Role of Moulding Water Content on the Strength Properties of Ground Granulated Blast furnace Slag Stabilized Lithomargic Soil in the Presence of Sodium Salts

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Abstract— Shedi soil or lethomargic soil is very common throughout west coast of India from Malabar (Kerala) to Ratnagiri in Maharastra. Lithomargic soils are considered to be "treacherous soil" by geotechnical engineers due to its low strength and unpredictable behavior. Studies on this type of soil are meager and this further enhances the difficulties in designing structure in lithomargic soil stratum. Few researchers have investigated the stabilization characteristics of this soil using ingredients such as lime, flyash, quary dust or pond ash with lime, coconut coir with lime, fly ash with sodium salts etc and have got encouraging results.The present 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. The quantities of slag added to the shedi soil, as percentage of dry soil mass were in the range of 10-60%. The results inferred that the 30% addition of slag gives optimum unconfined compressive strength ((UCS) values for 90 days of curing. The maximum dry density increases while the optimum water content decreases with increase in the GGBS content. Further investigations were carried out to find the effect of sodium salts on the compressive strength for various curing periods. From the results it is found that the addition of 1% sodium salts enhances the unconfined compressive strength (UCS) values of stabilized shedi soil. The investigations 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 show that the strength ratio increases by 2 – 10 folds. Shedi soil when stabilized with 30% GGBS and 1% sodium hydroxide salt developed maximum strength ratio with water content on wet of optimum side. This is due to sufficient water availability in the mixture which is used for the hydration of exces silicates and calcium forming C-S-H gel and making slag a more useful pozzolanic material.

Key words: Index properties, Shedi,Stabilisation, Moulding Water Content, Strength Ratio.

1 INTRODUCTION

In the coastal area of Karnataka, India, a special type of problematic soil called as Lithomargic soil (Shedi soil) is available from a depth of about 2meters to 20 meters which is underlying relatively good lateritic soil layer.This soil is having size distributed between Jedi (clay) and Godi (silt) soils but do not show the behavior of the clay or silt. These soils dissolve and flow like water when ever they come in contact with water, which creates cavities and this leads to sliding of the top layers. Some times it becomes inevitable to use the available Lithomargic soil for embankments and sub base course. Thus the soil needs to be strengthened by adopting stabilization technique or mechanical compaction or dewatering or earth reinforcement etc. Very few researchers have done work in the stabilization of black cotton soil using Gound Granulate Blast furnace Slag (GGBS). Present study involves, experimental investigation of stabilizing Lithomargic soil using ground granulated blast furnace slag along with 1% of sodium salts and finding suitable moulding water content on dry or wet side of optimum dry density.

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2.0 LITERATURE REVIEW

Lime was used as stabilizing agent since the stabilization technique was adopted.[1-3] However, it is not suitable for sulfate bearing clay soils. Use of industrial by products like fly ash and GGBS have been succesfully tried for stabilization of various types of soils in recent past [4-7]. Along with these major ingredients certain additives like sodium salts, gypsum, lime in small quantity were used for stabilization of weaker and expansive soils [8-9]. Akinmurusu studied the effect of mixing of GGBS on the compaction and strength characteristics of lateritic soil. It was observed that the compaction, cohesion and CBR value increases with increase in GGBS content up to 10% and then subsequently decreases [10].

Ramesh et.al. studied the effect of lime and sodium salts on the strength properties of flyash.[11]. It has been reported that the addition of sodium salts generally inceases the amount of pozzolanic reaction compounds and increases the strength. Sitharam Nayak et.al.investigated the effect of quary dust on engineering properties of shedi soil [12]. It was reported that UCS values increases up to addition of 20% quary dust and decreases with further increase of percentage of quarry dust.

Manjunath et.al. studied the effect of GGBS on black cotton soil with small percentage of lime. It is found to be very useful for the purpose and also it is benificial to the environment by utilizing an industrial waste to good cause [14].

3.0 Materials and Methods

3.1 Lithomargic soil

Lithomargic soil or shedi soil was collected from a depth of 1-1.50m below natural ground level near national high way side of Bhatkal, Karnataka, India. The soil was air dried for 6 days, pulverized manually and sieved through 425 micron before used for laboratory tests. The physical and Index properties of soil are listed in Table.1.

