Strength and Durability Enhancement of Soft Soil by Using Mineral Admixtures- A Study on Effect in Soil Fabric

Manepalli Gopikrishna, A Priyanka

Abstract: Sub soil strength is a key parameter engineers look upon while designing the pavement structures, its durability directly relies on the strength of sub base. Tropical countries like India have varying soil profile which need to be upgraded to attain desired strength and durability characteristics focussing on taking demanding loading pattern and weather conditions. Unfortunately the soil profile available in India in many states does not have sufficient strength and hence research works are directed towards obtaining the required strength by addition of mineral admixtures or chemicals that may alter the fabric structure of the soil and provide sufficient stability. In this research the stabilitisation and strength enhancement is done by using Ground granulated blast furnace slag which is an industrial by product that can effectively used as pozzola based strength enhancer for the soil. Results obtains shows that GGBS can be effectively used for any soil to strengthen it to a desired level.Soft soil samples were collected from Warangal District Telangana. This soil was classified as CH as per Indian Standard Classification system (ISCS). Different amounts of GBFS, i.e. 10, 20, and 30% were used to stabilize the soft soil. The performance of GBFS with soft soil was assessed utilizing compaction and California bearing ratio (CBR) test. In light of these presentation tests, optimum value of GBFS was resolved as 30%. Sensible enhancement has been watched for soaked CBR value of soil with this optimum value and the improved soil is used in the pavement subgrade and with the usage of stabilised soil there is a considerable decrease in the subgrade thickness.

Index Terms: GBFS, CBR, Pavement Subgrade.

I. INTRODUCTION

An enormous part of the world's surface is secured by soils, and they are generally used as establishment materials and for the development purpose. When suitable ground condition are not encountered at shallow depth or to improve the performance of borrow soil a geotechnical engineer opts for the modification of the soil. Black cotton soil is considered as a very difficult material in infrastructure industry because of the presence of high plastic clay. It exhibits significant swelling and shrinkage behavior depending upon the moisture content present in the interstices of soil particles. The significant clay mineral that is in charge of the swelling is the montmorillonite mineral. So as to conquer every one of these issues stabilization of soil is the most well-known strategy used to enhance the properties of soil. Some of the recent stabilizing materials that are used (Shaik Khader Vali Baba et al.,)[1] Coir fiber (AketiNookapathiRaju et al.,)[2], Geo grid (Suravaramsivasaipratap reddy et al.,)[3], SruthiVennamaneni et al.,) [4] lime, cement, ecosand (Ashwin et al., 2017), enzyme and alkali activated ground granulated blast furnace slag (Ansu Thomas et al., 2017), lime,GGBFS (kavak and bilgen 2016), (Obuzor et al., 2012), (Sharma and Sivapullaiah2011)[5], Granite dust and lime rice husk ash (Aziz et al., 2015),calcium carbide residue (Horpibulsuk et al., 2015), groundnut shell ash (Oriola and Moses,2010) In this research GBFS is used as stabilizing agent.GBFS is formed as by-product of iron industry and has very high potential of cementations reactivity. Soil is an unconsolidated material composed of natural aggregate of mineral grains which have resulted from the disintegration of rock. The type and characteristics properties of the soil depend on its formation and deposition by transportation agents. When suitable ground condition are not encountered at shallow depth or to improve the performance of borrow soil a geotechnical engineer opts for the modification of the soil in question. Black cotton soil is problematic in nature because it exhibits significant swelling and shrinkage behaviour depending upon the moisture content present in the interstices of soil particles. The sticky nature of the clay particles present various problems during construction (for example sticking to roller drum etc.). In order to overcome all these problems stabilization of black cotton soil using GBFS is proposed in the present study. Large amount of soil is needed for the construction of highways and embankments. Thus if the industrial waste by products can be effectively used, the natural soil can be preserved. Thus we can say that a stabilised soil not only help in the safe disposal of the waste by products but also preserves the natural soil. In the present scenario, cement stabilization isn't best a result of the expanding cost of concrete and ecological concerns identified with its creation. Lime is also not suitable for soils which contain sulphates. Industrial waste by products includes rice husk, fly ash, granulated blast furnace slag, coir fibres, quarry dust, poly propylene fibres, ground granulated blast furnace slag etc.

