INFLUENCE OF GGBS AND POFA IN THE STRENGTH CHARACTERISTICS OF EXPANSIVE SOIL

[1]R. Valli Mounica, [2] K.Sridevi, [3]Ch.Sivanarayana, [4] Dr. D S V Prasad
[1]M.Tech Student, [2]Assistant Professor, [3]Assistant Professor, [4]Professor & Principal
Department of Civil Engineering,
B V C Engineering College, Odalarevu, E.G.Dt., AP, INDIA

Abstract: Expansive Clays, also termed as swelling soils or shrink-swell soils, have a tendency to swell and shrink with the variation in moisture content. As a result of which significant distress in the soil occurs, causing severe damage to the overlying structure. During monsoons, these soils imbibe water, swell, become soft and their capacity to bear water is reduced, while in drier seasons, these soils shrink and become harder due to evaporation of water. These types of soils are generally found in arid and semi-arid regions of the world and are considered as a potential natural hazard, which if not treated well can cause extensive damages to the structures built upon them. Soils containing the clay mineral, montmorillonite generally exhibit these properties. In India, these soils are also called as Black cotton soils. Stabilization using solid wastes is one of the different techniques to improve the engineering properties of expansive clays to make them suitable for construction. Hence, in this project, the influence of two industrial wastes, Ground Granulated Blast Furnace Slag (GGBS) and Palm Oil Fuel Ash (POFA) in different percentages, as stabilizing materials for enhancing the properties of expansive clay is evaluated by conducting various tests. The results will be analyzed to assess the efficiency of the materials used.

***IndexTerms* - Expansive Soil, GGBS, POFA,CBR, UCS.**

I. INTRODUCTION

Black cotton soils of India are well known for their expansive nature. In India, the black cotton soil covers 7 lakh square kilometers approximately 20%–25% land area and are found in the states of Maharashtra, Gujarat, Rajasthan, Madhya Pradesh, Uttar Pradesh, Karnataka, Andhra Pradesh and Tamil Nadu. These are derived from the weathering action of Basalts and traps of Deccan Plateau. However, their occurrence on granite gneiss, shale, sandstone, slate and limestone is also recognized Uppal HL. (1965), Mohan D, Rao BG. (1965) and Desai MD.(1985), Gyanen Takhelmayum, Savitha AL, Krishna Gudi,(2013), evaluated the compaction and unconfined compressive strength of stabilized black cotton soil using fine and coarse ground granulated blast furnace slag. It was found that with the increase in water content the dry density also increases up to 20%–30%moisture content and with further increase inwater content the dry density increases gradually. The lowest dry density was observed at 5% GGBS mixture and maximum density was at 30% GGBS mixture. Thisvariation in density is primarily due to chemical composition, glass phase content, particle size distribution and surface morphology. The increase in the maximum dry unit weight with the increase of the percentage of GGBS mixture is mainly due to high specific gravity and immediate formation of cemented products by hydration which increases the density of soil Pathak and Pandey [2014] investigated the effect of GGBS on geotechnical properties like plastic limit, liquid limit, compaction, unconfined compressive strength, triaxial and California Bearing Ratio (CBR) test of the soil by adding GGBS from 0% to 25% by dry weight of soil. Abhijith S and Aruna T (2015), were carried a study to evaluated the effect of Ground Granulated Blast Furnace Slag (GGBS) and Sisal Fibre on compaction and strength properties of Black Cotton Soil. GGBS and Sisal Fibre are mixed in Black Cotton Soil at different percentages by dry weight of soil and GGBS percentages varies from 10%, 20%,30%, and 40%. Sisal Fibre percentages varies from 10.25%, 0.5%, 0.75%, 1.0%, 1.25%, and 1.5%. A series of tests were conducted to study the effect of GGBS and Sisal Fibres on strength characteristics of Black Cotton Soil and stated that the individual optimum percentages of GGBS is 20% and Sisal Fibre is 0.75%. From the study, the stated that the UCS is increased 4 times that of Black Cotton Soil and the curing period increased the UCS of specimens having GGBS and Sisal Fibre. In this investigation, different laboratory experiments like compaction, soaked CBR and unconfined compressive strength tests were conducted by varying percentages of GGBS as 10%, 20%, 30% and 40 % and Palm Oil Fuel Ash with 3%, 6% and 9% blended with expansive soil with a view to determine optimum percentages. From the test results, it is found that there is an improvement in geotechnical properties. Testing is conducted with a view to find the gradual variation of different geotechnical properties by increasing the quantity of GGBS and Palm Oil Fuel Ash at which the properties are reaching a definite improved value

