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STRENGTH CHARACTERISTICS OF CLAYEY SOIL STABILIZED WITH LIME AND GGBF SLAG

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Abstract — *Rapid industrialization and urbanization has made it mandatory to carry out construction activities on low bearing soils, which needs to improve the engineering performance of soils. Modification with Portland cement and lime being costlier increases the overall cost of the project and also cause severe environmental hazards. The aim of this research work is to study the suitability of Ground Granulated Blast Furnace Slag (GGBS) with lime as a stabilizer of soil. Use of this blend may develop new opportunities to improve the engineering properties of the soil. For the current research work, low plastic clayey soil sample was collected from Sanand region of Gujarat, India. The optimum lime content was determined as 5% by dry weight of soil using Eades and Grim's pH method. The GGBF Slag replaces lime in proportion of Lime:GGBF Slag ratio of 5:0, 4:1, 3:2, 2:3, 1:4 and 0:5.Based on unconfined Compressive Strength results, it has been observed that the Lime can be successfully replaced by GGBF Slag up to 60%.*

Keywords- *Soil Stabilization, Unconfined Compressive Strength, GGBF Slag Stabilization, Lime Stabilization, Stress-strain relationship*

I. INTRODUCTION

These days in most of the construction projects, the available site is not often suitable for the design requirements. The current practice is to modifying the engineering properties of the problematic soils to meet the design specifications. Nowadays, soils such as, soft clays can be improved by various methods from which soil stabilization using cement, lime or other admixtures is one of the several methods of soil improvement. The use of industrial waste products as supplements of construction materials is the demand of an hour. Fly ash-a waste product of thermal power plant has been widely used as a cement supplement due to its cementitious properties. Ground Granulated Blast Furnace (GGBF) slag is the by-product in the production of pig iron, which is extensively used as a substituting material of cement in the production of high strength concrete.

Suitability of Ground Granulated Blast Furnace (GGBF) slag as a stabilizing agent of soil has been investigated by many researchers. Anil Kumar Sharma & P.V. Sivapullaiah investigated that the strength characteristics of soil depends upon the amount of GGBF slag used. The compressive strength of soil increases with the addition of GGBS up to 20% for curing period of 7 and 14 days and up to 40% at 28 days.

K.V. Manjunath et al. have studied the effectiveness of blend of GGBF slag and lime as a stabilizer in the red soil. The results show that the improvement in unconfined compressive strength was drastic when blend of 30% Slag and 4% lime was mixed with soil. The reason for this may be 4% lime may be enough to activate the GGBF Slag as a stabilizer.

The objective of this research work is to investigate the suitability of Ground Granulated Blast Furnace slag as a substituting material to lime in the soil stabilization. For this purpose, the optimum lime content will be fixed using Eades and Grim's pH method. The Ground Granulated Blast Furnace slag will be replaced with Lime in the progressive substitution.

II. Materials Used

2.1 Soil Sample

Soil sample for the current research work was procured from Sanand region of Gujarat, India using method of disturbed sampling. Chemical compositions of collected soil sample have been described in Table 1.

2.2 GGBF Slag

Ground Granulated Blast Furnace slag was collected from the RMC plant where it is being used as the partial substitution of cement in manufacture of concrete. Chemical properties of GGBF slag have been mentioned in the Table 1.

2.3 Lime

Quick lime was purchased from the market and it was hydrated in the laboratory using distilled water.

Table 1 Chemical Analysis of Soil and GGBF Slag

Constituent	Soil Sample	GGBF Slag
SiO_2	62.40%	30%
Al_2O_3	18.30%	19%
FeO	10.78%	-
MgO	2.94%	5%
K_2O	2.48%	-
CaO	2.05%	42%
Na_2O	1.04%	-
MnO_2	-	0.15%

III. EXPERIMENTAL DESIGN

Optimum Lime content is to be determined using pH method given by Eades and Grim (1966), which is also mentioned in IRC 51:1992 "Guidelines for the use of Soil-Lime mixes in road construction". As per this method, blend of soil and lime is mixed with 100ml of distilled water. The pH value of mix should be 12.4 corresponding optimum content of lime for stabilization of soil. Hence, determined Lime content will be replaced with the GGBF Slag in a progressive manner.
The Unconfined Compressive Strength is to be performed on each content at 3 days, 7 days and 28 days of curing period to provide sufficient time for hydration process to take place. The samples for UCS were prepared in the PVC mould of 40mm in diameter and 80mm in height at Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of each content. The prepared samples were wrapped in a plastic food wrapping at room temperature for desired curing period as mentioned in ASTM D 4609-01.

Figure 1 Mositure Retaining Technique used for UCS Samples

IV. RESULTS AND DISCUSSION

The laboratory tests conducted on virgin soil include Atterberg's limits, pH value, Specific Gravity, Free Swell Index, Standard Proctor Compaction, and UCS. All the properties of soil were determined as per the methods of Indian Standards (IS).