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This research is centered on the utilization of granulated blast furnace slag in the stabilisation of black cotton soils.

II. MATERIALS

III. GRANULATED BLAST FURNACE SLAG (GBFS)

Granulated blast furnace slag (GBFS) is a non-metallic side-effect during the production of pig iron in a blast furnace. GBFS consists primarily of silicates, alumina-silicates, and calcium-alumina-silicates. GBS for the present study was collected from the industrial area at Visakhapatnam Steel Plant. The GBFS passing 4.75mm sieve was used. The colour of GBFS is whitish. The use of GBFS in the stabilization of soil not only minimizes their disposal problems but also saves the cost of stabilization.

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Table 2.1 Geotechnical properties of granulated blast furnace slag

S.No.	Properties	Particulars
1	Specific gravity	1.73
2	Gravel size Sand size Fines	3 % 94 % 4 %
3	Cohesion (kPa) Angle of internal friction ϕ (degrees)	4 43

Black cotton soil

Black cotton soil needed for the present study was sampled from a place in Warangal, Telangana.. Prior to testing, the soil was oven dried as per the relevant Indian Standard (for about 24 hours at a temperature of about 100^0 +/- 10^0 C). After drying various tests were conducted to characterize the test soil.

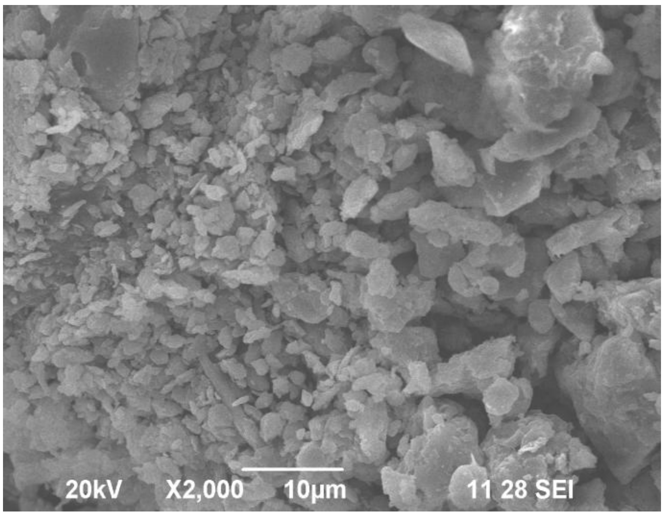

Fig 2.1 SEM image of Black cotton soil

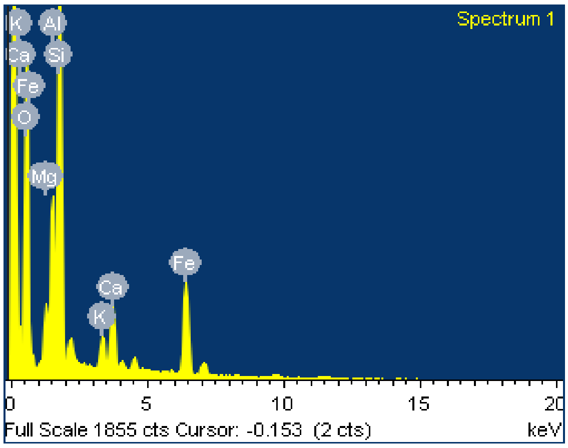

Fig 2.1 EDAX of black cotton soil

Table 2.2 Geotechnical properties of black cotton soil

S.No.	Properties	Particulars
1	Specific Gravity	2.69
2	Coarse fraction Silt &Clay IS classification	12 % 88 % CH
3	Liquid Limit Plastic Limit Plasticity Index	61 % 26 % 35 %
4	Maximum Dry Density Optimum Moisture Content	1.54gm/cm^3 22 %
5	CBR-Soaked	1.9%

