A study on the Impact of Discrete Reinforcing Inclusions (DRI) on GGBS and Lime Modified Expansive Soils

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Abstract- *Expansive soils could be defined as soils whose volume changes with introduction of moisture i.e. swell or shrinkage with increase or decrease in moisture content respectively. Expandable soils, expansive clays, shrink-swell soils and heavable soils are some of the synonyms used for these soils. The more water expansive soils absorb, the more their volume increases. Expansion of ten or more percent is not uncommon. This change in volume can exert enough force on a building or other structure to cause damage. This type of soil will also shrink when they dry out. This shrinkage can remove support from the foundations causing subsidence. It can also develop fissures. These fissures facilitate the deep penetration of water when moist conditions or runoff occurs. The spontaneous shrinkage and swelling process can place repetitive stress on structures.*

In the present study an effort is made to improve the geotechnical properties of Expansive clay using ground granulated blast furnace slag (GGBS) and Lime. Expansive clay is replaced by 0% to 40% GGBS by weight of soil and Lime is added (0%, 3%, 6%, 9%) by dry weight of soil. A detailed laboratory study is carried out to study the compaction and unconfined strength properties before and after stabilization with GGBS and Lime and different reinforcing inclusions.

Keywords- GGBS, discrete waste inclusions, expansive soil. LIME

I. INTRODUCTION

For centuries mankind was wondering at the instability of earth materials, especially expansive soil. One day they are dry and hard, and the next day wet and soft. Swelling soil always create problem for lightly loaded structure, by consolidating under load and by changing volumetrically along with seasonal moisture variation. As a result the superstructures usually counter excessive settlement and differential movements, resulting in damage to foundation systems, structural elements and architectural features.

Expansive soils are found in some regions of India and many other countries. These soils pose major foundation problems, causing damage to the super structure if proper precautions have not been taken. The expansive soils, with their expanding lattice structure and resulting capacity for wide ranges in water contents, can be particularly troublesome. Settlement due to shrinkage and heave due to swelling causes structural instability. This problem is magnified in hydraulic structures. For any land-based structure, the foundation is very important and has to be strong to support the entire structure. In order for the foundation to be strong, the soil around it plays a very critical role. So, to work with soils, we need to have proper knowledge about their properties and factors which affect their behavior. The process of soil stabilization helps to achieve the required properties in a soil needed for the construction work.

The objective of the present work is to study the experimental programme undertaken to investigate the relative performance of an industrial waste (partial replacement of expansive soil with optimum percentage of Fly ash (FA)) and different randomly distributed discrete waste inclusions in combination, on the behavior of a problematic expansive soil.

This project report deals with the complete analysis of the improvement of soil properties with different reinforcing inclusions and its stabilization using different waste materials like GGBS and LIME.

The study is focused on

- Improvement of locally available soil using some eco-friendly and cheap waste materials.
- Evaluation of strength characteristics of virgin as well as blended soil using different ratio of GGBS, LIME and Different reinforcing inclusions.
- Determination of appropriate soil, GGBS and lime content ratio to achieve the maximum gain in strength from the mixture.

II. REVIEW OF LITERATURE

Expansive soils are composed primarily of hydrophilic clay minerals, such as Montmorillonite, and with significant swelling and shrinking characteristics. Compared with the common clay, expansive soil has three characteristics, expansive, crack and over-consolidation. Crack is concentrated expression of expansion and over consolidation. With the decline of water content expansive soil will shrink and result in crack the changing of environment leads to drying and wetting effect and the crack will further develop.

PARIMAL JHA , NISHEET TIWARI (APRIL-MAY 2016) performed a research on black cotton soil & described that Black Cotton Soils exhibit high swelling and shrinking when exposed to changes in moisture content and hence have been found to be most troublesome from engineering considerations. This behaviour is attributed to the presence of a mineral montmorillonit. The wide spread of the black cotton soil has posed challenges and problems to the construction activities. To encounter with it, innovative and non traditional research on waste utilization is gaining importance now a days. Soil improvement using the waste material like Slags, Rice husk ash, Silica fume etc., in geotechnical engineering has been in practice from environmental point of view. The main objective of this study is to evaluate the feasibility of using Rice Husk Ash with lime as soil stabilization material. A series of laboratory experiment has been conducted on 0.5% lime mixed black cotton soil blended with Rice Husk Ash in 10%, 20% and 30% by weight of dry soil.

MANDEEP SINGH , ANUPAM MITTAL (29 MARCH 2014) observed that, solid waste materials such as rice husk ash and waste tyres are used for this intended purpose with or without lime or cement. Disposal of these waste materials is essential as these are causing hazardous effects on the environment. With the same intention literature review is undertaken on utilization of solid waste materials for the stabilization of soils and their performance is discussed. Soil stabilization means alteration of the soils properties to meet the specified engineering requirements. Methods for the stabilization are compaction and use of admixtures. Lime and Cement was commonly used as stabilizer for altering the properties of soils. Earth reinforcement techniques with commonly used with mild steel rods, geo synthetics etc.

