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Research Article

Study on the Effects of Blast Furnace Slag on Geotechnical Characteristics of Black Cotton Soil

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Abstract

The paper presents the study of Geotechnical Improvement in the properties of Black Cotton Soil by blending it with Blast Furnace Slag. The black cotton soil have high swelling and shrinkage properties, hence it requires improvement, in order to decrease its detrimental effect on the construction over it. The study provides an effective way for the utilization of Blast Furnace Slag, an industrial waste for the purpose of eco-friendly and cost effective soil improvement method. It is also effective in checking the disposal problem of the industrial waste. The testing is done by preparing the samples by blending blast furnace slag with black cotton soil with increasing percentage. The results indicated that there is ample improvement in geotechnical properties of soil by addition of blast furnace slag and volumetric changes by swelling and shrinkage are checked. However, to achieve high soil strength the percentage addition of blast furnace slag needs to be around15-20%.

Keywords: *Problematic soil, Black cotton soil, Industrial waste, Blast furnace slag (BFS), Blending.*

1. Introduction

The Black Cotton soils are problematic soils because of their nature to show volumetric variations with variable moisture content. When these soils come in contact with water they expand immensely but when the water content is decreased it shows shrinkage and development of cracks. The soil exerts nominal pressure in dry state but on increase in water content the soil swells and exerts high swelling pressure on the structure. The black cotton soil is extensively found in India; it covers around 0.85 million sq. kilometer area of the country which is about 20% of the total country land. Such soils damage the civil engineering structures constructed over and founded in it due to variable volumetric states. The soil becomes slushy during rains and dries in summers showing deep cracks which could be even 10-15 cm wide and 3m deep. With variable moisture content the soil shows variation in strength and exerts variable pressure on the structure constructed over it, it poses extremely high strength when dry but when water comes in contact the strength drops. The weathering of Basalt is supposed to be responsible for the formation of Black cotton soil and the clay minerals such as Illite, kaolinite and montmorillonite having expanded lattice are responsible for such soil behavior.

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In India, the problems have its own importance due to the fact that climatic changes are very frequent especially the water content and temperature and need for improvement of soil becomes must.

With rapid industrialization the problem of disposal of industrial waste is increasing day by day, arises the need of effective Waste management. The utilization and recycling of waste products has gained attention due to the shortage of suitable disposal land. The Blast furnace slag is a by-product obtained during the steel manufacturing and is available almost free of cost. Its annual production in India is around 10.0 million tonnes. The waste material utilization in the improvement of soil properties is of great interest since this would lead to cost effectiveness as well as Eco friendliness of the construction. This study is an attempt to understand the effectiveness of utilization of blast furnace slag in checking the detrimental properties of the black cotton soil.

2. Experimental Investigation

The main objective of the study is to evaluate the utilization of Blast furnace slag in improving the geotechnical properties of Black Cotton Soil. The study of each material is done before utilizing it; the laboratory tests were conducted on the intimate blend of black cotton soil-blast furnace slag with 5% lime as stabilizer. The variation in engineering properties of the original soil and soil-blend is studied under various Geotechnical parameters such as Californian rearing ratio, Differential free swell, Atterberg limits, Compaction and Optimum moisture (Proctor test).

3. Materials and properties

Black cotton soil- The properties of Black Cotton soil sample is tabulated as such:

Table 1 Properties of Black cotton soil

S no.	Particulars	Observation
1.	Specific Gravity	2.22
2.	Liquid Limit	51.3
3.	Plastic Limit	29.63
4.	Shrinkage limit	19
5.	Passing 75µ sieve	99 %

The Black cotton soil swells immensely due to imbibition of water during the monsoon, reducing strength and density. But in dry seasons, it shrinks due to evaporation of water, attaining harder mass due increase in density (Mckeen 1988).The alternate swelling and shrinkage causes distress to civil engineering structures built on these soil are severely damaged(Chen 1988,Nelson & Miller 1992). It is highly argillaceous and somewhat calcareous. Such soils have high percentage of iron oxide, Magnesium, Calcium carbonate and low organic matter. The clay of fraction in the Black cotton soil is very rich in silica ranging 60-70 %. The remaining fraction is mostly iron and alumina. The pH value of soils varies from 7-9. The soils having high sodium % shows higher swelling & shrinkage characteristics than the Calcium rich soils.

Blast furnace Slag-The Blast furnace slag used in the study is collected from a disposal site of Bhilai Steel plant, Chattisgarh. The Properties of Blast Furnace Slag is tabulated as such,

Table 2 Properties of Blast furnace slag

S no.	Particulars	Observation
1.	Colour	off-white to grey
2.	Specific Gravity	2.705
3.	Fineness	>350m²/kg
4.	Bulk density	1250 kg/m3
5.	Type	Granular

It is a non-metallic by-product produced in the iron making in a blast furnace consisting of silicates, alumino silicates and calcium alumina-silicates.