IV. TESTS CONDUCTED

The various tests conducted to obtain geotechnical parameters are

- Free swell index (IS 2720-1977 Part 40)
- Specific gravity analysis (IS 2720-1980 Part 3)
- Hydrometer analysis (IS 2720-1985 Part 4)
- Atterberg's limit (IS 2720-1985 Part 5 and 6)
- Proctor compaction test (IS 2720-1980 Part 7)
- California bearing ratio (IS 2720-1987 Part 16)

V. RESULTS AND DISSCUSSIONS

The geotechnical properties of natural black cotton soil are presented in Table 2.2.From Table 2.2 it is observed that the specific gravity of the test soil is about 2.69. The grain size analysis results show that black cotton soil is predominantly a silty clayey soil which classifies as CH as Indian standard classification. The liquid limit and the plasticity index of the soil are about 61% and 35% respectively. Using standard Proctor test the black cotton soil can be compacted to a maximum dry density of 15.7kN/m^3 at an OMC of 24 %. The unconfined compressive strength, soaked CBR of the test soil are about 34kN/m^2, 1.9% respectively. The entire test results are tabulated in Table 4.1.

The grain size distribution curve and moisture - density relationship of black cotton soil used in this study are shown in Fig 4.1 and Fig 4.2.respectively.

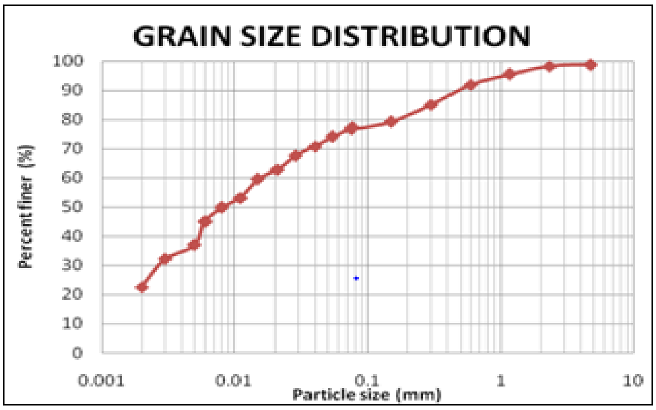

Fig 4.1 Grain size distribution curve of study soil

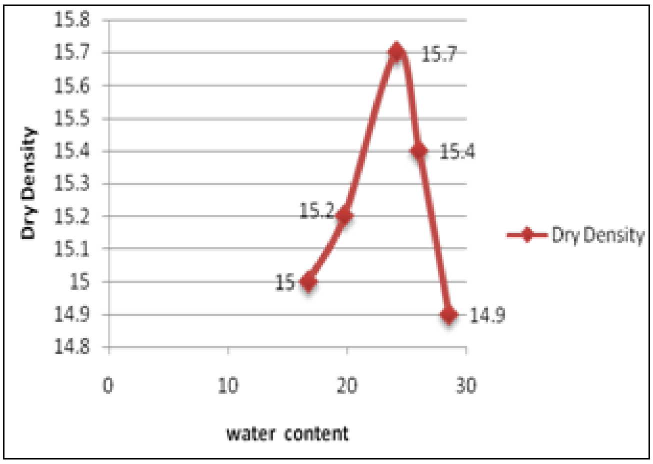

Fig 4.2 Standard Proctor test results for black cotton soil

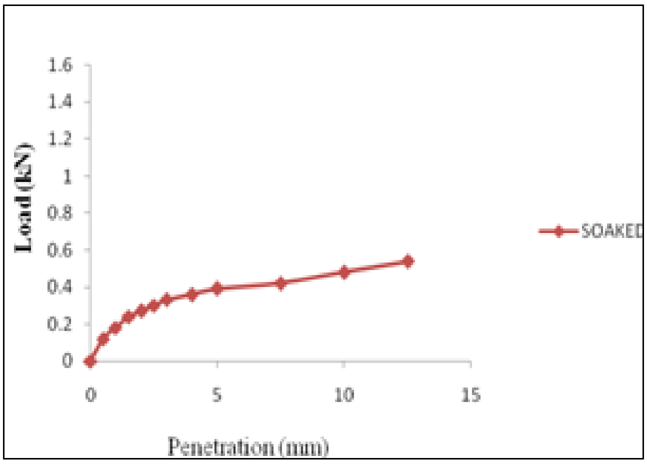

Fig 4.3 CBR test result for black cotton soil

