Effect of Granulated Blast Furnace Slag in the Stabilization of Expansive Soil for the Pavement Sub-Grades

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Abstract - *The objective of the present investigation is to study the effect of blending GBFS on black cotton soil. Various laboratory experiments were conducted on the basic soil blend. The soil was replaced with granulated blast furnace slag in different proportion of 10, 20, 30% and 40% by dry weight of soil. The effect of this stabilizer on grain size distribution, Atterberg's limits, swelling percentage and rate of swell of soil samples were determined. GBFS replacement was shown not only to successfully decreasing the total amount of swell but also significant improvement has been observed for un-soaked and soaked CBR value of soils. The GBFS replaced BC soil in pavement sub-grade has turned out to reduce the thickness of individual layers.*

Key Words: Granulated Blast Furnace Slag, Black Cotton Soil, Soil Stabilisation, California Bearing Ratio.

1. INTRODUCTION

Black cotton soils are one of the major soil deposits in India and it is considered to be a challenging task to construct infrastructure facilities because of expansive nature of these soils or due to large settlements. In India, it covers an approximate portion of 20% of the total land area. The major clay mineral that is responsible for the expansiveness is the montmorillonite mineral group. Due to the presence of this clay mineral swell nature increases. Soil with these properties will be unsuitable for civil engineering purposes either as foundation or embankment material. Hence the stabilisation of such soils gains the importance. Whilst mechanical compaction, dewatering and soil-reinforcement have been found to enhance the strength of the soils, other methods like stabilization using admixtures are more preferential. The stabilisation by cement on the other hand is expensive and its manufacture produces bulk CO_2.

Blast furnace slag is obtained during the production of iron. A blast furnace is a type of metallurgical furnace used for smelting to produce industrial metals, generally iron. Generally blast furnace slag consists of oxides of calcium, silica, alumina, etc. The percentages of these components vary from slag to slag depending on the composition of iron ores used & the manufacturing process adopted in the steel or iron making industry. A pozzolanic reaction which utilizes the surplus SiO_2 from the slag source, $Ca(OH)_2$ produced by the silicate hydrates and H_2O to produce the desirable minerals to attain soil stabilization with Granulated Blast Furnace Slag (GBFS).

2. MATERIALS AND METHODS

Properties of black cotton soil and GBFS:

The soil classification according to IS-Soil Classification System is CH. The properties are evaluated according to BIS. The properties of the GBFS and black cotton soil of present study were shown in Table 2.1 and Table 2.2 respectively.

Table2.1 Properties of GBFS

Sl. no	Properties	Particulars
1.	Specific gravity	2.8
2.	GRAIN SIZE DISTRIBUTION	
	Gravel size	3%
	Sand size	94%
	Fines	4%
3.	STRENGTH PARAMETERS	
	Cohesion (kPa)	4
	Angle of internal friction ϕ (degrees)	43

Table2.2 Properties of Black Cotton Soil

Sl No	Properties	Particulars
1.	Specific gravity	2.59
2.	GRAIN SIZE ANALYSIS	
	Coarse fraction	11%
	Fine fraction (Silt &Clay)	89%
	IS Soil classification	CH
3.	ATTERBERG'S LIMIT	
	Liquid Limit	61%
	Plastic Limit	26%
	Plasticity Index	35%
4.	COMPACTION CHARACTERISTICS	
	Maximum Dry Density	15.7kN /m3
	Optimum Moisture Content	26.4%
5.	Unconfined Compressive Strength	34 kPa
6.	CBR(Soaked)	1.90%
	CBR(unsoaked)	7.60%
7.	Angle of internal friction	20
8.	Free swell index	92%

2.1 Mix proportion of blended soil:

In the present study, granulated blast furnace slag was used as a stabilizer. The soil was replaced with granulated blast furnace slag in different proportion of 10, 20, 30% and 40% by dry weight of soil. The properties of blended mix were evaluated in the laboratory and compared to obtain an optimum GBFS content for stabilizing the black cotton soil.