Table 1: Properties of Lethomargic soil.

Parameters	Values
Atterberg limits Liquid limit Plastic limit Plasticity index Shrinkage limit	 41.20% 36.45% 4.75% 31.48%
Specific gravity	2.68
Maximum Dry Density.	15.60kN / m^3
Optimum Moisture Content	20%
Unconfined Confined Compressive Srength @ Maximum Dry Density.	108.00 KN / m^2
C.B.R(soaked)	2.85
IS classification	MI

3.2 Ground granulated blast furnace slag

Ground granulated blast furnace slag (GGBS) was procured from Jindal Steels, Bellary. The properties of GGBS are given in table 2.

Table 2: Properties of GGBS.

Parameters	Values
Atterberg limits Liquid limit Plastic limit Plasticity index Shrinkage limit	 32% NP NP -
Specific gravity	*2.81*
Maximum Dry Density	14.21 kN / m^3
Optimum Moisture Content	20.00%
IS classification	ML

3.3 Sodium Salts

Sodium Chloride (NaCl) and Sodium Hydroxide (NaOH) are commercially available in the market and are procured from Vasavi chemicals, Bangalore.

3.4 Methodology adopted.

3.4.1 Compaction characteristics;

Mini compaction apparatus developed by Sreedharan and Sivapullaiah [13] is used to determine the compaction characteristics of the Lithomargic(shedi) soil and GGBS mix.

3.4.2 Unconfined compressive Strength.

To ascertain the strength of the stabilized soil Unconfined Compressive Strength (UCS) test was carried out for Lithomargic soil treated with varying percentage of Ground Granulated Blast furnace Slag (GGBS)(10-60%). The test samples were prepared using static compaction, adopting maximum dry density and optimum moisture content condition. Samples were also prepared for Lithomargic soil having optimum content of GGBS and 1% of Sodium salts (NaCl and NaOH,each one separately). To study the effect of moulding water content UCS test samples were prepared having 95% of maximum dry density and moisture content at dry of optimum and wet of optimum condition. Immediate strength of soil stabilised with different combination of ingredients were determined for various moulding water content. Test samples were separately prepared for 7, 30, 60 and 90 days of curing periods and were moist cured in desiccators to maintain the water content of samples. After curing the samples for above specified days, UCS test was conducted as per BIS: 2720 (part X) (1973)(15).

4.0 Results And Discussion:

4.1 Effect of GGBS on the compaction characteristics

The compaction behavior of shedi soil has been studied by mixing various percentages of GGBS. The result obtained is shown in fig.1. The maximum dry density of shedi soil alone is found to be 15.60 kN / m3. With the addition of GGBS upto 10% by weight of soil, the MDD decreases.

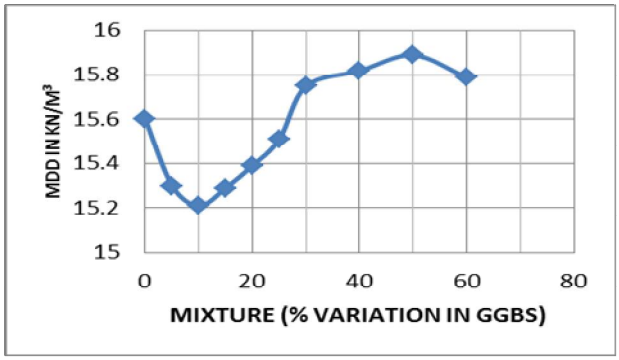

Fig.1: Variation of MDD with various percentage of GGBS

The decrease in MDD is due to the partial replacement of soil particle in a given volume by angular shaped GGBS and partial filling of voids by GGBS, which prevent soil particle coming closer, resulting in voids.With the further addition of GGBS the MDD increase up to 50% addition of GGBS. The increase of MDD with the increase of the percentage of GGBS is

