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Stabilization of Soil using Ground Granulated Blast Furnace Slag and Fly Ash

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ABSTRACT: The aim of the present investigation is to assess the usefulness of industrial waste i.e GGBS and Fly ash as a soil admixture and focused to improve the engineering properties of soil to make it capable for the subgrade construction of road, moreover to minimize the dumping problems of GGBS and Fly ash in open places. The outcome of this investigation intends to minimize the cost of construction as conventional materials such as cement , lime etc. used in stabilization of soil are becoming expensive. The present investigation deals with the behavioral aspect of soil when mixed with GGBS and Fly ash.
From the experimental results, conclusions have been obtained that some properties of modified soil has improved. The unconfined compressive strength, unsoaked CBR and soaked CBR of modified soil is increased with respect to natural soil sample.Thus, the properties of soil have been changed after mixing GGBS and fly ash as stabilizer and may be used as infrastructure development. Also modified soil, reduces the environmental degradation caused by waste materials.

KEYWORDS: Compaction, CBR, Unconfined Compressive Strength, GGBS, Fly ash

I. INTRODUCTION

A. *GENERAL*

With the increase in various road construction activities, an intense need has arisen to minimize the cost of construction. As the sub-grade supports the road pavements and the load coming from the moving vehicles, it is very important to improve the quality of weak sub-grade so that its load bearing capacity increases. The quality of pavement depends on the strength of its sub-grade. The sub-grade is the layer of pavement on which the pavement is built acts as a support for the entire pavement system. In case of the flexible pavement the sub-grade must be uniform in terms of geotechnical properties like shear strength, compressibility, etc. Materials selected for use in the construction of sub-grade must be of adequate strength and at the same time it must be economical for use. The materials selected must also be ensured for the quality and compaction requirements. If the natural soil is weak it needs some improvement to act as a sub-grade. It is therefore, needed to add the natural soil by stabilization with improved strength and compressibility characteristics at the same time lesser thickness of the pavement is required makes the construction economical.

For soil modification we have to add certain amount of additive 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. Moreover, 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. Safe disposal of these materials is of prime concern and this situation can be addressed by the bulk utilization of these materials mainly in the field of civil engineering applications. In recent years the use of various waste products in civil engineering construction has gained considerable attention in view of the shortage and high costs of conventional construction materials, the increasing costs of transportation and environmental constraints. A considerable amount of research works concerning stabilization of soil with additives such as cement, lime, Fly ash, GGBS, bitumen, etc are available in

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the literature. In recent times the demand for suitable sub-grade materials has increased due to increased constructional activities in the road sector and also the scarcity of nearby lands to allow excavating fill materials for making sub-grade. Moreover, soft soil deposits are problematic and needs large scale displacement to facilitate road construction works. These mass replacement methods which are highly cost and labour intensive can be avoided if the poor soil is being improved or modified in situ and reused as road construction materials.

Soil stabilization is the process of improving the engineering properties of soil by mixing some binding agent to the soil particles. Stabilization, in broad sense, incorporates the various methods employed for modifying the properties of a soil to improve its engineering performance. Soil stabilization is required where the road alignment passing through poor soil sub-grade does not comply with the engineering requirements as per any given standard specification.

B. MATERIAL USED

a. *GROUND GRANULATED BLAST FURNACE SLAG (GGBS)*

GGBS 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. In general the presence of sufficient quantity of CaO results in enhanced slag basicity and compressive strength. This waste material is easily available and also cost efficient.

The chemical composition of a slag varies considerably depending on the composition of the raw materials in the iron production process. Silicate and aluminate impurities from the ore and coke are combined in the blast furnace with a flux which lowers the viscosity of the slag. In the case of pig iron production the flux consists mostly of a mixture of limestone and forsterite or in some cases dolomite. In the blast furnace the slag floats on top of the iron and is decanted for separation. Slow cooling of slag melts results in an unreactive crystalline material consisting of an assemblage of Ca-Al-Mg silicates.

