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EFFECT OF GROUND GRANULATED BLAST FURNACE SLAG ON EXPANSIVE SOILS UNDER STATIC LOADING

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ABSTRACT

Expansive soils undergo a large swell when they are subjected to water. Thus, expansive soils are one of the most abundant problems faced in geotechnical engineering applications. It causes heavy damages in structures, especially in water conveyance canals, lined reservoirs, highways, airport runways etc., unless appropriate measures are taken. Utilization of industrial waste materials in the improvement of problematic soils is a cost efficient and also environmental friendly method in the sense that it helps in reducing disposal problems caused by the various industrial wastes. The main objective of the present study is to improve various engineering properties of the soil by using waste material Ground Granulated Blast Furnace Slag (GGBS) as an alternative to lime or cement. In this study, usage of GGBS with different proportions in sub grade was analysed. Soil samples were collected from Astraa Chemicals (Sodium and Calcium Bentonite Clay), Uppiliapuram (Organic Clayey Soil) and Nagapattinam (Black Cotton Soil) in Tamil Nadu and GGBS from Salem Steel Plant, Salem, Tamil Nadu, India. The Index and Engineering properties (Standard proctor compaction, Unconfined compression test, California bearing ratio test) of soil with and without GGBS was determined for different combinations of GGBS with soil and an optimum content of usage of GGBS was found out. Based on strength performance tests, the optimum content of GGBS for Calcium Bentonite Clay, Sodium Bentonite Clay, Black cotton soil and Organic Clay was found to be 24%, 12%, 24% and 25% respectively. It is observed that the strength improvement depends on the amount of GGBS. The work is further extended to know the variation in strength of soil with and without GGBS based on strength parameters and also X-ray diffraction (XRD) test carried out on soil to know the micro structural analysis of soil with and without admixture. Economic analysis was carried out based on material savings in pavement design. Based on results, the limitations of GGBS in the ground improvement is addressed.

Index Terms— **Expansive soil; Ground Granulated Blast Furnace Slag; CBR, Standard Proctor; Unconfined compression test.**

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I. INTRODUCTION

Expansive soils expand when water is added, and shrink when they dry out. This change in soil volume cause structures built on this soil to move unevenly and crack. The clay mineral responsible for most expansive damage is smectite, although Bentonite and Illite also have some expansive potential. The montmorillonite clay minerals, one of the smectite groups, are considered as a highly expansive and the most effective ones for swelling behaviour. Because of this phenomenon, pavements constructed on swelling sub-grades experience distress and develop cracks until remedial measures are taken.

At present the use of various industrial waste products for stabilizing the soft soil have attained considerable attention in view of the increasing cost of waste disposal and environmental aspect (*LaxmikantYadu and Tripathi, 2013).* Successful utilization of industrial waste results considerable savings in construction cost. One of the solid wastes generated by industries in huge quantities is Blast Furnace Slag. Very few studies have been reported on use of blast furnace slag in stabilizing the soils.

Laxmikant Yadu et al. (2013)studied the effect of granulated blast furnace slag in the engineering behaviour of stabilised soil. The results show that inclusion of GGBS increases the strength of soft soils. Similarly, significant improvement has been observed for unsoaked and soaked CBR value of soils.

This paper presents work in utilising industrial by-products as suitable admixtureto enhance the geotechnical properties of soft soils.Hence an attempt has been made to improve the strength and swell behaviour of expansive black cotton soil using GGBS in this work.

II. MATERIALS

The soils used in the study were collected from Ramky Chemicals (Sodium and Calcium Bentonite Clay), lankelapalem (Organic Clayey Soil) and gopalapatnam (Black Cotton Soil) in vskp, A.P, India.

The slag produced at blast furnace during pig iron manufacturing is called blast furnace slag.Depending upon the cooling process, three types of slags are generated; namely, air-cooled slag, granulated slag and expanded slag.The GGBS used in this study was collected from RINL- Steel Plant in VSKP,A.P, India.