TAPASH KUMAR ROY (APRIL 29-MAY 4TH 2013) investigated the benefits of using rice husk ash (RHA) with clayey soil as the subgrade material in flexible pavements with addition of small amount of lime. Four ratios of RHA of 5%, 10%, 15% and 20% mixed with the clayey soil by weight of soil sample. Further for getting the better performance, lime has been added in this study in the varying proportions from 1% to 3% by weight of soil. The compaction characteristics and unconfined compressive strength tests were conducted on these different mixed soils. The test results shows that the rice husk ash can be used advantageously with addition of clayey soil and lime as cost effective mix for construction of subgrade of the roadway pavement.

DR. D. KOTESWARA RAO , G.V.V. RAMESWARA RAO , P.R.T. PRANAV (APRIL 29-MAY 4TH 2013) reported that The soil found in the ocean bed is classified as marine soil. It can even be located onshore as well. The properties of marine soil depend significantly on its initial conditions. The properties of saturated marine soil differ significantly from moist soil and dry soil. Marine clay is microcrystalline in nature and clay minerals like chlorite, kaolinite and illinite and non-clay minerals like quartz and feldspar are present in the soil. The soils have higher proportion of organic matters that acts as a cementing agent. Clay is an impermeable soil, meaning it holds water, as opposed to permeable soil that allows water to rapidly drain, like a gravel or sand. It is also an expansive soil, such as the marine clay which predominates in almost all countries of the world, which when shrinking or expanding, can damage foundations and structures. The shrink and swell movements are due to changes in soil moisture. Providing uniform soil moisture next to and under your foundation is the only best thing to reduce or minimize the damaging effects of expansive soil. Accumulation of various waste materials is now becoming a major concern to the environmentalists. Rice Husk ash is one such by-product from Timber industries and Wood cutting factories. Rice Husk ash by itself has little cementitious value but in the presence of moisture it reacts chemically and forms cementitious compounds and attributes to the improvement of strength and compressibility characteristics of soils. So in order to achieve both the need of improving the properties of marine clays and also to make use of the industrial wastes, the present experimental study has been taken up. In this paper the effect of Rice Husk ash and Lime on strength properties of marine clay has been studied.

LAXMIKANT YADU AND DR. R K TRIPATHY (2013) studied the effect of Granulated blast furnace slag and fly-ash stabilization on soft soil. The soil was classified as CI-MI as per Indian Standard Classification System. Different amount of GBS (3%, 6%, 9%, and 12%) and fly ash (3%, 6%, 9%, 12%) was mixed to the parent soil and both UCS and CBR are carried out. They found that there was an increase in maximum dry density but decrease in Optimum Moisture Content with increasing GBS content. Addition of GBS increased the UCS value and this increase was maximum up to 9% and then it started falling. In case of both soaked and unsoaked CBR samples, addition of GBS caused sharp increase in CBR value and it is maximum up to 6%. Hence they found out 3% fly ash + 6% GBS mix to be optimum.

AKINMUSURU (1991) put his effort in finding out the effect of mixing of GGBS on the consistency, compaction characteristics and strength of lateritic soil. GGBS content varied from 0% -15% by dry soil weight. He observed a decrease in both the liquid and plastic limits and an increase in plasticity index with increasing GGBS portion. Further, he observed that the compaction, cohesion and CBR increased with increasing the GGBS content up to 10% and then subsequently decreased. The angle of friction was to be decreased with increasing percentage of GGBS.

GUPTA AND SEEHRA (1989) studied the effect of lime-GGBS on the strength of soil. They found that lime-GGBS soil stabilized mixes with and without addition of gypsum, or containing partial replacement of GGBS by fly ash produced high UCS and CBR in comparison to plain soil. They also concluded that partial replacement of GGBS with fly ash further increased the UCS

SREERAMA RAO, G. SRIDEVI AND M. RAMA RAO (2009) 25 reported about heave studies on expansive clays with stabilized granulated blast furnace slag cushion. Experiments were also conducted to study the effect of the cement content as well as the cushion thickness on the heave of the black cotton soil bed. The study also aimed at comparing the performances of Granulated Blast Furnace Slag (GBFS) and the ground granulated blast furnace slag (GGBFS) and to study the effect of cushion thickness on the swelling behaviour of black cotton soil. It was reported that both the slag cushions, stabilized with cement, are effective in minimizing the swell of black cotton soils. For GGBFS, there is a significant reduction of heave at low cement contents itself but for GBFS, as the cement content is increased, the swell potential decreased steeply. 6% to 8% cement content has been found to be optimum. No such optimum was observed in GGBFS. As the thickness of the cushion increased, there was a corresponding decrease in the swell potential.

III. SOIL STABILIZATION

The soil stabilization means the improvement of stability or bearing power of the soil by the use of controlled compaction, proportioning or the addition of suitable admixture or stabilizers.

Mechanical stabilization:

This method involves the correctly proportioning of aggregates and soil, adequately compacted to get mechanically stable layer. The basic Principles of mechanical Stabilization are correct proportioning and effective compaction.

