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A Study On Engineering Propeites Of Black Cotton Soil Mixed With Ground Granulated Blast Furnace Slag And Embedded With Polypropylene Fibres

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Abstract: ***Black cotton soils which are well known for their expansive nature are a worldwide problem posing many challenges to civil engineers, construction firms and owners. Stabilization of black cotton soils with different additive materials has likewise achieved great progress and on account of fast industrialization all through the world; the generation of enormous amount of waste materials creates ecological issue as well as disposal problems. Numerous methods have been developed by many researchers to enhance the mechanical properties of soil by incorporating an extensive variety of stabilizing materials. An attempt has been made in this paper to utilize Ground granulated blast furnace slag(GGBS), an industrial by product and polypropylene fibres as stabilizing materials. The impact of GGBS and polypropylene fibers on certain properties of soil, for example, Atterberg limits, compaction characteristics (MDD, OMC), Unconfined compressive strength (UCS) and Free swell had been examined. All the tests were performed on the samples by utilizing GGBS and 12mm polypropylene fibers. A series of UCS and Free swell tests were carried out on black cotton soil by varying percentage of GGBS (0%, 10%, 20%, 30%, 40% 50%, 60%) and polypropylene fibers of length 12 mm and proportions (0%, 0.25% 0.50%, 0.75%, 1.00%) by weight of dry soil with optimum percentage of slag). Results of various tests demonstrated the inclusion of GGBS and polypropylene fibers in soil with appropriate proportion improved strength and swelling behavior of soils.***

Index Terms— *Black cotton soil; GGBS; Polypropylene fibre; unconfined compressive strength; free swell index*

I. INTRODUCTION

Black cotton soils cause serious harm to property on account of their expansive nature. They are highly fertile for agricultural purposes but pose severe problems to the pavements, embankments and light to medium loaded residential buildings resting on them due to cyclic volumetric changes caused by moisture fluctuation. This volume change behaviour is the reason for cracking to the overlying structures. The reason for this behaviour isdue to presence of clay mineral such asmontmorillonitethat has an expanding lattice structure. During monsoon's, this montmorillonite mineral has the behaviour of absorbing water, swelling and becoming soft due to which the water bearing ability of the soil is reduced.In summer seasons, on account of evaporation of water, the soil shrinks and becomes harder.This type of alternate swelling and shrinkage behaviour of black cotton soil resulting in severe losses to buildings, pavements and embankments.

Thus black cotton soils are to be stabilized in order to resolve its insufficiencies in engineering properties to use especially asa pavement material. Different stabilizers like lime, fly ash, blast furnace slag are available. Lime and cementare the most widely used stabilizers for improving the strength of the black cotton soils (Yong et al. 1996; Du et al. 1999). On account of cement and lime being expensive these days resulting in increment of the totalproject cost. Thus research has mainly focused on lessening the expenditure of the binders. One more issuewhich the world is confronting these days is the disposal of industrialwastes like Fly ash, Ground granulated blastfurnace slag (GGBS). Use of these byproducts as additives for black cotton soils not only reduces the project cost but also helps in reducing landfill problems (Kamon and Nontananandh 1991).Addition of fibers to the soil-binder mix leads to the improvement of tensile and flexural strength of the soil.Tang et al. (2007) observed the effect of polypropylene fibers on cemented and uncemented clayey soils and found that fiber inclusions leads to the increment in the shear strength and reduction in post peak strength. Kar and Pradhan (2012) studied the effect of fibers on fly ash embedded clayey soil and observed a drastic improvement in unconfined compressive strength and soaked CBR. Amadi (2014) performed durability tests on expansive soil with and without lime kiln dust and quarry fines and concluded that addition of lime kiln dust is more durable when compared to quarry fines addition to expansive soil.

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From the above literature, it is observed that less research has been done on the effect of fiber on the binder embedded black cotton soil. In the present study, effect of polypropylene fibers on the unconfined compressive strength of GGBS embedded black cotton soil has been studied. Compaction characteristics and swelling behaviour of GGBS-fiber reinforced soil are compared with virgin black cotton soil.

Materials and methods

Black Cotton Soil: Local Black Cotton soil was collected, air dried and stored in containers. Below natural ground level at a depth of 1m, soil was collected by open excavation and sieved through 4.75mm sieve for performing various tests and the index properties of BC soil are listed in Table 1

Ground Granulated Blast Furnace Slag (GGBS): GGBS which is popularly known as steel slag was collected from nearby steel manufacturing unit which contains nearly 33% calcium oxide which can be observed from Table 2.

