

# Enhancing the Properties of Soil Using GGBFS & Bottom Ash

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**ABSTRACT:** An experimental investigation has been carried out to study the effect of GGBFS and Bottom ash on the geotechnical properties of the local soil. The replacement of the natural soil has been done by the GGBFS and Bottom ash at various percentages, i.e. 5%, 10%, 15% 20% and 25% (GGBFS) and 10% (Bottom ash) by weight of the soil. The results obtained from the laboratory tests on the samples have been studied. From the experimental results, it has been found that various properties of the soil varying percentage of these stabilizers percentage show remarkable changes as compared to the natural soil. From standard Proctor compaction test it has been found that the mass of natural soil increases whereas OMC decreases by increasing percentage replacement of natural soil by GGBFS. Also the LL, PL and PI value decreased by increasing percentage replacement of natural soil by GGBFS. The maximum value of UCS of the soil has been obtained as 4.96 kg/cm<sup>2</sup> with the replacement of natural soil by 25% GGBFS and 10% Bottom ash (by weight) which is 66.44% more than that of the natural soil. The CBR value of natural soil increases in both Soaked and un-soaked condition, and the permeability of soil increases by increasing percentage replacement of natural soil by GGBFS.

**KEYWORDS:** Natural Soil, GGBFS, Bottom Ash, Proctor Compaction Test, Atterberg's Limit, CBR, UCS, Permeability

## I. INTRODUCTION

The properties of Soil can be modified by Soil-Stabilization to make the properties of Soil adequate. Now-a-day there are many soil stabilizers, which are used apart from the conventional soil stabilizers such as fly ash, bottom ash, GGBFS, coal waste, stone dust etc. These stabilizers are the by-product of various plants and industries. Hence they are economic and abundantly available depending upon the location. To protect the environment from degradation due to these wastes, the utilization of waste is the major task for civil engineers. Keeping these objectives in mind, this project is taken for the utilization of Bottom ash with GGBFS as stabilizing agents. The greatest challenge before the processing and manufacturing industries is disposal of the residual waste products. One of the common and feasible ways to utilize these waste products is to go for construction of roads, highways and embankments, and then the pollution problem caused by the industrial wastes can be significantly reduced. Soil stabilization is the process of improving the engineering properties of the soil and thus making it more stable. It is required when the soil available for construction is not suitable for the intended purpose. In its broadest sense, stabilization includes compaction, drainage and many other such processes. However, the term stabilization is generally restricted to the strength properties. A cementing material or a chemical is added to a natural soil for the purpose of Stabilization. The decreasing availability and increasing cost of construction materials and uncertain economic climates force engineers to consider more economical methods for building Roads. An obvious solution is to use locally available materials. However, all too often, these Materials fall outside of required specifications. This situation becomes even more critical when an increasing demand for roads in underdeveloped rural areas and informal settlements comes into play. Soil stabilization is the alteration of one or more soil properties, by mechanical or chemical means, to create an improved soil material possessing the desired engineering properties. There are three purposes for soil stabilization. These include increasing strength of an existing soil to enhance its load-bearing capacity, permeability improvement and enhancement of soil resistance to the process of weathering, and traffic usage.

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## II. NEED FOR SOIL STABILIZATION

1. Limited financial resources to provide a complete network road system to build in Conventional method.
2. Effective utilization of locally available soils and other suitable stabilizing agents.
3. Encouraging the use of industrial wastages or innovative materials in building low cost Construction of roads.