III. RESULTS AND DISCUSSION

A.Properties of Soil and GGBS :

The laboratory tests carried out on the natural soil include Sieve analysis, Atterberg limits, Specific gravity, Free swell test, Standard Proctor test, Unconfined Compressive strength test and California Bearing Ratio test and the results are shown in **Table 3.1**. The laboratory tests carried out on Ground Granulated Blast Furnace Slag are shown in **Table 3.2.**

Table 3.1.Properties of Soil

Soil Properties	Calcium Bentonite Clay	Sodium Bentonite Clay	Black Cotton Soil	Organic Clayey Soil
Indian Standard Soil Classification	CL	CH	CI	OH
Specific gravity	2.68	2.63	2.08	2.13
Liquid limit (%)	45	343	38	53
Plastic limit (%)	29	51	18	31
Plasticity index	16	292	20	24
Free swelling index (%)	0	76.67	44.83	16.67
Maximum dry density (g/cc)	1.71	1.41	1.67	1.54
Optimum moisture content (%)	18	21	22	23
Unconfined compressive strength (Kg/cm²)	1.57	0.76	1.92	2.55

Table 3.2. Properties of GGBS

Properties	GGBS
Specific gravity	2.69
Liquid limit (%)	15
Plastic limit (%)	NP
Plasticity index	NP
Maximum dry density (g/cc)	1.82
Optimum moisture content (%)	16

B. Standard Proctor Test(SPT) :

For performing the standard proctor tests, the soils were prepared by adding the admixture at varying percentages of GGBS. The variation in the strength was observed in **Fig. 3.1**.

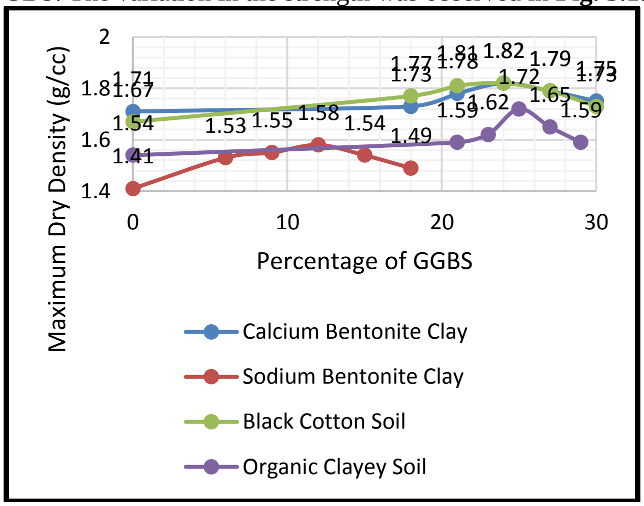

Fig. 3.1 Effect of GGBS on Maximum Dry Density(MDD)

C. Unconfined Compressive Strength Test(UCS) :

For performing the UCS tests the soils were prepared by adding the optimum moisture content obtained by conducting the standard proctor test. The admixture was added at varying percentages of GGBS. The variation in the strength was observed in **Fig. 3.2**.

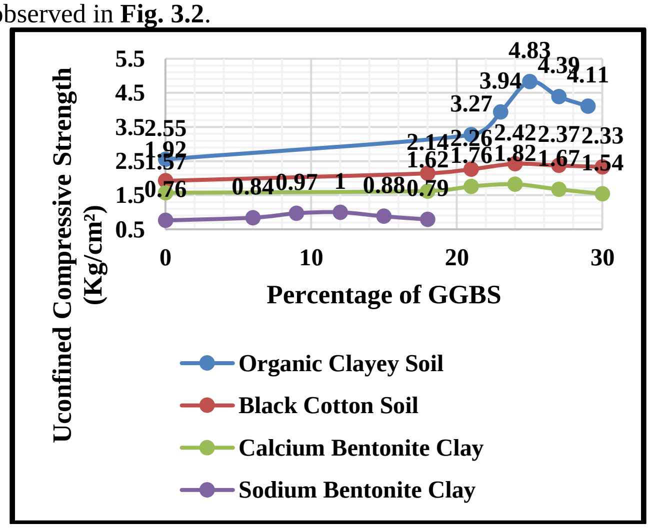

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Fig. 3.2 Effect of GGBS on UCS