Polypropylene Fibers: In recent years the uses of fibers in various fields have gained much importance. The research on fiber-reinforced soils demonstrated that this material might be a practical and cost efficient. Polypropylene fibres of aspect ratio 300 are used and the properties of the fibres are presented in table 3.

Table 1: Properties of Black cotton soil

S. No	Properties	BC Soil
1	Specific gravity	2.65
2	Grain size analysis Gravel (%) Sand (%) Silt (%) Clay (%)	 4 29 40 27
3	Liquid limit	59
4	Plastic limit	18
5	Plasticity index	41
6	IS Soil classification	CH
7	Compaction properties Optimum moisture content (%) Maximum dry density (g/cm^3)	 16.6 1.68
8	Unconfined compressive strength (kg/cm^2)	2.01

Table: 2 Chemical Composition of GGBS (% by mass)

Chemical Composition	SiO_2	MgO	Fe_2O_3	SO_3	Cao	MnO	Na_2O	Al_2O_3	LOI
GGBS	34.06	7.89	0.8	0.9	32.6	0.31	0.22	20	NIL

Table: 3 Physical properties of Polypropylene fibres (given by manufacturer)

S. No	Type of Fibre	Polypropylene
1	Length (mm)	12mm
2	Specific gravity	0.90-0.91
3	Diameter (mm)	0.04mm
4	Tensile strength (Mpa)	450
5	Melting point (^{0} c)	165
6	Heat resistance (^{0} c)	<130

Specific gravity test was carried out by Pycnometer as per IS 2720 Part 3 (1980) for BC soil. Grain size analysis tests are conducted according to IS 2720 Part 4 (1985) respectively which consists of 40% silt and 27% clay. This method is followed for size of particles more than 75micron only. Hydrometer analysis was carried out for size of particles less than 75micron. Atterberg limits, liquid limit as per IS 2720 Part 5 (1985) and plastic limit were performed on various soil-GGBS mixes and the optimum content was determined. Standard proctor compaction tests were conducted as per IS: 2720 Part 7 (1980) on the soil-GGBS mixtures where increment in OMC and decrement in MDD is observed with increase in GGBS content.Unconfined compressive strength tests were performed on different fibre embedded GGBS soil mix according IS 2720 part 10 (1973). The Free Swell Index of the soil was carried in accordance with the IS.2720 part 40(1977) for the various soil-GGBS mixes.

II. RESULTS AND DISCUSSIONS

Atterberg's limits

The test results from fig. 1 shows that LL and PI decreased whereas PL increased for BC Soil mixed with GGBS. This is because of the diffused double layer thickness reduction and flocculation of clay particles. Addition of GGBS to BC soil significantly reduced the plasticity index of black cotton soil. This implies there is a significant reduction in swell potential by addition of GGBS to BC Soil. From the fig, we can observe that the liquid limit and plastic limit shows similar results for 40%, 50% and 60% soil-GGBS mixes thereby indicating 40% GGBS content as optimum value.

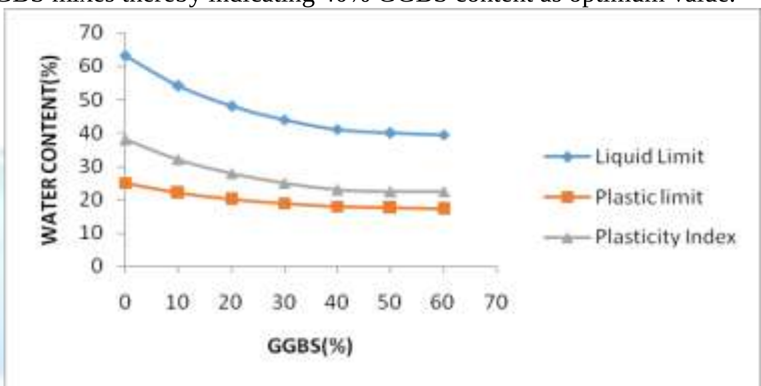

Fig 1**:** variations of liquid limit, plastic limit and plasticity index with addition of GGBS

Standard proctor test

The standard proctor tests were conducted by mixing different percentages of GGBS from 10% to 50% to the Black cotton soil. After selecting suitable proportion of GGBS as 40%, polypropylene fibres were mixed from 0.25% to 1% in increments of 0.25% and standard proctor tests were conducted on these mixes.

