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Ground granulated blast furnace slag as an expansive soil stabilizer

T. Geeta Rani[1], K.Tulasi[2] , Y. Sai Rama Krishna[3]
Assistant Professor[1,2&3], Vignan's Institute of Information Technology
Visakhapatnam-530049
geetarani142@gmail.com[1], tulsikolla22@gmail.com[2]

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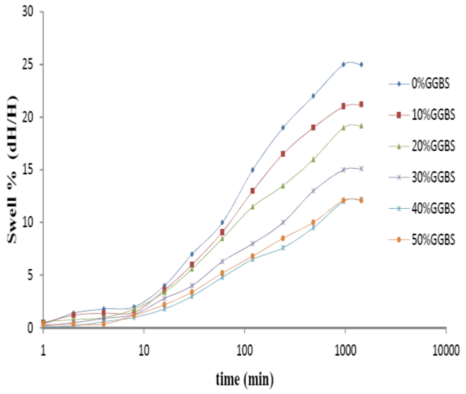
GRAPHICAL ABSTRACT



ABSTRACT

Locally available soils are readily available and relatively cheap, but they are often problematic and do not satisfy the required geotechnical properties. To improve these properties the common method followed is stabilization. Soil stabilization using industrial waste materials has been widely recommended for developing countries for the construction of various elements of pavements. Ground-granulated blast-furnace slag (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. Thus, the current work is carried out to estimate the optimal GGBS content s for improvement of black cotton soil. In order to obtain the optimum content of GGBS, unconfined compression test (UCC) conducted. The UCC samples are tested under different curing periods (7 and 28 days).**

***Key words* — GGBS, expansive soils, black cotton soil, stabilizer.**

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I. Introduction

Expansive soils are known worldwide for their volume change behaviour due to variation in the water content. Expansive soils contain clayey minerals such as montmorillonite, which increase in volume during wetting and decrease in volume during drying. This change in volume can exert sufficient stress on a building, sidewalks, driveways, basement floors, pipe line sand even foundation to cause damage. Expansive soils are clayey soils with large specific surface area and high cation exchange capacity (Nalbantoğlu, 2004). Since expansive soils are found worldwide, the challenge geto civil engineers is one felt around the globe. If not adequately treated, expansive soils may act as a natural hazard resulting in severe damage to structures(Al-Rawasetal.,2002). To date, distress problems related to this type of soil have resulted in the loss of billions of dollars in repairs and rehabilitation (Nelson and Miller, 1992). Expansive soils are found worldwide, mainly in the arid and semi-arid regions (Mishra et al.,2008) such as India, Australia.

Considerable research has been done on fly ash for the stabilization of expansive soils. Nalbantoglu (2004) studied the effect of Class C fly ash on expansive soil and shown the improvement in the plasticity characteristics of the expansive soil. Only few studies have been done to check the effectiveness of GGBS in the Black cotton Soils (BC soils). Cokca et al. (2009) have carried out experiments to determine the effect of GGBS on grain size distribution, Atterberg limits, swelling percentage and rate of swell of soil samples. But its effect on strength characteristics is not known. The results showed that GGBS was effective in decreasing the total amount of swell while increasing the rate of swell. In another attempt GGBS was found to be efficient to improve the strength of lime stabilized Kaolinitic clays by partially substituting lime for GGBS

(Wild et al. 1998). Recently in UK, red gypsum – GGBS binders were used as soil binders for UK soils and high strength and stiffness were achieved suggesting that these binders could satisfy construction project specifications (Hughes et al. 2011). But not much effort has been made in the past to evaluate the compaction, strength and stiffness characteristics of the GGBS stabilized soils, particularly for expansive soils

An attempt made in the study to utilize the mixture of GGBS and to stabilize the expansive soil. Atterberg limits, compaction characteristics, unconfined compressive strength, swell potential of the expansive soil have been taken into account for evaluating performance.