The geotechnical properties of granulated blast furnace slag are presented in Table 2.1.From Table 2.1 it is observed that the specific gravity of the GBFS is about 1.73. The grain size analysis results show that granulated blast furnace slag is predominantly a sandy soil. By conducting direct shear test, it was found that the cohesion is 4kPa and the angle of internal friction is about 43^0. All the test results are tabulated in table 2.1. The grain size distribution curve of granulated blast furnace slag used in this study is shown in Fig4.4.

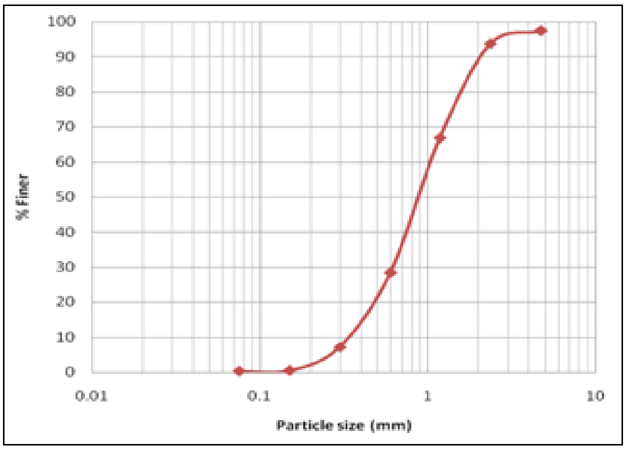

Fig 4.4 Grain size distribution curve for GBFS

Geotechnical parameters of black cotton soil blended with GBFS.

In the present examination, granulated blast furnace slag was utilized as a stabilizer. The soil was substituted with granulated blast furnace slag in various extents of 10, 20, and 30% by dry weight of soil. The summary of the test results of black cotton soil before and after blending with granulated blast furnace slag are shown in Table 4.1.

Table 4.1Geotechnical parameters of blended black cotton soil

Properties	Percentage of granulated blast furnace slag replacing soil (%)			
	0%	10%	2%	30%
SpecificGravity	2.59	2.57	2.53	2.48
Free swell index (%)	80	65	40	30
Max dry unit weight (kN/m^3)	15.7	15.4	15.3	15.1
OMC (%)	24	24.35	24.6	25.12
CBR soaked (%)	1.9	4.1	5.1	11.5
SpecificGravity	2.59	2.57	2.53	2.48

The variation of the soaked CBR for the soil blended with various percentages of GBFS is represented by the Fig 4.5. The soaked CBR esteem increments as the measure of granulated blast furnace slag supplanting the soil increments.

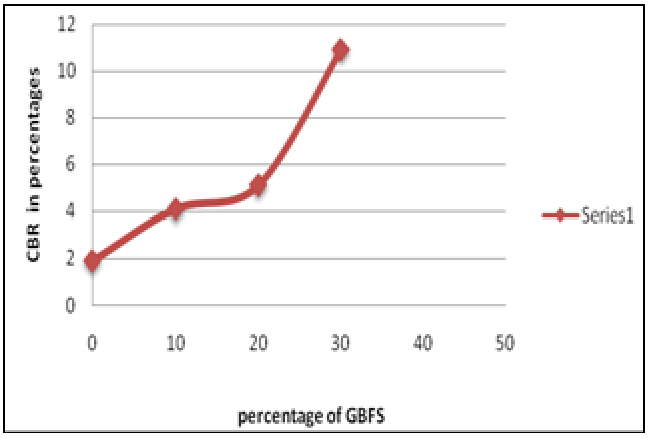

Fig 4.5 Variation of soaked CBR with the percentage of GBFS replacing the soil

Based on the experiments conducted, it is noticed that the maximum dry density is decreasing up to 30 %.

