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Role of Moulding Water Content on the Strength Properties of Black Cotton Soil treated with Ground Granulated Blast furnace Slag (GGBS)

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Abstract—*The strength of soils is more at the densely compacted state, to find the strength of soils in laboratory, soils are compacted to its maximum dry density which is obtained by adding a certain amount of moulding water known as Optimum Moisture Content (OMC). As the water content changes from dry of optimum to wet of optimum while compacting the structure of soil particles changes from flocculated to disperse structure. Therefore the study of strength properties with the effect of moulding water content for the original black cotton soil and the same soil treated with Ground Granulated Blast furnace Slag (GGBS) were presented in this paper. Standard Proctor compaction, Unconfined Compressive Strength tests have been conducted to the soil at a dry side of optimum, OMC and wet side of optimum to investigate the strength properties. The quantities of slag added to the soil, as percentage of dry soil mass were in the range of 0-25% with the interval of 5% (0, 5, 10, 15, 20 and 25%). Specimens for the UCS were prepared at moulding water contents of -4, -2, 0, +2 and +4 % of the moisture content and cured for 0, 7, 14, 21 and 28 days. From the test results it is found that moulding water contents have significant effects on the geotechnical properties of stabilized expansive soil. The strength of black cotton soil and GGBS mixtures increases with increase in curing period for all the moulding water contents. However, higher strength was observed in dry of optimum condition compare to optimum and wet of optimum conditions.*

1. INTRODUCTION

Black cotton soil is one of the most commonly encountered materials in soil mechanics. As these soils are sensitive with increase or decrease in moisture content, the studies on the behavior of black cotton soil at different moisture contents have been increased in the field of Geotechnical engineering. Black cotton soil is known for its high swell potential and low shear strength.

Soil Stabilization may be defined as alteration or modification of one or more soil properties to improve the engineering characteristics and performance of a soil. The strength gain of stabilized soils is not only influenced by the type and proportion of the stabilizers and its curing time, but also by the water content needed to maintain the reaction. In general, the chemical and physical properties of these soils can be improved by both chemical and mechanical stabilization. Chemical stabilization of soil consists of chemical additives like lime, cement, fly ash, GGBS and other chemical additives.

Blast furnace slag is an industrial by-product which is produced in large quantity from iron industries after extraction of iron from iron ores in a blast furnace and poses serious disposal problems and creating environmental hazards. In recent years there is an increase in trend to utilize the Blast furnace slag for geotechnical applications. Stabilization is found to be one of the effective methods to improve the engineering properties of soils. Blast furnace slag can be effectively utilized for civil engineering constructions which will minimize the disposal problems and reduce the environmental hazards

2. LITERATURE REVIEW

Ashish Kumar Pathak, et.al. (2014), investigated the effect of GGBS on the engineering property of the soil and determine the engineering properties of the stabilised. GGBS are added from 0% to 25% by dry weight of soil. The addition of GGBS resulted in a dramatic improvement within the test ranges covered in the programme. The maximum dry density increased and the optimum moisture content decreased with increasing GGBS content and at 25% they got the maximum value of dry density.

Oormila.T.R. et.al. (2014), Studied stabilisation of the soil by using fly ash and ground granulated blast furnace slag. This paper includes the evaluation of soil properties like UCS test and CBR test. Different percentages of fly ash (5, 10%, 15% and 20%) and GGBS (15%, 20%, 25%) was added to find the variation in its original strength and determined the optimum of both and combination of optimum fly ash with varying GGBS percentages (15%, 20%, and 25%) has carried out. From these results, it was found that optimum GGBS (20%) gives the maximum increment in the CBR value compared with all the other combinations.

Laximanth Yadu (2013) evaluated the potential of granulated blast furnace slag (GBS) with fly ash to stabilize a soft soil. Different amounts of GGBS, i.e. 3, 6, and 9% with different amount of fly ash i.e. 3%, 6%, 9% and 12% were used to stabilize the soft soil. The performance of GBS with fly ash modified soils was evaluated using compaction and California bearing ratio (CBR) test. Based on these performance tests, optimum amount of GGBS with fly ash was determined as 3% fly ash + 6% GGBS. Reasonable improvement has been observed for unsoaked and soaked CBR value of soils with this optimum amount.

Agus Setyo Muntohar (2005), investigated the results of the laboratory study on the unconfined compressive strength (UCS) of soils stabilized with lime and RHA, compacted at the OMC, and at the dry and wet side of OMC. He concluded that the strength of the stabilized soil decreases with increase in moulding water content, but it is still higher than of un-stabilized soil.