3. RESULTS AND DISCUSSIONS

3.1. Atterberg's limits:

Atterberg's limits of the blended soil was determined as per IS:2720(Part5)-1985.Liquid limit and plastic limit both decrease with increasing percentage of GBFS .Variation of plasticity index with various percentage of GBFS is shown in chart-1 ,it was inferred that Plasticity Index decreases with increase of GBFS.

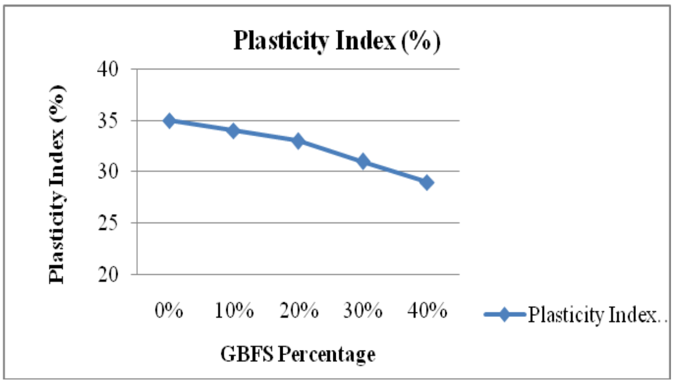

Chart -1: Variation of Plasticity Index with GBFS

3.2. Compaction Properties:

3.2.1. Maximum Dry Density:

The plot between the maximum dry density and the percentage of GBFS replacing the soil is shown in chart-2. The maximum dry density slightly increases by increasing the content of granulated blast furnace slag in soil. The dry density was found to be increased by 7% at 30%GBFS proportion.

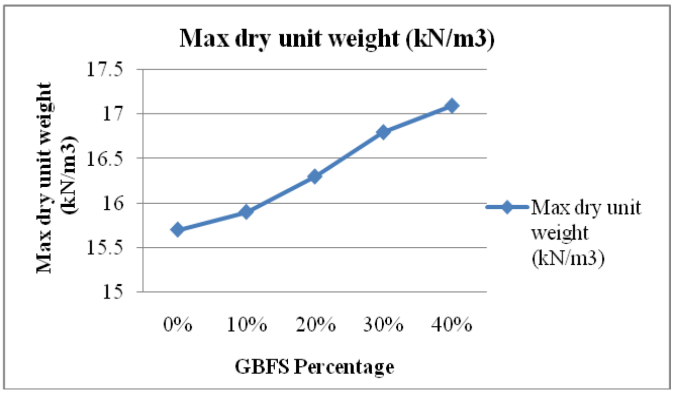

Chart -2: Variation of M.D.D

3.2.2. Optimum Moisture Content:

The plot between the optimum moisture content (OMC) and the percentage of GBFS replacing the soil is showed in chart-3. OMC decreases as the amount of GBFS replacing the soil increases. The decrease in OMC with the increase in quantity of GBFS replacing the soil is due to the cohesion less nature of GBFS.

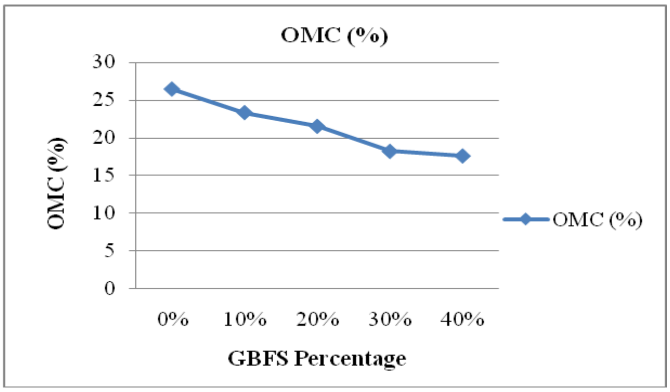

Chart -3: Variation of OMC with GBFS

3.3. Swell property:

The variation of free swell index with varying amount of granulated blast furnace slag (GBFS %) is represented by the chart-4. The free swell index shows a decreasing trend with the increase in the percentage of GBFS content. GBFS has zero swell index. As the amount of GBFS increases in the blended mix, the swell index also decreases.

