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Performance analysis of Ground granulated Blast Furnace Slag on contaminated soil

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Abstract

The aim of the present work is to examine the efficacy of ground granulated blast furnace slag (GGBFS) as an additive to improve the engineering properties of contaminated soft soil. Expansive soil is a problem all over the world and it is challenge for the civil engineers to bring certain changes in it's parameters so that the quality of the soil parameters gets improved in terms of using it as construction material. In this paper, the emphasis is given on that part mainly. Various soil parameters like grain size distribution, specific gravity, moisture content, dry density, liquid limit, plastic limit, liquidity index, consistency index, co-efficient of curvature, co- efficient of uniformity of natural soil has been determined using BIS 2720 (1). The soil parameters like dry density, shear strength, specific gravity, void ratio got changed when 5%,10%,15% Ground granulated blast furnace slag (GGBFS) was added with contaminated soil. The shear strength of collected soil has been improved from 1.46N/cm2 to 2.33N/cm2 for 15% mixture of GGBFS. The specific gravity also improved from 2.06 of collected soil and it goes up to 2.65 for 15% GGBFS addition. The maximum dry density (MDD) of collected soil improved from 1.81gm/cc to 1.88gm/cc for 15% addition of GGBFS. So, from the basic inter relationships of dry density of soil, specific gravity , void ratio and density of water it can be concluded that void ratio decreased with the addition of 5%, 10% and 15% GGBFS. The reduction of void pores increases the stability of the soil. Thus GGBFS can be used as an additive for contaminated land reclamation.

Keywords:

Contaminated soil;
MDD;
Shear strength;
GGBFS;
Land reclamation.

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1. Introduction

The road network construction as well as embankment stabilization has been increased over the years in developing nations like India. The low strength of contaminated soil increases the construction cost as the contaminated soil bears very low bearing capacity. Normal practice is to replace the contaminated soil with a good quality of soil. Therefore new technics are required for the ease of low cost construction. Improvement of strength characteristics of soil was started long ago. Chemical Soil Stabilization can be a way regarding this. Shear strength of cohesive soil was improved using polypropylene fibers (2). The shear stress of cohesive soils stabilized with lime or with the combination of lime and natural pozzolana was found to increase with cure time (3). Rice husk ash, a waste product was also used for improvement of engineering properties of soils (4). In this study, a waste product GGBFS was used to improve the various engineering properties of contaminated soil. GGBFS is a bi-product of iron manufacturing industry. GGBFS is not obtained directly. It is obtained by heating iron ore, coal and limestone at about 15000C in blast furnace. The molten slag consists of silica, alumina and certain oxides. The slag is obtained by cooling it by passing it through a high pressure water jet. The main ingredients of the slag are CaO, SiO2, Al2O3, MgO etc. The slag particles are later dried and grinded in a rotating ball mill to convert it to form powder and this is known as GGBFS. This GGBFS was taken into laboratory and crushed properly for blending with contaminated soil. When GGBFS is added with the soil, the engineering properties of soil get improves. So the replacement of natural soil is no more required for constructional activities in contaminated soil. And automatically the cost involved in embankment, road or any other construction is reduced. In the previous researches, certain soil parameters especially the bearing capacity of soil was improved by addition of a certain quantity of GGBFS. But in this paper the emphasis is mainly given on the improvement of shear strength of soil as well as increasing the dry density by reducing the void spaces within the soil mass.

2. Research Method

The soil samples were collected by augur boring at a depth of 1m below the ground level from a municipal solid waste dumping site located near Ram Mandir, Bidhannagar, Durgapur, West Bengal, India. The landfill is 20 years old. Granulated blast furnace slag can be added in proportions of 5–25% of dry weight of soil (5). The soil after being dried up is blended with 5%, 10%, 15% GGBFS respectively. A series of laboratory tests were performed as per BIS as depicted in BIS 2720 on the GGBFS blended soil.