Coal-based thermal power plants are the major source of power generation in India and Bottom ashes are the by-products of these thermal power plant. The coal reserve of India is about 200 billion tones and its annual production reaches 250 million tones approximately. In India, unlike in most of the developed countries, ash content in the coal used for power generation is about 30 to 40. The ash generation has increased to about 131 million tone during 2010-11 and shall continue to grow. The finer ash particles are carried away by the flue gas to the electrostatic precipitators and are referred as bottom ash, whereas the heavier ash particles fall to the bottom of the boiler and are called as bottom ash. Primarily, the GGBFS is disposed of using either dry or wet disposal scheme. In dry disposal, the GGBFS is transported by truck and conveyor at the site and disposed of by constructing a dry embankment (dyke). In wet disposal, the GGBFS and bottom ash are transported as slurry through pipe line. Most of the power plants in India use wet disposal system, and when the lagoons are full, four basic options are available:

- (a) Constructing new lagoons using conventional constructional material,
- (b) Hauling of fly ash from the existing lagoons to another disposal site,
- (c) Raising the existing dyke using conventional constructional material, and
- (d) Raising the dyke using fly ash excavated from the lagoon ("ash dyke").

The objectives of the present work are to stabilize the natural soil by using industrial waste. Therefore the experiment program has been setup with following objective

- To determine the geotechnical properties of soil & soil with GGBFS & Bottom ash.
- To determine the effects of adding Bottom Ash & GGBFS on the properties of soil.
- To reduce the cost of soil stabilization by using the industrial waste as a soil stabilizer.

## III. MATERIALS AND THEIR PROPERTIES

Material used in this project are given in following table 1.

Table 1

Sl. No.	Name of Materials	Source of the Materials
1.	Soil	Procured from the new Hostel construction site in B.I.T Campus
2.	GGBFS	Procured from ACC Cement Plant, Sindri
3.	Bottom Ash	Procured from BTPS Bokaro
4.	Water	Soil mechanics Laboratory, BIT Sindri
5.	Distilled Water (H <sub>2</sub> O)	Sai Enterprises, Sindri, Dhanbad
6.	Sodium Hexametaphosphate (NaPO <sub>3</sub> ) <sub>6</sub>	Manufactured by LABALO CHEMIE LTD.
7.	Sodium Carbonate (NaCO <sub>3</sub> )	Manufactured by LABALO CHEMIE LTD.

**SOIL:** The soil sample for this study was collected from B.I.T. Sindri campus. It was collected from a depth of 2feet below the natural ground level by open excavation. The soil was dried and pulverized to perform the various experimental studies. Soil is a naturally occurring granular material composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. Soil can also refer to a textural class of soil

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or soil type; i.e. a soil containing more than 85 sand-sized particles (by mass). The properties of soil are given below in table 2.

Table 2

Property	Value
Specific gravity	2.46
Coefficient of uniformity ( $C_U$ )	26
Coefficient of curvature ( $C_C$ )	0.98
Optimum Moisture Content (%)	17.4
Maximum Dry Density (g/cc)	1.69

**GROUND GRANULATED BLAST FURNACE SLAG (GGBFS):** It is obtained by quenching molten iron slag which is 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 raised slag basicity and an increase in compressive strength. This waste material is easily available and also cost efficient. GGBFS is used to make durable concrete structures in combination with ordinary portland cement and/or other pozzolanic materials. GGBFS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years. The properties of GGBFS are given below in table 3.

Table 3

Colour	Off white
Specific gravity	2.9
Bulk density	1200 kg/m <sup>3</sup>

**BOTTOM ASH:** Bottom ash is part of the non-combustible residue of combustion in a furnace or incinerator. In an industrial context, it usually refers to coal combustion and comprises traces of combustibles embedded in forming clinkers and sticking to hot side walls of a coal-burning furnace during its operation. The portion of the ash that escapes up the chimney or stack is, however, referred to as fly ash. The clinkers fall by themselves into the bottom hopper of a coal-burning furnace and are cooled. The above portion of the ash is referred to as bottom ash too.

Bottom ash is collected at the end of the grate in a Waste-to-Energy plant. It consists of non-combustible materials, and is the residual part from the incineration of household and similar waste. Raw bottom ash is a granular material that consists of a mix of inert materials such as sand, stone, glass, porcelain, metals, and ash from burnt materials

Since the fused bottom ash is still hot, when it is removed from the boiler, it falls into a water bath or quench tank where it is cooled before passing through a clinker grinder, which reduces the size of any large chunks to smaller than approximately 2 inches. The crushed bottom ash is then removed for storage, disposal or use. The properties of bottom ash are given below in table 4.