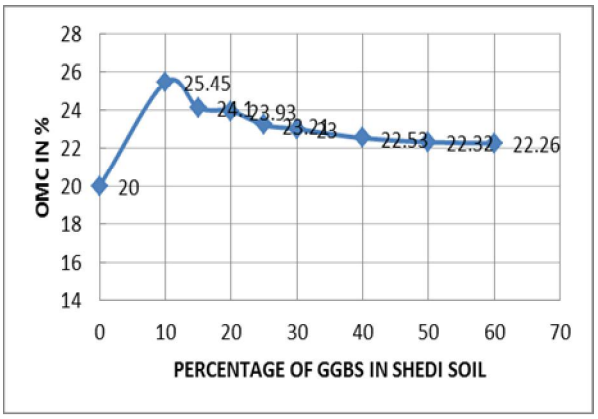

Fig.2: Variation of OMC with the GGBS

mainly due to higher specific gravity of the GGBS compared to that of shedi soil. The further decrease in MDD with further increase in GGBS may be due to voids which is created due to angular GGBS particles.

4.2 Effect of moulding water content.

Based on the compaction test results an attempt has been made to find the optimum percentage of GGBS to be added to shedi soil by conducting UCS test. The samples are prepared by adding various percentage of GGBS to shedi soil from 10 to 60% and tested for immediate, 7 days and 30 days curing. From the results as seen from Table 3, it was found that 30% addition of GGBS to shedi soil is found to be optimum percentage.

Table. 3: Variation of UCS with the GGBS content for diferent curing periods.

Mixture	Unconfined Compressive strength (kN / m^2)		
	Curing periods		
	0days	7 days	30 days
Shedi soil(SS)alone	108	108	108
SS+10%GGBS	89.12	122.44	132.34
SS+15%GGBS	115.73	125.68	136.65
SS+20% GGBS	113.48	123.06	142.44
SS+25% GGBS	115.73	133.32	165.89
SS+30% GGBS	113.58	163.12	182.94
SS+40% GGBS	109.16	142.57	151.67
SS+50% GGBS	111.34	124.80	132.33
SS+60%GGBS	112.80	125.68	131.40

The strength of shedi soil and optimum GGBS mixture increases with the addition of NaCl with curing. However with the addition of 1 % of NaOH to shedi soil –optimum GGBS mixture, the strength increase is enormous which is more than 7 folds compared to strength of shedi soil alone as shown in fig 4. An attempt is also made to study the role of moulding water content on UCS with optimum GGBS and 1% sodium salts. In all the cases namely shedi soil + optimumGGBS and with addition of 1% NaCl and 1% NaOH, the UCS is more on dry of optimum compared to optimum and wet of optimum as shown in Table 4,5 and 6 respectively. Also it can be observed that the immediate strength of wet of optimum condition is less than optimum condition, the increase in strength is observed with curing period for wet of optimum condition in all three cases.

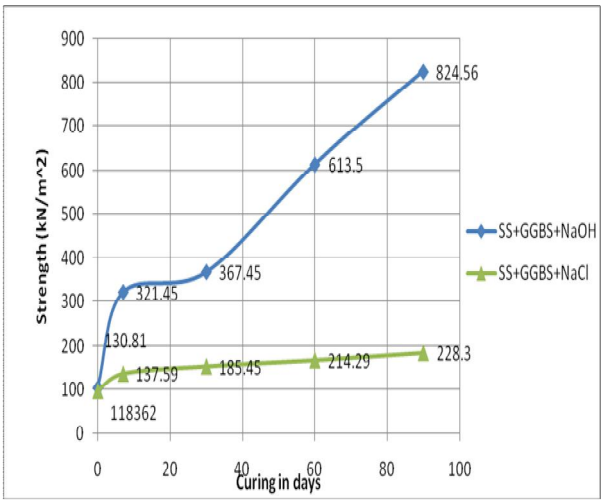

Fig. 3. Variation of UCS with optimum GGBS treated with 1% Sodium salts.

Table.4. Variation of UCS values for optimum stabilized soil for various moulding water content and curing periods.