Soil Cement Stabilization:

Soil-cement is an intimate mix of soil, cement & water, compacted to form a strong base course. Cement modified soil refers to the compacted mix when cement is used in small proportions to impart some strength.

Soil Lime Stabilization:

Soil-Lime is used as modifier in high plasticity soils in lime stabilization. It also imparts binding action even granular soils. Lime could be used in powder form or pulverized form with soil to make a homogenous blend.

Soil Bituminous Stabilization:

The basic Principles of this Stabilization are water proofing and binding. By water proofing inherent strength and other properties could be retained. Bitumen stabilized layer may be used as Sub-base or base course for all the roads. Most commonly used materials are Cutback and Emulsion.

Thermal Stabilization:

Thermal change causes a marked improvement in the properties of the soil. Thermal stabilization is done by heating the soil or cooling.

Chemical Stabilization:

Soils are stabilized by different chemicals. The advantage of chemical stabilization is that setting time and curing time can be controlled.

MATERIALS USED AND THEIR PROPERTIES

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

Soil

The soil used was a typical black cotton soil collected from ‘Mummidivaram’ near Amalapuram, in East Godavari District, Andhra Pradesh State, India. The properties of soil are presented in the Table All the tests carried on the soil are as per IS specifications.

Table 1. shows properties of soil.

Properties of Expansive Soil		
S. No.	**Property**	**Value**
1	Specific gravity	2.63
2	Differential free swell Index (%)	100
3	Atterberg's Limits	
	i) Liquid limit (%)	64.6
	ii) Plastic limit (%)	24.1
	iii) Plasticity index (%)	40.5
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)	1.43
	ii) Optimum Moisture Content (%)	28
8	Penetration Parameters	
	i) CBR - Unsoaked (%)	3.2
	ii) CBR - Soaked (%)	1.6
9	Shear Parameters at OMC & MDD	
	i) Cohesion, Cu (kPa)	40
	ii) Angle of Internal Friction, Øu (Degrees)	0

Ground Granulated Blast Furnace Slag (GGBS)

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." In the production of iron, blast furnaces are loaded with iron ore, fluxing agents, and coke. When the iron ore, which is made up of iron oxides, silica, and alumina, comes together with the fluxing agents, molten slag and iron are produced. The molten slag then goes through a particular process depending on what type of slag it will become. Air cooled slag has a rough finish and larger surface area when compared to aggregates of that volume which allows it to bind well with portland cements as well as asphalt mixtures. GGBS is produced when molten slag is quenched rapidly using water jets.

WASTE PLASTIC FIBER

The bottled water is the fastest growing beverage industry in the world. According to the international bottled water association (IBWA), sales of bottled water have increased by 500 percent over the last decade and 1.5 million tons of plastic are used to bottle water every year. Plastic bottle recycling has not kept pace with the dramatic increase in virgin resin polyethylene terephthalate (PET) sales and the last imperative in the ecological triad of reduce / reuse / recycle, has emerged as the one that needs to be given prominence.

The general survey shows that 1500 bottles are dumped as garbage every second. PET is reported as one of the most abundant plastics in solid urban waste. In 2007, it was reported that the world's annual consumption of PET bottles is approximately 10 million tons and this number grows about up to 15% every year. On the other hand, the number of recycled or returned bottles is very low. On an average, an Indian uses one kilogram (kg) of plastics per year and the world annual average is an alarming 18 kg. It is estimated that approximately 4-5% postconsumer plastics waste by weight of Municipal Solid Waste (MSW) is generated in India and the plastics waste generation is more i.e. 6-9 % in USA, Europe and other developed countries.

LIME

The use of lime-soil mixture as a construction material has been known from ancient times in various parts of the world. Commercial Birla lime was used for this project.

TESTS CONDUCTED

1) DFSI
2) ATTERBERG LIMITS
3) COMPACTION
4) CBR
5) UCS

IV. RESULTS AND DISCUSSIONS

Details of the laboratory experimentation carried-out with different combinations of materials have been discussed in the previous chapter. In this chapter a detailed discussion on the results obtained from various laboratory tests done on untreated and treated expansive soil are presented.

In the laboratory, 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 lime 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 Lime as a binder.

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.

1. EFFECT OF % GROUND GRANULATED BLAST FURNACE SLAG (GGBS) AS REPLACEMENT ON THE SWELL CHARACTERISTICS OF EXPANSIVE SOIL

The individual influence of Ground Granulated blast furnace slag (GGBS) on the Swell characteristics of expansive soil are clearly presented in Figure 4.1. 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 treatment as individually with 30% Ground Granulated blast furnace slag (GGBS) has moderately improved the expansive soil. It can be inferred from the graphs, that there is a gradual decrease in free swell with an increment in the % replacement of Ground Granulated blast furnace slag (GGBS) up to 40% with an improvement of about 10%