Fig. 1: Area of Study (Courtesy Google Map)

Fig. 2: Collection of soil sample from municipal solid waste landfill

Laboratory tests as per BIS 2720 (1) were carried out on the collected soil which includes, moisture content, specific gravity, grain size distribution by sieve analysis, liquid limit, plastic limit, standard proctor test, shear test etc. Later, the soil was added with 5%, 10% and 15% GGBFS and a homogenous mixture was prepared. The engineering properties of this homogeneous mixture were determined in laboratory. The variation of shear strength for 5%, 10% and 15% GGBFS mixture with soil was determined. From the standard proctor test optimum moisture content (OMC) and maximum dry densities (MDD) were found out. The changes of specific gravity of GGBFS blended soil were also observed. Depending upon the co relation of dry density, specific gravity and density of water the void ratio was calculated. The main parameters which helps in decision making and coming to a conclusion for this study are shear strength, dry density and void ratio.

3. Results and Analysis

Properties like moisture content, specific gravity, grain size distribution, coefficient of uniformity, coefficient of curvature, liquid limit, plastic limit, liquidity index, consistency index, optimum moisture content and maximum dry density, shear strength are found out by the various laboratory experiments on the collected soil. The collected soil from landfill is possibly contaminated with heavy metal like Ni, As, Cr etc. (6).

Engineering properties of collected contaminated soil:
Moisture content = 8%
Specific gravity of the collected soil= 2.06

SL. NO.	IS SIEVE NO. (1)	PARTICLE SIZE (D) IN mm (2)	SOIL MASS RETAINED (M=1000) (gm) (3)	SOIL MASS % RETAINED $\frac{col(3) \times 100}{M = 1000gm}$ (4)	SOIL MASS CUMMULATIVE % RETAINED (5)	% FINER $100-col.5$ (6)
1	4.75mm	4.75	160	16.0	16	84
2	2.36mm	2.36	127	12.7	28.7	71.3
3	1.18mm	1.18	90	9.0	37.7	62.3
4	600 micron	0.6	140	14.0	51.7	48.3
5	425 micron	0.425	197	19.7	71.4	28.6
6	300 micron	0.30	228	22.8	94.2	5.8

7	150 micron	0.150	45	4.5	98.7	1.3
8	75 micron	0.075	10	1.0	99.7	0.3
9	Pan		3	0.3	100	0