Table 4

Colour	Off black
Specific gravity	2.2
Bulk density	720- 1600 kg/m <sup>3</sup>

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## IV. EXPERIMENTAL INVESTIGATION

Description of Samples is given below in table 5.

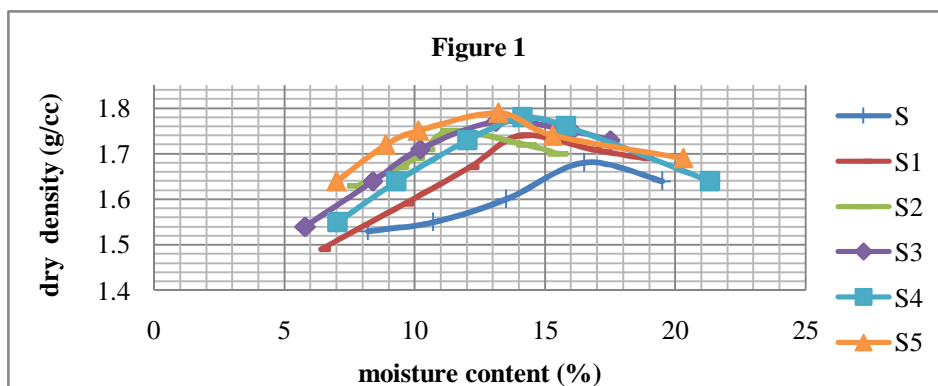
Table 5

SL.No.	Sample Type	Description of the additives added with the soil		
		Soil (%)	GGBFS by (%) of weight of soil	Bottom Ash by (%) of weight of soil
1.	S	100	0	0
2.	S <sub>1</sub>	85.00	5.0	10.0
3.	S <sub>2</sub>	80.00	10.0	10.0
4.	S <sub>3</sub>	75.00	15.0	10.0
5.	S <sub>4</sub>	70.00	20.0	10.0
6.	S <sub>5</sub>	65.00	25.0	10.0

**Compaction characteristics:** The soil with different percentage of Bottom Ash & GGBFS standard proctor's test was conducted for silty clayey soils. Test results of expansive soil are presented. It is observed that addition of Bottom Ash & GGBFS individually has a general trend of decreasing optimum moisture content (OMC) and increasing maximum dry density (MDD). Optimum MDD of 1.93g/cc was with addition of Bottom Ash & GGBFS for 15 OMC. OMC and MDD of Stabilized Soil with different percentage is given below in table 6.

Table 6

Sl.Number	Sample Type	Standard compaction(light)	
		OMC (%)	MDD (gm/cc)
1.	S	17.4	1.69
2.	S <sub>1</sub>	17	1.73
3.	S <sub>2</sub>	16.3	1.75
4.	S <sub>3</sub>	16	1.77
5.	S <sub>4</sub>	15.8	1.78
6.	S <sub>5</sub>	15	1.79