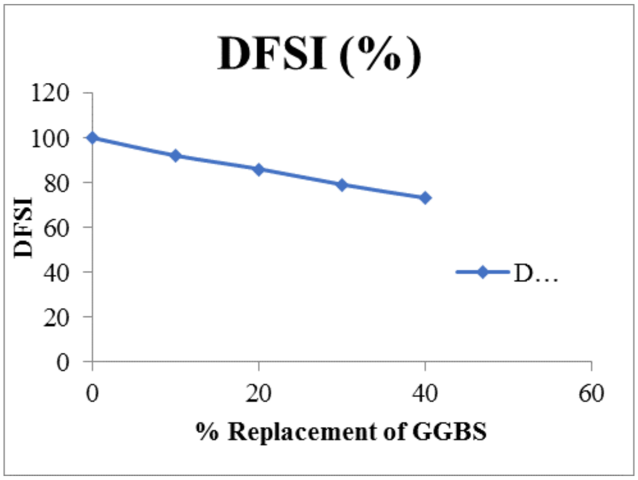

Figure 1. Variation of DFS with % replacement of GGBS

2. EFFECT OF % GROUND GRANULATED BLAST FURNACE SLAG (GGBS) AS REPLACEMENT ON THE ATTERBERG LIMITS OF EXPANSIVE SOIL

The individual influence of Ground Granulated blast furnace slag (GGBS) on the ATTERRBERG LIMITS of expansive soil are clearly presented in Figure 4.2. 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 30% Ground Granulated blast furnace slag (GGBS) has moderately improved the expansive soil.

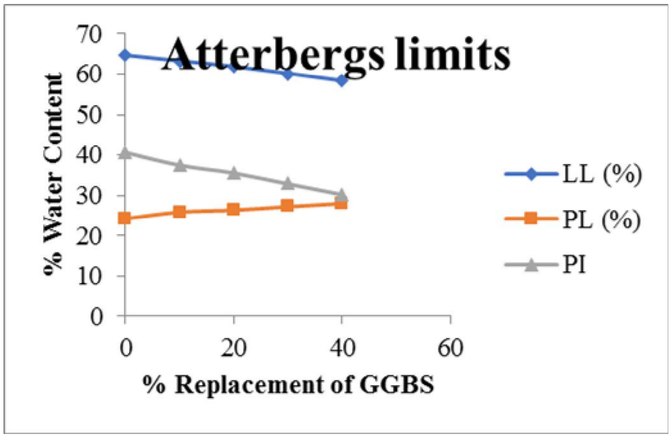

Figure 2. Variation of ATTERBERG LIMITS with % replacement of GGBS

3. EFFECT OF % GROUND GRANULATED BLAST FURNACE SLAG (GGBS) AS REPLACEMENT ON THE COMPACTION CHARACTERISTICS OF EXPANSIVE SOIL

The individual influence of Granulated blast furnace slag (GGBS) on the Compaction of expansive soil is clearly presented in Figures 4.3 and 4.4. 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 30% 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 2.8% for strength characteristics.

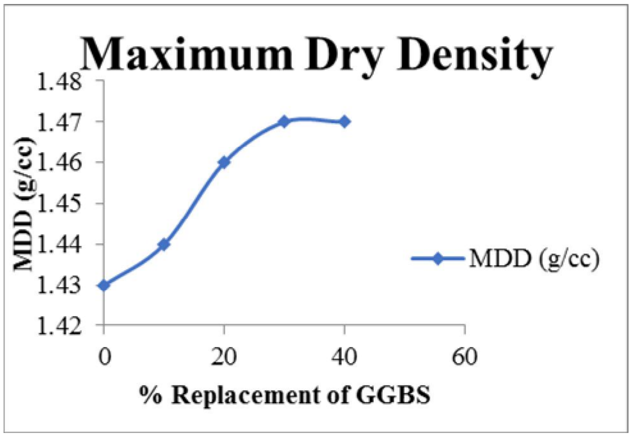

Figure 3. Variation of MDD with % replacement of GGBS

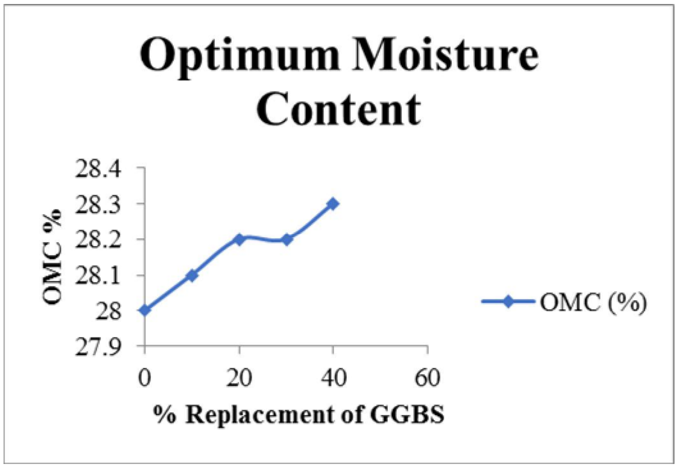

Figure 4. Variation of OMC with % replacement of GGBS

4. EFFECT OF % GROUND GRANULATED BLAST FURNACE SLAG (GGBS) AS REPLACEMENT 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 4.1, Figures 4.5 and 4.6. 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 30% 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 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 30% there is an increment of 31.25% for CBR (US) and 56.25% for CBR(S) and 37.5% for UCS on expansive soil.