The soil is identified as low plastic clay (CL) type as per Indian Standard Classification System. The Specific Gravity and pH of virgin soil was found out to be 2.70 and 7.50 respectively. The engineering properties of raw soil have been tabulated in table 2.

Table 2 Properties of Soil

Soil Characteristics	Value
Specific Gravity	2.70
Liquid Limit	32%
Plastic Limit	21%
Plasticity Index	11%
Soil Classification	CL
Free Swell Index	9.09%
pH Value	7.5
UCS Value	47.75 kPa

The optimum lime content was fixed using Eades and Grim's pH test. The results show that the optimum lime content for stabilization of the soil in this case is 5% by dry weight of soil. Fig 3 shows the results of Eades and Grim's pH test. Different solution of soil, lime and water were prepared and pH values of each were determined.

Figure 2 Determination of pH Value

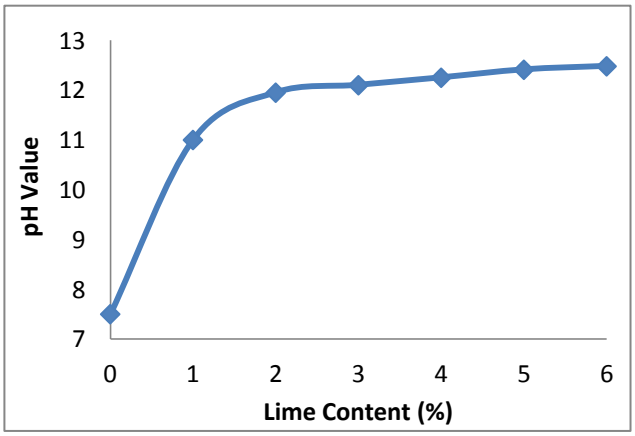

Figure 3 Optimum Lime Content Determination

This 5% of Lime by dry weight of soil was substituted with GGBF Slag in the progressive manner. Lime:GGBF ratio of 5:0, 4:1, 3:2, 2:3, 1:4 and 0:5 were used with soil to check out the effect of lime replacement on the strength characteristics of soil.

Table 3 Sample Formulation

Formulation	Lime Content (%)	GGBF Slag Content (%)
5L0S	5	0
4L1S	4	1
3L2S	3	2
2L3S	2	3
1L4S	1	4
0L5S	0	5

4.1 Standard Proctor Test curves for GGBF Slag substituting Lime

The Standard Proctor tests were carried out on each variation in accordance with IS: 2720 (Part VII). The Optimum Moisture Content (w) and Maximum Dry Unit Weight (γ_d) were determined as 12,80% and 19,18 kN/m^3.

Addition of lime the optimum moisture content (w) increases to 14,10% and maximum dry unit weight (γ_d) decreased to 17,90 kN/m^3. By substituting GGBF Slag with lime, the optimum moisture content (w) reduced and Maximum Dry Unit

Weight (γ_d) increases. A fluster in Maximum Dry Unit Weight (γ_d) takes place at 3L2S. The standard proctor test curves are shown in figure 4. The variation in OMC and MDD is represented in figure 5.