Table 1: Grain size distribution of collected contaminated soil

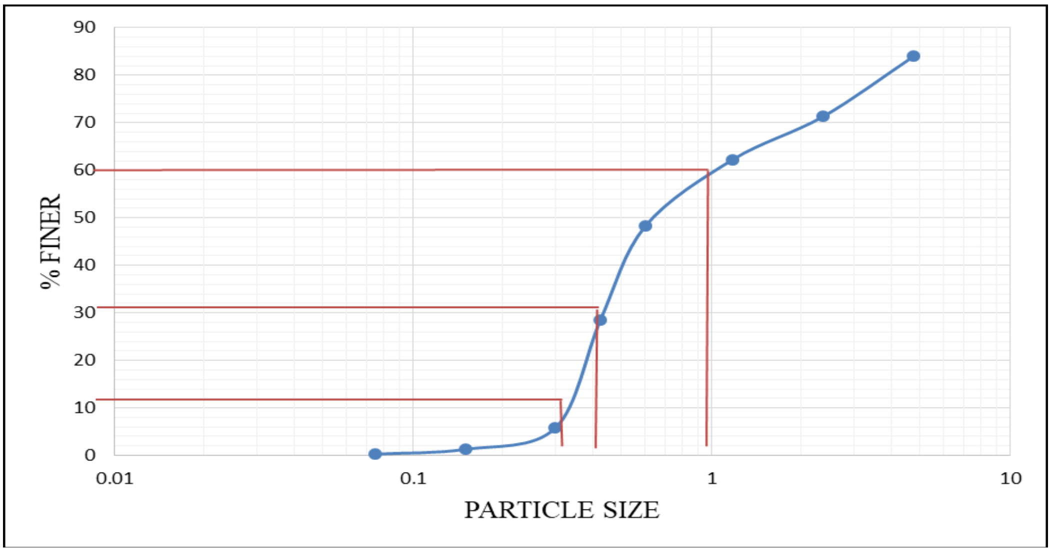

Fig. 3: Particle size distribution curve for collected contaminated soil

From fig. 3, D_{10}=0.33
D_{30}=0.42
D_{60}=0.6

Coefficient of uniformity ($\mathbf{C_u}$) = $\frac{D_{60}}{D_{10}}$

$=\frac{0.6}{0.33}$

=1.81

Coefficient of curvature (C_c) = $\frac{{D_{30}}^2}{D60\times D_{10}}$

$=\frac{0.42^2}{0.6\times 0.33}$

=0.89

The collected soil can be termed as uniform soil as the value of C_u lies between 1 and 3. The index properties of the collected soil were also determined. From Plasticity Index Chart, the collected soil can be characterized as silty clay or clayey silt.As the consistency index falls within 25% - 50%, the consistency of the soil can be termed as soft.

Plasticity Index = Liquid Limit – Plastic Limit = 11.24% - 4% = 7.24%.
Water Content of Collected Soil = 8%.
Consistency Index = (Liquid Limit – Water Content) X 100 /Plasticity Index = 44%.
Liquidity Index = (Water Content – Plastic Limit) X 100/Plasticity Index = 55%.
From fig. 4, the maximum dry density and optimum moisture content were found 1.8125 gm/cc and 12% respectively.
The shear strength of the collected soil has been found 1.46 N/cm^2.

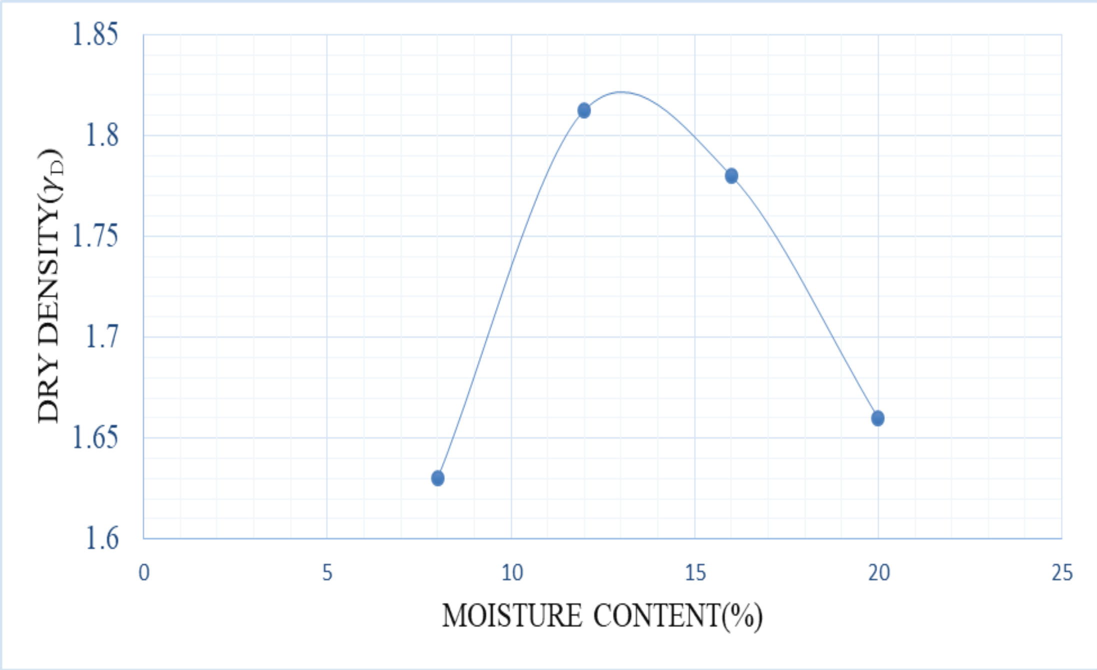

Fig. 4: MDD vs OMC for collected contaminated soil

The test data for 5% addition of GGBFS with collected contaminated soil are as follows:
The specific gravity of the soil (5% addition of GGBFS) was 2.57.
From fig. 5, the maximum dry density and optimum moisture content were found 1.84 gm/cc and 12% respectively for 5% addition of GGBFS with the collected soil.
The shear strength has been improved to 1.63 N/cm^2.