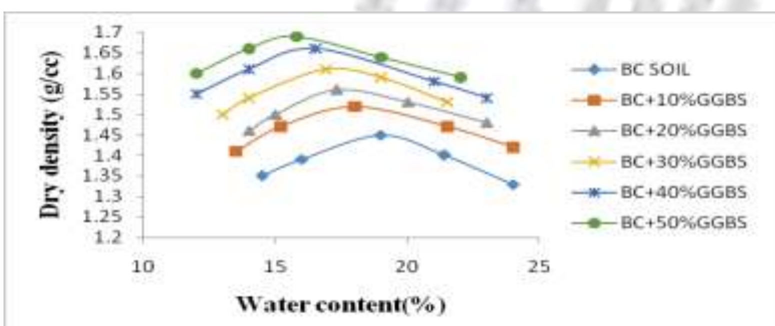

Figure 2: showing changes in OMC and MDD with addition of GGBS to BC soil.

From figure 2, it is observed that there is an increase in the OMC and decrease in MDD when GGBS is added to BC Soil. The decrease of the MDD by adding GGBS to BC Soil is mainly due to its lower specific gravity and the immediate formation of cementation products. The pozzolanic reaction between BC soil and GGBS is responsible for increase in OMC. As GGBS content increases, the water sensitivity of GGBS stabilized clay decreases i.e., causing only a minor change in dry density with large increase in water content. The dry density increased with GGBS increment upto 40% whereas for 50% GGBS addition, the dry density decreases indicating 40% GGBS content as optimum value.From figure 3, is can be seen that the MDD value decreases with increase in fibre content whereas maintaining nearby constant OMC of 16%.

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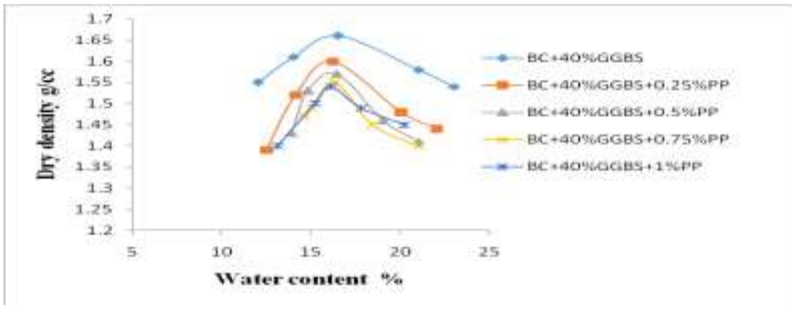

Figure: 3 Showing changes in OMC and MDD of BC soil treated with 40% GGBS with varying percentages of Polypropylene fibres

Unconfined compressive strength

The unconfined compressive strength tests were conducted on the optimum mixes which are selected from standard proctor's compaction test. The stress-strain behaviour of different composites with 28 curing period is shown in figure 4. Up to 40% GGBS, there is a drastic increment in unconfined compressive strength and there after reduction in UCS strength is observed.The reason for this behaviour is due to the fact that complete consumption of $Ca(OH)_2$ by the natural pozzolonic material in the soil happening at 40% GGBS. It can be observed that the maximum UCS is coinciding with the GGBS fixation point obtained from the Atterbergs limits. For more than 40% increment in GGBS content results in non-occurrence of pozzolonic reaction and the added GGBS particle remain as unbounded particles thereby resulting in the reduction of overall strength.

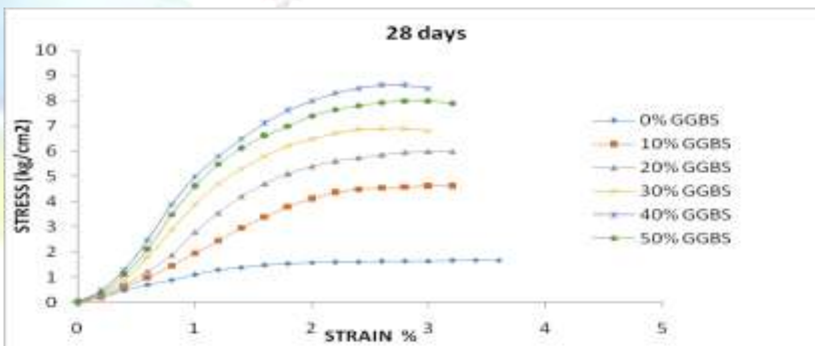

Figure 4: Stress-Strain behaviour of BC soil treated with GGBS for a curing period of 28 days

In the presence of fibers, even when the soil deforms in compression, the normal strains in certain other directions may be a tensile extension. The deformation is resisted by fibers in the direction of the tensile strains through fiber–soil frictional interactions, and the high tensile strength of the fiber itself. The overall failure surface is larger and non-planar, owing to the presence of fibers, and the failure load and energy are increased. Thus, from the figure 5, it is observed that the peak strength increases for fibre mixed soil-GGBS samples when compared to soil-GGBS mixes. The UCS value increases till 0.75% fibre inclusions whereas on 1% addition of fibres UCS value decreased thereby indicating 0.75% fibres as optimum content.