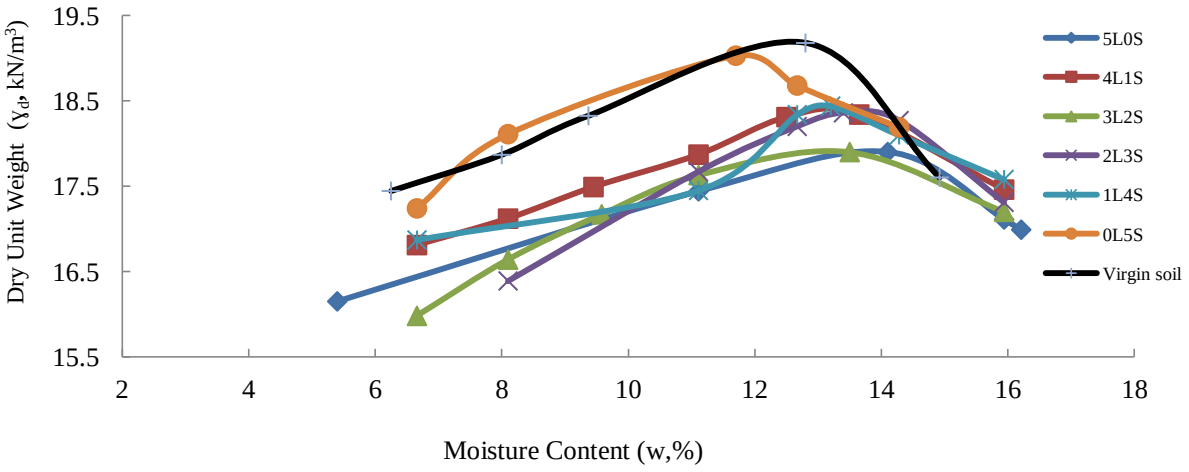

Figure 4 Standard Proctor Test curves for GGBF Slag substituting Lime

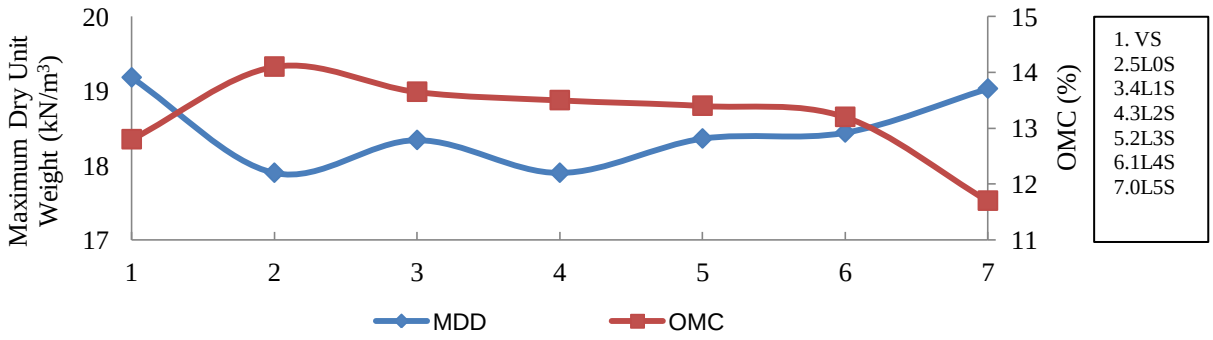

Figure 5 Variation in OMC and MDD for GGBF Slag substituting Lime

4.2 Unconfined Compressive Strength Test Results

In this research work, total 54 unconfined Compressive strength tests were done on various contents of Lime and GGBF Slag with soil. Stress-Strain curves of each test were plotted for each test. The mean value of Unconfined Compressive Strength of virgin soil was calculated as 47.75 kPa and strain at failure was observed to be about 5%.

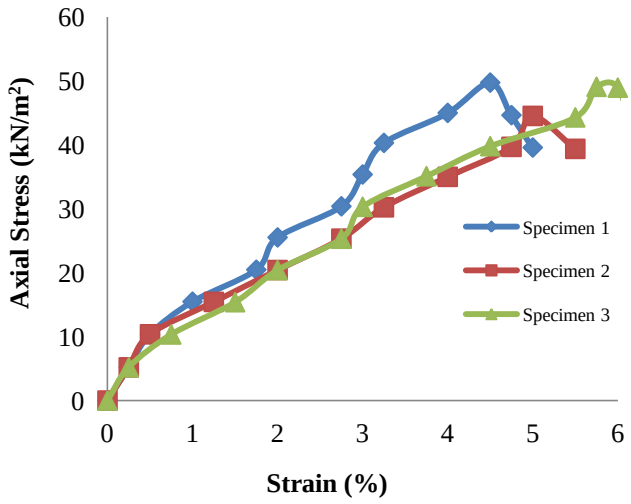

Figure 6 Stress-Strain relationship in Virgin

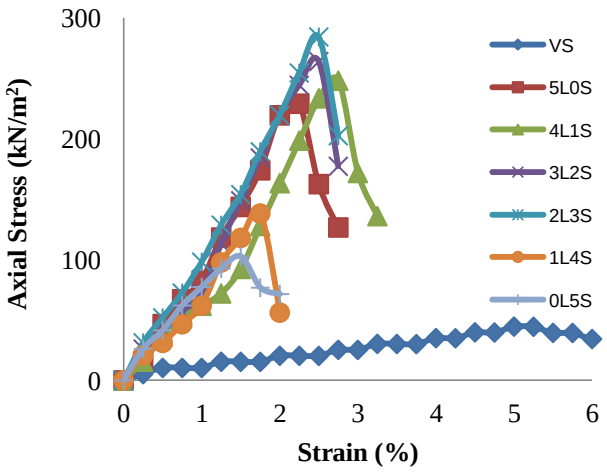

Figure 7 Stress-Strain relationship in GGBF Slag substituting Lime at 3 days of curing