Unconfined Compressive Strengh of ShediSoil(SS) +Opt.GGBS mix for differint curing periods in kPa					
Days→	0 day	7days	30days	60days	90days
DRY OF OPTIMUM	125.68	169.70	189.25	227.56	308.64
OPTIMUM	113.58	163.12	182.94	196.9	220.64
WET OF OPTIMUM	110.31	152.54	204.65	214.66	282.45

Table.5:Variation of UCS values for optimum GGBS stabilized soil with 1% of NaCl. for various moulding water content and curing periods.

UCS of Shedi soil+ Opt.GGBS+1% NaCl mix for differint curing periods in kPa					
Days→	0	7days	30days	60days	90days
DRY OF OPTIMUM	131.19	162.64	201.19	222.54	294.48
OPTIMUM	118.62	137.59	185.45	214.29	228.3
WET OF OPTIMUM	109.36	142.23	214.65	234.43	252.74

Table.6:Variation of UCS values for optimum GGBS stabilized soil with 1% of NaOH for various moulding water content and curing periods.

UCS of SS+Opt.GGBS+1% NaOH mix for differint curing periods in kPa					
Days→	0	7days	30days	60days	90days
DRY OF OPTIMUM	138.58	335.321	587.03	887.72	1334.33
OPTIMUM	130.81	321.45	367.45	613.5	824.56
WET OF OPTIMUM	118.78	360.27	645.67	803.45	1208.54

The unconfined compressive strength of Lithomargic soil and Ground Granulated Blast furnace Slag mixture having water content at wet of optimum conditions was found to be 110.31kPa on immediate testing. Further strength of 90 days cured sample on wet of optimum condition was 282454kPa,

2.56 fold more than corresponding sample without curing. It indicates that strength increased by 2.61 folds compared to Lithomargic soil alone. Similarly unconfined compressive strength of shedi soil-optimum Ground Granulated Blast furnace Slag mixture treated with 1% of sodium Chloride salt was found to be more for dry of optimum condition compared to wet of optimum and optimum conditions (Fig.4). The UCS values after 90 days curing period of shedi soil-GGBS-NaOH mixture is observed to be 1334.33 kPa for dry of optimum condition as shown in fig. 5 . It indicates that the strength increased by 12.35 fold compared to shedi soil alone.

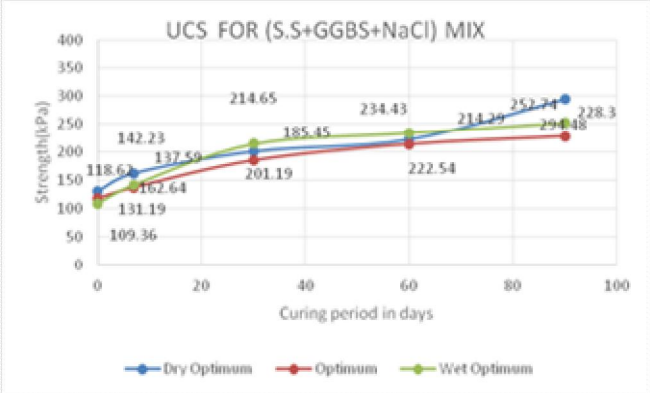

Fig. 4: Effect of Moulding Water Content on the strength of Shedi Soil- Optimum GGBS and 1% NaCl.

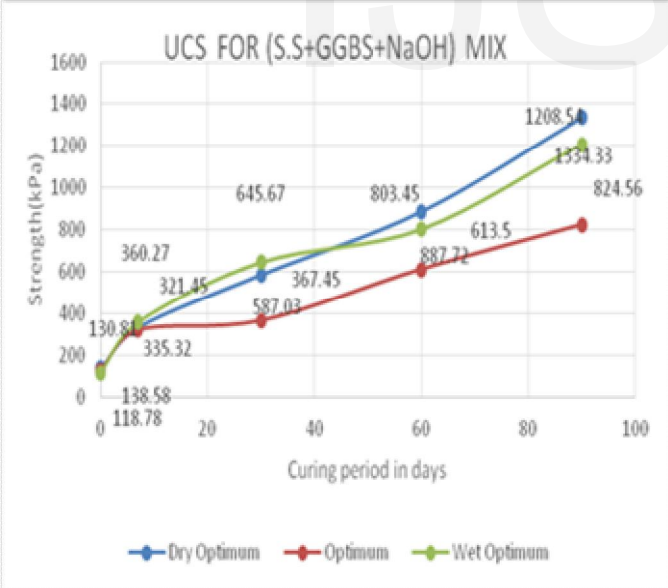

Fig. 5: Effect of Moulding Water Content on the strength of Shedi Soil- Optimum GGBS and 1% NaOH