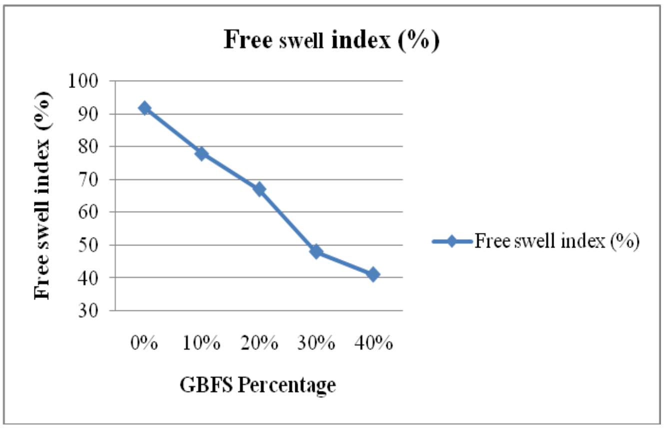

Chart -4: variation of F.S.I with GBFS

3.4. Angle of Internal friction:

The chart-5 represents the plot between the angle of internal friction (ϕ) and the amount of granulated blast furnace slag added (GBFS %). As the amount of GBFS increases, the angle of internal friction also increases. It is due to the fact that GBFS particles alone having good interlocking and rough surface leading to the increase in frictional angle.

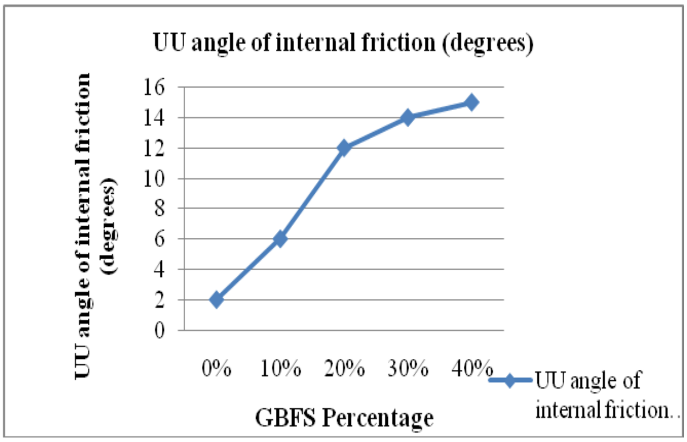

Chart -5: variation of Frictional Angle with GBFS

3.5. Cohesion :

The plot between cohesion and the amount of granulated blast furnace slag added is shown in chart-6 .For the increase in GBFS content, the cohesion decreases. GBFS is of little or of no cohesion. So as the amount of GBFS increases in the blended mix, cohesion decreases.

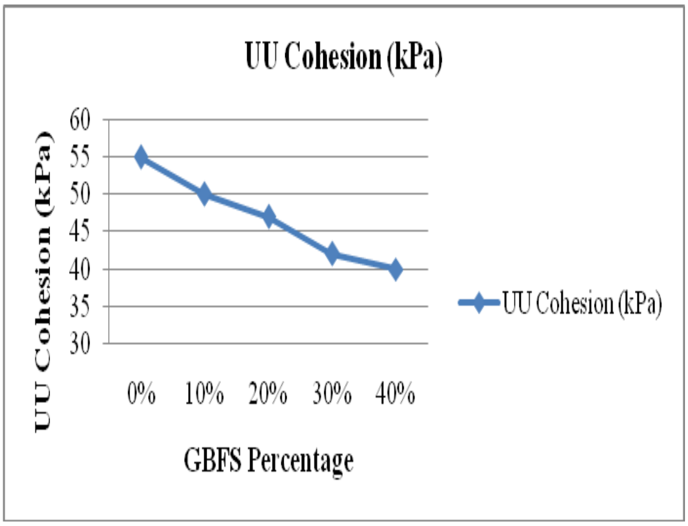

Chart -6: variation of cohesion with GBFS

3.6. California Bearing Ratio:

3.6.1. Variation of soaked CBR for GBFS blend soil

The variation of the soaked California Bearing Ratio (CBR) with the percentage of granulated blast furnace slag replacing the soil (GBFS %) is represented by the Chart-7. The soaked CBR value increases as the amount of granulated blast furnace slag replacing the soil increases.