D.California Bearing Ratio Test(CBR) :

The CBR test has been carried out for Black Cotton Soil and Organic Clayey Soil. The CBR test has not conducted on Calcium Bentonite Clay and Sodium Bentonite Clay because the soils exhibits too much of swelling characteristics, it is difficult to carry out CBR test. For performing CBR tests the soils were prepared by adding the optimum moisture content obtained by conducting the standard proctor test. The admixture was added at varying percentages of GGBS. The variation in the strength was observed in **Fig. 3.3**.

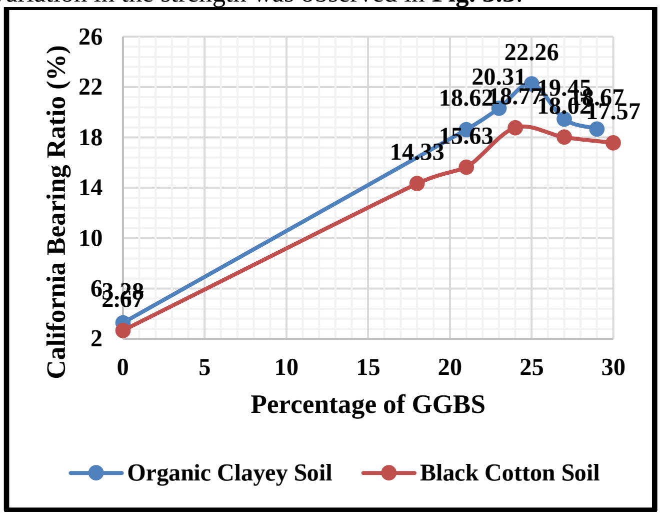

Fig. 3.3 Effect of GGBS on CBR

D. Optimum Content of GGBS :

In this paper the GGBS content at which any two or three properties of soil namely MDD, CBR and UCS should be maximum is considered as optimum content of GGBS.

For Black cotton soil the optimum content of GGBS was calculated based on MDD, UCS and CBR. The optimum content of GGBS obtained for Black Cotton Soil is 24%. Table 3.3 shows variation of MDD, UCS and CBR results with GGBS content for Black cotton soil.

For Organic Clayey soil the optimum content of GGBS was calculated based on MDD, UCS and CBR. The optimum content of GGBS obtained for Organic Clayey soil is 25%. Table 3.4 shows variation of MDD, UCS and CBR results with GGBS content for Organic Clayey soil.

For Calcium Bentonite Clay, the optimum content of GGBS was calculated based on MDD and UCS. The optimum content of GGBS obtained for Calcium Bentonite Clay is 24%. Table 3.5 shows variation of MDD and UCS results with GGBS content for Calcium Bentonite Clay.

For Sodium Bentonite Clay the optimum content of GGBS was calculated based on MDD and UCS. The optimum content of GGBS obtained for Sodium Bentonite Clay is 12%. Table 3.6 shows variation of MDD and UCS results with GGBS content for Sodium Bentonite Clay.