After that it is found to be constant. But the optimum moisture content is increasing. It may be due to the absorption of water by GBFS. Also CBR value for soaked is also found to be increasing.CBR value increases because of the formation of the cementations compounds (CSH) since it contains around 40.83 % of CaO and 35 % of silica. It can be concluded that, up to 30% GBFS can be effectively used as a stabilising agent with black cotton soils.

VI. DESIGN OF FLEXIBLE PAVEMENT

In the present examination, the pavement is designed for a single subgrade soil.
The structure information was accepted according to ***IRC: 37-2012*** and it is as below:
Initial traffic in year of completion of construction = 100 msa
Design Life = 10 year
Width of the pavement = 3.75 m (min width Single lane)
For unstabilized soil (soaked CBR= 1.9 %)
From the chart given in ***IRC: 37-2012***

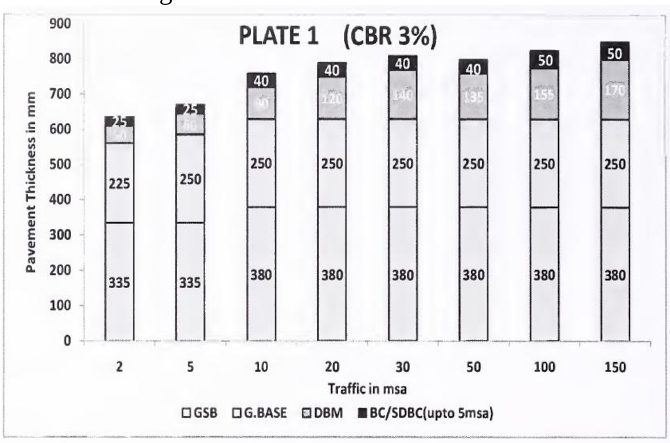

Fig 5.1: Thickness of different layer of pavement section for CBR 3%

Thickness of Bituminous Course (B.C.) = 50 mm
Thickness of Dense Bituminous Macadam (D.B.M.) =155 mm
Thickness of Water Bound Macadam (W.B.M.) = 250 mm
Thickness of Granular Sub base (G.S.B.) = 500 mm
Thickness of Subgrade(S.G.) = 500 mm
Figure 4.5 show the pavement section for unstabilized soil for subgrade which was made up of black cotton soil (CBR (soaked) = 1.9 %).

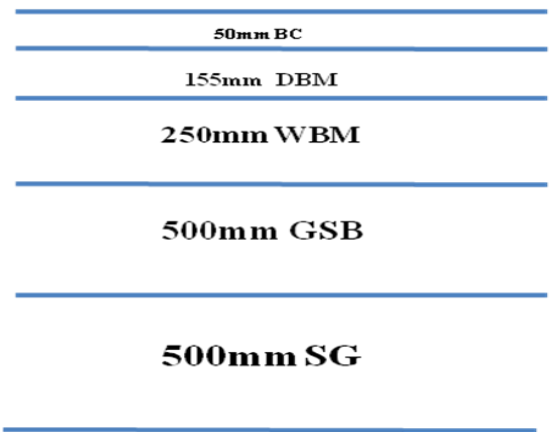

Fig 5.2 Pavement section showing thickness of various layers for unstabilized black cotton soil

For stabilized soil (CBR= 11.5%)
From the chart given in IRC: 37-2012

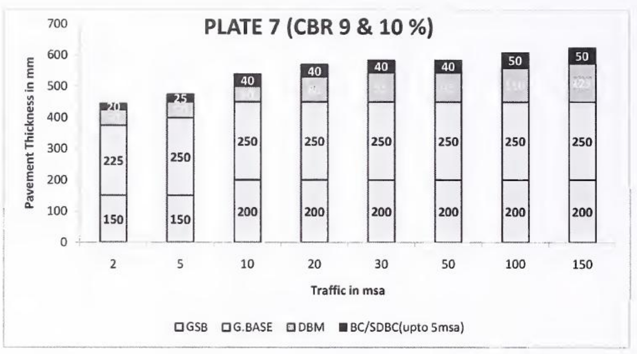

Fig 5.3 Thickness of different layer of pavement section for CBR 9% and 10%

Thickness of bituminous course (BC) = 50 mm
Thickness of Dense Bituminous Macadam (DBM)= 110 mm
Thickness of Water Bound Macadam (WBM) = 210 mm
Thickness of Granular Sub base (GSB) = 200 mm
Thickness of subgrade (SG) = 500 mm
Figure 4.14 shows the pavement section for subgrade which was made up of black cotton soil mixed with 50% of granulated blast furnace slag (CBR (unsoaked) = 12.09 %)