Properties of GGBS(Source ACC Plant sindri)

Chemical Compounds	SiO_2	Al_2O_3	Fe_2O_3	Cao	MgO	SO_3	Na_2O	K_2O	Cl	TiO_2	P_2O_5
Percentage(%)	33.67	18.69	0.49	36.2	8.18	0.2	0.14	0.57	0.01	0.7	0.02

Specific gravity = 2.95

Residue on 45µ sieve = 5.82%

Specific surface area = 3000m^2/kg

b. *FLY ASH*

Fly ash, also known as "pulverised fuel ash" is one of the coal combustion products, composed of the fine particles that are driven out of the boiler with the flue gases from power plants. Ash that falls in the bottom of the boiler is called bottom ash. In modern coal-fired power plants, Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler, it is known as **coal ash**. Depending upon the source and type of the coal being burned, the components of Fly ash vary considerably, but all Fly ash includes substantial amounts of silicon dioxide (SiO_2), aluminium oxide (Al_2O_3) and calcium oxide (CaO).

Properties of Fly ash(Source BTPS Bokaro)

Sl.No.	Parameter	Range
1	Specific Gravity	2.39
2	Plasticity	Non plastic
3	Maximum dry density(gm/cc)	0.9 –1.6
4	Optimum moisture content(%)	38 – 18
5	Cohesion	Negligible
6	Angle of internal friction	30° –40°
7	Coefficient of consolidation C_v(cm^2/sec)	1.75×10^{-3} – 2.01×10^{-3}
8	Compression index C_c	0.05 – 0.4
9	Permeability(cm/sec)	8×10^{-6} – 8×10^{-4}
10	Coefficient of uniformity	3.1 – 10.7

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II. EXPERIMENTAL INVESTIGATIONS

A. GENERAL

In order to study the modified properties of stabilized soil, the different laboratory test have been conducted. Those test are unconfined compressive strength test, CBR test, Permeability test. The details of preperation of samples, experimental setup, and the results have been discussed.

B. PREPARATION OF TEST SAMPLES

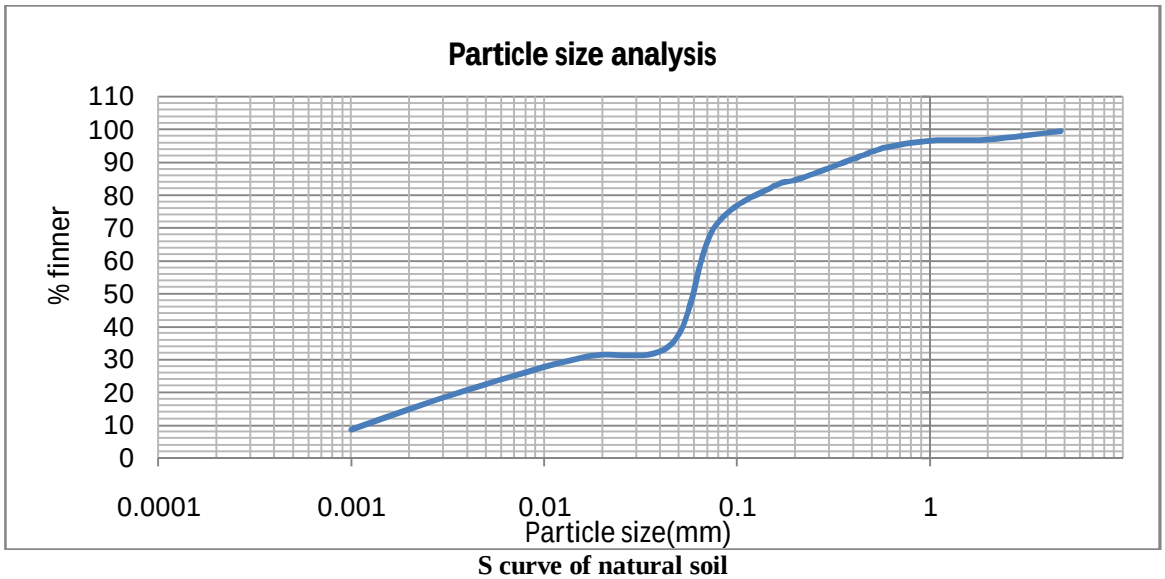
For experimental study different samples have been prepared with different proportions of Soil, GGBS and Fly ash.

