacity of the soil by the utilization of controlled compaction, addition of reasonable stabilizer or admixture, improve toughness which at last improves

the performance. The industrial waste materials which are commonly toxic, ignitable, corrosive or reactive pose serious health and environmental consequences. Their use has just been demonstrated as the promising solution for disposal issues and cuts the production cost.

2. Literature Review

FushengZhaet. al. (2008)[1] presented the study of behavior of the soil stabilization with fly ash. It was found that the free swell, swelling pressure, swelling potential and linear shrinkage were decreased with the increase in the content of fly ash and lime-fly ash. This increment decreased Optimum Moisture Content and Maximum Dry Density. Negligible changes in the UCS value were observed. With increase in the content of fly ash without curing. Shear strength was increased with the addition of lime. It was concluded that the Optimum content of fly ash for treating soils with curing time of 7 days is 9-12%.

Anil Kumar Sharma et. al. (2012)[2] represented the experimental study on the improvement of strength of expansive soil with waste granulated blast furnace slag. It was observed that the Optimum Moisture Content and Maximum Dry Density were decreased with the addition of GGBS to the black cotton soil. The strength was observed when GGBS added up to 20% for the curing period of 7 days and 14 days up to 40% for the curing period 28 days. Further addition decreased the strength. When GGBS content was added up to 20% the initial tangent modulus was improves, further addition made a small change.

LaxmikantYaduet. al. (2013)[3] presented the study on the effect on the properties of soft soil with GGBS and fly ash. It was observed from the study that the Optimum Moisture Content goes on increasing with the addition of definite percentage of fly ash and GGBS to the black cotton soil. CBR value was increased with the increase in the GGBS percentage. It was found that 3% fly ash and 6% GGBS gives the best result with black cotton soil.

Oormila T.R. et. al. (2014)[4] presented a study on using Fly ash and GGBS for improving soil characteristics. Series of test have been conducted on Black Cotton soil mixed with Fly ash (5%, 10%, 15%, 20%) and GGBS (15%, 20%, 25%). The UCS test results was found to give optimum strength when added with 10% fly ash. The addition of 20% GGBS to black cotton soil gives optimum strength. The CBR test was performed with combination of 10% fly ash and 20% GGBS and with combination of 10% fly ash and varying percentage of GGBS (15%, 20%, 25%). It was found that the combination of 10% fly ash and 25% GGBS gives an increment of 78.29% in the CBR value when combined with the CBR value of virgin soil.

Dayalan J. et. al. (2016)[5] conducted a comparative study on stabilization of soil with GGBS and fly ash. It was observed from the study that the OMC keeps on

decreasing while MDD keeps on increasing with the addition of GGBS and fly ash. It was observed that CBR value increases with increase in percentage of fly ash up to 15% and again decreasing likewise for GGBS up to 15%. The OMC is 14.8%found at 10% of fly ash and of 13.7% is found at 10% of GGBS. The overall study concluded that the optimum value is 15% and 20% for fly ash and GGBS respectively.

C. Neeladharanet. al. (2019)[6] presented a study on stabilization of soil using fly ash with Ground Granulated Blast Furnace as binder. It is observed that with the increase in the addition of fly ash and GGBS, Optimum Moisture Content decreases and Maximum Dry Density increases. The soil group changed from CH to ML when 15% fly ash and 10% GGBS were added in combination. At this percentage, the shear stress increases and decreases with further addition. The CBR value was found to be increased at this percentage. It is concluded that 15% fly ash and 10% GGBS by weight of soil gives the better results.

