

Stabilization of Black Cotton Soil using Lime and Ground Granulated Blast Furnace Slag (GGBFS)

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Abstract - The black cotton soil is one of the major soil deposits of India. Black cotton soil exhibit high swelling and shrinkage when exposed to changes in moisture content and hence have been found to be most troublesome from engineering considerations. The properties of black cotton soil can be modified by stabilizing the soil with the use of additives or by mechanical means. In this study the black cotton soil are stabilized with ground Granulated Blast furnace Slag (GGBFS) and lime. The percentage of GGBFS added to the BC soil, as percentage of dry soil mass, varied from 10 to 30%. GGBFS is a waste product produced by manufacturing process of steel. Different lab tests on expansive soil without the addition of this waste and with the addition of this waste were performed and their effect on plasticity index, liquid limit and other properties were determined and this may be an economical solution for the areas where steel plants are located.

Key Words: Ground granulated blast furnace slag (GGBFS), Black cotton soil (BCS), Lime, Index properties, UCS test.

1. INTRODUCTION

In India expansive soil are popularly known as black cotton soil due to its black in color and high productivity of cotton in it. In India the black cotton soil covers an area about 0.66 million sq. Km. which is about 20% of the total land area. Expansive soils are those soils which have the tendency to increase in volume when water is available and to decrease in volume if water is removed. This volume change in swelling soils is the cause of many problems in structures that come into their contact or constructed out of them. Foundations constructed on these expansive soils are subjected to large uplift forces caused by swelling and inducing heaving, cracking and break up building foundations and slabs on grade members. Soils containing montmorillonite mineral swell considerably when it comes to contact water.

Thus the need of treating soil arises in order to utilize the locally available soil, Lime is well known additive for the stabilization of expansive soils. Lime is produced from industrial processes and is associated with the emission of greenhouse gases such as carbon dioxide (CO₂), sulfur dioxide (SO₂) and nitrous oxide (N₂O). Industrial by-product materials such as fly ash, GGBFS, cements kiln dust and lime stone dust can also used as a stabilizer. By using this by-

products environmental and economical problems can be solved. And GGBFS has great potential to be used as a stabilizing agent.

The objective of this study is to investigate the effect of lime and ground granulated blast furnace slag in the stabilization of expansive soils.

Use of industrial by-product GGBFS have been successfully tried for stabilization of various types of soils in recent past. Along with this major ingredient certain additives like sodium salts, gypsum, and lime in small quantity were used for stabilization of weaker and expansive soils

Investigation on the effect of addition of GGBFS on the clayey soil carried out by Pathak A.k. et al. (2014) reveals that the Specific gravity value increases with increase in percentage of GGBS [3]. While Liquid limit plastic limit, Shrinkage limit and cohesion value decreases with increase in the quantity of GGBS in lime stabilized soil.

Takhelmayum G. et al. (2013), work on Experimental studies on stabilization of black cotton soil using fine and coarse GGBS [7]. Their study shows that stability of soil increases.

Sharma A.k. et al. (2016) studied ground granulated blast furnace slag amended fly ash as an expansive soil stabilizer [4]. Their investigation shows that the addition of small quantities of GGBFS to lime stabilized expansive soil, is effective in reducing liquid limit, plastic limit and differential free soil index.

But in all of the above studies lime content taken only 1 to 2%. Present study envisages the experimental investigation of effect of stabilizing BC soil using ground granulated blast furnace slag along with lime.

2. MATERIALS AND PROPERTIES

Ingredients used for the stabilization of black cotton soil (BC) are ground granulated blast furnace slag (GGBFS) and lime. The properties and availability are mentioned below.

2.1 Black cotton soil - The black cotton soil used in this study was collected from a depth of 1-1.50 m below the natural ground level near national high-way site of Jabalpur, Madhya Pradesh. The properties of the BC soil collected from the site tabulated such as:

Table 1 Properties of black cotton soil

S. no.	Particulars	observation
1.	Specific gravity	2.21
2.	Liquid limit	62.23
3.	Plastic limit	21.56
4.	Plasticity index	40.67
5.	Passing 75 μ sieve	77.54%
6.	Differential Free swell index	52.22%

2.2 Ground granulated blast furnace slag (GGBFS)-

Ground-granulated blast-furnace slag (GGBS or GGBFS) is a non-metallic by product obtained in the process of iron and steel manufacturing. Produce by quenching of molten iron slag from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. The GGBFS used in this study is obtained by Ambica steel limited, Sahibabad, Ghaziabad, Uttar Pradesh, India. The physical and chemical properties of the ground granulated blast furnace slag tabulated in table no.2 and 3.