II. MATERIALS USED AND PROPERTIES

The details of the various materials used in the laboratory experimentation are reported in the following sections

Expansive Soil: The soil used was a typical black cotton soil collected from Komarigiripatnam, East Godavari District, Andhra Pradesh State, India. The properties of soil are presented in the Table.1. All the tests carried on the soil are as per IS specifications.

Table. 1 Properties of Expansive Soil

S. No.	Property	Values
1	Specific Gravity	2.63
2	Differential Free Swell Index (%)	110
3	Atterberg's Limits	
	i) Liquid limit (%)	71.3
	ii) Plastic limit (%)	27.5
	iii) Plasticity Index (%)	43.8
5	Grain Size Distribution	
	i) Sand Size Particles (%)	10
	ii) Silt & Clay Size Particles (%)	90
6	IS soil classification	CH
7	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.4
	ii) Optimum Moisture Content (%)	28.6
8	CB R - Soaked (%)	1.5
9	Shear Parameters at OMC & MDD	
	i) Cohesion, Cu (kPa)	37
	ii) Angle of Internal Friction, Øu	0^0

Ground Granulated Blast Furnace Slag (GGBS)

Ground Granulated Blast Furnace Slag (GGBS) is a recyclable material created when the molten slag from melted iron ore is quenched rapidly and then ground into a powder. Ground Granulated Blast Furnace Slag (GGBS) is a byproduct of the steel industry. Blast furnace slag is defined as "the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace. This waste material is easily available and also cost efficient. It has a cementations property which acts as binding material for the soil. In general, the presence of sufficient quantity of CaO results in enhanced slag basicity and compressive strength. The GGBS used in this project work is collected from Rashtriya Ispat Nigam Limited, Visakhapatnam. The physical properties of Ground Granulated Blast Furnace Slag as shown in the Table.2..

Table. 2 Properties of Ground Granulated Blast Furnace Slag (GGBS)

S. No.	Property	Value
1	Specific Gravity	2.74
2	Atterberg's Limits	
	i) Plasticity index (%)	NP
3	Grain Size Distribution	
	i) Sand Size Particles (%)	18
	ii) Silt & Clay Size Particles (%)	82
4	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.64
	ii) Optimum Moisture Content (%)	16.5

Palm Oil Fuel Ash (POFA):

Palm oil trees are abundant in the Andhra Pradesh and the effectiveness of using its fly ash (waste from the process of burning the palm oil fiber) in soft soil stabilization was investigated. It exhibits high shear strength which is highly beneficial for its use as a geotechnical material. It has a good permeability and variation in water content does not seriously affect its desirable properties. The dry density increased with the addition of Palm Oil Fuel Ash with attendant decrease in the optimum moisture content. The physical properties of ash as shown in the Table.3

Table. 3 Properties of Palm Oil Fuel Ash (POFA)

S. No.	Property	Value
1	Specific Gravity	2.19
2	Atterberg's Limits	
	i) Plasticity index (%)	NP
3	Grain Size Distribution	
	i) Sand Size Particles (%)	9
	ii) Silt & Clay Size Particles (%)	91
4	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.31
	ii) Optimum Moisture Content (%)	19.5

III. LABORATORY EXPERIMENTATION

Various experiments were conducted by replacing different Percentages of Ground Granulated blast furnace slag (GGBS) in the expansive soil and also further stabilizing it with POFA as a binder. Compaction, Strength and CBR tests were conducted with a view to determine the optimum combination of Ground Granulated blast furnace slag (GGBS) as replacement in expansive soil and POFA as a binder material.