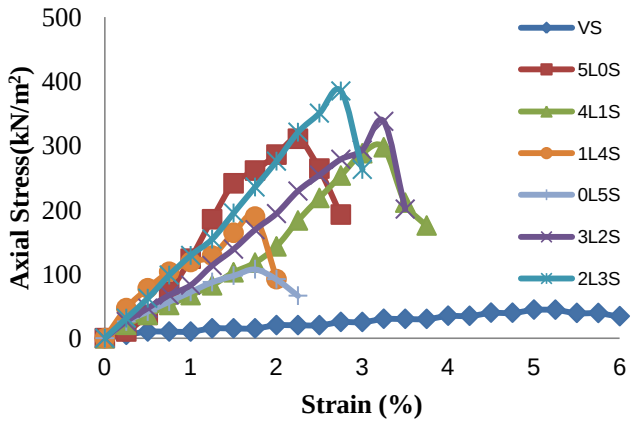

Figure 8 Stress-Strain relationship in GGBF Slag substituting Lime at 7 days of curing

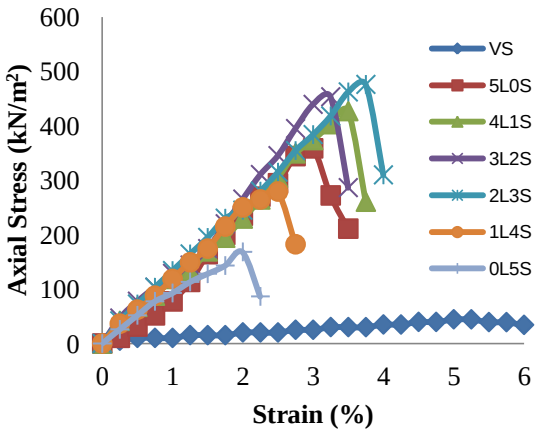

Figure 9 Stress-Strain relationship in GGBF Slag substituting Lime at 28 days of curing

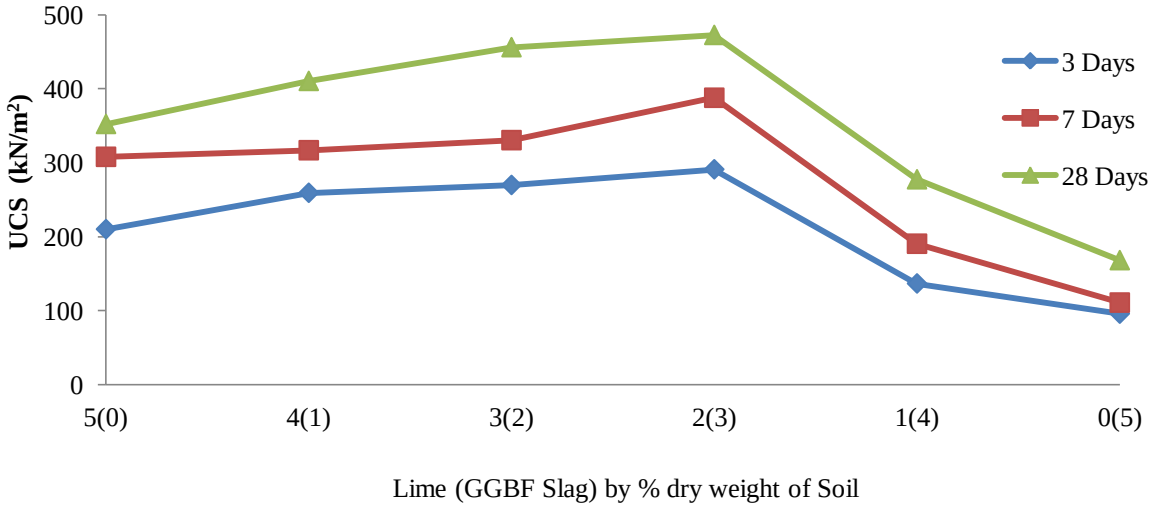

Figure 9 Effect of Curing age on the UCS of GGBF Slag substituting Lime

Figure 9 shows the effect of curing age on the strength characteristics of treated soils. It can be seen that by replacing lime with GGBF Slag the early as well as later strength increases since $Ca(OH)_2$ activates GGBF Slag rapidly compared to other alkali activators. It can be also seen that the self hardening property of GGBF Slag alone is very low so the strength increase is not much pronounced**.**

V. CONCLUSION

The current research work was undertaken to check the effectiveness of GGBF Slag as a soil stabilizing agent with lime. Lime is used as activator of GGBF Slag to enhance the strength of soil. Following conclusions can be made based on the study conducted here.

- GGBF Slag can substitute the lime by 60% as the unconfined compressive strength of soil stabilized using blend of 2% lime and 3% GGBF Slag is maximum.
- Lime can activate GGBF Slag for soil stabilization to produce compounds like C-S-H, C-A-H and C-S-A-H gel which are ultimately responsible for enhancement of strength.
- The unconfined compressive strength of soil has though increased but strength achieved at 28 days is not much desirable when GGBF Slag alone is used. Hence the self hardening process of GGBF Slag alone is not much effective.

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