3. Methodology Materials used

3.1 Methodology:-

This study deals with the details of the experimental work carried out using black cotton soil, Ground Granulated Blast Furnace Slag (GGBS) and Fly ash. Soil sample used for this experimental work was collected from Borkheda (devaliarab road) area, Kota, Rajasthan,India. GGBS was collected from Bajaj TMT Prem Jain Ispat Pvt. (RIICO, Ranpur), Kota, and Rajasthan. Fly ash used in this study was collected from Thermal Power Plant, Kota, and Rajasthan. The soil sample was collected at the depth of 1.5 to 2 m to avoid upper soil which may contain other waste and can affect the experimental results. It is very necessary to improve the geotechnical properties of expansive soils before using it for any constructional work due to their swelling and shrinkage characteristics. Hence an attempt is made in this study to improve the strength of raw soil by stabilizing it with different percentages of GGBS (4%, 8%, 12%, 16%, 20%) and fly ash (4%, 8%, 12%).

3.2 Materials used

3.2.1 Black Cotton Soil

Soil sample was collected at the depth of 1.5 to 2 m from Borkheda, Kota, Rajsthan. The soil sample was air dried to remove natural water present in it, which may affect test results.

The following laboratory tests are conducted on soil

- Atterberg Limit Test(As per IS 2720 – Part 5: 1985).
- Specific Gravity Test (As per IS 2720- Part 3 (Section 1): 1980.
- Differential Free Swell Test (As per IS: 2720- Part 40: 1977).
- Compaction Test (As IS 2720- Part 7: 1980 & Part 16: 1979).

- California Bearing Ratio Test (As per IS 2720- Part 16: 1979).
- Unconfined Compression Test (As per IS 2720- Part 10: 1991).

Some Geotechnical properties of raw Black cotton soil, as obtained from these laboratory test conducted in soil mechanics lab are mentioned in the Table 3.1.

Table1. Geotechnical Properties of Black Cotton Soil

S. No.	Properties	Values
1.	Specific gravity(G)	2.46
2.	Consistency Limits Liquid Limit (%) Plastic Limit (%) Plasticity Index (%)	 54.52% 34.70% 19.81%
3.	IS Soil Classification	CH
4.	Proctor Test MDD (g/cc) OMC	 1.773 21.2%
5.	CBR Value (%)	1.29%
6.	UCS (KN/m^2)	1.039

3.2.2 Ground Granulated Blast Furnace Slag (GGBS)

The Ground Granulated Blast Furnace Slag is as a by-product during the manufacturing of iron in a blast furnace. Molten Blast furnace slag has a temperature range of 1300-1600°C and cooled very rapidly to prevent the crystallization. The cementing property of GGBS is very useful to improve the strength of the black cotton soil when it is blended with the soil.

The general characteristics of GGBS are as following:-

- Composition:- CaO (30-50%), SiO_2 (28-38%), Al_2O_3 (8-24%), MgO (1-18%) and few percentage of Fe_2O_3, K_2O.
- The specific gravity is between 2.7 to 2.9.
- The Particle size is from 75μm to 2.5 mm.

3.2.3 Fly ash

Fly ash is fine, glass powder recovered from the gases of burning coal during the producing of electricity. The fly ash is also known as “pulverized fuel ash”. Fly ash includes substantial amount of silicon dioxide (SiO_2), aluminum oxide (Al_2O_3) and calcium oxide (CaO).

General Characteristics of Fly ash as following:-

- Specific gravity -1.9 to 2.96
- Particle size – 10 to 100 micron.
- Type of Fly ash based on IS 3812-1981.

Grade -1 (SiO_2+Al_2O_2+Fe_2O_3)>70%
Grade -2 (SiO_2+Al_2O_2+Fe_2O_3>50%

4 RESULT AND DISCUSSION

4.1 STANDARD PROCTOR TEST

This test was conducted based on IS: 2720, Part VIII (1983), Bureau of Indian Standards, New Delhi, 1-9. The standard proctor test is conducted in soil laboratory to find out the maximum dry density (MDD) and optimum moisture content (OMC) of black cotton soil and GGBS mix specimen.