Specific Gravity: Specific gravity was determined by using the soil fraction passing 4.75 mm IS sieve by using a density bottle of 50 ml capacity. The test was conducted in accordance with IS: 2720 (part - III).

Atterberg's Limits: Standard procedures recommended in the respective I.S. Codes of practice [IS:2720 (Part-5)-1985; IS:2720 (Part-6)- 1972], were followed while finding the Atterberg's limits viz. Liquid Limit and Plastic Limit of the samples tried in this investigation.

Compaction Properties: Optimum moisture content and maximum dry density of expansive soil with different percentages of GGBS and POFA mixes were determined according to I.S heavy compaction test IS: 2720 (Part VIII).

California Bearing Ratio (CBR) Tests: The percentages of GGBS were variation from 0 to 40% were determined. The CBR tests were conducted in the laboratory for all the samples as per IS Code (IS: 2720 (Part-16)-1979)

Unconfined Compressive Strength Test: Unconfined compressive strength is one of the most widely referenced properties of stabilized soils. Unconfined compressive test at OMC is conducted as per IS: 2720 (part - X)-1991.

IV RESULTS AND DISCUSSIONS

The influence of the above said materials on the Compaction and Strength characteristics were discussed in following sections. In the laboratory, all the tests were conducted per IS codes of practice

Table. 4: Variation of Geotechnical Properties of Expansive Soil Treated with Different Percentages of GGBS

GBBS (%)	DFS (%)	LL (%)	PL (%)	MDD (g/cc)	OMC (%)	CBR (%)	UCS (kPa)
0	110	71.3	27.5	1.4	28.6	1.5	74
10	103	68.1	27.9	1.41	28.2	2.3	86
20	91	67.7	28.6	1.44	27.9	3.1	99
30	84	65.9	29.3	1.43	27.5	2.6	94
40	75	64.5	30.1	1.42	27.1	2.2	88

Effect of Ground Granulated Blast Furnace Slag (GGBS) on Differential Free Swell Index of Expansive Soil

The individual influence of Ground Granulated blast furnace slag (GGBS) on the Swell Properties of expansive soil are clearly presented in table 4 and Figure 1. The percentage of Ground Granulated blast furnace slag (GGBS) was varied from 0%, to 40% with an increment of 10%. From the above graphs, it was observed that the swelling behavior of Expansive is decreasing for the percentage replacement of GGBS from 0 to 40%

Effect of % Ground Granulated Blast Furnace Slag (GGBS) on Atterberg's Limits of Expansive Soil

The individual influence of Ground Granulated blast furnace slag (GGBS) on the Atterberg's limits of expansive soil are clearly presented in table .4 and Figure .2. The percentage of Ground Granulated blast furnace slag (GGBS) was varied from 0%, to 40%

with an increment of 10%. From the above graphs, it was observed that the treatment as individually with 20% GGBS has moderately improved the expansive soil.