II. MATERIALS AND METHODS

A. Materials

1) Black cotton soil:

Locally available Black cotton soil (BC) is used in the present work. soil are oven dried and passing through 4.75 mm sieve. The physical properties of soil are determined as per Indian Standard codes. The physical properties of the soils used for the present study are listed in Table 1.

TABLE 1. BC soil physical properties

S.NO	Properties	BC Soil
1	Specific gravity	2.65
2	Grain size analysis Gravel (%) Sand (%) Silt (%) Clay (%)	 0 29 44 27
3	Liquid limit	63
4	Plastic limit	21
5	Plasticity index	42
6	IS Classification	CH
7	Compaction properties Optimum moisture content (%) Maximum dry density (g/cm3)	19 1.45
8	Unconfined compressive strength (kg/cm2)	1.65

2) Ground granulated blast furnace slag

Ground granulated blast furnace slag (GGBS) is non-metallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water to form a glassy sand like granulated material when further ground to less than 45micron will have specific surface about 400 to 600 m2/kg. The chemical composition of ground granulated blast furnace slag (GGBS) is shown in table 2.

TABLE 2. Chemical Composition of GGBS (% by mass)

S.No	Chemical composition	GGBS (%)
1	SiO_2	34.06
2	MgO	7.89
3	Fe_2O_3	0.8
4	SO_3	0.9
5	CaO	32.6
6	MnO	0.31
7	Na_2O	0.22
8	Al_2O_3	20

B. Testing methodology

A variety of tests can be used to characterize the engineering properties of stabilized soils. Some of the basic and important properties include soil classification, compaction and compressive strength. These properties lead to a routine laboratory soil testing procedure for stabilized soils and are related to other engineering properties including stiffness and durability. The present study focuses one valuating the physical properties, compaction characteristics and strength behavior. Experimental investigations have been carried out on expansive soil with the addition of varying percentages of binder(10–40%).

The specific gravity of the soil sample was determined according to the Indian Standards, IS:2720(Part-3)(1980). The grain size analysis of the soil was determined in accordance with IS:2720(Part-4)(1985).

For the determination of Atterberg limits, oven dried expansive soil was mixed with a different among of GGBS. There after, water was added and the mixture was again thoroughly mixed to get paste like consistency. The soil paste was then put inside the plastic bags and kept in a desiccators for20–24 h for moisture equilibrium. The liquid limit of the soil was determined by the cone penetration method and the plastic limit by the conventional procedure described in IS:2720(Part-5) (1985). Compaction characteristics carried out using standard proctor test as described in IS:2720(part-7) (1980). Compaction tests were then conducted to determine the optimum moisture content (OMC) and maximum dry density (MDD). The Free Swell Index of the soil was carried in accordance with the IS.2720 part 40(1977)

Unconfined compressive strength(UCS) testing has been carried out on the soil–GGBS mixtures in accordance with IS:4332(Part-5)(1970).The specimen dimensions for UCS testing were 38 mm in diameter and 76 mm in length. The specimen was prepared by statically molding the soil–GGBS mixtures to their respective optimum conditions. At first, an oven dried soil sample was thoroughly mixed with different percentages of GGBS in the dry state, and then the required amount of water was added. A wet mix sample was then fed into a cylindrical mould and statically compacted from both ends. After extruding the sample, it was wrapped in plastic covers and kept in desiccators for curing. The UCS test was conducted at different curing periods of 7, 14 and 28 days.

III. RESULTS AND DISCUSSIONS

A. Atterberg's limits

The test results from figure 1 shows that LL, PL and PI decreased when BC Soil mixed with GGBS. It is known by addition of GGBS to BC Soil can, (1) Reduce the thickness of the diffuse double layer, (2) Cause flocculation of clay particles, and (3) increases the coarser particles content by substituting finer soil particles with coarser GGBS particles. These reasons all together cause the decrease in LL and PI, and the increase in PL.