(01) Standard proctor Test for Black cotton soil mixed with GGBS

Table 2. Test results obtained for the black cotton soil mixed with GGBS

Mix Specimen	OMC (%)	MDD (g/cc)
BC Soil	21.23	1.773
BC + 4% GGBS	19.23	1.785
BC + 8% GGBS	18.29	1.826
BC + 12 % GGBS	17.26	1.856
BC + 16 % GGBS	15.86	1.892
BC + 20% GGBS	16.4	1.873

From table 2, it is observed that the MDD of black cotton soil is increased up to 1.892 gm/cc at 16% with the addition of GGBS and after further addition, the MDD of soil is decreased while OMC of soil is increased. The MDD is found to be increased by 6.28%.

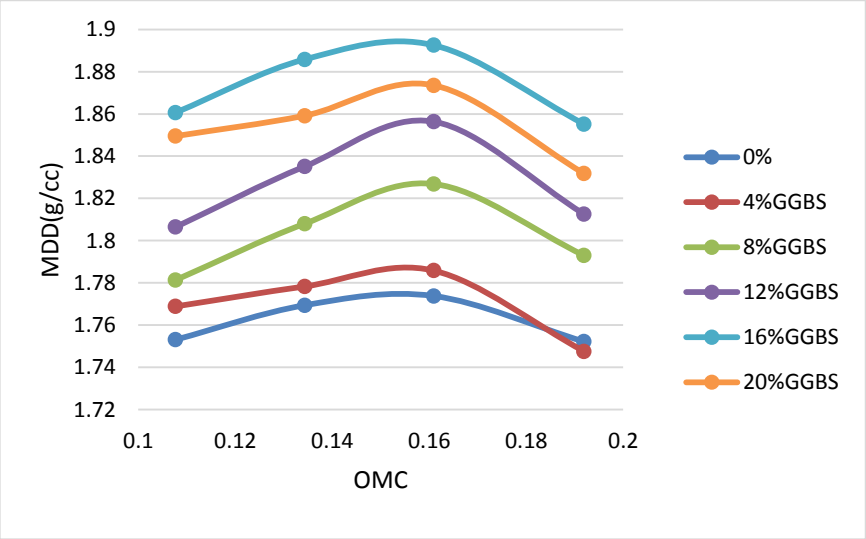


Figure 1. Compaction characteristics of the black cotton soil and GGBS

From Figure 1, it is observed that 16% GGBS gives the best results.

(02)Standard Proctor Test For Black Cotton Soil Mixed with GGBS and Fly ash

Table 3. The results obtained for black cotton soil mixed with GGBS and Fly ash.

Mix Specimen	OMC (%)	MDD (g/cc)
BC +16%GGBS +4%FA	17.05	1.90
BC + 16%GGBS + 8%FA	15.02	1.85
BC + 16% GGBS + 12%FA	16.09	1.89

From table 3, it is observed that the MDD of black cotton soil is increased up to 1.933gm/cc at 16% GGBS + 8% Fly ash, further addition decreases the MDD. Whereas, the OMC of soil is observed to be increased. The MDD is found to be increased approximately by 9%.

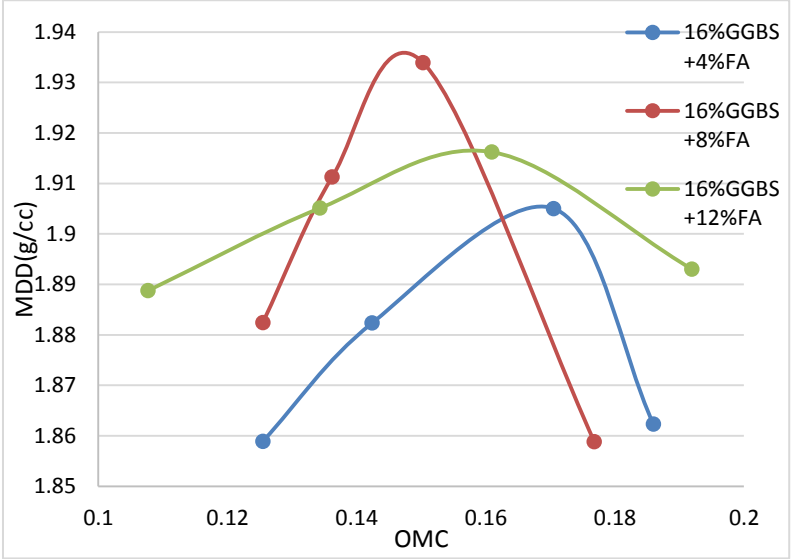


Figure 2. Compaction characteristics of the black cotton mixed with GGBS and Fly ash

