Experimental Investigation of Laterite Soil Properties Using Ground Granulated Blast Furnace Slag

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Abstract— Laterite soil found mainly in the Konkan region which has relatively poor engineering properties due to the significant percentage of fine-grained soil properties and heavy rainfall. Its formation is noticed by about 70.7% in the Konkan region. When laterite soil comes in contact with water it loses its strength. Due to heavy rainfall in the Konkan region, problems like landslides, poor soil strength, slope instability are noticed. Hence stabilization of soil is necessary. It can be done by adding some additives into the soil to enhance its properties. In Konkan Steel and Iron industries are found which produces waste at large scale. It not only creates a land problem but also creates environmental problems. To utilize the industrial waste, an attempt is made to stabilize the laterite soil by adding ground granulated blast furnace slag (GGBS). The present study aims to evaluate the effect of the addition of 0%, 5%, 10%, 15% of GGBS. For this series of mechanical tests are carried out like MPT, DCT. The experimental analysis shows results that additions of GGBS effectively improve the engineering properties of laterite soil. Hence 10% is the suitable percentage of GGBS with laterite soil will be suggested for stabilization of soil.

Keywords: ground granulated blast furnace slag (GGBS), Laterite Soil

I. INTRODUCTION

Konkan region is situated at the west shoreline of Maharashtra which is completely covered by the Laterite rock and Deccan trap. Significantly Ratnagiri and Sindhudurg district in Maharashtra comprises of Laterite soil. Laterite formation occupies about 70.7% of the Konkan Region. Laterite soil is an important group of residual soils in India. It is a blend of hydrated iron and aluminum oxides with certain impurities.

Due to the presence of iron oxide, it has a reddish-brown color. Laterite soil is formed by the sedimentation action of parent rock 'Laterite' (sedimentary rock) under high temperature and heavy rainfall. During the unearthing of laterite soil, due to the presence of lithomargic clay, engineering problems like instability of slopes, landslides, cavity formation in tunnel works, settlement of foundation can occur. The laterite soil behaves as a hard material during the dry season and when it interacts with water, it loses its strength and behaves like a liquid. Due to heavy rainfall in the Konkan region, water seeps through porous laterite soil, which tends to gush out at the interface of laterite layers leading to engineering problems, safety problems, and unforeseen delays in the project. The widespread presence of laterite soils in tropical regions often requires some soil improvement to be performed to use it in various civil engineering applications, such as soil stabilization.

Soil stabilization refers to enhancing both index and engineering properties of soil (density, shear strength are improved while compressibility, settlement, and permeability are reduced). This is done when accessible soil isn't fit for the expected purpose and improvement is needed. For this purpose, we have to add some admixture which enhances its properties. Steel industries are found to a large extent in the Konkan region and blast furnace slag is a major waste of steel industries. To utilize waste, an attempt is made to stabilize the laterite soil by adding GGBS.

GGBS is a waste industrial by-product obtained during the production of iron. The Blast Furnace slag is a non-metallic product having oxide composition i.e. essentially of silicates and aluminates of calcium and contains lesser calcium oxide. When cooled rapidly, it solidifies in a granulated (glassy) form that is reactive with water having basic medium. This Slag is to be added in Laterite soil samples collected from different locations of the Konkan region where instability of slope had occurred in different proportions of the dry unit weight of soil. The use of GGBS for soil treatment can develop a greener approach and sustainable development along with soil stabilization.

A. *Objectives of the Study*

1) To determine the index properties of Laterite soil with Ground Granulated Blast Furnace Slag (GGBS)
2) To determine strength, permeability of Laterite Soil using different percentages of GGBS
3) To suggest a suitable proportion of GGBS in Laterite soil.

II. MATERIALS

A. *Laterite Soil*

The word laterite has been derived from the Latin word that means brick. Laterite is a soil and rock type rich in iron and aluminum and is commonly considered to have formed in hot and wet tropical areas. Nearly all laterites are of rusty-red coloration, because of high iron oxide content. They develop by intensive and prolonged weathering of the underlying parent rock. The laterite soil is formed under conditions of high temperature and heavy rainfall with alternate wet and dry periods, which leads to leaching of soil, leaving only oxides of iron and aluminum. For project work, Laterite soil samples were collected from Ganpatipule, district- Ratnagiri in Maharashtra.

Fig. 1: Laterite Soil (LS)

B. Ground Granulated Blast Furnace slag

The main components of blast furnace slag are CaO (30-50%), SiO_2 (28-38%), Al_2O_3 (8- 24%), and MgO (1-18%). GGBS is an environmentally friendly product and made from a by-product of iron and steel manufacturing industries. It has an off-white color. It is a cementitious material mainly used in concrete as an admixture. GGBS cement has benefits like durability, appearance, strength, sustainability. Due to its siliceous and calcareous materials, it can be used as a stabilizing agent. GGBS is collected from nearly available RMC plants.