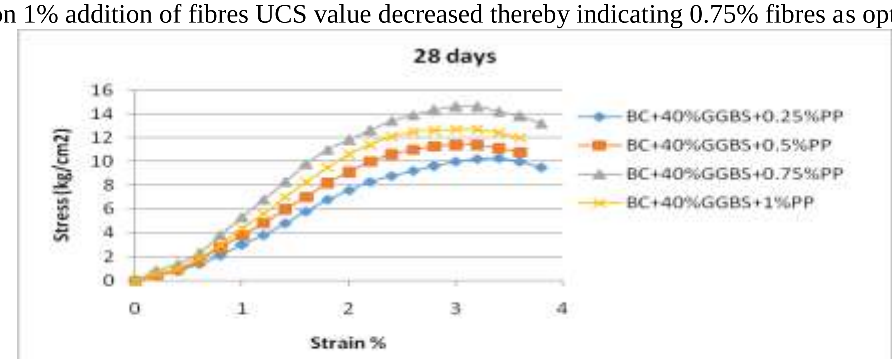

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Figure 5: Stress-Strain behaviour of BC soil treated with 40% GGBS with varying percentages of Polypropylene fibres for a curing period of 28 days

Free swell

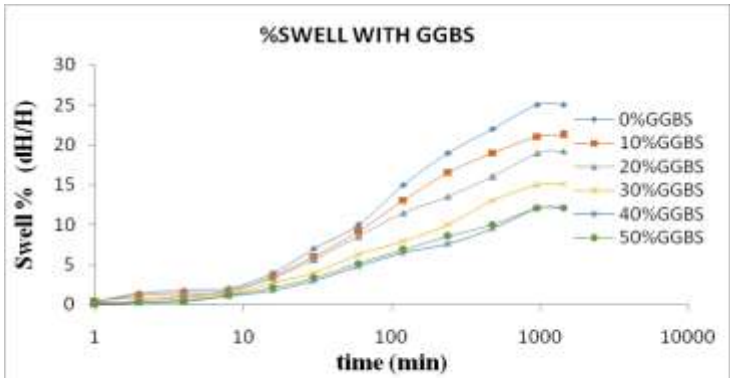

Figure 6: Swell% of BC soil treated with varying percentages of GGBS

From fig. 6, it is observed that when free swell tests were performed on BC soil with different GGBS mixes and it was observed that the swell percent reduced from 24% to 5% for 1000 mins with increase in GGBS from 0% to 40% and for 50% GGBS mix the swell percent was observed to be nearly same as 40% GGBS mix which can be observed from fig6.

In the expansive soil swell percentage is reduced due to exchange of sodium ions in expansive soils with calcium ions presented in the in GGBS there by leading to the formation of calcium aluminates and calcium silicates which reacts with water and hydration takes place due to pozzolonic reaction The paste which is formed will form a stable cementitious bonded-structure on treatment with slag.On the other hand, as expansive soil is sensitive to the moisture and swelling occurs whereas for treated soils GGBS helps in the prevention of moisture to expel out of soil particles.