From Figure 2, we conclude that peak value obsererved at 16%GGBS +8% fly ash

4.2 California Bearing Ratio

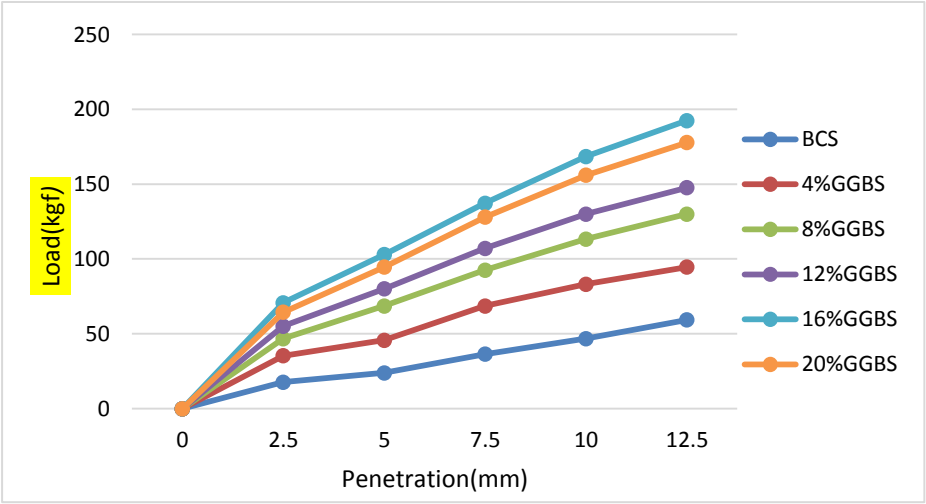
This test was conducted based on IS: 2720, Part XVI (1987), Bureau of Indian Standards, New Delhi, 1- 5. California Bearing Ratio Test is performed in soil laboratory to find out the CBR value of black cotton soil mixed with different percentage of GGBS and Fly ash in soaked condition.

(01) California Bearing Ratio Test for Black Cotton soil with GGBS

Table 4. CBR test results for black cotton soil mixed with GGBS and Fly ash

Test Specimen	CBR%	% Increase
BC Soil	1.29	-
BC + 4% GGBS	2.58	100
BC + 8% GBBS	3.42	165.11
BC + 12% GGBS	4.02	211.62
BC +16% GGBS	5.16	300
BC + 20 %GGBS	4.93	282.17

From table 4, it is observed that the CBR value of black cotton soil is 1.29 % which is increased with the addition of GGBS up to 5.16 % at 16 % GGBS with



black cotton soil, further addition of GGBS the CBR value of soil is decreased.

Figure 3.CBR Test results for black cotton soil mixed with various percentage of GGBS

From figure 3, we see that on adding GGBS up 16% it gives optimum value, further increasing in percentage of GGBS CBR value Found decreases.

(02) California Bearing Ratio Test For black Cotton Soil with GGBS and Fly ash

Table 5. CBR test results for black cotton soil mixed with different percentage of GGBS and Fly ash.

Test Specimen	CBR%	% Increase
BC+ 16%GGBS+4%FA	5.31	311.62
BC+16%GGBS+8%FA	6.15	376.74
BC+16%GGBS+12%FA	5.39	317.82

From table 5, it is observed that when 16 % GGBS + 8% Fly ash is added with black cotton soil the CBR value of soil increased up to 376.74 % ,which is decreased on further adding 12% Fly ash.

