Influence on Properties of Cohesionless Soil with Utilization of Blast Furnace Slag

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Abstract: Utilization of industrial waste materials in the improvement of problematic soils is a cost efficient and also environmental friendly method in the sense that it helps in reducing disposal problems caused by the various industrial wastes. There are many wastes generated from various industrial processes and manufacturing. This waste has variety of different characteristics which may or may not be suitable for virgin soil materials. It is necessary to know the characteristics of waste material before it is utilized with soil. Out of many materials available Blast Furnace Slag is one of them. The main objective of the present study is to improve various engineering properties of the soil by adding waste material Blast Furnace Slag (BFS) in different proportions. Different experiments were performed on soil, BFS and mixture of both. The characteristics of BFS and cohesionless have been done for various engineering properties which is necessary for soil improvement. The soil improvement has been measured in terms of OMC-MDD and CBR values for different proportion of BFS i.e. 15% and 25% with cohesionless soil. This paper contains results of the experiments and analysis of results between virgin soil and BFS mixed soil and shown the influence on properties of cohesionless soil.

***Keywords* — Blast Furnace Slag , Cohesionless Soil, Soil Improvement, Utilization of BFS**

I. INTRODUCTION

Economic development of any country is controlled to a great extent by construction of roads, buildings and different kind of infrastructures in developing countries like India. The base of any structure lies on the soil. Sub base is the main load bearing layer of every structure. So soil stabilization is very much important before constructing any kind of structure. So certain amount of additive is added to the soil for improving their properties but these additions finally proves to be more expensive whereas in case of soil stabilization some inferior materials or some industrial or agricultural wastes can be used in place of cement or lime with the soil to improve its quality. This will result in cost effective construction.

Due to rapid industrialization throughout the country the productions of huge quantity of waste materials create not only the environmental problems but also disposal hazards. By using these waste materials for improvement of soil, the problem of disposal of industrial waste materials can be eliminated. So, BFS is used for experimental studies. BFS is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. It has a cementitious property which acts as binding material for the soil.

This research work includes the materials, Cohesionless soil and Blast Furnace Slag (BFS). Cohesionless soil was collected from Riverfront Sabarmati, Ahmedabad. Blast Furnace Slag was collected from Furnace Factory, Rajkot. This paper contains different experimental studies on virgin soil, BFS and the mixture of them with different proportions. The different proportion of BFS i.e. 15% and 25% were taken in cohesionless soil.

II. LITERATURE REVIEW

Many researcher and technocrat put their sincere effort in this area and investigate the influence on properties of various soils with utilization of BFS. Some of the findings are narrated here related to this study.

Dayalan J (2016) studied on the stabilization of Soil with Blast Furnace Slag (BFS) and Fly Ash. Soil stabilization has become the major issue in construction engineering and the researches regarding the effectiveness of using industrial wastes as a stabilizer are rapidly increasing. This study briefly describes the suitability of the local fly ash and Blast Furnace Slag (BFS) to be used in the local construction industry in a way to minimize the amount of waste to be disposed to the environment causing environmental pollution. In this present study, different amount of fly ash and BFS are added separately i.e. 5, 10, 15 and 20% by dry

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weight of soil are used to study the stabilization of soil. The performance of stabilized soil are evaluated using physical and strength performance tests like specific gravity, Atterberg's limits, standard proctor test and California Bearing Ratio (CBR) test at optimum moisture content. From the results, it was found that optimum value of fly ash is 15% and BFS is 20% for stabilization of given soil based on CBR value determined [1].

Tarkeshwar Pramanik et al (2016) studied the behavior of Soil for Sub Grade by using Marble Dust and Blast Furnace Slag. In this paper, sandy clayey soil was stabilized using the combination of Marble Dust and BFS in different proportion (i.e.0%+0%, 5%+5%, 10%+10%, 15%+15% & 20%+20%) and the Characteristic behavior (i.e. OMC, MDD, UCS, CBR & Permeability) of modified soil in the laboratory was studied. The series of test has been conducted in laboratory and it is found that Marble Dust and BFS (15%+15%) is sufficient to increases the California bearing ratio in unsoaked and soaked condition value up to 195% and 100% approximately [2].