Detail of Sample

S.NO.	Sample Type	Detail of the additive added with the soil		
		Soil(%)	GGBS(%) by Weight of soil	FLY ASH(%) by Weight of soil
1.	S	100	0	0
2.	S1	85	10	5
3.	S2	80	10	10
4.	S3	75	10	15
5.	S4	70	10	20
6.	S5	65	10	25

C. PROPERTIES OF SOIL.

***A. PARTICLE SIZE DISTRIBUTION OF NATURAL SOIL*:** This test is conducted to determine the percentages of different particle sizes in the soil so that it can be classified according to its gradation. This test is done in accordance with IS: 2720 (Part IV) – 1980**.**



S curve of natural soil

Percentage finner than 2μ = 11.80%

Coefficient of uniformity (C_U) = D_{60}/D_{10} = 40

Coefficient of curvature (C_C) = $(D_{30})^2/ (D_{10}\times D_{60})$ = 2.84

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From the above and graph it is concluded that the soil is clayey silt.

S. NO.	Properties	Values
1	Type of Soil	Silty clay
2	Coefficient of Curvature (Cc)	2.84
3	Uniformity Coefficient (Cu)	40
4	Specific Gravity	2.47
5	OMC	16.5%
6	MDD	1.73gm/cc
7	Permeability	$1.01x10^{-5}$ cm/sec
8	Liquid limit	41.1%
9	Plastic limit	23.66%
10	Plasticity Index	17.44%
11	UCS	2.35 kg/cm^2
12	Soaked CBR	1.6%
13	Unsoaked CBR	4.01%

III. RESULTS AND DISCUSSION

A. TEST RESULTS OF THE MODIFIED SOIL

In this chapter the result of natural soil sample is compared with the results of the mixture of soil, GGBS and Fly ash. Table below showing the variation of different parameters such liquid limit, plastic limit, optimum moisture content, maximum dry density, CBR and unconfined compressive strength.

S.NO	Sample Type	Liquid limit(%)	Plastic limit(%)	Plasticity index(%)	OMC(%)	MDD(gm/cc)	UCS(kg/cm^2)	Unsoaked CBR(%)	Soaked CBR(%
1	S	41.4	23.66	17.44	16.5	1.73	2.35	4.01	1.6
2	S1	39.6	23.16	16.44	16	1.75	3.79	5.13	3.53
3	S2	36.75	22.75	14.00	15.8	1.77	4.51	6.74	4.17
4	S3	34.4	21.69	12.71	17	1.76	4.145	6.42	3.85
5	S4	31.6	20.82	10.78	17.5	1.68	4.05	5.78	2.40

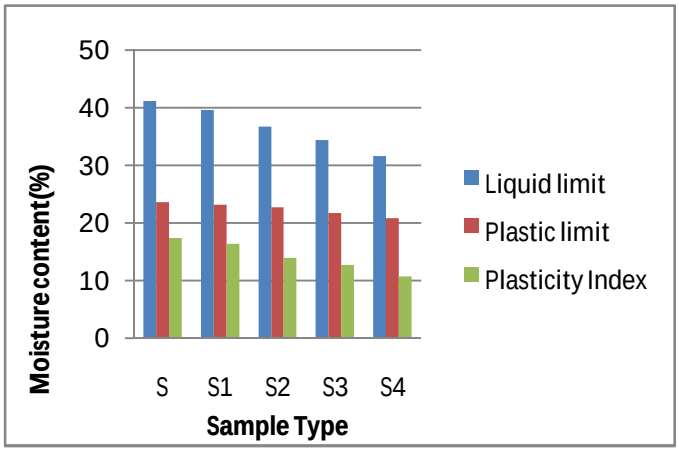

Fig. comparisionof liquid of liquid limit, plastic limit and. Plasticity index of different samples