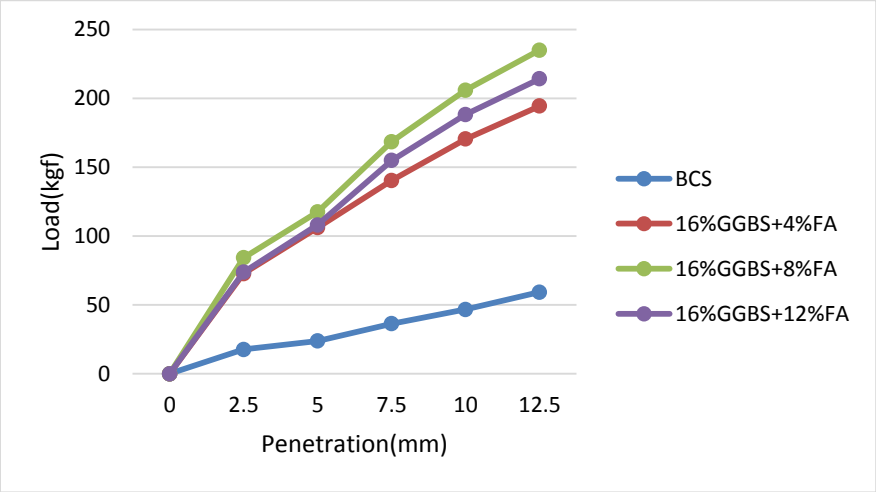


Figure 4. CBR test results for black cotton soil mixed with GGBS and Fly ash

From figure 4, we observed that 16% GGBS with 8% Fly ash gives the best results, peak value found on this combination.

4.3 UNCONFINED COMPRESSIVE STRNGTH TEST

This test was conducted based on IS: 2720, Part X (1991), Bureau of Indian Standard, New Delhi, 1 – 4. To determine the unconfined compressive strength of black cotton soil by loading an axial cylindrical specimen in soil laboratory, Unconfined Compressive Strength test is conducted for 4 days in soaked condition. Variations of UCS results for black cotton soil with specimen are show below:-

Table 6. UCS test results obtained for black cotton soil mixed with GGBS and Fly ash

Test Specimen	Unconfined Compressive Strength (Kg/cm^2)	% Variation of Compressive Strength	Shear Strength, C_u(Kg/cm^2)	% Variation of shear strength
BC Soil	1.045	0	0.5225	0
BC +4%GGBS	1.123	7.464	0.5615	7.464
BC + 8% GGBS	1.388	32.822	0.694	32.822
BC +12% GGBS	1.605	53.588	0.8025	53.588
BC +16% GGBS	2.588	147.655	1.294	147.655
BC +20% GGBS	2.433	132.822	1.2165	132.822

From table 6, it is observed that the UCS value of black cotton soil is 1.045 Kg/cm^2 which is increased up to 147.655% with addition of 16% GGBS. With further addition of GGBS, the UCS value of soil decreased

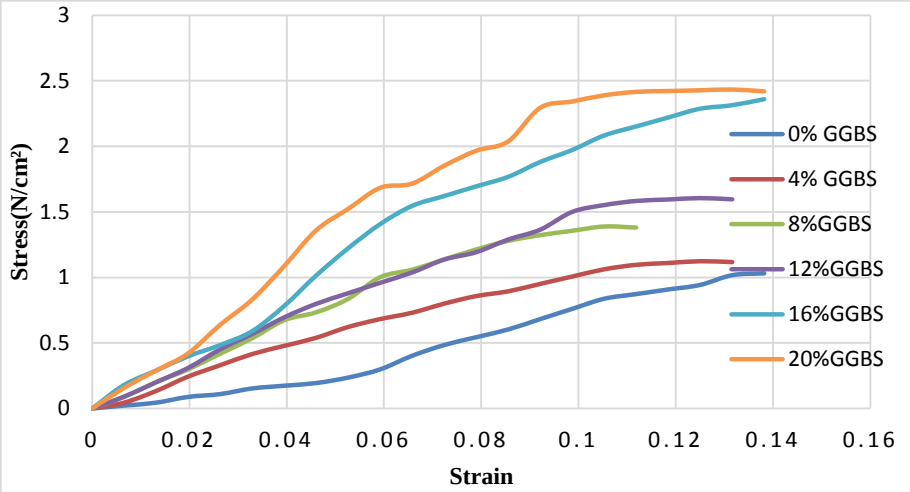


Figure 5. UCS results obtained for black cotton soil with various percentage of GGBS.