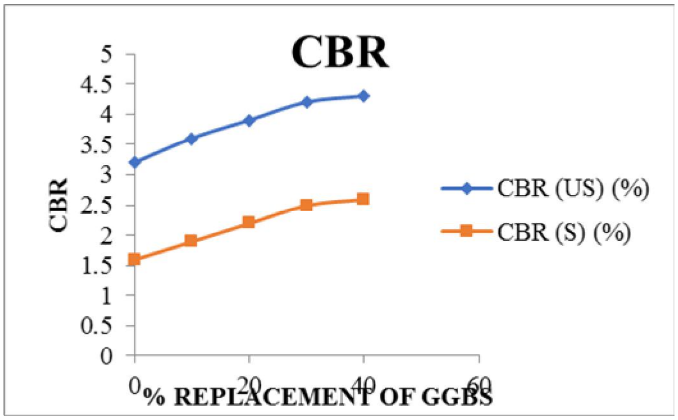

Figure 5. Variation of CBR with % replacement of GGBS

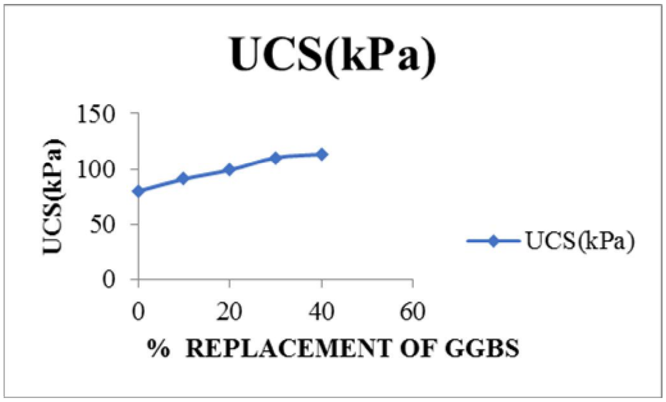

Figure 6. Variation of UCS with % replacement of GGBS

From the above results the 30% replacement of Expansive Soil with GGBS can be considered

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 30% replacement of Expansive Soil with GGBS can be considered and on further blending it with Different percentages of lime from 0% to 9% with an increment of 3%.

Laboratory tests were done on the expansive soil and 30% replacement of expansive soil with percentage addition of lime and the results are….

5. EFFECT OF LIME CONTENT ON THE STRENGTH CHARACTERISTICS OF EXPANSIVE SOIL + 30% REPLACEMENT OF GGBS ON THE SWELL CHARACTERISTICS OF EXPANSIVE SOIL

The influence of LIME as a binder on the Swell characteristics of expansive soil is clearly presented in table 4.2 and Figure 4.7. The percentage of lime 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 lime as a binder with 9% has moderately improved the expansive soil. It can be inferred from the graphs, that there is a gradual decrease in free swell with an increment in the % addition of lime up to 9% with an improvement of about 3%.

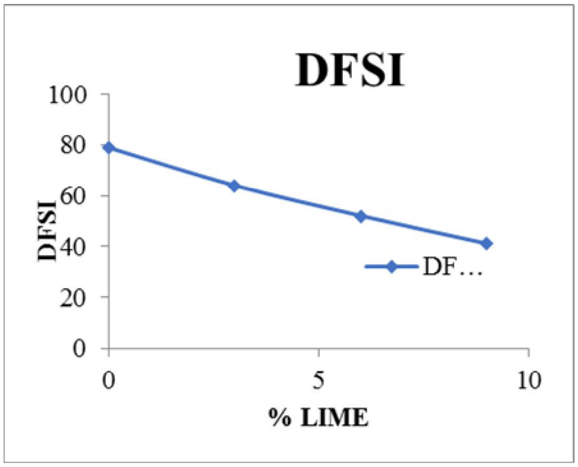

Figure 7. Variation of DFSI with % addition of LIME

6. EFFECT OF LIME CONTENT ON THE STRENGTH CHARACTERISTICS OF EXPANSIVE SOIL + 30% REPLACEMENT OF GGBS ON THE ATTERBERG LIMITS OF EXPANSIVE SOIL

The influence of LIME as a binder on the Atterberg limits of expansive soil are clearly presented in Figure 4.8. The percentage of lime 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 lime as a binder with 9% has moderately improved the expansive soil. It can be inferred from the graphs, that there is a prominent results of Atterberg limits on treated expansive soil with an increment in the % addition of lime up to 9% with an improvement of about 3%.