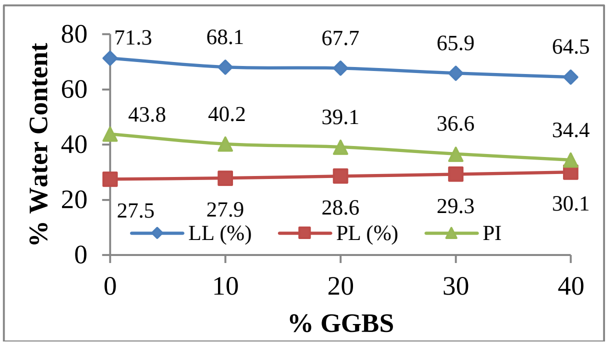

Fig .2: Variation of Atterberg's Limits with Different % of GGBS

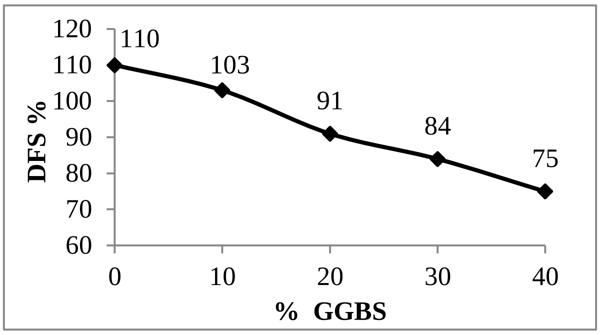

Fig .1: Variation of DFS with Different % of GGBS

Effect of Ground Granulated Blast Furnace Slag (GGBS) on Compaction Characteristics of Expansive Soil

The individual influence of Granulated blast furnace slag (GGBS) on the Compaction of expansive soil is clearly presented in table 4 and Figures 3 and 4. The percentage of Ground Granulated blast furnace slag (GGBS) was varied from 0%, to 40% with an increment of 10%. From the above graphs, it was observed that the treatment as individually with 20% Ground Granulated blast furnace slag (GGBS) has moderately improved the expansive soil. It can be inferred from the graphs, that there is a gradual increase in maximum dry density with an increment in the % replacement of Ground Granulated blast furnace slag (GGBS) up to 40% with an improvement of about 10% and it was about 2.85% for strength.

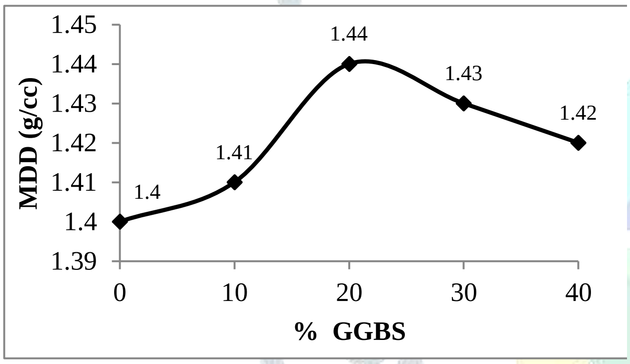

Fig .3Variation of MDD with Different % of GGBS

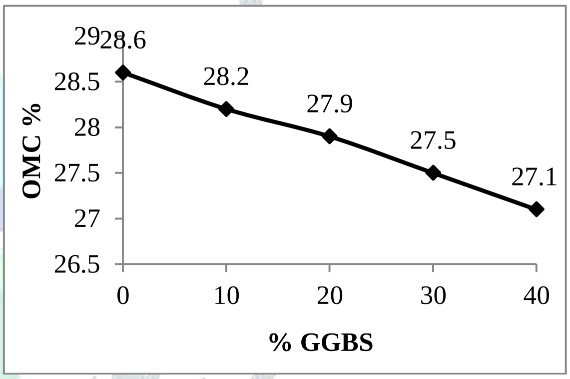

Fig .4: Variation of OMC with % Different of GGBS

Effect of Ground Granulated Blast Furnace Slag (GGBS) on the CBR and UCS of Expansive Soil

The individual influence of Granulated blast furnace slag (GGBS) on the CBR and UCS of expansive soil are clearly presented in table 4 , Figures 5 and 6. The percentage of Ground Granulated blast furnace slag (GGBS) was varied from 0%, to 40% with an increment of 10%. From the above graphs, it was observed that the treatment as individually with 20% GGBS has moderately improved the expansive soil. It can be inferred from the graphs, that there is a gradual increase in CBR VALUES with an increment in the % replacement of Ground Granulated blast furnace slag (GGBS) up to 40% with an improvement of about 10% and it was absorbed that for the replacement of 20% there is an increment of 106% for CBR(S) and 33.78% for UCS on expansive soil.