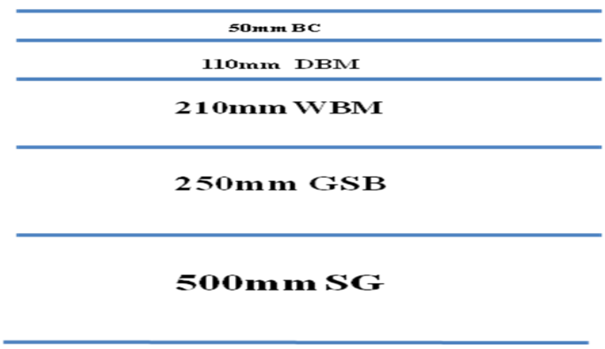

Fig 5.4 Pavement Section showing thickness of various layers for stabilized black cotton soil.

Table 5.1 Thickness of various layer of pavement

S.No.	Description	Layers	Layer Thickness (mm)
1	Unstabilized soil (Soaked CBR = 2.23 %)	GSB	500
		WBM	250
		DBM	155
		BC	50
		TOTAL	**955**
2	Stabilized soil (Soaked CBR= 12.53%)	GSB	200
		WBM	210
		DBM	110
		BC	50
		TOTAL	**570**

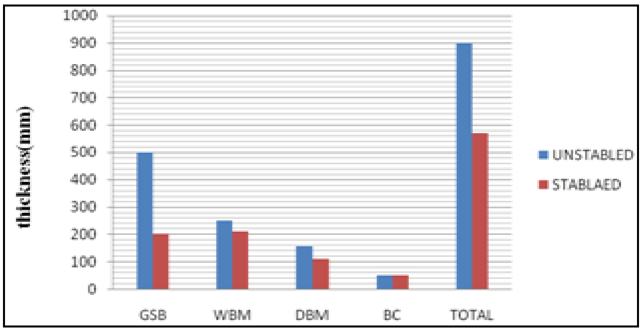

Fig 4.15 Thickness of various layer of pavement

The thickness of crust differs with the adjustment in the estimation of C.B.R. with higher estimation of C.B.R. the crust thickness is less and the other way around. For unstabilized subgrade the total thickness of pavement is 955 mm where as the thickness reduced to 570 mm for stabilized subgrade. At the point when the black cotton soil balanced out utilizing granulated blast furnace slag the sparing in asphalt thickness is 385 mm.

VII. CONCLUSIONS

This work is carried out to study the stabilization of black cotton soil using GBFS in various proportions. The following are the conclusions drawn from the study

- After stabilization, the specific gravity was found to decrease from 2.59 to 2.48. The reduction in specific gravity was due to the replacement of soil with GBFS having low specific gravity
- The MDD of the soil decreased from 15.7kN/m^{3}to 15.1kN/m^3 upon increasing the percentage of GBFS replacing the soil. The OMC of the soil blended with GBFS increased slightly with slag percentage. Absorption of more water by GBFS may be the cause as the percentage of GBFS increases.
- The CBR value (soaked) demonstrated an extreme improvement when 30% GBFS supplanted the soil. The expansion in CBR value for splashed was discovered (CBR from 1.9% to 11.5%). The arrangement of cementations mixes was the explanation for this improvement.
- The thickness of the pavement decreased from 955 mm to 570 mm for balanced out subgrade. That implies the thickness is spared by 385 mm when soil is supplanted by granulated blast furnace slag and the pavement thickness decreased by 385 mm which thus lessens the expense of development

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