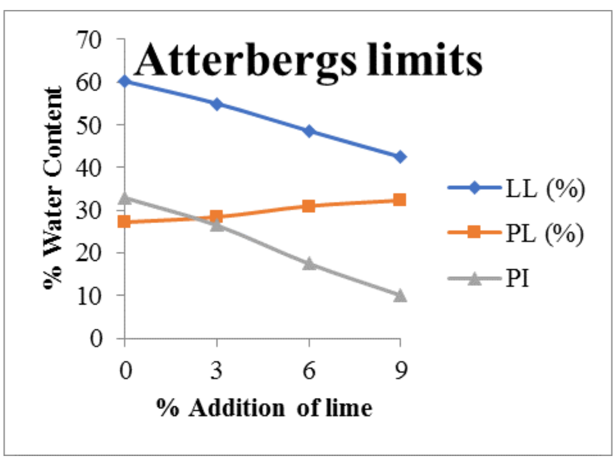

Figure 8. Variation of ATTERBERG LIMITS with % addition of LIME

7. EFFECT OF LIME CONTENT ON THE STRENGTH CHARACTERISTICS OF EXPANSIVE SOIL + 30% REPLACEMENT OF GGBS ON THE COMPACTION CHARACTERISTICS OF EXPANSIVE SOIL

The influence of LIME as a binder on the compaction characteristics of expansive soil are clearly presented in Figure 4.9. The percentage of lime 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 lime as a binder with 9% has moderately improved the expansive soil. It can be inferred from the graphs, that there is a increment in MDD for the 9% addition of lime to the 30 % replacement of GGBS is about 4.7 % and OMC DECREASED about 2.8%.

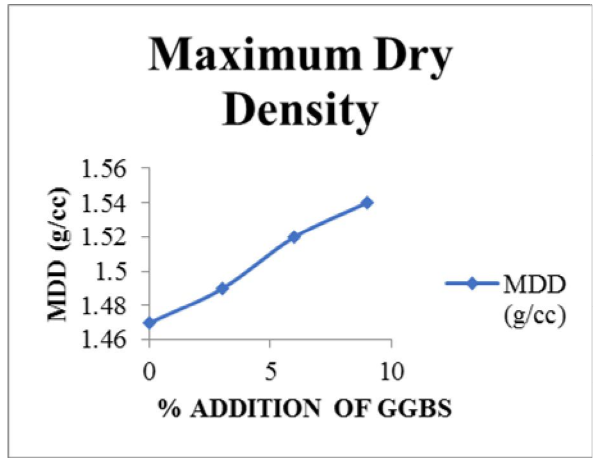

Figure 9. Variation of MDD with % addition of LIME

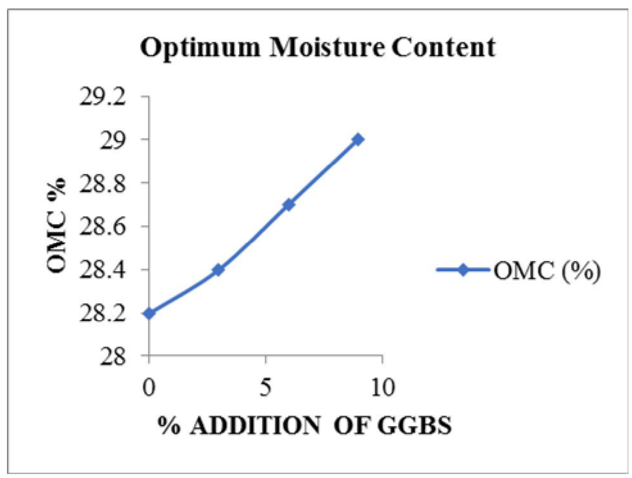

Figure 10. Variation of MDD with % addition of LIME

8. EFFECT OF LIME CONTENT ON THE STRENGTH CHARACTERISTICS OF EXPANSIVE SOIL + 30% REPLACEMENT OF GGBS ON THE CBR AND UCS OF EXPANSIVE SOIL

The influence of LIME as a binder on the CBR and UCS of expansive soil are clearly presented in Figures 4.11 and 4.12. The percentage of lime 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 lime as a binder with 9% 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% lime as a binder and it was absorbed that for the replacement of 30% GGBS and 9% lime there is an increment of 101 % for CBR (US) and 160% for CBR(S) and 52% for UCS on expansive soil.