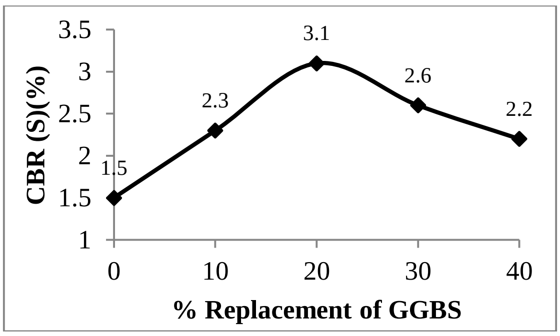

Fig .5 Variation of CBR with Different % of GGBS

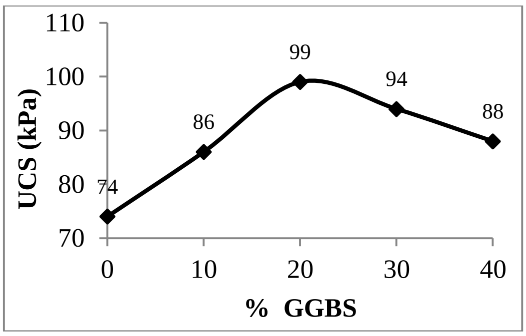

Fig .6: Variation of UCS with Different % of GGBS

Finally, from the above discussions, it is clear that there is improvement in the behaviour of Expansive soil stabilized with Ground Granulated blast furnace slag (GGBS). It is evident that the replacement of Ground Granulated blast furnace slag (GGBS) to the virgin Expansive soil showed an improvement in Compaction and Strength characteristics to some extent. From the above results the 20% replacement of Expansive Soil with GGBS can be considered.

Laboratory tests were done on the expansive soil with 20% optimum GGBS with different percentage addition of POFA and the results are furnished below in the Table.5 and Figs. 8 to 14 respectively.

Table. 5 Variation of Geotechnical Properties of Expansive Soil Treated 20% GGBS and Different Percentages of POFA

POFA (%)	DFS (%)	LL (%)	PL (%)	MDD (g/cc)	OMC (%)	CBR (%)	UCS (kPa)
0	91	67.7	28.6	1.44	27.9	3.1	99
3	77	60.4	30.5	1.46	27.5	4.9	112
6	53	55.9	32.4	1.49	26.7	6.1	126
9	45	50.2	34.1	1.47	26.1	5.3	117

Effect of % of POFA on Expansive Soil + 20% GGBS on Differential Free Swell

The influence of POFA as a binder on the Swell properties of expansive soil is clearly presented in table 5 and Figure 7. The percentage of POFA was varied from 0%, to 9% with an increment of 3%. From the above graphs, it was observed that the treatment as percentage replacement of GGBS and POFA as a binder up to 9% has moderately improved the expansive soil. It can be inferred from the graphs, it was observed that the swelling behaviour of Expansive is goes on decreasing for the percentage with an increment in the % addition of POFA up to 9% with an improvement of about3%.

Effect of % of POFA on Expansive Soil + 20% GGBS on Atterberg's limits of Expansive Soil

The influence of POFA as a binder on the Atterberg's limits of expansive soil is clearly presented in table 5 and Figure 8. The percentage of POFA was varied from 0%, to 9% with an increment of 3%. From the above graphs, it was observed that the treatment as percentage replacement of GGBS and POFA as a binder with 6% has moderately improved the expansive soil. It can be inferred from the graphs, that there is a prominent results of Atterberg's limits on treated expansive soil with an increment in the % addition of POFA up to 9% with an improvement of about3%.