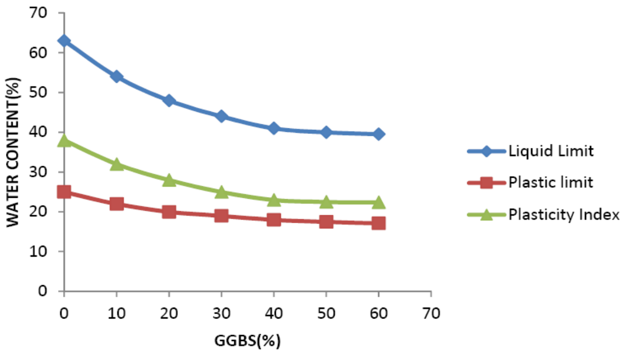

Fig. 1. Variations of liquid limit, plastic limit and plasticity index with addition of GGBS

Mitchell (1993) indicated that PI is a good indicator of swell potential, the lower PI is, and the lower swell potential will be. Addition of GGBS to BC soil decreased the plasticity index of expansive soil significantly. This implies there is a significant reduction in swell potential by addition of GGBS to BC Soil.

B. Compaction characteristics

The variation of OMC Vs. MDD with addition of GGBS to BC soil is shown in figure 2. It is observed that there is an decrease in the optimum water content and increase in maximum dry unit weight when GGBS is added to BC Soil, this can be explained as follows: The increase of the maximum dry unit weight by adding GGBS to BC Soil is mainly due to its higher specific gravity and reduction in the repulsive forces between the soil particles. This results in increase in the density. The pozzolanic reaction between BC soil and GGBS is responsible for decrease in OMC.

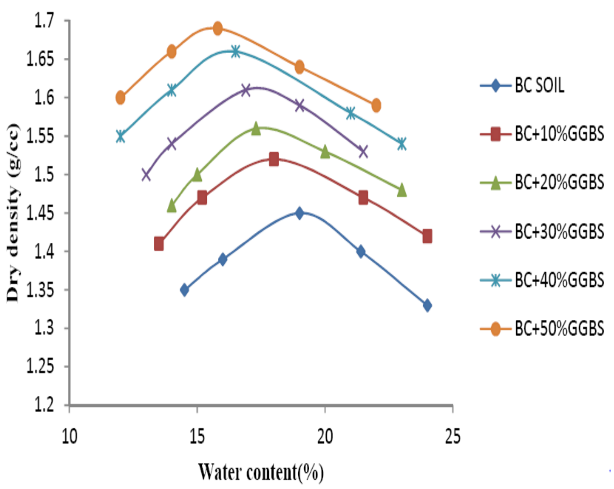

Fig.2. Variation of OMC vs. MDD with addition of GGBS to BC soil.

C. UNCONFINED COMPRESSIVE STRENGTH

The unconfined compressive strength tests were conducted on the optimum mixes which are selected from Mini compaction test. The unconfined compressive strength tests were carried out for 2 curing periods 7 and 28 days. The stress-strain behaviour of different composites with corresponding curing periods is shown in the following figures 3 and 4. From the stress strain behaviour of BC soil, it was observed that BC soil reached its maximum stress at low strain only whereas strain absorption rate at same loading intensity is increased. With the addition of GGBS to the BC soil, it is absorbing higher stresses than BC soil at similar strains. However, with increase in curing period the stress absorption rate is increased at higher strains than BC soil, but brittle nature is observed. The unconfined compressive strength of GGBS stabilized soil improved up to 40 % of GGBS content and slight decrease in strength is observed for later percentages. All the input CaO is consumed by the natural pozzolanic material in the soil to produce a pozzolanic reaction. Strength development in the inert zone tends to slow down; the incremental gradient becomes nearly zero and does not make any further significant improvement. A decrease in strength, which appears when the GGBS content is in the deterioration zone.