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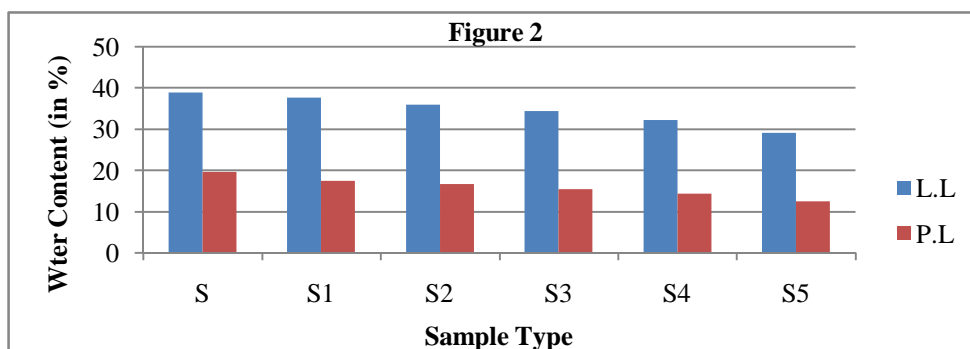
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MDD & OMC for soil samples having 10% bottom ash and different percentages of GGBFS (5%, 10%, 15%, 20%, 25% replacing soil sample by weight of soil). The result indicates that the MDD of soil sample increases with increase in the percentage replacement of soil sample with GGBFS. Whereas the OMC of soil samples decreases with increase in the percentage replacement of soil sample with GGBFS. The highest MDD value and lowest OMC value was obtained for soil sample having 25% GGBFS by weight of soil. The percentage increase in the MDD value for soil sample having 25% GGBFS by weight of soil was 5.92% more than soil sample containing no GGBFS. But the OMC value for soil sample with 25% GGBFS by weight of soil decreased by 13.79% with respect to soil sample having 0% GGBFS.

**Atterberg's Limit:** A fine-grained soil can exist in any of several states; which state depends on the amount of water in the soil system. When water is added to a dry soil, each particle is covered with a film of adsorbed water. If the addition of water is continued, the thickness of the water film on a particle increases. Increasing the thickness of the water films permits the particles to slide past one another more easily. The behavior of the soil, therefore, is related to the amount of water in the system. The value of Atterberg's Limit is given below in table 7.

Table 7

Sl. No	Sample type	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
1	S	38.80	17.46	21.54
2	S <sub>1</sub>	37.60	17.35	20.25
3	S <sub>2</sub>	35.90	16.57	19.33
4	S <sub>3</sub>	34.30	15.41	18.89
5	S <sub>4</sub>	32.10	14.27	17.83
6	S <sub>5</sub>	29	12.43	16.57



When proportion of Soil: Bottom ash: GGBFS is added different percentage by weight of soil and the percentage is increased i.e.100:0:0, 85:10:5, 80:10:10, 75:10:15, 70:10:20 and 65:10:25, Liquid Limit is decreased as 38.80%, 37.60%, 35.90%, 34.30%, 32.10% and 29%, Plastic limit is decreased as 17.46%, 17.35%, 16.57%, 15.41%, 14.27% & 12.43% and Plasticity index also decreases as 21.54%, 20.25%, 19.33%, 18.89%, 17.83% and 16.57%.

**Unconfined compressive strength (UCS):** The Unconfined compressive strength test is used to measure the shearing resistance of soil. Which may be undisturbed or remoulded specimens? An axial load is applied using either strain control or stress control condition. The Unconfined Compressive Strength is defined as the maximum unit stress obtained within the first 20 strain. The Compression device is a hydraulic-actuated loading piston, electronically controlled, with the capability of infinite rates of strain and stress loads. A load cell of 44.5kN or 222.5kN capacity is fastened to the piston to measure load on specimen Test data are displayed on control panel board readouts. The value of unconfined compressive strength is given below in table 8.

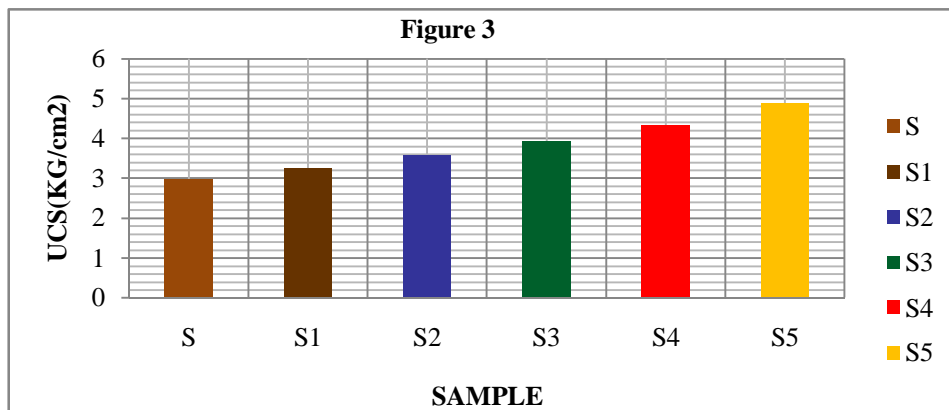
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Table 8