Fig. 2: Ground Granulated Blast Furnace Slag (GGBS)

C. Sample Preparation

There are two methods of sample Preparation, dry and wet methods. The Dry method was adopted for sample preparation. In this method, the required amount of soil was taken(1), optimum moisture content obtained from the Standard Proctor Test, and the desired content of additive (GGBS) was mixed (2,3 & 4). The mixture was oven-dried (5).

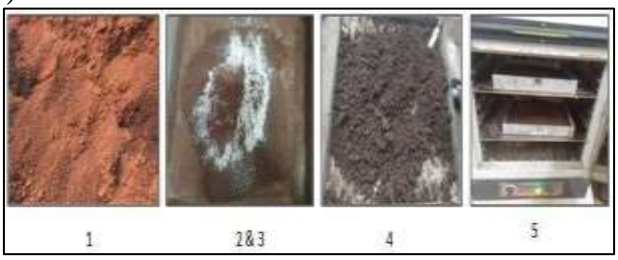

Fig. 3: Sample Preparation – (LS + GGBS)

III. EXPERIMENTAL INVESTIGATION

This chapter deals with the different geotechnical tests need to be carried out and find out the basic Index and Engineering properties of soils.

A. Index Properties-

1) Specific Gravity- IS 2720 (Part-3/Sec 1) 1964

The specific gravity of the solid particles is defined as the ratio of the weight of a given volume of solids at a given temperature to the weight of an equal volume of distilled water at the temperature both weights being taken in air. The specific gravity of laterite soil is measured by pycnometer as per IS 2720.

Sr. No.	Content	Value
1	Mass of Empty Pycnometer (M1) gm	687
2	Mass of Pycnometer + Soil (M2) gm	1281
3	Mass of Pycnometer + Soil + Distilled Water (M3) gm	2089
4	Mass of Pycnometer + Distilled Water (M4) gm	1705
5	Specific gravity = (M2-M1)/ (M2-M1)(M3-M4)	2.92

Table 1: Specific Gravity of Laterite Soil

2) Atterberg's Limits

The water content at which the soil changes from one state to another is known as consistency limits or Atterberg's limits.

a) Liquid Limit- IS 2720 (Part -5)1985

Liquid limit is the minimum water content at which the soil is still in liquid state, but has a small shearing strength against flowing which can be measured by standard available means. Liquid limit is calculated by Casagrande's apparatus as per IS 2720 (Part-5)1985.The water content corresponding to 25 no. of blows taken as Liquid limit.

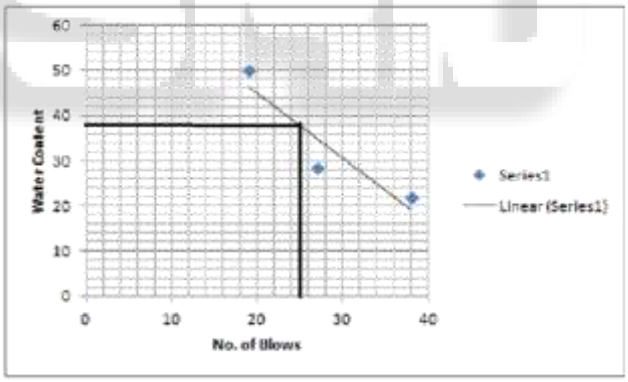

Fig. 4: Liquid Limit - Laterite Soil (LS)