H.N.Ramesh. et.al. (2016), Investigation involves a study on the effect of "Ground Granulated Blast Furnace Slag" (GGBS) and chemical admixture such as sodium salts on the geotechnical properties (compaction and unconfined strength) of lithomargic soil. This investigations further extended on the role of moulding water content from the dry of optimum to wet of optimum condition with all the above stabilizing ingredients and additives for various curing periods.

3. MATERIALS USED

3.1. Soil

The soil sample was collected from Ibrahimbag, Hyderabad, Telangana in India, at a depth of 1m below the natural ground level by open excavation. Hence, various relevant tests have been performed on the black cotton soil and these tests include the index properties for soil classification, the engineering properties to understand the behavior of the soil**.**

3.2. GGBS

Ground Granulated Blast furnace Slag (GGBS) used in this study was collected from ACC ready mix plant

3.3. Water

Tap water has been used for all the experimental works.

4. EXPERIMENTAL WORK

In the present study, GGBS was mixed with the black cotton soil in different proportions, varying from 0% to 25% in the intervals of 5% in each case. To avoid misleading, designation was given for each type of mixes. The designations for various mixes are shown in Table 1.

Table 1: Mix Designations

Designation	Mix
BC0G	100% Black cotton soil + 0% GGBS
BC5G	95% Black cotton soil + 5% GGBS
BC10G	90% Black cotton soil + 10% GGBS
BC15G	85% Black cotton soil + 15% GGBS
BC20G	80% Black cotton soil + 20% GGBS
BC25G	75% Black cotton soil + 25% GGBS

Specific gravity of fine grained (black cotton) soil has been determined by using density bottle, as per [6].

The Wet sieve analysis and hydrometer tests have been performed as given in [7] to determine the particle size of the soil and [12] for soil classification, so that it can be used to differentiate the coarser and finer particles. The liquid limit and plastic limit of black cotton soil and GGBS treated soil were determined according to [8]. The results of index properties of black cotton soil and Atterberg's limits of GGBS treated black cotton soil are shown in Tables 2 & 3. The compaction tests were conducted according to [9] of soil and [11] for stabilized soils. Initially an oven dried soil sample of 3 kg, which is passed through 4.75 mm sieve was used. Then required amount of water content is added for various identical soil samples. The hand mixing process was used during the tests, so that mixed soil samples are stored in plastic bags for a period of about 24 hours for obtaining uniform mixtures till the test begins. Then the wet sample was compacted in standard proctor mould with a rammer of 2.6 kg from a height of 31cm for three equal layers with 25 blows for each layer. By the relationship of dry density and moisture content, the optimum moisture content corresponding to the maximum dry density was determined. The soil, which is to be treated by different percentages of GGBS (5, 10, 15, 20 and 25%) by weight of oven dried soil is also taken. Similar tests were conducted on identical soil samples using the above procedure. The results obtained are shown in Table 4.

Table 2: Index Properties of Black Cotton Soil

Soil property	Value
Specific gravity	2.6
Free swell index (%)	40
Liquid Limit (%)	53
Plastic Limit (%)	19.66
Plasticity Index (%)	33.34
Soil Classification	CH

Optimum moisture content (%)	15.04
Maximum dry density(g/cc)	1.792
Unconfined compression strength(kg/cm2)	6.66

Table 3: Atterberg's Limits of GGBS treated Black Cotton Soil

Soil	Liquid Limit (%)	Plastic Limit (%	Plasticity Index (%)
BC0G	53	19.66	33.34
BC5G	49	21.95	27.05
BC10G	46	23.71	22.29
BC15G	44	25.73	18.27
BC20G	41	26.81	14.19
BC25G	40	29.54	10.46

5. SAMPLE PREPARATION

The unconfined compression test was performed [10] to observe the strength (UCS). Specimens were compacted by static compaction method. The known amount of soil was placed into cylindrical mould (Figure 1). During filling, the materials were tamped gently and uniformly so that the upper plug could be inserted in about 15 mm. The assembled mould was then placed on a hydraulic jack to gently force the upper plug in contact with the barrel of the mould. That was maintained for about 30 seconds before the specimens were dismantled. The dimension of the specimens measured 38 mm in diameter and 76 mm of length. The mass of specimen was determined immediately after preparation and then kept in plastic bag, thus cured for 7, 14, 21, and 28 days.