Table 2 Physical properties of GGBFS

S. no.	Particulars	Observation
1.	Type	powder
2.	Specific gravity	2.82
3.	Passing 75 μ sieve	98%

Table 3 Chemical properties of GGBFS

S. No.	Particulars	Percentage
1.	SiO ₂	37.5 %
2.	Al ₂ O ₃	11.43 %
3.	CaO	42.8 %
4.	MgO	6.61 %
5.	Fe ₂ O ₃	3.8 %
6.	K ₂ O	0.41 %
7.	Na ₂ O	0.21 %
8.	Cr ₂ O ₃	<0.01 %
9.	TiO ₂	0.22 %
10.	MnO	0.03 %

Source: <http://www.nationalslag.org/blast-furnace-slag>

Table 4 Effect of GGBFS and Lime on index properties of BCs

Details of mix (%)		Index properties			
Lime (%)	GGBFS (%)	LL (%)	PI (%)	DFS (%)	Classification
0	0	62.23	40.67	52.2	CH
0	10	53.92	28.58	25	CH
0	20	51.25	23.32	19	CH

2.3 Lime- Lime has number of effects when it added in to the soil like soil drying, soil modification and soil stabilization. Commercially available pure quicklime was used in this laboratory work. This quicklime was thoroughly mixed and hydrated with water to be added to the soil.

3. TESTING METHODOLOGY

The various tests can be conducted in the geotechnical laboratory to characterize the index properties of plain black cotton soil and lime stabilized soil. Some important tests were performed in the laboratory as per the relevant IS codes:

1. Specific gravity (IS: 2720 PART III/ Sec I) - 1980.
2. Liquid limit (IS: 2720 PART-V)-1985.
3. Plastic limit (IS: 2720 PART-V)-1985.
4. Differential free soil index (IS: 2720 PART-XL)-1977.

4. SAMPLE PREPARATION

The samples used in the study are prepared by blending black cotton soil (BCS) with different percent of GGBFS. Lime is used as a stabilizer in this laboratory work. The samples are prepared as such-

1. The black cotton soil, lime and GGBFS are oven dried separately.
2. The oven dried black cotton soil, lime (0%, 4%, and 6%) and GGBFS (0%, 10%, 20%, and 30%) are mixed in proportions by weight to form various mixes.
3. The formed dry mixes are being blended together with water in order to get a homogeneous blend as per the requirement of test.
4. In these blended soil samples geotechnical test performed as per the IS specifications.

5. RESULTS AND DISCUSSION

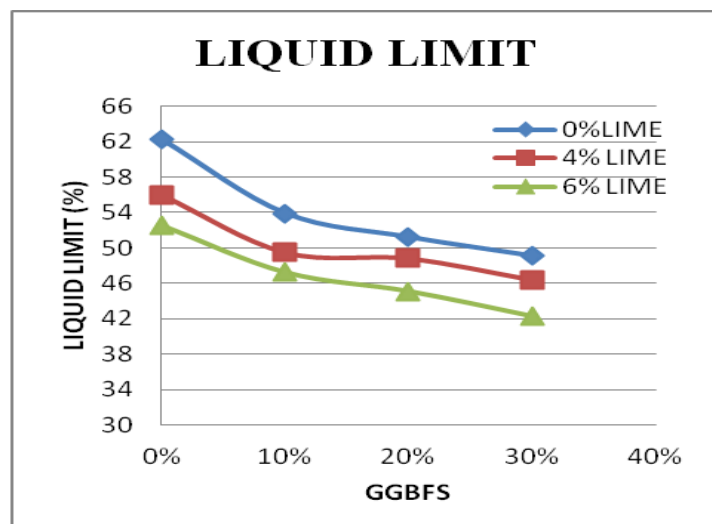
The laboratory tests are conducted in the geotechnical laboratory, Jabalpur engineering college, Jabalpur. Based on the extensive laboratory investigations on the various samples the following test results have been made, that's tabulated in the table given below.