SL. No	Sample type	Average Compressive strength (kg/cm <sup>2</sup> )	Percentage variation of UCS w.r.t S
1	S	2.98	_____
2	S1	3.25	9.06
3	S2	3.58	20.13
4	S3	3.92	31.54
5	S4	4.32	44.96
6	S5	4.96	66.44



UCS for soil samples having different percentages of GGBFS (5%, 10%, 15%, 20%, 25% replacing soil sample by weight of soil) with fixed amount of bottom ash (about 10%). The result indicates that the UCS of soil samples increases when the percentage of soil sample replaced with GGBFS is increased. The highest (optimum) UCS value of about 4.96 kg/cm<sup>2</sup> was obtained for soil sample having 25% GGBFS by weight of soil. The percentage increase in the UCS value for soil sample having 25% GGBFS by weight of soil was 66.44% more than soil sample containing 0% GGBFS.

**California Bearing Ratio (CBR):** This test are carried out on natural or compacted soils in water soaked or un-soaked conditions and the results so obtained are compared with the curves of standard test to have an idea of the soil strength of the sub grade soil. The California bearing ratio (CBR) is a penetration test for evaluation of the strength of natural ground, sub-grades and base courses beneath new carriageway construction. It was developed by the California Department of Transportation before World War II. The basic site test is performed by measuring the pressure required to penetrate soil or aggregate with a plunger of standard area. The measured pressure is then divided by the pressure required to achieve an equal penetration on a standard crushed rock material. The CBR rating was developed for measuring the load-bearing capacity of soils used for building roads. The CBR can also be used for measuring the load-bearing capacity of unimproved airstrips or for soils under paved airstrips. CBR at 2.5mm of Stabilized Soil & their mixing with Bottom Ash and GGBFS different percentage for soaked and unsoaked condition is given below in table 9.

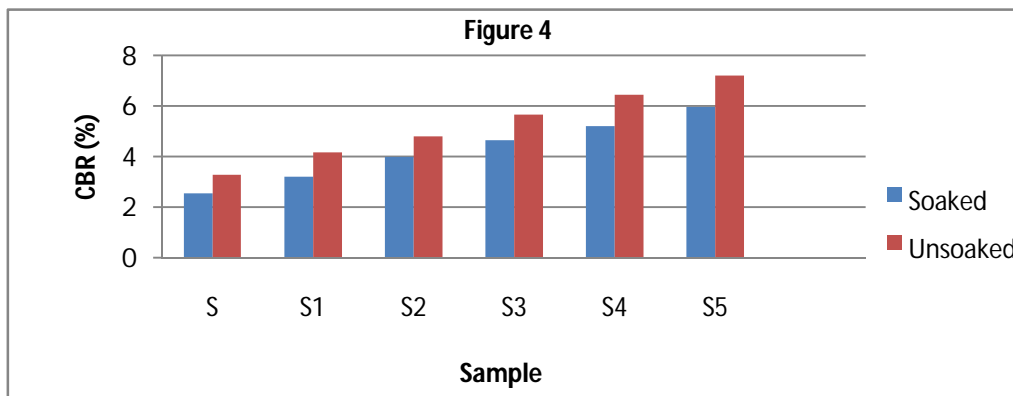
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Table 9

SL. No	Sample type	Soaked		Unsoaked	
		CBR at 2.5mm	Percentage variation of CBR w.r.t S	CBR at 2.5mm	Percentage variation of CBR w.r.t S
1	S	2.56	-----	3.29	-----
2	S <sub>1</sub>	3.21	25.39	4.17	18.13
3	S <sub>2</sub>	4.01	56.64	4.81	36.26
4	S <sub>3</sub>	4.65	81.64	5.66	77.34
5	S <sub>4</sub>	5.22	103.90	6.46	49.86
6	S <sub>5</sub>	5.97	133.20	7.22	40.79