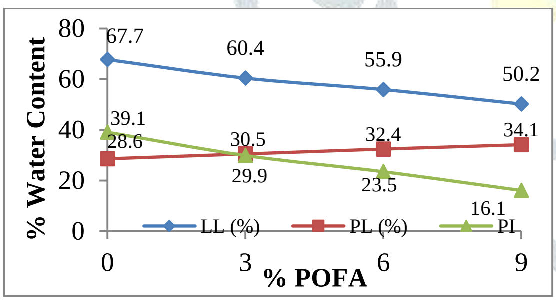

Fig .8: Variation of Atterberg's Limits with Different % of POFA

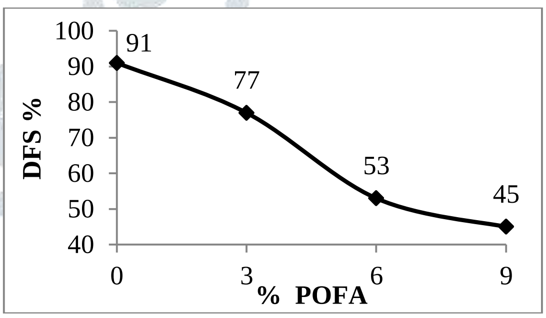

Fig .7: Variation of DFS with Different % of POFA

Effect of % of POFA on Expansive Soil + 20% GGBS on Compaction Characteristics of Expansive Soil

The influence of POFA as a binder on the compaction characteristics of expansive soil is clearly presented in table 5 and Figure .9 and 10. The percentage of POFA was varied from 0% to 9% with an increment of 3%. From the above graphs, it was observed that the treatment as percentage replacement of GGBS & POFA as a binder with 6% has moderately improved the expansive soil. It can be inferred from the graphs, that there is an increment in MDD for the 6% addition of POFA to the 20% replacement of GGBS is 3.47 %

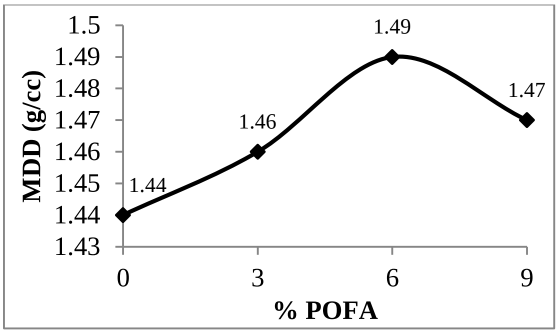

Fig .9: Variation of MDD with Different % of POFA

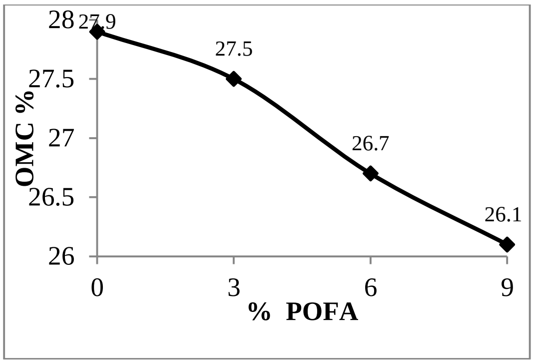

Fig .10: Variation of MDD with Different % of POFA

Effect of % of POFA on Expansive Soil + 20% GGBS on CBR and UCS of Expansive Soil

The influence of POFA as a binder on the CBR and UCS of expansive soil are clearly presented in table 5 and Figures 11 and 12. The percentage of POFA was varied from 0%, to 9% with an increment of 3%. From the above graphs, it was observed that the treatment as percentage replacement of GGBS and POFA as a binder with 6% has moderately improved the expansive soil. It can be inferred from the graphs, that there is a gradual increase in CBR VALUES with an increment in the % replacement of Ground Granulated blast furnace slag (GGBS) and 9% POFA as a binder and it was absorbed that for the replacement of 20% GGBS and 6% POFA there is an increment of 96.7% for CBR(S) and 27.2% for UCS on expansive soil