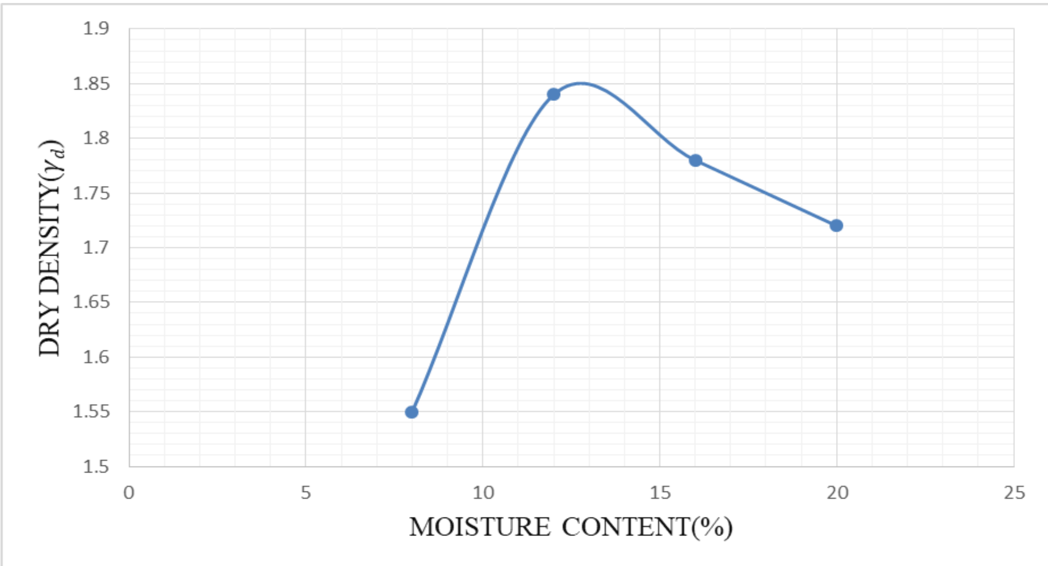

Fig. 5: MDD vs OMC for 5% addition of GGBFS

The test data for 10% addition of GGBFS with collected contaminated soil are as follows:
The specific gravity of the soil (10% addition of GGBFS) was found 2.64.
From fig. 6, the maximum dry density and optimum moisture content were found 1.90 gm/cc and 16% respectively for 10% addition of GGBFS with the collected soil.
The shear strength has been improved to 2.04 N/cm^2.