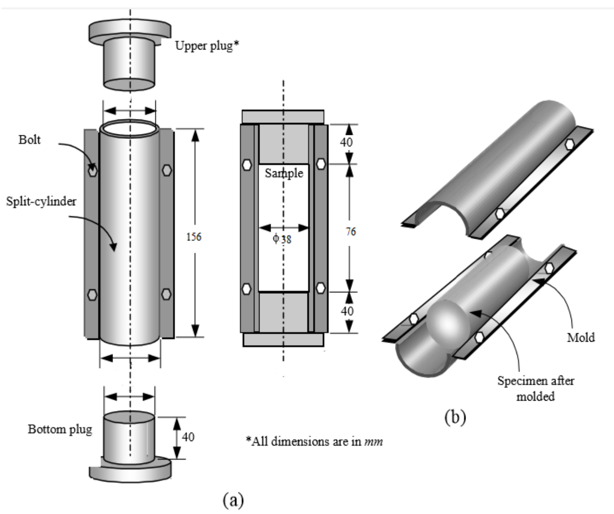

Figure 1: UCS Split Mould

6. RESULTS AND DISCUSSIONS

6.1. Compaction

The compaction tests were carried out on original black cotton soil and soil mixed with GGBS respectively. The tests were carried out for dry of optimum, optimum and wet of optimum conditions. The wet of optimum and dry of optimum conditions the water content corresponding to maximum dry density were selected from the compaction curve on dry side and wet side of optimum values as represented in Fig.2.

6.2. Unconfined compressive strength

The unconfined compressive strength tests were carried out on Black cotton soil alone and soil treated with GGBS respectively. Addition of various percentages of GGBS to Black cotton soil, unconfined compressive strength tests were conducted for immediate effect as well as with curing periods and 20% of GGBS for Black cotton soil was found to be optimum percentage. Unconfined compressive strength tests were carried out for Black cotton soil treated with GGBS at dry of optimum, optimum and wet of optimum conditions respectively for 0, 7, 14, 21, and 28 days of curing periods and the results are presented.

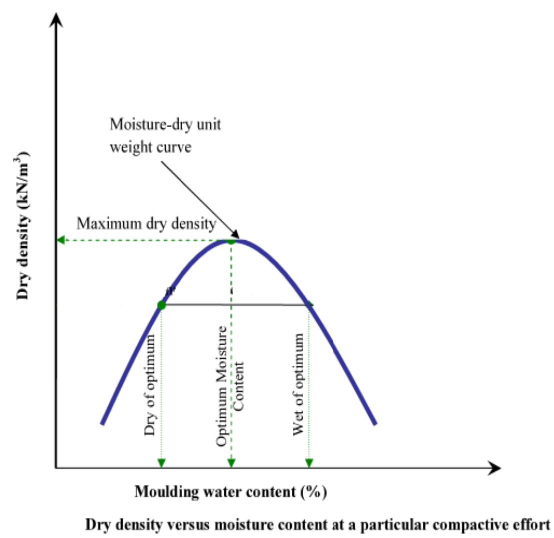

Figure 2: Compaction Curve

Based on the compaction test results an attempt has been made to find the optimum percentage of GGBS to be added to Black cotton soil by conducting UCS test. The samples are prepared by adding various percentage of GGBS to Black cotton soil from 5 to 25 % at an intervals of 5% and tested for immediate, 7, 14, 21, days and 28 days curing. From the results as seen from Figure 3, it was found that 20% addition of GGBS to Black cotton soil is found to be optimum percentage.

Figure 7 represent the UCS of black cotton soil at different moulded water contents of dry side of optimum (-2 OMC & -4 OMC), near (OMC) and wet side of optimum (+2 OMC & +4 OMC), from an obtained compaction curve of BC0G. Figure 8 shows that UCS decreases (9.18 kg/cm^2 to 1.94 kg/cm^2) with increase in water content from dry side of optimum (-4 OMC) to wet side of optimum (+2 OMC). The reason behind this, the soil samples which was compacted at dry side of optimum attains flocculated structure and whereas at wet side of optimum it attains dispersed structure.

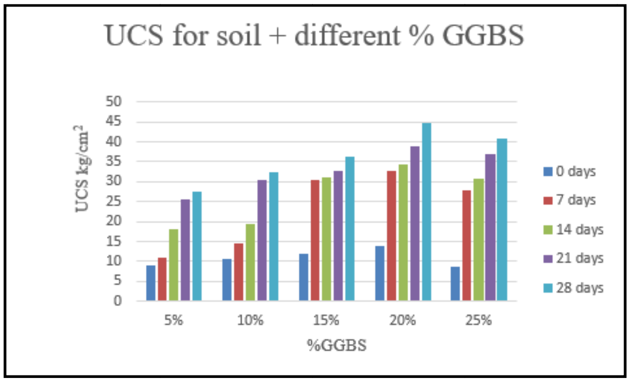

Figure 3: Variation of UCS values for Black Cotton soil at Different % GGBS and curing days