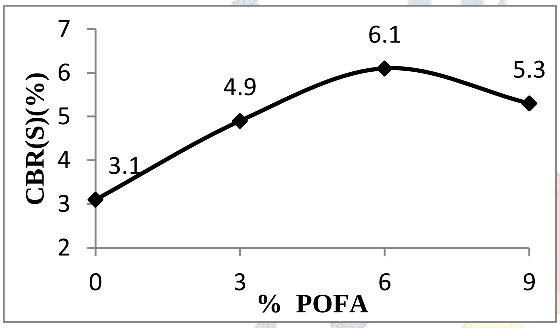

Fig .11: Variation of CBR with Different % of POFA

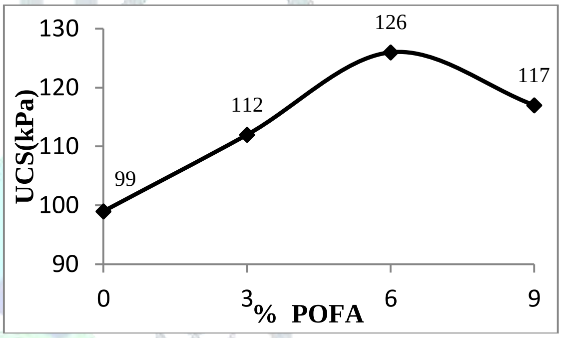

Fig .12: Variation of UCS with Different % of POFA

From the above discussions, it is clear that there is improvement in the behaviour of Expansive soil replaced with Ground Granulated blast furnace slag (GGBS) and POFA. It is evident that the addition of POFA to the percentage replacement of Ground Granulated blast furnace slag (GGBS) to the virgin Expansive soil showed an improvement in Compaction and Strength characteristics to some extent. From the above results the Optimum Content of POFA with 30% GGBS as replacement of Expansive Soil is 6%.

V.CONCLUSION

The following conclusions are made based on the laboratory experiments carried out in this investigation.

1. From the laboratory studies, it is observed that the Expansive Soil chosen was a problematic soil having high swelling, and high plasticity characteristics.
2. It was observed that the treatment as individually with 20% GGBS has moderately improved the expansive soil.
3. There is a gradual increase in maximum dry density with an increment in the % replacement of GGBS up to 40% with an improvement of about 10% and it was about 2.85% and further stabilized with POFA the strength characteristics increases about3.47%.
4. There is a gradual increase in CBR values with an increment in the % replacement of Ground Granulated blast furnace slag (GGBS) up to 40% with an improvement of about 10% and it was absorbed that for the replacement of 20% there is an increment of 106.25% for CBR(S) and 33.78% for UCS on expansive soil.
5. Further blending with POFA with a percentage of 0% to 9% with an increment of 3% there is a gradual increase in the dry density about 3.47% and there is a gradual increase in CBR values with an increment in the % replacement of Ground Granulated blast furnace slag (GGBS) and 9% POFA as a binder and it was absorbed that for the replacement of 20% GGBS and 6% POFA there is an increment of 96.7 % for CBR(S) and 27.2% for UCS on expansive soil.

Finally, it can be summarized that the materials Ground Granulated blast furnace slag (GGBS), POFA had shown promising influence on the strength characteristics of expansive soil, thereby giving a two-fold advantage in improving problematic expansive soil and also solving a problem of waste disposal.

REFERENCES

[1] Uppal HL. (1965),” Field Study on the Movement of Moisture in Black Cotton Soils Under Road Pavements” , symposium on Moisture Equilibria and Moisture Changes in Soils Beneath Covered areas, Butterworths, Australia, pp. 687–693.

[2] Mohan D, Rao BG.(1965)" Moisture variation and Performance of Foundations in Black Cotton Soils in India", Symposium and Moisture Equilibrium and Moistur Changes in Soils Beneath Covered Areas, Butterworth's, Australia, pp. 143–155.

[3] Desai MD.(1985)," Geotechnical Aspects of Residual Soils of India, Sampling and Testing of Residual Soils", A Review of Int Practice, pp. 83–98.

[4] Gyanen Takhelmayum, Savitha AL,Krishna Gudi,(2013)," Experimental Studies on Soil Stabilization Using Fine and Coarse GGBS", Int J Emerg Tech Adv Eng, Volume- 3(3), pp. 917–923..

[5] Asish Kumar Pathak, Pandey V. (2014), "Soil Stabilization Using Ground Granulated Blast Furnace Slag", International Journal of Engineering Research Applications, Volume- 4(4),pp. 164–171.

[6] Abhijith S andAruna T,(2015),"Effect of Sisal Fibre and GGBS on Strength Properties of Black Cotton Soil", International Journal of Innovative Research in Science, Engineering and Technology, Vol.4, Issue 7,pp.5409-5417.