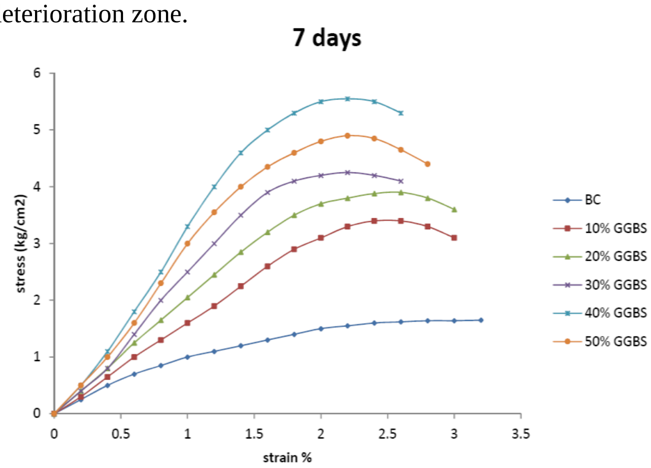

Fig.3. Stress-Strain behaviour of BC soil treated with GGBS for a curing period of 7 days

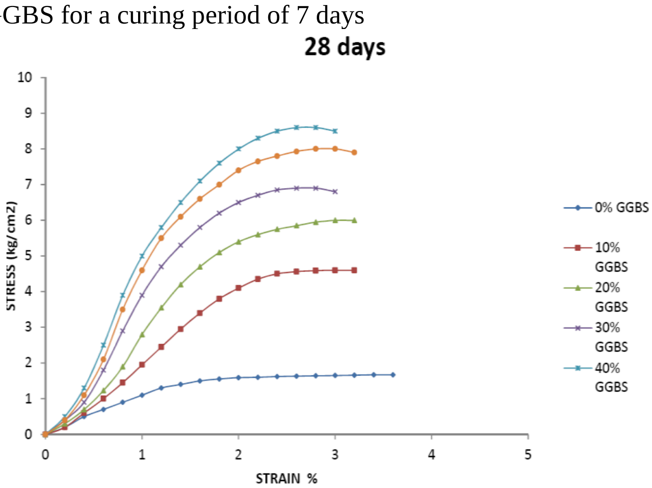

Fig.4. Stress-Strain behaviour of BC soil treated with GGBS for a curing period of 28 days

D. Free swell index

Test samples are prepared as per the specifications with varying contents of GGBS with BC soil. One dimensional swell tests are conducted on the samples. The variation of Swell % with time is shown in the figures 5. It can be observed that swell % decreases with increase in GGBS content due to cation exchange reaction.

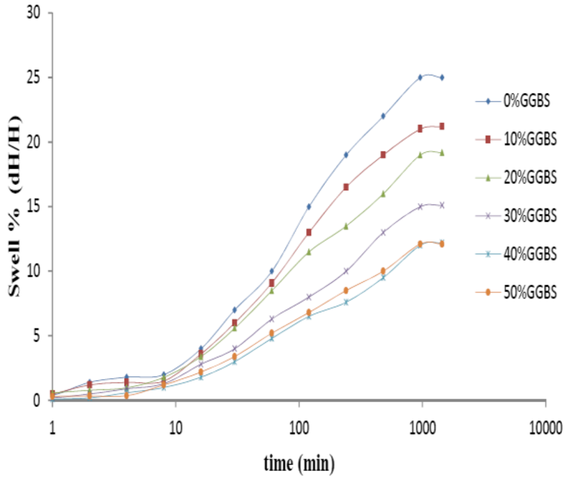

Fig.5. Variation of % swell vs. Time for different GGBS proportions

IV. CONCLUSIONS

The addition of GGBS to the soil decreased liquid limit and plasticity index while increasing the plastic limit. It is found that the addition of GGBS causes flocculation of clay particles and increases the number of coarser particles which help in reducing the Atterberg limits.

The strength of BC soil increased with addition of GGBS up to 40% for the curing periods of 7 and 28 days. Further addition of GGBS decreased the strength of Soil GGBS mixture.

The addition of 40% GGBS to the BC soil reduced the swell percent from 25 % to 12.1 %. Further additions of GGBS to the BC soil do not have significant reduction in swell percentage.

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