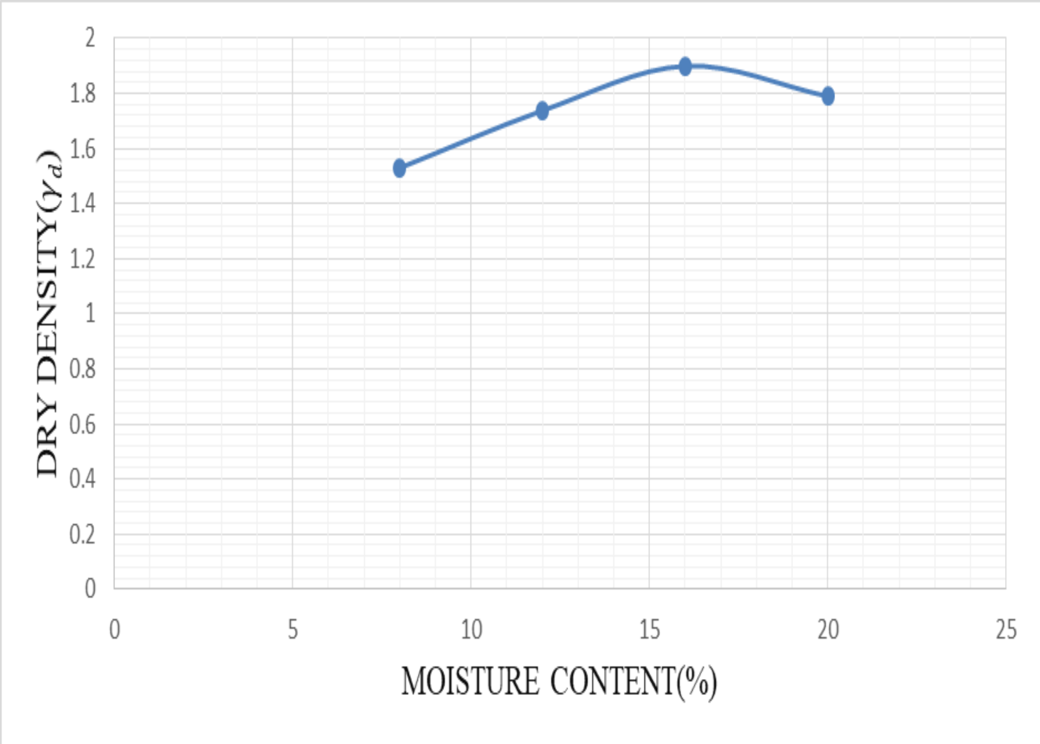

Fig. 6: MDD vs OMC for 10% addition of GGBFS

The test data for 15% addition of GGBFS with collected contaminated soil are as follows:
The specific gravity of the soil (15% addition of GGBFS) was found 2.65.
From fig. 7, maximum dry density and optimum moisture content were found 1.88 gm/cc and 16% respectively for 15% addition of GGBFS with the collected soil.
The shear strength has been improved to 2.33 N/cm^2.