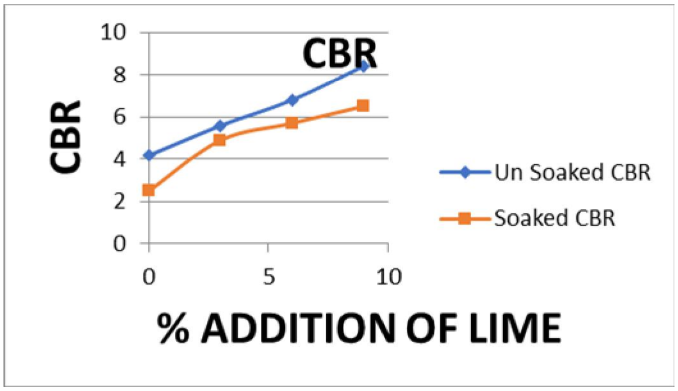

Figure 11. Variation of CBR with % addition of LIME

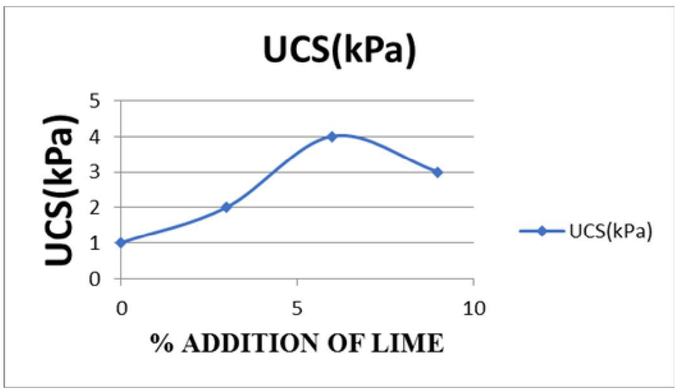

Figure 12. Variation of MDD with % addition of LIME

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 lime. It is evident that the addition of lime 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 Lime with 30% GGBS as replacement of Expansive Soil is 9% and on further blending it with Different percentages of DRI (Different Reinforcing Inclusions) from 0% to 2% with an increment of 0.5%. Laboratory tests were done on the expansive soil and 30% replacement of expansive soil with 9% addition of lime and different percentages of DRI Inclusions and the results are….

Table 4.3: showing the results of the tests conducted on expansive soil replaced with 30 % of GGBS and 9% addition of lime and different percentages of DRI