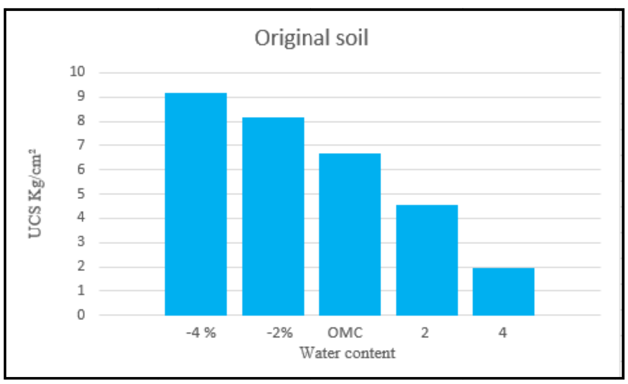

Figure 4: Variation of UCS for Black Cotton soil at Different Moulded Water Contents

It is observed that with the increase in GGBS content of 5%, the UCS of untreated soil increases from 9.18 kg/cm^2 to 11.73 kg/cm^2 at -4 OMC, 8.15 kg/cm^2 to 10.15 kg/cm^2 at -2 OMC, 6.66 kg/cm^2 to 9.02 kg/cm^2 at OMC, 4.54 kg/cm^2 to 7.89 kg/cm^2 at +2 OMC and 1.94 to 6.98 kg/cm^2 at +4 OMC. Further, with the increase in curing periods (i.e. 7, 14, 21 and 28 days) the UCS of GGBS treated soil decreases from the dry side to wet side of optimum, which is shown on Figure 5. Mainly, the gain in strength of stabilized black cotton soil to increase in curing period is due to long term pozzolanic reaction.

Figure 5 shows that the UCS of 10% GGBS treated black cotton soil increases more than that of the natural soil (i.e. BC0G), and 5% of GGBS treated soil (i.e. BC5G). It is observed that at a dry side of optimum, the strength obtained was 12.36 kg/cm^2 at -4 OMC, and 11.55 kg/cm^2 at -2 OMC.

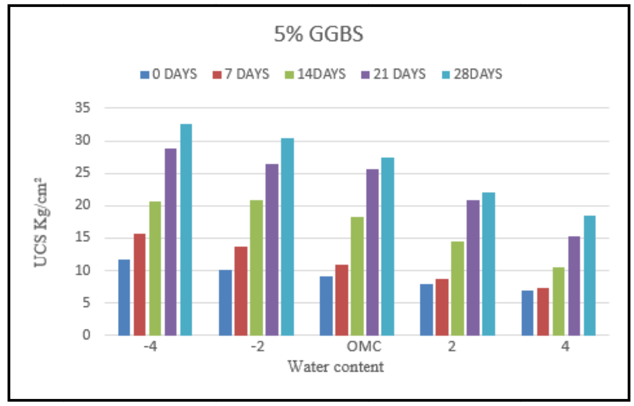

Figure 5: Variation of UCS for Black Cotton soil +5% GGBS at Different Moulded Water Contents

At wet side of optimum, it was 8.64 kg/cm^2 at 2 OMC and 7.49 kg/cm^2 at 4 OMC for 0 days. This was mainly due to short term reaction of GGBS with black cotton soil and the flocculated structure of the particles. It has shown that with the increase in moulded water content, the strength decreases.

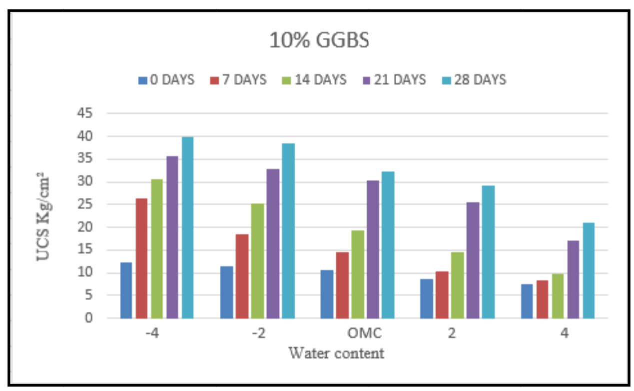

Figure 5: Variation of UCS for Black Cotton soil +10% GGBS at Different Moulded Water Contents

The UCS of 15% GGBS treated black cotton soil shows an increase in its value, when compared with that of 0%, 5%, and 10% of GGBS stabilized soil. From Figure 6, observe that the UCS of 15% GGBS treated soil decreases from the dry side of optimum to the wet side of optimum with a range of 14.38 kg/cm^2 to 8.47 kg/cm^2 for 0 days. The increase in age of curing of soil specimens shows an increase in its strength.