**Permeability Characteristics:** The use of this test is to determine the permeability (hydraulic Conductivity) of Bottom ash by the variable head permeability test. The coefficient of permeability (or hydraulic conductivity) refers to the ease with which water can flow through a soil. The coefficient of permeability of Bottom ash and GGBFS falls in the range of 'k' of silts. This property is essential for the calculation of seepage through earth dams or under sheet pile walls, the calculation of the seepage rate from waste storage facilities (landfills, ponds, etc.). The Permeability of Bottom ash depends upon grain size, degree of compaction, pozzolanic activity etc. The codal provision follows for this experiment is IS: 2720 ( Part 17 ) – 1986 . Calculate the permeability, using the following equation:

$$\text{Permeability } K = \frac{2.303aL}{At} \log_{10} \frac{h_1}{h_2}$$

The permeability of soil is given below in table 10.

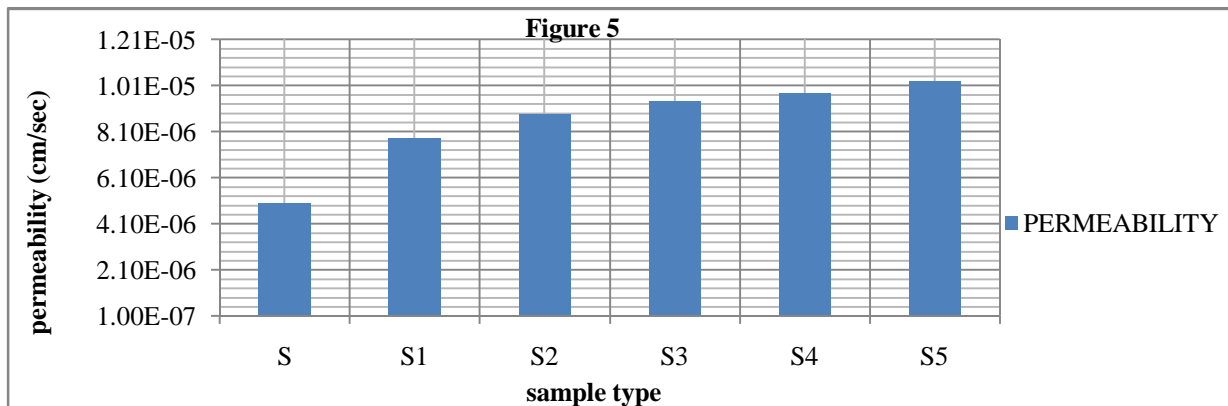
Table 10

Sl.No	Sample type	Coefficient of permeability(K)	% variation of k w.r.to S
1	S	$4.997 \times 10^{-6}$	-----
2	S <sub>1</sub>	$7.820 \times 10^{-6}$	+56.49%
3	S <sub>2</sub>	$8.859 \times 10^{-6}$	+77.29%
4	S <sub>3</sub>	$9.394 \times 10^{-6}$	+88.00%
5	S <sub>4</sub>	$9.757 \times 10^{-6}$	+95.27%
6	S <sub>5</sub>	$1.028 \times 10^{-5}$	+105.70%

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## V. CONCLUSION

From the analysis of results, following points were concluded:-

- The MDD of natural soil increases with increase in the percentage replacement of soil sample by GGBFS.
- The OMC of natural soil decreases with increase in the percentage replacement of soil sample by GGBFS.
- The LL, PL & PI value of soil sample decreases with increase in the percentage replacement of soil by GGBFS.
- The UCS of natural soil increases with increases in the percentage replacement of soil sample by GGBFS.
- CBR value of natural soil for Soaked and Un-soaked condition increases with increase in percentage replacement of soil sample by GGBFS.
- The Permeability of soil sample increases with increases in percentage replacement of soil sample by GGBFS.

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