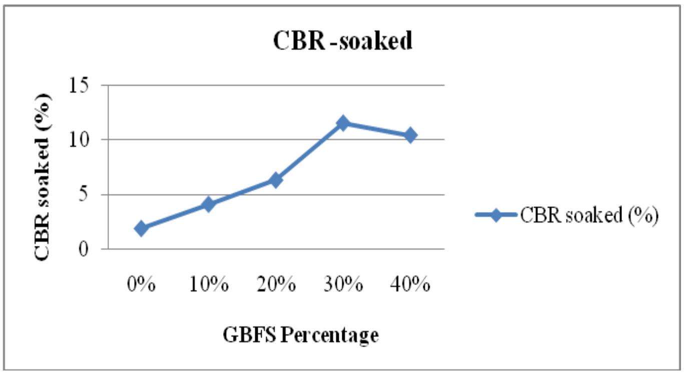

Chart -7: variation of CBR(soaked) with GBFS

3.6.2. Variation of unsoaked CBR of GBFS blend soil

The variation of the un-soaked California Bearing Ratio (CBR) with the percentage of granulated blast furnace slag replacing the soil (GBFS %) is represented by the Chart-8. The un-soaked CBR value increases as the amount of granulated blast furnace slag replacing the soil increases.

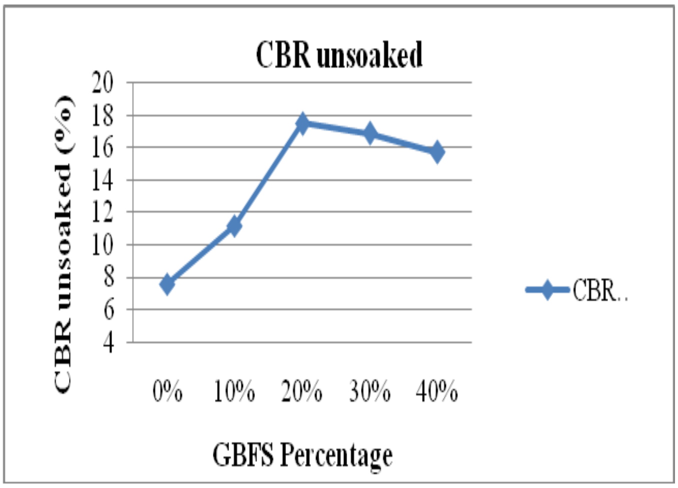

Chart -7: variation of CBR (unsoaked) with GBFS

4. FLEXIBLE PAVEMENT DESIGN

As per IRC: 37-2012 the thickness of the layers on SG (Sub Grade) comprises of GSB (Granulated Sub base), WBM (Water Bound Macadam), DBM (Dense Bituminous Macadam) and BC (Base Course) of the flexible pavement for soaked and un-soaked CBR values pre and post stabilising of black cotton soil with optimum GBFS are determined and shown in Table 4.1, Chart-8 and Table 4.2, Chart-9 respectively.

4.1. For Soaked CBR

Table -4.1: Details of pavement layers for soaked CBR

Sl No	Description	Layer	Thickness (mm)
1	Un-stabilized soil (soaked CBR = 1.9%)	GSB	380
		WBM	250
		DBM	155
		BC	50
		TOTAL	835
2	Stabilized soil (soaked CBR= 11.5%)	GSB	200
		WBM	250
		DBM	110
		BC	50
		TOTAL	610