Table 7, Table 8 and Table 9 shows the increase in strength ratio due to the effect of moulding water content and curing periods. Strength ratio is defined as the ratio of strength of stabilised soil mixture at any stage of curing with strength of the soil matrix at immediate testing of the same combinations [16] .The UCS value after 90 days of curing periods for samples of Shedi soil-GGBS-NaOH mixture prepared with water content at wet of optimum condition is observed to be 1208.54kPa. It indicates that strength ratio increases by 10.17 fold compared to the corresponding strength after immediate testing as shown in Table.9. The increase in Strength is 11.20 fold compared to shedi soil alone. This may be due to the presence of more water which is available at wet of optimum condition which enhances the pozzolanic reaction for long term curing.

Table.7.Variation of Strength ratio values for optimum GGBS stabilized soil for various moulding water content and curing periods.

Strength ratio of Shedi Soil+Opt.GGBS mix for differint curing periods				
	7days	30days	60days	90days
DRY OF OPTIMUM	1.35	1.50	1.81	2.45
OPTIMUM	1.44	1.61	1.73	1.94
WET OF OPTIMUM	1.38	1.86	1.95	2.56

Table.8: Variation of Strength ratio values for optimum GGBS stabilized soil with 1% of NaCl. for various moulding water content and curing periods.

Strength ratio of Shedi soil + Opt.GGBS+1% NaCl mix for differint curing periods.				
	7days	30days	60days	90days
DRY OF OPTIMUM	1.24	1.53	1.70	2.24
OPTIMUM	1.16	1.56	1.81	1.92
WET OF OPTIMUM	1.30	1.96	2.14	2.31

Table.9: Variation of Strength ratio values for optimum GGBS stabilized soil with 1% of NaOH. for various moulding water content and curing periods.

Strength ratio of SS+Opt.GGBS+(1%)Na0H mix for differint curing periods				
Days→	7days	30days	60days	90days
DRY OF OPTIMUM	2.42	4.24	6.40	9.62
OPTIMUM	2.46	2.81	4.7	6.3
WET OF OPTIMUM	3.03	5.43	6.76	10.17

5.0 CONCLUSIONS.

Stabilization of Lithomargic soil using Ground Granulated Blast furnace Slag (GGBS) is found to be advantageous means for improving the strength properties of the soil. Based on the results of present experimental investigation following conclusions are drawn:

1. Increase of GGBS content in the soil increases the maximum dry density of stabilized soil and decreases optimum moisture content. This is due to the effect of replacement of soil by GGBS of higher specific gravity and formation of cementitious product by hydration.

2. Based on experimental investigations, addition of 30%

GGBS is found to be optimum which gives the strength ratio of 2.6 for 90 days of curing.

3. Addition of 1% of sodium salts to optimum GGBS-soil mixture predominently increases the strength.

4. NaOH proved to be predominent additive for GGBS stabilized soil mixture. 1% of NaOH to optimum GGBS- Shedi soil mix gives the strength ratio of 6.3 for 90 days of curing.

5. Moulding water content plays an important role on varying the strength of shedi soil treated with Ground Granulated Blast furnace Slag alone and soil treated with Ground Granulated Blast furnace Slag and Sodium salts. Strength ratio increases with increase in water content and higher strength ratio can be achieved by stabilising soil with water content on the wet of optimum condition. This is due to the presence of sufficient water provided in the mixture which is used for the hydration of excess silicates and calcium forming C-S-H gel and making slag a more useful pozzolanic material.

From the present study, it has been concluded that Ground Granulated Blast furnace Slag and sodium salts can be effectively used in the stabilization of Lithomargic soils and the moulding water content on the wet of optimum side proved to play the most advantageous role for effective stabilization.

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