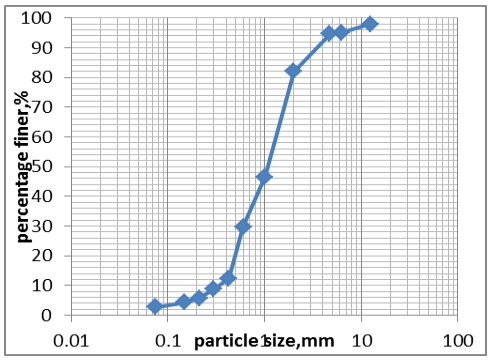


Fig 4.1 Particle size Distribution of BFS

4. Sample Preparation

The samples are prepared by blending increasing amount of Blast Furnace slag with Black cotton soil with 5% lime as stabilizer. The samples are prepared and designated as such-

Sample I –Plain Black cotton soil.
Sample II –Black cotton soil with Stabilizer (5% lime)
Sample III –Black cotton soil with 5% blast furnace slag & Stabilizer
Sample IV –Black cotton soil with 10% blast furnace slag & Stabilizer
Sample V –Black cotton soil with 15% blast furnace slag &Stabilizer
Sample VI –Black cotton soil with 20% blast furnace slag and Stabilizer
Sample VII –Black cotton soil with 25% blast furnace slag and Stabilizer

5. Result and Analysis

The analysis and laboratory testing work is done as per relevant IS Codes and the results are tabulated as such,

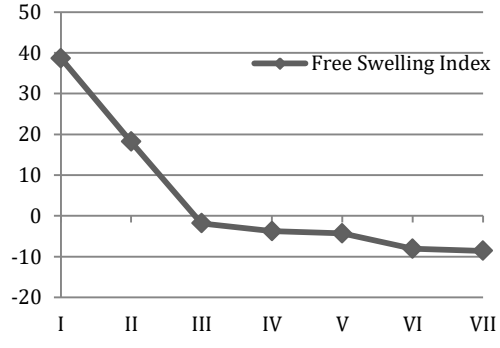
Table 3 Resulting observations of the Samples

Test	Results of the tested samples with sample no.						
	I	II	III	IV	V	VI	VII
F.S.I. (%)	38.63	18.2	-1.82	-3.76	-4.3	-8.1	-8.6
MDD	1.39	1. 47	1.43	1.42	1.47	1.51	1.54
OMC	28.7	25.2	26.5	31.2	23.4	20.9	23.6
CBR	0.57	3.31	3.39	3.42	3.60	4.90	3.40
UCS kN/m²	110	119	121	178	188	196	236

FSI - Free Swelling Index
MDD- Maximum Dry Density
OMC - Optimum Moisture Content
UCS - Unconfined Compressive Strength
CBR - California Bearing Ratio

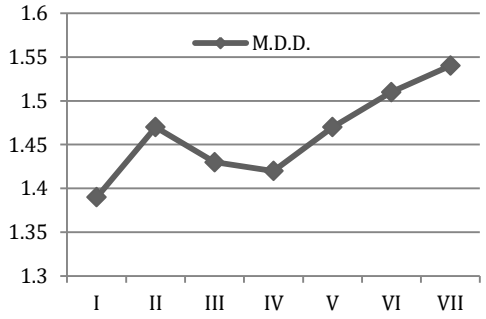
The graphical presentation of the results analyzed is shown below:

1) Free Swelling Index



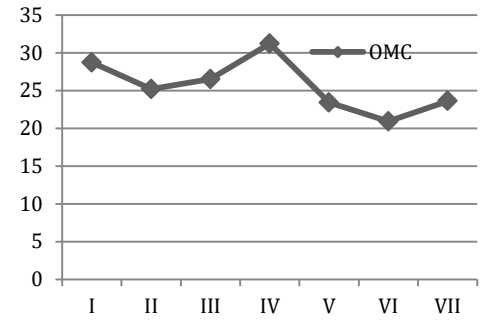
Graph 1 Observations of FSI

2) Maximum Dry Density



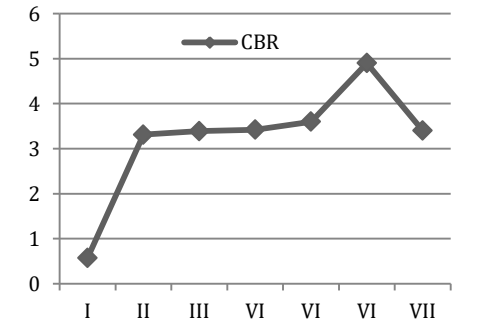
Graph 2 Observations of MDD

3) Optimum Moisture Content



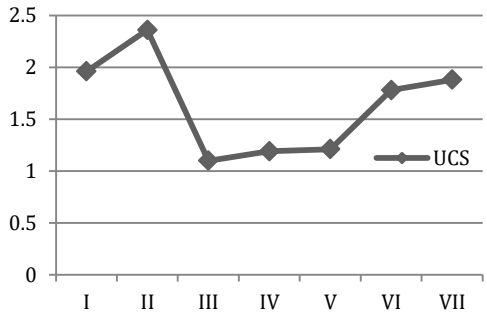
Graph 3 Observations of OMC

4) California Bearing Ratio



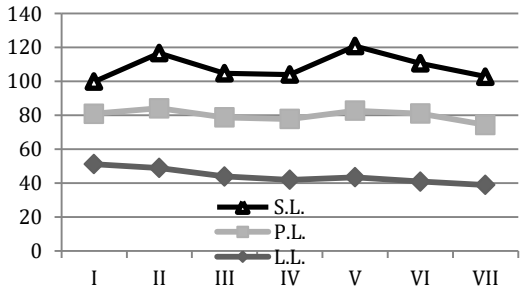
Graph 4 Observations of CBR

5) Unconfined Compressive Strength



Graph 5 Observations of UCS

6) Index Properties of the soil and blended samples



Graph no.6 Observations of Index properties

Conclusions

The conclusions made by the study are as under-

1) The study presents an effective method for improvement of problematic black cotton soil by utilizing an industrial waste blast furnace slag,
2) It is an ecofriendly and cost effective method. Since BFS available almost free of cost.
3) The CBR of the soil increases with the increasing percent of Blast Furnace slag.
4) The MDD is Increasing with increase in Percentage of Blast Furnace slag. The Swelling of the Black cotton soil is completely checked with addition of the blast furnace slag.
5) The blending of material should be properly done in order to achieve homogeneity of the blend, for better results.

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