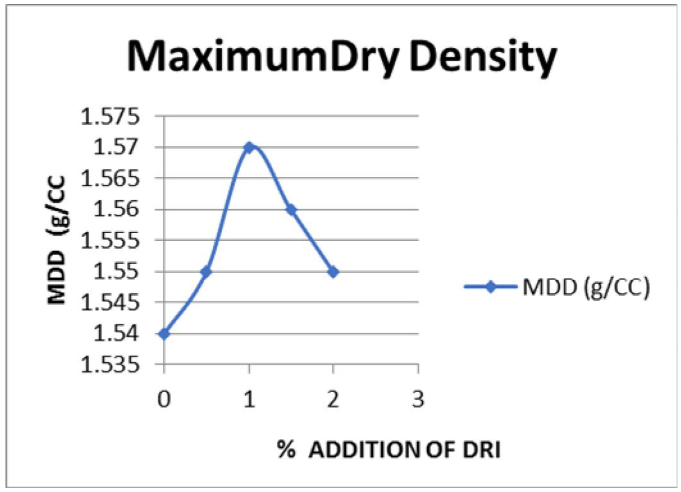

Figure 13. Variation of MDD with % addition of DRI

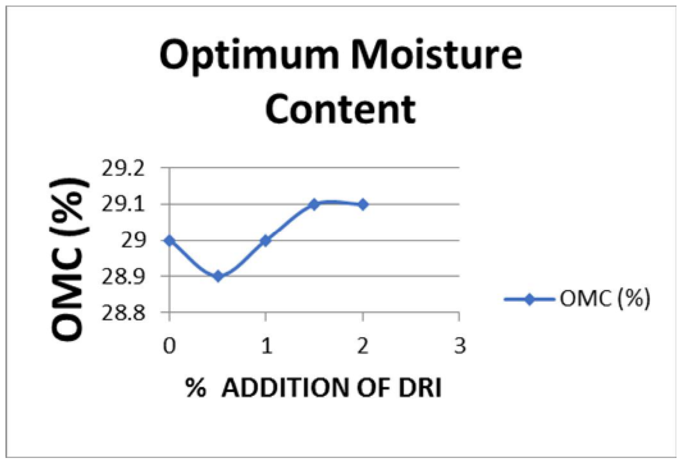

Figure 14.Variation of OMC with % addition of DRI

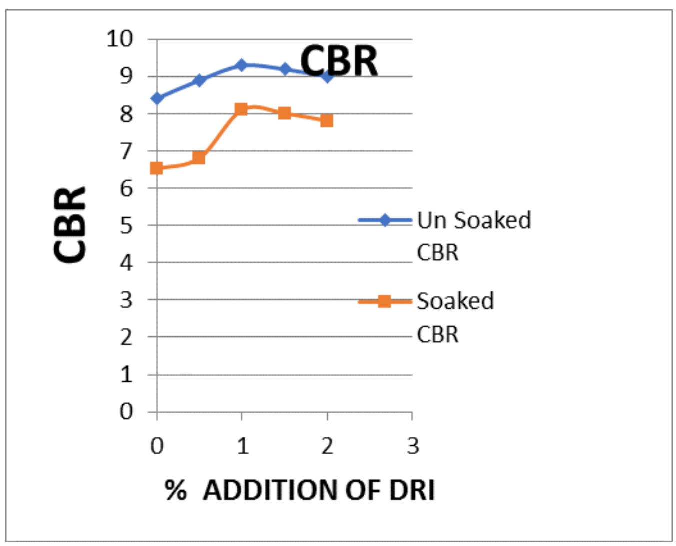

Figure 15. Variation of CBR with % addition of DRI

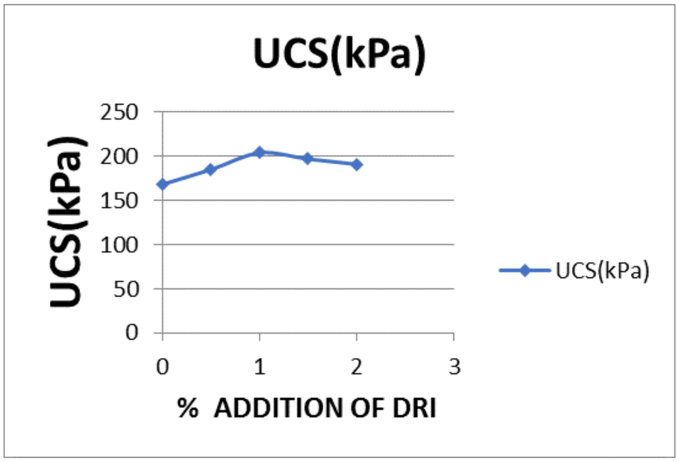

Figure 16. Variation of UCS(kPa) with % addition of DRI

From the above results the Optimum Content of DRI with 9% Lime + 30% GGBS as replacement of Expansive Soil is 1.0%

9. DURABILITY STUDIES:

Durability studies done on the GGBS and LIME modified expansive soil with different reinforcing inclusions and the results obtained are.......

Table 4.4 showing durability studies on lime and GGBS modified Expansive soil

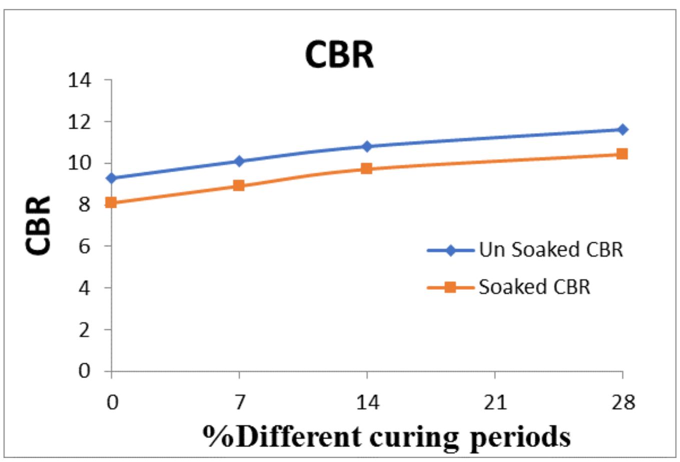

Figure 17. Variation of CBR with Different Curing Periods

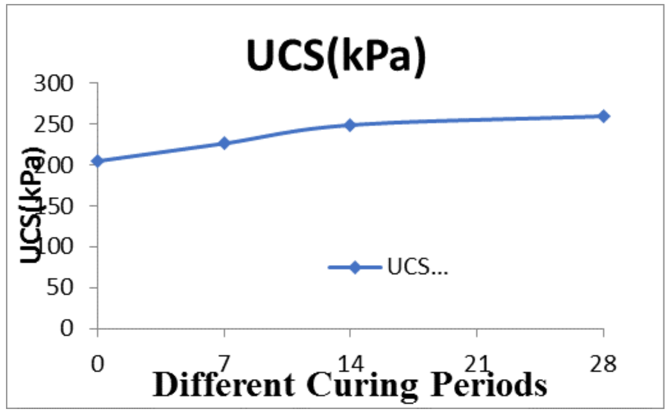

Figure 18. Variation of UCS (kPa) with % addition of DRI

V. CONCLUSIONS

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

- From the laboratory studies, it is observed that the Expansive Soil chosen was a problematic soil having high swelling, and high plasticity characteristics.
- It was observed that the treatment as individually with 30% GGBS has moderately improved the expansive soil.
- 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 2.8% for strength characteristics.
- 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 30% there is an increment of 31.25% for CBR (US) and 56.25% for CBR(S) and 37.5% for UCS on expansive soil.
- Further blending with lime with an percentages of 0% to 9% with an increment of 3% there is a gradual increase in the dry density about 4.7% and there is a gradual increase in CBR VALUES with an increment in the % replacement of Ground Granulated blast furnace slag (GGBS) and 9% lime as a binder and it was absorbed that for the replacement of 30% GGBS and 9% lime there is an increment of 101 % for CBR (US) and 160% for CBR(S) and 52% for UCS on expansive soil.
- Further blending it with Different percentages of DRI (Different Reinforcing Inclusions) from 0% to 2% with an increment of 0.5%. Laboratory tests were done on the expansive soil and 30% replacement of expansive soil with 9% addition of lime and different

percentages of DRI Inclusions and 1.0% different reinforcing inclusions shows prominent results.

- Durability studies done on the GGBS and LIME modified expansive soil with different reinforcing inclusions and the results obtained are there is an increase of 24% in CBR(US) and 28% in CBR(S) and 27% for UCS.

Finally it can be summarized that the materials Ground Granulated blast furnace slag (GGBS), lime and Different Reinforcing Inclusions 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.

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