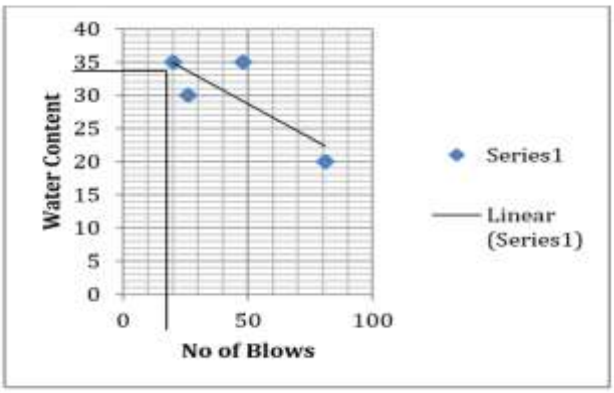

Fig. 5: Liquid Limit - Laterite Soil + 5 % GGBS

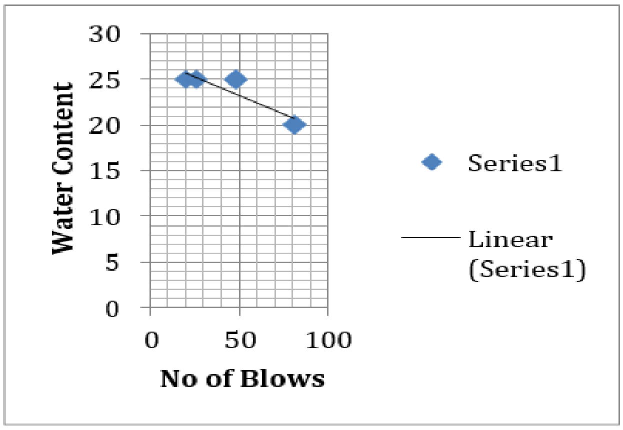

Fig. 6: Liquid Limit - Laterite Soil + 10 % GGBS

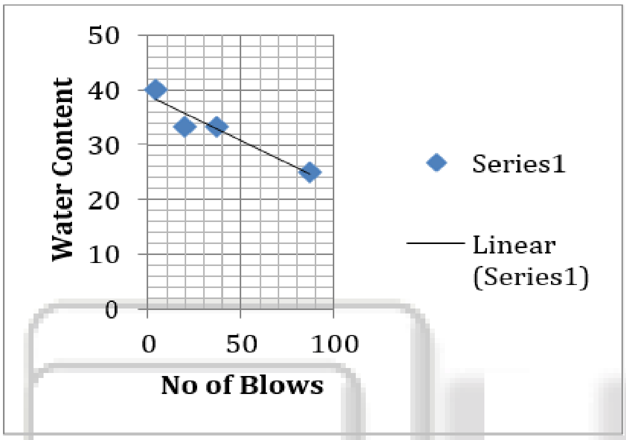

Fig. 7: Liquid Limit - Laterite Soil + 15 % GGBS

b) Plastic Limit- IS 2720 (Part -5) 1985

Plastic Limit is the water content corresponding to an arbitrary limit between the plastic and the semi-solid state of a consistency of a soil. Plastic Limits the minimum water content at which the soil will just begin to crumble when rolled into a thread approximately 3 mm in diameter as per IS 2720 (Part-5)1985.

Tests Conducted			Without GGBS (0 % GGBS)	LS+ 5 % GGBS	LS+10 % GGBS	LS+15%GGBS
Index Properties						
1	Specific Gravity		2.92	2.72	2.57	2.71
2	LL	%	38	33	25	35
3	PL	%	28.57	20	16.66	25

Table 2: Index Properties of Laterite Soil with GGBS

c) Direct Shear Test- IS 2720 (Part-39/sec1) 1977

The shear strength of the soil is the resistance to deformation by continuous shear displacement of soil particles or on masses upon the action of shear stress. The shearing resistance of soil is constituted basically of interlocking, frictional resistance, and cohesion or adhesion of soil particles. Size of shear box used- 60 mm X 60 mm X 25 mm. The test was conducted using four different normal stresses of 0.5, 1, 1.5, and 2 kg/cm^2.

Normal Stress (kg/cm^2)	Shear Stress (kg/cm^2)			
	Without GGBS (LS only)	LS+5%GGBS	LS+10% GGBS	LS+15% GGBS
0.5	0.35	0.37	0.3683	0.2
1.0	0.325	0.52	0.6355	1.3972
1.5	0.68	0.9316	1.054	0.6067
2.0	1.01	1.4227	1.408	0.9317