A. Kavak et al (2016) studied on the reuse of Blast Furnace Slag (BFS) in Lime Stabilized Embankment Materials. In this paper presents an effective way of utilizing the Blast Furnace Slag (BFS), which is a by-product of the steel manufacturing process with lime for stabilization of road materials. In the study Ankara clay was used for stabilization. Although slag, lime and clay mixtures do not affect optimum water contents of clay significantly, they decrease dry density and smoothes Proctor curve. Then, the soil transforms into a rapid structure and the modulus of elasticity increases. When the results of the experiments were evaluated, unconfined compressive strength (UCS) and soaked California Bearing Ratio (CBR) values of the soils have shown significant increases. These increases reach to 46 times in CBR values for Ankara clay compared to natural case in 28 day-cured samples. This stabilization technique is more effective than the lime alone and also the slag will prevent the ettringite formation that occurs in lime stabilization with sulfate rich soils that leads swelling behavior. And finally the slag may turn from a waste material into a valuable product for road construction works with huge volumes even at far away from the steel factories [3].

Sridevi G et al (2014) et al studied on the efficacy of BFS Stabilized Soil Cushions With and Without Lime in Pavements. In this study, expansive soil, stabilized with Blast Furnace Slag (BFS), with and without lime was used as cushioning material above an expansive clay sub-grade to study its performance in improving the properties of the sub-grade. The investigations show that the BFS-stabilized expansive soil, with and without lime, as a cushioning material is effective in reducing the heave of the underlying clay bed apart from improving the soaked CBR and increasing the unconfined compressive strength of the soil, BFS mix system. The studies also indicate that the cushioning material possesses all the properties needed for use as sub-base material. So, the cushion also serves as a sub-base layer in the pavement structure. The use of BFS-stabilized soil alone, or in combination with lime, has significant effect in improving the properties of potentially swelling clays [4].

Ashish Kumar Pathak et al (2014) studied the soil Stabilization Using Blast Furnace Slag. In this research the soil are stabilized by Blast Furnace Slag (BFS) and this material is obtained from the blast furnace of cement plant, which is the byproduct of iron (from ACC plant, sindri). It is generally obtained in three shaped one is air cooled, foamed shaped and another is in granulated shaped. The use of by-product materials for stabilization has environmental and economic benefits. Blast Furnace Slag (BFS) material is used in the current work to stabilize soil (clay) [5].

Laxmikant Yadu and Dr. R K Tripathi (2013) Conducted to assess the potential of GBS to stabilize the soft soil. Selected soft soil for study was identified as CI-MI as per Bureau of Indian Standard Classification System. The soft soil was mixed with various percentages of GBS(i.e. , 3,6,9 and 12%) . The physical and strength properties have been evaluated experimentally on raw and blended soil. The results indicate that the use of GBS significantly improves the physical and strength properties of soil. MDD increased while OMC decreased with addition of GBS to the soft soil. There is significant reduction in the swelling behavior of the soil. Based on the strength tests, optimum amount of GBS was determined as 9%. Soaked CBR and UCS values increased about 400% and 28% respectively by the addition of optimum amount of GBS. Moreover blended mix of 9% GBS reduces the free swelling index and swelling pressure at about 67% and 21% respectively from its unstabilized counterpart [6].

Ms. Radha Gonawala et al. evaluated Soil and GGFS (10, 15 and 20%), Soil and lime (3, 4, and 5%), Soil and cement (0.5, 1 and 1.5%) for their engineering characteristics by laboratory investigations for embankment construction. Different laboratory tests carried out included: grain size analysis, Atterberg's limit test, Proctor compaction test, CBR test, aggregate impact value test, Abrasion test and moisture absorption test [7].

Akin Musuru (1991) studied the cause of mixing of BFS on the consistency, compaction, characteristics and strength of lateritic soil. He observed decrease in both the liquid and plastic limit. The compaction, cohesion and CBR improved with increasing BFS up to 10%. Then if add 15% of BFS decrease the strength. The angle of internal friction decreased with increase in BFS [8].