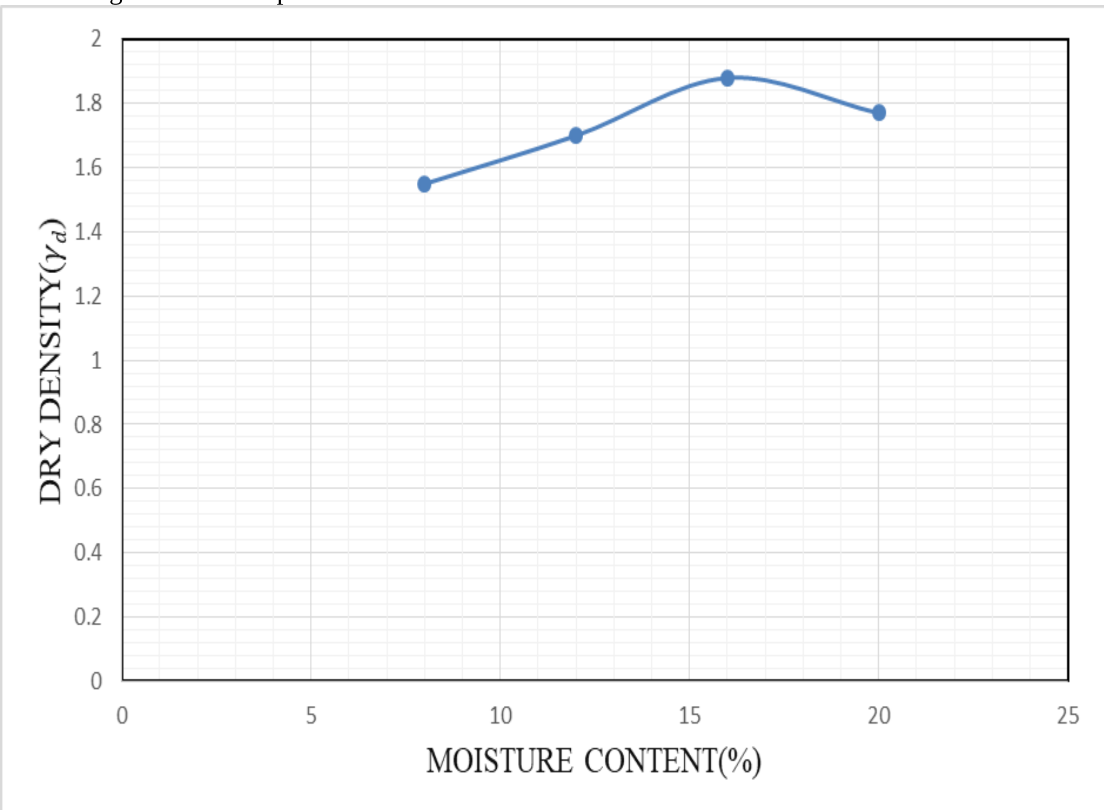

Fig. 7: MDD vs OMC for 15% addition of GGBFS

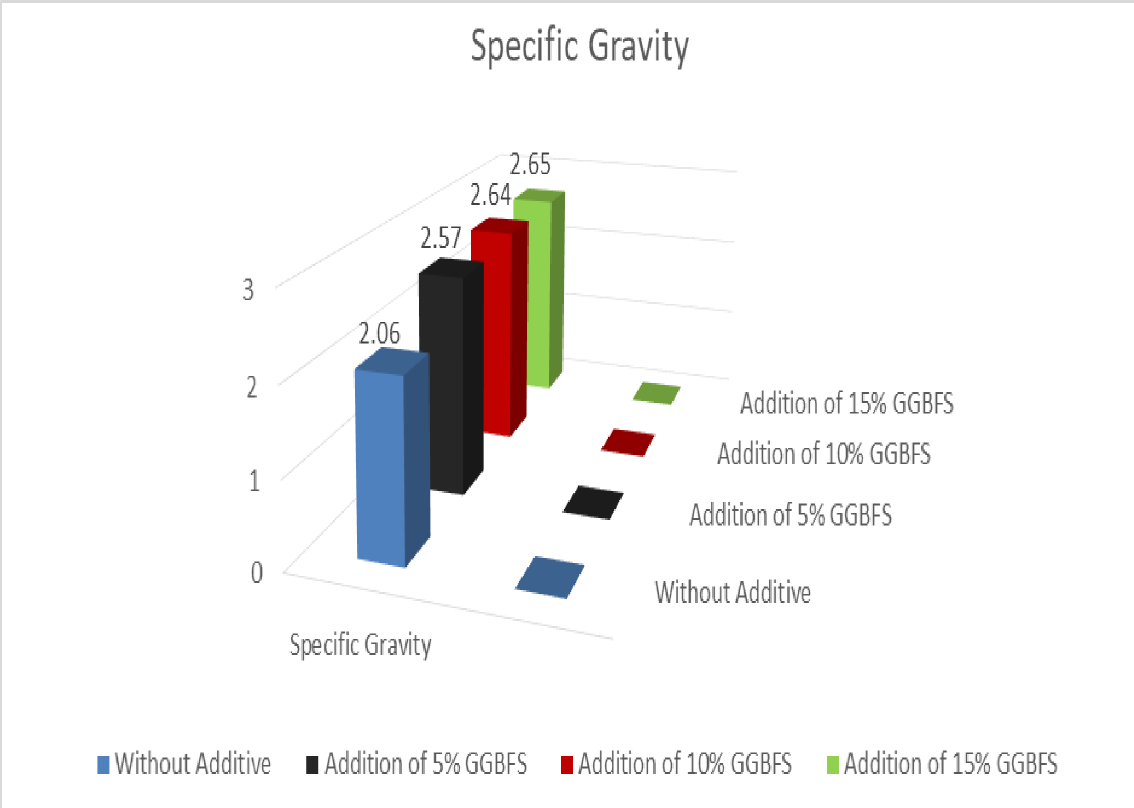

Fig. 8: Improvement of specific Gravity

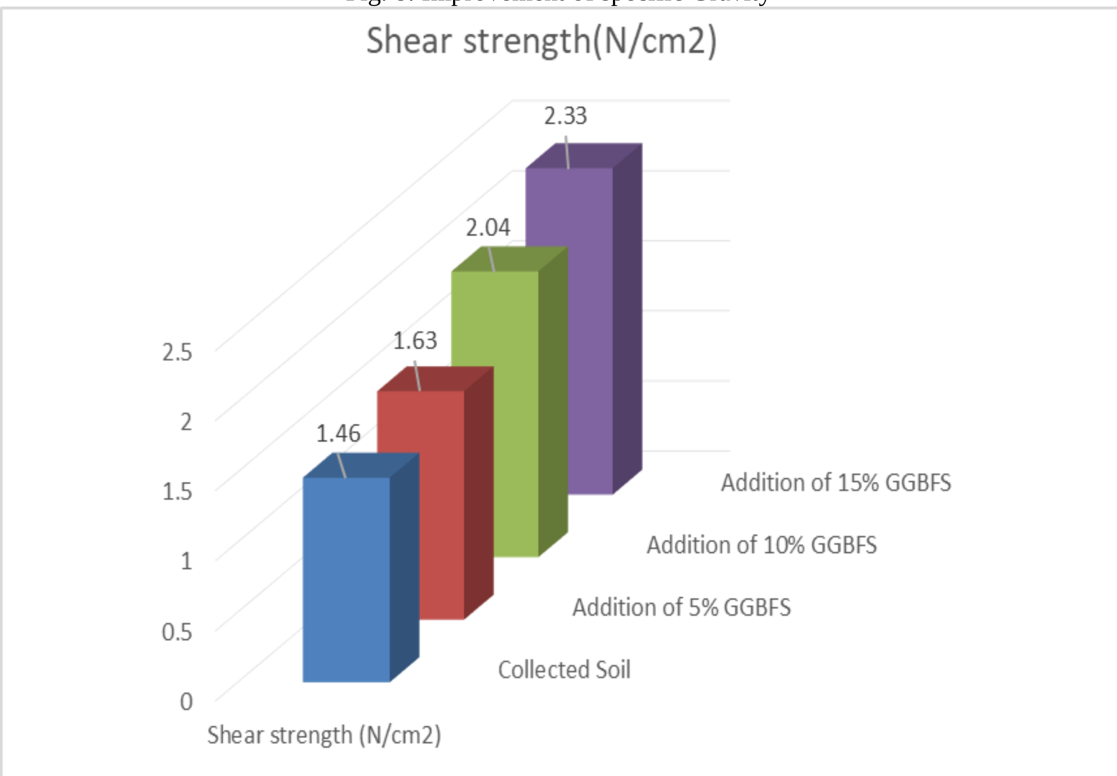

Fig. 9: Improvement of Shear strength

4. Conclusion

After studying all the test data following conclusions can be drawn:

•The maximum dry density of collected soil is 1.81 gm/cc which increased to 1.84 gm/cc for 5% addition, again increased to 1.90 gm/cc for 10% addition and then slightly comes down to 1.88 gm/cc for 15% addition of GGBFS.
•The specific gravity of collected soil was found 2.06. After addition of 5%, 10% and 15% dry weight of GGBFS with the contaminated soil, the specific gravity were found 2.57, 2.64 and 2.65 respectively (fig. 8).
•The shear strength of the collected soil was 1.46 N/cm2 which increases for 5%, 10% and 15% GGBFS addition and the values found were 1.63 N/cm2, 2.04 N/cm2 and 2.33 N/cm2 respectively (fig. 9).
•There is interdependency between maximum dry density, shear strength, specific gravity and void ratio. Void ratio is inversely proportional to maximum dry density and shear strength. As the maximum dry density increases over the mix and specific gravity also increases, the void ratio decreases.
•So, finally it can be concluded that GGBFS can be used as an additive for improvement of engineering properties of contaminated soil. Thus, contaminated land can be reclaimed and constructional activities can be started without replacing the weak contaminated soil. Hence, the contaminated soil replacement cost can be minimized. The mix proportion has to be decided after studying the optimization of additive percentage.

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