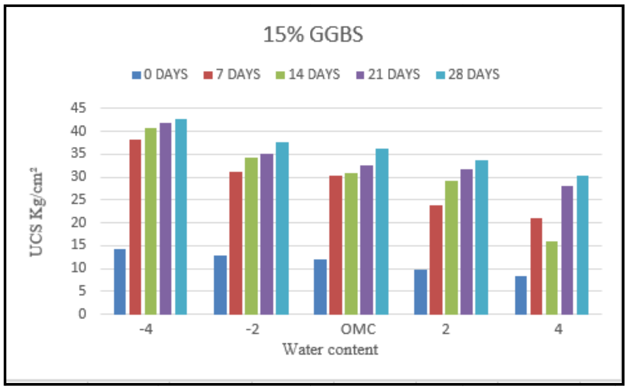

Figure 6: Variation of UCS for Black Cotton soil +15% GGBS at Different Moulded Water Contents

The UCS of 20% GGBS treated black cotton soil shows an increase in its value, when compared with that of 0%, 5%, 10% and 15% of GGBS stabilized soil. From Figure 7, observe that the UCS of 15% GGBS treated soil decreases from the dry side of optimum to the wet side of optimum for all curing days with a range of 16.35 kg/cm^2 to 9.25 kg/cm^2 for 0 days. The increase in age of curing of soil specimens shows an increase in its strength.

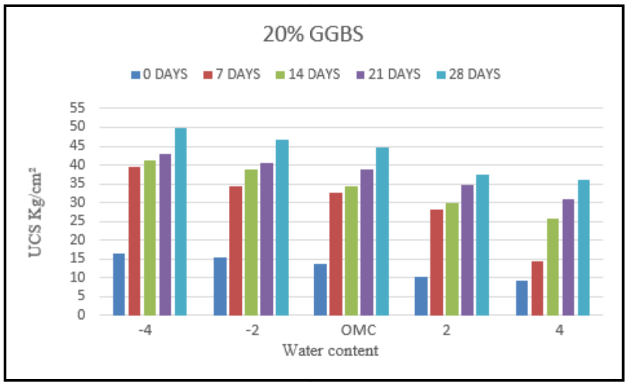

Figure 7: Variation of UCS for Black Cotton soil +20% GGBS at Different Moulded Water Contents

The 25 % GGBS treated black cotton soil also shows the same scenario of decreasing strength from dry side of optimum to wet side of optimum with a range of 12.34 kg/cm^2 to 3.87 kg/cm^2 but the UCS values of all the curing days are less than that of 20% GGBS treated soil. This might be due to replacement of more soil particles by GGBS From Figure 7, observe that the UCS of 25% GGBS treated soil decreases from the dry side of optimum to the wet side of optimum for all curing days.

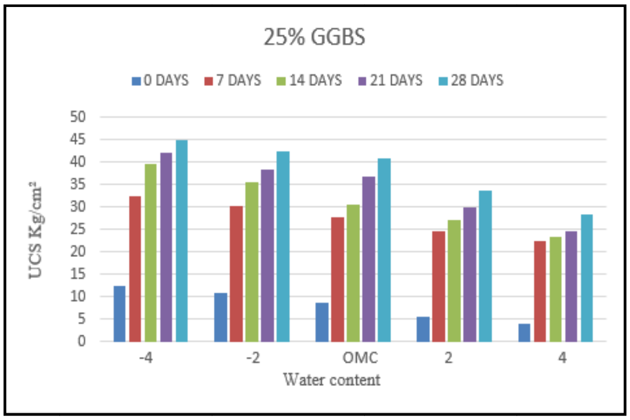

Figure 8: Variation of UCS for Black Cotton soil +25% GGBS at Different Moulded Water Contents

7. CONCLUSION

By conducting the UCC test for virgin and treated soil (5%, 10%, 15%, 20% and 25% of GGBS), it was found that the soil treated with 20% of GGBS gives the optimum strength when compared with the original soil at an increment of 106% for 0 days of curing

The UCS of uncured GGBS treated black cotton soil increased with decreasing moulded water content, but it is still higher than the untreated black cotton soil.

The strength of Black cotton soil and GGBS mixtures increases with increase in curing period for all the moulding water contents. However, higher strength was observed in dry of optimum condition compare to optimum and wet of optimum conditions

The un-stabilized black cotton soil showed higher strength at a dry side of optimum. Therefore, it is best preferred to compact the natural soil at a dry side of optimum.

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