0	30	49.13	19.68	13	CI
4	0	55.95	32.48	43	CH
4	10	49.50	16.92	18	MH
4	20	48.83	13.43	15	MI
4	30	46.42	9.89	10	MI
6	0	52.53	28.23	34.5	CH
6	10	47.24	12.51	15	MI
6	20	45.11	8.48	9	MI
6	30	42.29	4.97	4	MI

LL=Liquid limit, PI=Plasticity index, DFS=Differential free swell

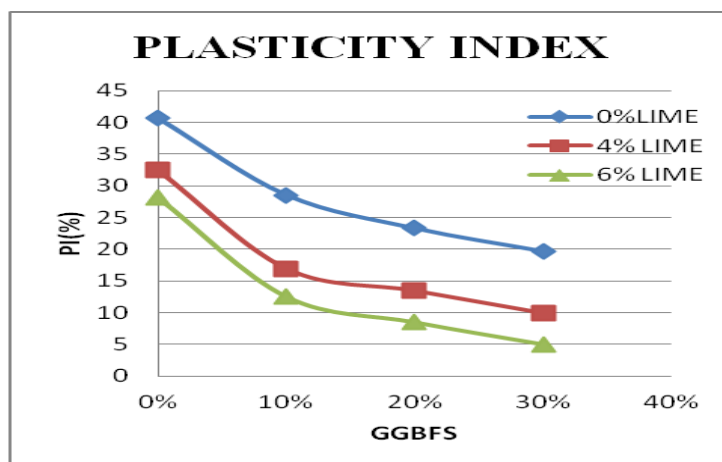
The following graphs were observed-

Liquid limit of the lime stabilized soil and blended samples



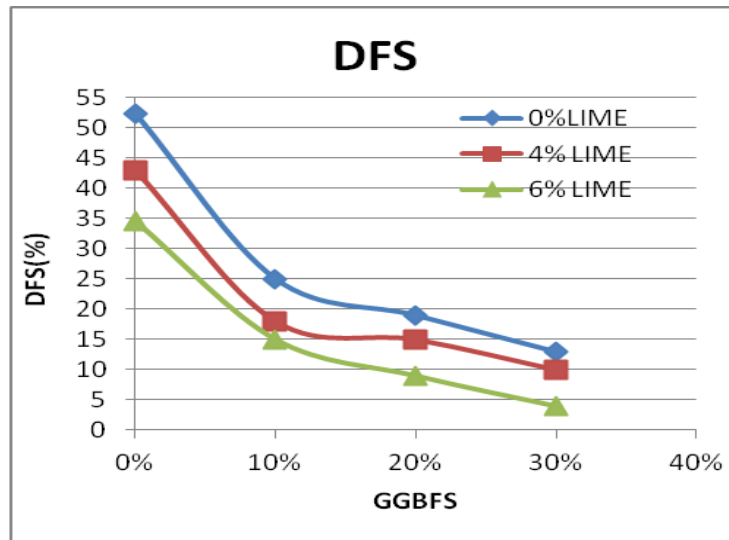
Graph 1 Variation of liquid limit of soil in different percent of GGBFS

Plasticity index of lime stabilized soil and blended samples



Graph 3 Variation of plasticity index of soil in different percent of GGBFS

Differential free soil index of lime stabilized soil and blended samples



Graph 4 Variation of differential free swell index of soil in different percent of GGBFS

6. CONCLUSION

The initial value of plasticity index of the plain BC soil is very high 40.67%, it decrease gradually on addition of lime and GGBFS. The value decreases to 19.68%, 9.89% and 4.97% with the addition of 30% GGBFS and 0%, 4% and 6% lime respectively. The expansive behaviour of soil has been reduces significantly as it reduces from 52.2% to 4% on addition of 30% GGBFS and 6% lime. Based on the above study it can be concluded that ground granulated blast furnace slag has good potential to utilize it for the stabilization of weak soil and to utilize it in many geotechnical applications like road sub grades, foundation soils and embankments etc.

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