From figure 5, it is observed that the UCS value with addition of 16% GGBS increases and with further addition of GGBS, the UCS value decreased.

Table 7. UCS test result obtained for black cotton soil mixed with 16%GGBS and Fly ash

Test Specimen	Unconfined Compressive Strength,(Kg/cm^2)	% Variation of Compressive Strength	Shear Strength, C_u(Kg/cm^2)	% Variation of shear strength
BC+16% GGBS +4%FA	2.372	126.985	1.186	0.1513
BC+ 16% GGBS +8%FA	3.007	187.751	1.5035	0.1184
23BC+16% GGBS + 12%FA	2.855	173.205	1.427	0.1382

From table 7, it is observed that the UCS value of black cotton soil is 1.503 Kg/cm^2 which is increased up to 187.751% with addition of 16% GGBS+ 8% fly ash. With further addition of Fly ash, the UCS value of soil decreased.

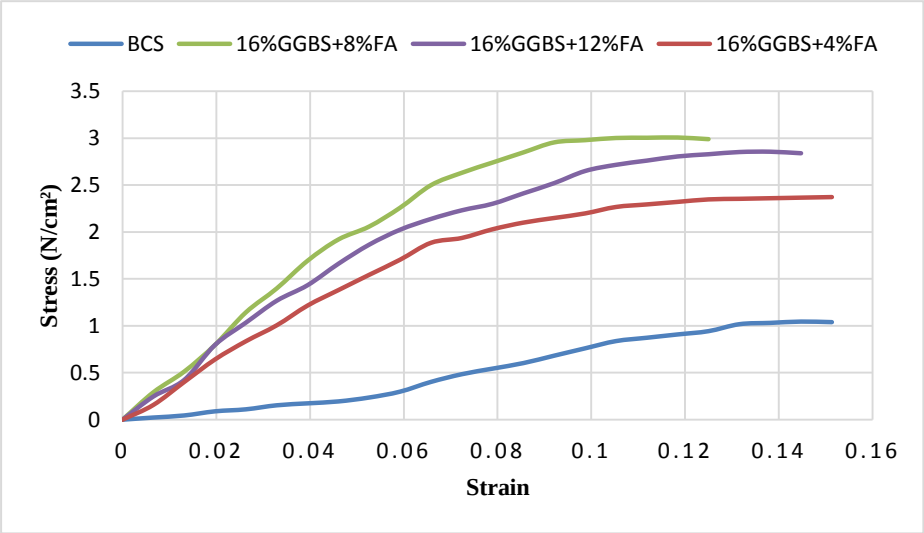


Figure 6. UCS results for black cotton soil with GGBS and fly ash

From figure 6, it is observed that combination of 16% GGBS with 8% fly ash gives the optimum value, peak value observed at this combination.

5 CONCLUSION

(i) It is concluded that on increase the percentage of GGBS and Fly ash up to the definite percentage, optimum moisture content goes on decreasing while maximum dry density goes on increase.

(ii) It is observed that the MDD of black cotton soil is increased up to 1.933 gm/cc at 16% GGBS and 8% Fly ash.

(iii) It is observed that the CBR value of black cotton soil is 6.15% on adding 16% GGBS and 8% Fly ash, further addition of GGBS and Fly ash decrease the CBR value.

(iv) UCS value of black cotton soil is found 1.045 Kg/cm^2, which is increased up to 187.75% with addition of 16% GGBS and 8% Fly ash, so optimum value of UCS is found 2.855 Kg/cm^2.

(v) It is observed from the overall experimental work, that the 16% GGBS and 8% Fly ash gives the optimum results when mixed with black cotton soil.

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