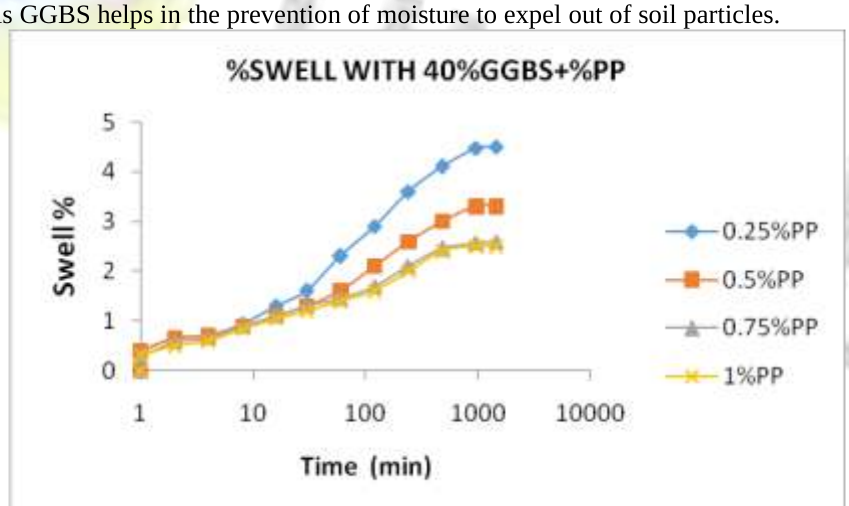

Figure 7: Swell percentage of BC soil treated with 40% GGBS with varying percentages of polypropylene fibres

Free Swell percent tests were performed on BC soil + 40% GGBS content which is considered as optimum percentage and the glass fibres were added in increments of 0.25% till 1%. From fig. 7 it is observed that the swell percent at 40% GGBS was observed to be 5% which was further decreased to 2% with increase in glass fibres from 0.25% to 0.75% where similar results were observed for soil-GGBS mix with 1% glass fibre inclusion. The reason behind this is that as the soil swells, the stretching of the fiberoccurs and throughout the length of the fiber tension will be induced which helps in reduction of further swelling. The more the fibers connection with the soil particles, the better effects on swelling reduction.

III. CONCLUSIONS

The following conclusions can be drawn from the experimental results:

1. The LL, PI decreased and PL increased with increase in GGBS content on account of the reduction in the thickness of the diffuse double layer and flocculation of clay particles. On further increment in GGBS content from 40% LL, PL and PI values are nearly constant. Thus, 40% GGBS is taken as optimum content.
2. Addition of GGBS to the BC soil results in increment of maximum dry density and decrement in optimum moisture content because of the reduction in clay content and increment in frictional resistance.
3. The increment in Unconfined Compressive strength is observed on addition of GGBS up to 40% for 28 days curing period whereas decrement in strength is observed on further addition of GGBS. The UCS value of soil- GGBS- mix is observed to be higher when compared to soil-GGBS mix on account of the higher tensile strength of fibre itself.
4. Free swell percent is reduced considerably with increment in GGBS content because of the stable cementitious bonded-structure formed through the slag treated soil

References

1) Yong, R. N., Ouhadi, V. R., & Mohamed, A. M. O. (1996). Physicochemical evaluation of failure of stabilized marl soil. In *Proceedings of the 49th Canadian geotechnical conference frontiers in geotechnology* (Vol. 2, pp. 769-776).

2) Du, Y., Li, S., & Hayashi, S. (1999). Swelling–shrinkage properties and soil improvement of compacted expansive soil, Ning-Liang Highway, China. *Engineering Geology*, *53*(3-4), 351-358.

3) Kamon, M., &Nontananandh, S. (1991). Combining industrial wastes with lime for soil stabilization. *Journal of geotechnical engineering*, *117*(1), 1-17.

4) Tang, C., Shi, B., Gao, W., Chen, F., &Cai, Y. (2007). Strength and mechanical behavior of short polypropylene fiber reinforced and cement stabilized clayey soil. *Geotextiles and Geomembranes*, *25*(3), 194-202.

5) Kar, R. K., & Pradhan, P. K. (2012). Laboratory tests of reinforced fly ash mix for use as sub-base in low volume rural roads. *Indian Highways*, *40*(1).

6) Amadi, A. A. (2014). Enhancing durability of quarry fines modified black cotton soil subgrade with cement kiln dust stabilization. *Transportation Geotechnics*, *1*(1), 55-61.

7) IS 2720 (1980) Part 3: Laboratory determination of specific gravity of soil, Bureau of Indian Standards, New Delhi, India.

8) IS 2720 (1985) Part 4: Laboratory determination of Grain size distribution of soil, Bureau of Indian Standards, New Delhi, India.

9) IS 2720 (1985) Part 5: Determination of liquid & plastic limit of soil, Bureau of Indian Standards, New Delhi, India.

10) IS 2720 (1980) Part 7: Determination of water content dry density relation using light compaction, Bureau of Indian Standards, New Delhi, India.

11) IS 2720 (1973) Part 10: Determination of unconfined compressive strength of soil Bureau of Indian Standards, New Delhi, India.

12) IS 2720 (1977) Part 40: Determination of free swell index of soil Bureau of Indian Standards, New Delhi, India.