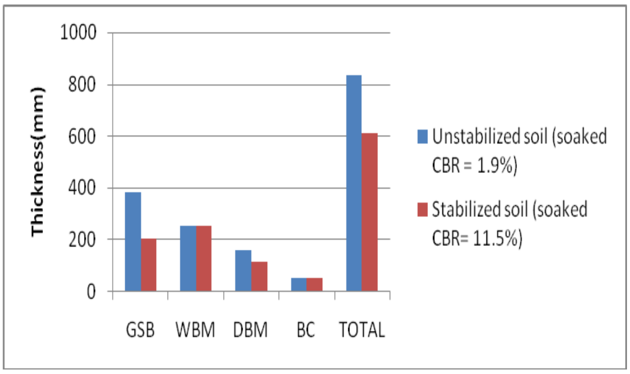

Chart -8: variation of thickness pre & post-stabilization

Saving in pavement thickness

For un-stabilized sub-grade the total thickness of pavement is 835 mm (soaked CBR) where as the thickness reduced to 610 mm for stabilized sub-grade. When the black cotton soil stabilized using granulated blast furnace slag the saving in pavement thickness is 225 mm.

4.2. For un-soaked CBR

Table -4.2: Details of pavement layers for unsoaked CBR

Sl No	Description	Layer	Thickness (mm)
1	Unstabilized soil (unsoaked CBR = 7.6%)	GSB	200
		WBM	250
		DBM	115
		BC	50
		TOTAL	615
2	Stabilized soil (unsoaked CBR= 16.9%)	GSB	200
		WBM	250
		DBM	80
		BC	50
		TOTAL	580

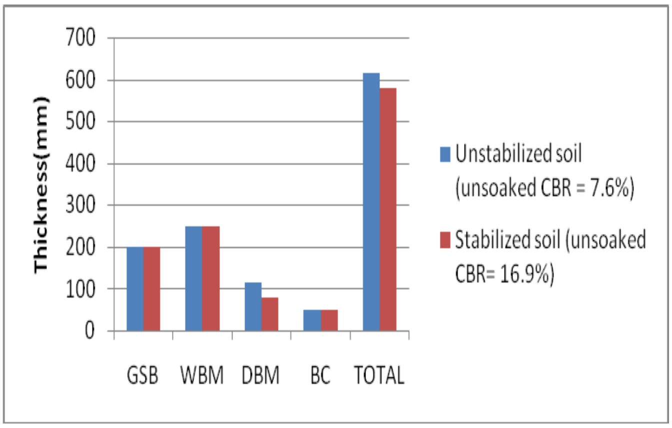

Chart -9: variation of thickness pre & post-stabilization

Saving in pavement thickness

For un-stabilized sub-grade the total thickness of pavement is 615 mm (un-soaked CBR) where as the thickness reduced to 580 mm for stabilized sub-grade. When the black cotton soil stabilized using granulated blast furnace slag the saving in pavement thickness is 35 mm.

5. CONCLUSONS

The black cotton soil was stabilized using granulated blast furnace slag by replacing the soil with granulated blast furnace slag in 10%, 20%, 30% and 40% by dry weight. The conclusions were represented below

- The MDD of the soil increased from 15.7kN/m3 to 16.8kN/m3 upon increasing the percentage of GBFS replacing the soil. The OMC of the soil blended with GBFS increased slightly with slag percentage.
- Free swell index of the soil was found to be decreased by 44% for 30% of slag replacement and thereby degree of expansiveness also decreased.
- The angle of internal friction showed a considerable improvement from 2° to 14° when GBFS replaced the soil by 30%. The cohesion value on the other hand was found to decrease with increase in the percentage of GBFS. The decrease in cohesion occurred from 55kpa to 42kpa when 30% GBFS replaced the soil.
- The CBR value (soaked and unsoaked) showed a drastic improvement when 30% GBFS replaced the soil. The increase in CBR value for soaked (CBR from 1.9% to 11.5%) and for unsoaked (7.6% to 17.5%). The formation of cementatious compounds was the reason behind this improvement.
- The thickness of the pavement reduced from 835 mm to 610 mm for stabilized sub-grade (soaked CBR) and from 615mm to 580mm. That means the thickness is saved by 225 mm and 35mm when soil is replaced by granulated blast furnace slag which in turn reduces the cost of construction.

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