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III. PROCEDURES

In the present study, an exhaustive experimental programme was conducted to evaluate effect of the blast furnace slag available locally when it is used as construction material in various proportions to the soil in different Civil engineering applications. The characterization of blast furnace slag is done which is locally available. Some selected soil samples were adopted for the study. Geotechnical parameters like OMC-MDD and CBR values are studied for soil sample selected by adding various percentage of slag mix with it. Details of material used, processing test procedure adopted are described.

A. *Methodology used :*

- Classification of Soil
- Determination of Water Content
- Determination of Specific Gravity
- Determination of Liquid Limit
- Determination of Plastic Limit
- Determination of Maximum Dry Density (MDD) and Optimum Moisture Content (OMC)
- Determination of California Bearing Ratio (CBR)

All the above tests are performed for both the materials which are Virgin Soil and Blast Furnace Slag (BFS).

The procedure for the above experiments were referenced from IS: 2720 (Part – 1 to Part – 40)

B. *About Material used:*

Cohesionless Soil:

Cohesion as the word itself denotes, is the attraction between particles of same type/origin/nature. Hence cohesive soil is a type of soil where there is inter-particular attraction. This adds to the shear strength of the soil.

Cohesionless soil as the name indicates does not have cohesive forces. They are comparatively coarser particles with self-weight governing their behavior. The particles have internal friction and their shear strength depends upon the angle of internal friction between particles. Sand is a typical example. Exclusively non-cohesive soils will have zero cohesion.

Blast Furnace Slag (BFS) – A Waste Material:

Blast furnace slag is the byproduct of metallurgical operations, typically containing gangue from the metal ore, flux material, and unburnt fuel constituents. Slag is often classified into nonferrous and ferrous slag, where nonferrous slag includes those derived from copper, lead-zinc, nickel, and phosphorus metallurgical operations, and ferrous slags are those derived from the production of iron and steel.

The physical properties of ACBFS (Air Cooled Blast Furnace Slag) are largely controlled by how it cools and solidifies. The color of ACBFS coarse aggregate usually varies from light to dark gray, depending on chemical composition, although blue, green, and pink staining of smaller areas have been observed. As mentioned, the aggregate particles have a very rough texture due to the "vesicular" structure formed by gases entrapped in the ACBFS as it cools. Typical chemical composition and physical as well as chemical properties of blast furnace slag is shown in Table – 1.

TABLE: 1. CHEMICAL COMPOSITION AND PHYSICAL AND CHEMICAL PROPERTIES OF ACBFS

Item			Blast Furnace Slag Coarse Aggregate Class L	Blast Furnace Slag Coarse Aggregate Class N
Chemical composition	Calcium oxide (as CaO)	%	45.0 max.	
	Total sulfur (as S)	%	2.0 max.	
	Sulfur trioxide (as SO_3)	%	0.5 max.	
	Total iron (as FeO)	%	3.0 max.	
Density in oven dry condition		g/cm^3	2.2 min.	2.4 min.
Water absorption		%	6.0 max.	4.0 max.
Bulk density		kg/L	1.25 min.	1.35 min.
Immersion in water			Shall be no phenomena such as cracks, decomposition, muddiness, powdering.	
Irradiation by ultraviolet light (360.0 nm)			Shall be no light emission or uniform purple luminance.	

IV. RESULTS

The major aim to perform the experiment on blast furnace slag along with some soil is to evalute the feasability of this waste material with soil. The experimental outcome may lead to an extent for utilization of this blast furnace slag with cohesiveless soils. Based on the experimentation done, the effect of BFS on various properties of soil is checked. The results are evaluated for soil properties like OMC-MDD and CBR. The index properties of soil and BFS are also evaluated before the mix of BFS and soil in various proportions. The results are shown in Table-2 for index properties of virgin soil and BFS, Table-3 for OMC-MDD for various proportions of 15% and 25% of BFS by the weight of soil along with OMC-MDD value of virgin soil as well as BFS. The CBR value for various proportions of 15% and 25% of BFS by the weight of soil is narrated in Table-4 along with CBR value of virgin soil as well as BFS. The behavior of soil mix with BFS in various proportions of 15% and 25% of BFS by the weight of soil for optimum moisture content and maximum dry density is shown in figure-1 and figure-2 respectively.