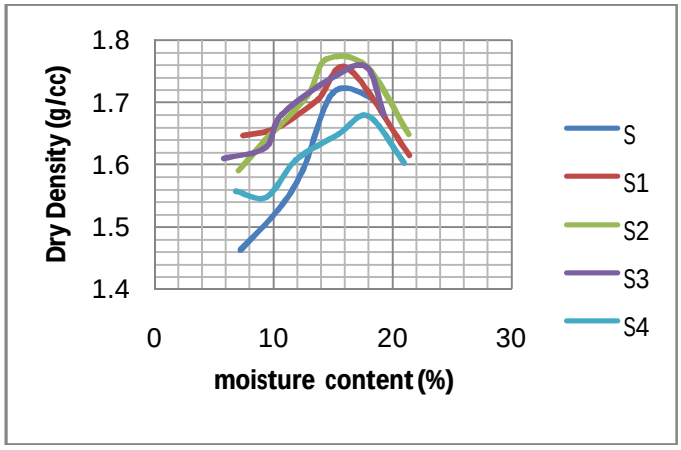

Fig. comparision graph of OMC and MDD of different samples

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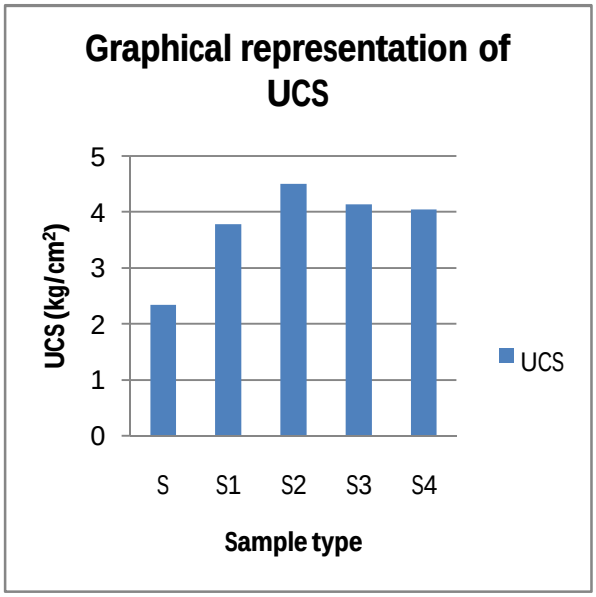

Fig. Comparison of UCS of different sample

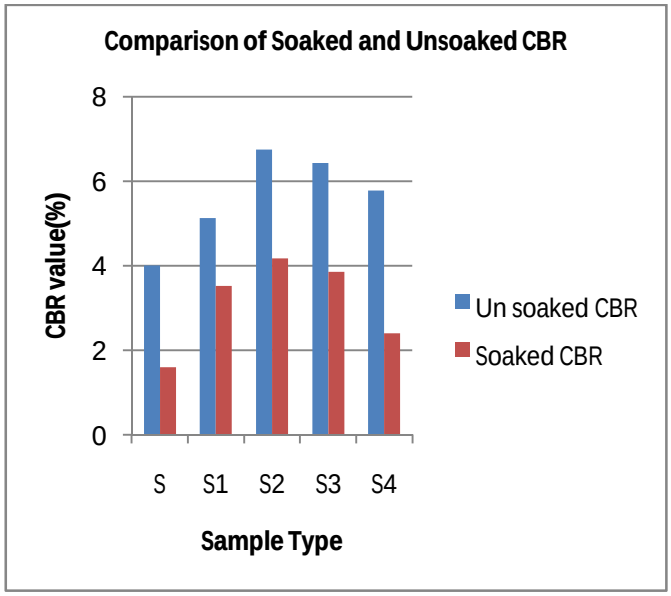

Fig. Comparison of soaked and unsoaked CBR of different samples

IV. CONCLUSIONS

With the studies of results in this work, following conclusion have been arrived.

- On fix percentage of GGBS (10%) and varying percentage of Fly ash upto 10% the OMC decreases but MDD increases. But further increase of Fly ash content the result is vice versa.
  The OMC and MDD of natural soil sample is 16.5% and 1.73gm/cc respectively. On addition of 10% GGBS and 10% Fly ash, the value of OMC and MDD is 15.8% and1.77gm/cc which is 2.31% more than the MDD of natural soil sample.
- The CBR value for soaked and unsoaked condition increases with fix percentage of GGBS(10%) and varying percentage of Fly ash up to 10% by weight of soil then decreases with increase in percentage of Fly ash.
  (a). The unsoaked CBR value of natural soil sample is 4.01% and the maximum value is found at 10% GGBS and 10% Fly ash is 6.74% which is more than 68.08% from natural soil.
  (b). The soaked CBR value of natural soil sample is 1.6% and maximum value is found at 10% GGBS and 10% Fly ash is 4.17% which is more than 160.62% from natural soil.
- The UCS of natural soil sample is 2.35 kg/cm^2 and the maximum value is found at 10% GGBS and 10% Fly ash is 4.51 kg/cm^2 ,which is more than 91.91% from natural soil.
- With this study it may be recommended to use 10% GGBS and 10% Fly ash by weight of soil for better results.

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