Table 3: Direct Shear Test (DST) Results of Laterite Soil with GGBS

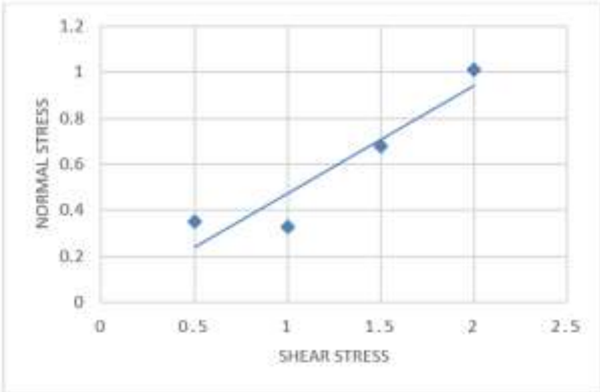

Fig. 8: DST - Laterite Soil

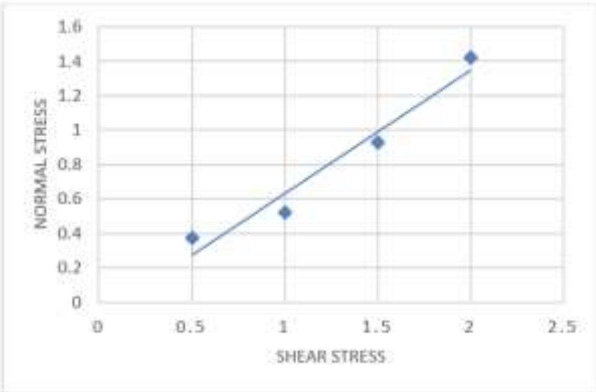

Fig. 9: DST - Laterite Soil + 5 % GGBS

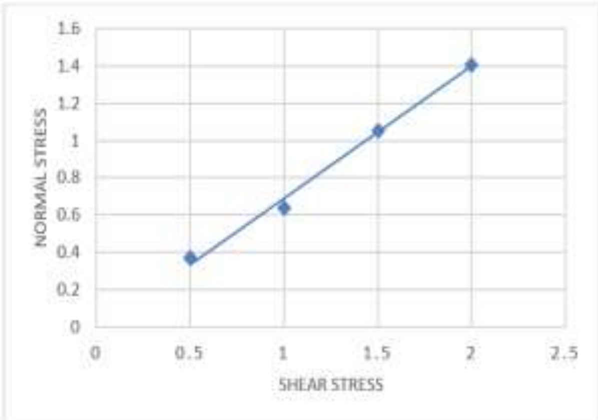

Fig. 10: DST - Laterite Soil + 10 % GGBS

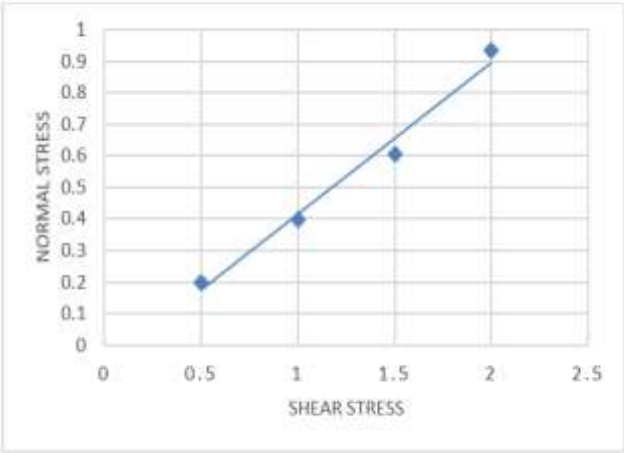

Fig. 11: DST - Laterite Soil + 15 % GGBS

Sample	LS	LS + 5% GGBS	LS + 10% GGBS	LS + 15% GGBS
Φ (Degrees)	23.75	29.25	34.45	28.76
C (kg/cm2)	0.13	0.0975	0.0252	0.0145

Table 4: Cohesion and Angle of Internal Friction

d) Permeability Parameter

Sample	LS	LS + 5% GGBS	LS + 10% GGBS	LS + 15% GGBS
Time (seconds)	118	101	97	127
Coefficient of Permeability K (cm/sec)	0.005968	0.00697	0.00726	0.00554

Table 5: Coefficient of Permeability Readings

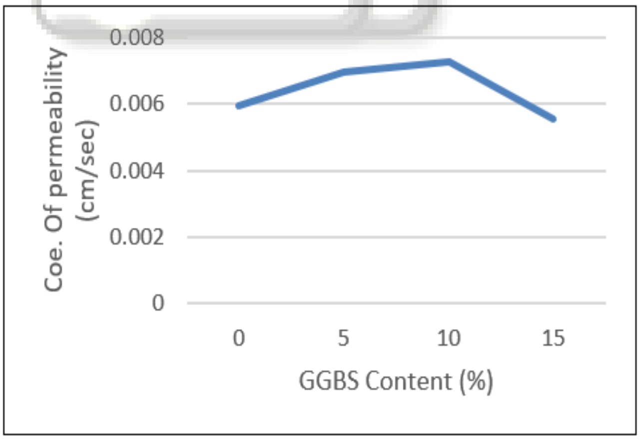

Fig. 12: Permeability – k Vs GGBS Content

IV. Conclusions

Based on the experimental work carried out in the present study the following conclusions are drawn

1) Specific gravity of soil decreases up to 2.57 with the addition of 10% GGBS with laterite soil.
2) Plasticity index decreases up to 16.67% also liquid limit decreases up to 25% with the addition of 10% GGBS with laterite soil and afterward increases.
3) Permeability increases up to 10% of GGBS and further decreases with the addition of GGBS.
4) Cohesion of soil increases as a percentage of GGBS increases whereas the angle of internal friction increases up to 34.45 degrees with a 10% addition of GGBS and further decreases with the addition of GGBS.

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