Table: 2 Index properties of virgin soil and BFS [9, 10,11]

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Sr. No.	Description	Virgin Soil	Blast Furnace Slag
1.	Gradation	SM-SC	Similar to Sand Size
2.	Water Content	1.01	15.037
3.	Specific Gravity	2.66	2.72
4.	Liquid Limit	20.20	28
5.	Plastic Limit	14.28	Non-Plastic Material

Table: 3 OMC-MDD values

Sr. No.	Description	OMC (%)	MDD (gm/cm^3)
1.	Virgin Soil	23.08	1.738
2.	BFS	9.02	1.789
3.	15% BFS Proportion	5.15	2.044
4.	25% BFS Proportion	7	2.075

Table: 4 CBR values

Sr. No.	Description	CBR in %
1.	Virgin Soil	7.30
2.	BFS	19.90
3.	15% BFS Proportion	10.12
4.	25% BFS Proportion	13.10

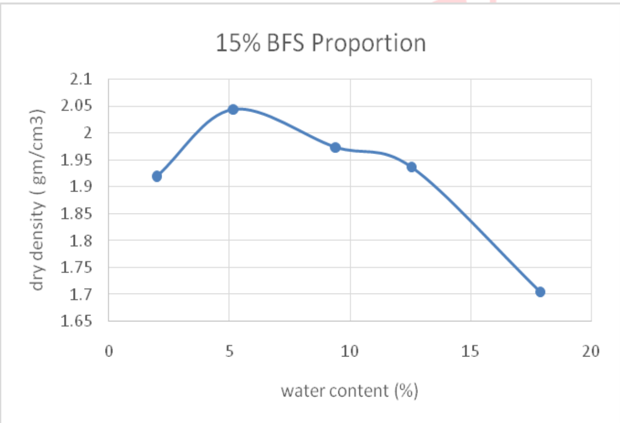

Figure-1 OMC-MDD for 15% BFS

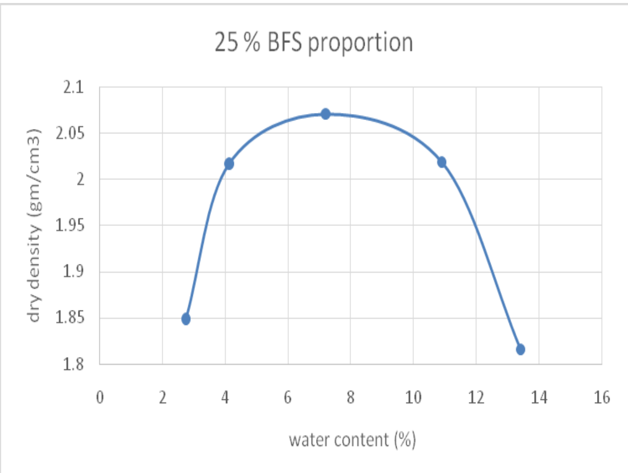

Figure-2 OMC-MDD for 25% BFS

V. CONCLUSION

The paper work includes the materials, Cohesionless soil and Blast Furnace Slag (BFS). In this paper the utilization of blast furnace slag was done on cohesionless soil. The experimental studies have been done on virgin soil and BFS. The soil is classified as SM-SC. The specific gravity and water content of soil are 2.666 and 1.01% respectively. The liquid limit and plastic limit are 20.20% and 14.28% respectively. The gradation of BFS is similar as cohessionless soil. The specific gravity and water content are 2.72 and 15.037% respectively. The liquid limit of BFS is 27.27%. It is non-plastic material. Based on experimental studies various proportions of BFS are decided as 15% and 25%.

MDD increases and OMC reduces as compared to virgin soil so less water is required to reach MDD. From above results it is observed that with increase of 10%BFS proportion, increase in MDD is comparatively less nearly 0.031 (g/cm^3).

From CBR test, it is concluded that CBR of 25% mix proportion is increased than virgin soil by 5.8. So there is a possibility that with more proportion of BFS, MDD and CBR might increase which will be helpful in soil improvement.

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