Table 3.3. Optimum dosage of GGBS for Black Cotton soil

Black Cotton Soil				
Description	**OMC (%)**	**MDD (g/cc)**	**UCS (kg/cm^2)**	**CBR (%)**
Soil	22	1.67	1.57	2.67
Soil+ 18%GGBS	19	1.77	2.14	14.33
Soil+ 21%GGBS	17	1.81	2.26	15.63
Soil+ 24%GGBS	16	1.82	2.42	18.77
Soil+ 27%GGBS	16	1.79	2.37	18.02
Soil+ 30%GGBS	15	1.73	2.33	17.57

Table 3.4. Optimum dosage of GGBS for Organic clayey soil

Organic Clayey Soil				
Description	**OMC (%)**	**MDD (g/cc)**	**UCS (kg/cm^2)**	**CBR (%)**
Soil	23	1.54	2.55	3.28
Soil+ 21%GGBS	21	1.59	3.27	18.62
Soil+ 23%GGBS	20	1.62	3.94	20.31
Soil+ 25%GGBS	18	1.72	4.83	22.26
Soil+ 27%GGBS	16	1.65	4.39	19.45
Soil+ 29%GGBS	15	1.59	4.11	18.67

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Table 3.5. Optimum dosage of GGBS for Calcium Bentonite Clay

Calcium Bentonite Clay			
Description	OMC (%)	MDD (g/cc)	UCS (kg/cm^2)
Soil	18	1.71	1.5
Soil+ 18%GGBS	17	1.73	1.62
Soil+ 21%GGBS	15	1.78	1.76
Soil+ 24%GGBS	14	1.82	1.82
Soil+ 27%GGBS	12	1.79	1.67
Soil+ 30%GGBS	11	1.75	1.54

Table 3.6. Optimum dosage of GGBS for Sodium Bentonite Clay

Sodium Bentonite Clay			
Description	OMC (%)	MDD (g/cc)	UCS (kg/cm^2)
Soil	21	1.41	0.76
Soil+ 6%GGBS	20	1.53	0.84
Soil+ 9%GGBS	19	1.55	0.97
Soil+ 12%GGBS	17	1.58	1.00
Soil+ 15%GGBS	15	1.54	0.88
Soil+ 18%GGBS	14	1.49	0.79

D. Atteberg's limits at optimum content of GGBS:

The Liquid limit and Plastic limit tests were conducted on virgin soils and the tests are repeated by adding the optimum content of GGBS to soil and the results are shown in **Table 3.7.**

Table 3.7. Atterberg's limits for optimum GGBS percentage

Description		Liquid Limit	Plastic Limit	Plasticity Index
Calcium Bentonite Clay	Soil	45	29	16
	Soil+ 24% GGBS	38	21	17
Sodium Bentonite Clay	Soil	343	51	292
	Soil+12% GGBS	313	43	270
Black Cotton soil	Soil	38	18	20
	Soil+24% GGBS	27	11	16
Organic Clayey Soil	Soil	53	31	22
	Soil+25% GGBS	38	23	15

IV. CONCLUSIONS

From the test results, the following conclusions can be made:

- It was found that with addition of GGBS content the liquid limit and plastic limit values are decreasing.
- It was found that with the increase in GGBS content the dry density also increases up to optimum content of GGBS and with further increase in GGBS content the dry density decreases gradually. This variation in density is mainly due to high specific gravity and immediate formation of cemented products by hydration which increases the density of soil.
- It was found that optimum moisture content for virgin soils i.e., Clayey Sand, Organic Clayey soil and Black cotton soil was decreased with the addition of GGBS from 17%, 23% and 22% to 13%, 18% and 16% respectively.
- It was found that with the increase in GGBS content the Unconfined compressive strength also increases up to optimum content of GGBS, but it is not significant and with further increase in GGBS content the value UCS value decreases.
- It was found that with the increase in GGBS content the CBR also increases up to immediate formation of cemented products by hydration which increases the density of soil.
- It was found that optimum moisture content for virgin soils i.e., Clayey Sand, Organic Clayey soil and Black cotton soil was decreased with the addition of GGBS from 17%, 23% and 22% to 13%, 18% and 16% respectively.
- It was found that with the increase in GGBS content the Unconfined compressive strength also increases up to optimum content of GGBS, but it is not significant and with further increase in GGBS content the value UCS value decreases. optimum content of GGBS and with further increase in GGBS content the value CBR value decreases.
- This study has revealed that the use of GGBS waste material has the potential to modify the properties of clays.

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