

Effect of addition of GGBS and lime in soil stabilisation for stabilising local village roads in Thanjavur region

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Abstract. Construction of pavements uses various filling materials and due to the cost factor, the local soil is used for pavement construction. The strength of the soil is improved by stabilisation. This stabilisation increases the load bearing capacities of soil for heavy wheeled vehicle traffic. GGBS, silica fume, rice husk are the basic waste materials used as a waste material, which improves the quality of soil and reduces the cost of pavements. In this study, a detailed investigation is made on the Ground Granulated Blast-furnace Slag (GGBS), activated by lime, in the stabilisation of low bearing capacity sand and clay soils collected from Thanjavur district (Budalur, Sengipatti, Vallam and Palliahgraharam villages). The tests are carried out as per Indian Standards. The test procedures separated into two phases, namely Stage-I and Stage-II. In Stage-I the soil tests include soil type, particle size distribution, soil index properties, standard proctor tests, shear tests and CBR test. In Stage-II the soil tests include shear tests and CBR test for the suitable required proportions of GGBS along with lime in the collected soil samples. The test results from stage-I and stage-II are compared and from the study, it is inferred that the application of GGBS is a useful material for soil stabilisation.

1. Introduction

In India, major problems associated with the construction of village road are the preparation of subgrade. In many of the cases, the newly constructed road deteriorates rapidly due to the poor subgrade. If the in-situ subgrade soil doesn't have enough strength properties, that local soil is needed to be removed and is replaced by the better and healthier soil from the nearby available areas. The transportation of subgrade soil to those local areas is mostly uneconomic and increase the cost of the project exponentially. Soil stabilisation is the best way to make the construction more feasible and cost effective. For efficient and economic stabilisation, we need to utilise the Stabilising techniques for existing soil by adding some chemicals or some waste materials-fly ash, GGBS, iron slag, natural fibres, etc., In this project, the soil is Stabilised by adding GGBS, with lime activators to enhance the soil properties and strength aspects. The process of adding GGBS and lime will induce the calcium silicate hydrate bond in the soil, this would help in the formation of cementitious substance in soil.

GGBS or GGBFS (Ground Granulated Blast Furnace Slag) is the waste product drawn by the rapid cooling of molten iron slag. It is obtained from steel manufacturing process. In order to make use of GGBS, an attempt has been made for adopting it in soil stabilisation. From the previous studies, it is clear that the GGBS induces the strength of cement and is extensively used as cement additives. This can be implemented in the soil for stabilisation, but the results of addition of GGBS alone in soil will not giving sufficient satisfactory results. GGBS is mixed with lime (CaO) in the form of lime powder, lime is used as the activator in this process to initiate the bonding of soil with GGBS. Due to the



inclusion of lime and GGBS, there is a significant decrement in linear expansion of lime stabilised clays.

Lime is also one of the old construction material in practice from the ancient time. Lime stabilisation is one of the common methods of stabilising soil, due to its resourceful and economic usage. The finding from the previous studies shows that, on addition of lime is added to clay soils induces flocculation. This induces variations in the engineering and index properties of soil. The studies reported in the literature indicates the addition of lime increased the optimum water content, swelling potential, liquid limit, plasticity index, shrinkage limit and maximum dry density of the soil. The findings from studies shows the optimum usage of lime in soil will be 1% by its dry weight, from this finding the 1% of lime is used as an activator in this study. The work was intended to study the suitability of GGBS over different types of soil and to improve the soil strength by increasing its CBR value, shear resisting properties. To make efficient utilization the waste material from steel industries (GGBS) and finding out the optimal percentage of addition of GGBS to the soil for obtaining better results. To reduce the impact on the environment by excavating soil and hazardous chemical addition to soil and make pavement construction as cost effective and increase the life of local village roads in Thanjavur region.

2. Materials and Methodology

2.1 Materials

2.1.1 Soil. For the purpose of deep investigation, 4 representative samples collected from various places of Thanjavur district. Soil 1 is collected from Tirumalaisamudram village, Soil 2 from Vallam, Soil 3 from Palliahgraharam villages and Soil 4 from Muniyampatti village.

2.1.2 Lime. The lime is procured and used in the form of quicklime (CaO), in the form of a white powder and is obtained from limestone quarries site from Ariyalur zone. This lime has the specific gravity of 1.57.

2.1.3 GGBS. The GGBS is obtained as a fine white powder. The GGBS is obtained from Indian Steel Company in Salem. The GGBS used in this study is having a specific gravity of 2.68 and GGBS is used as basic additives for stabilisation.

2.2 Material Collection

A sequence of tests was carried out on soil specimens without adding any additives to collected soil and then followed by tests for soil samples with additives, in which GGBS is added at different proportions and lime in a constant percentage. The tests have been executed in two stages which includes Initial and preliminary soil test as stage-I and in stage-II soil is mixed with 2%, 4% and 6% of GGBS and 1% of lime. Soil samples are prepared by mixing 1% of lime by its dry unit weight and their respective proportions with GGBS by its dry unit weight. The suitability of the soil is accessed principally by the CBR (California Bearing Ratio) test value. In this study, the soil is classified and identified according to IS:1498 part 1-1970. Soil samples are prepared according to IS:2720 part 1-1983. Specific gravity test was done using IS:2720 part 3-1980. Subsequently, the liquid and plastic limit test and shrinkage limit tests were done in accordance with IS:2720 part 5 and 6 respectively. The optimum moisture content and maximum dry density of the soil samples using light compaction were determined using to IS:2720 part 7-1980 test methods. Using optimum moisture content the Unconfined Compressive Strength (UCC) of soil samples was determined according to IS:2720 part 10-1991. To conclude the study, the CBR value is found out for the result comparison, using the lab testing in accordance with IS:2720 part 16-1992.

2.2.1 Stage-I. For initial and preliminary soil test without any additives, following tests were performed in this stage.

- Specific gravity, sieve analysis, test for index properties for soil classification.

- Standard proctor test for accessing of maximum dry density and optimum moisture content.
- UCC/ direct shear and CBR test for determination strength properties.

2.2.2 *Stage-II*. In this stage, soil samples mixed with 2%, 4% and 6% of GGBS and 1% of lime by its dry unit weight. The soil with additives are tested for

- Standard proctor test for accessing of maximum dry density and optimum moisture for strength property tests.
- UCC/ direct shear and CBR test for determination strength properties.
- Based on the results obtained the strength characteristics of soil is analysed.

3. Test Results

The initial test results for all 4 samples are listed in Table 1. Test results for Soil 1, 2, 3 and 4 with 2, 4 and 6% of GGBS, with a constant 1% of lime are listed in Table 2-5.

Table 1. Soil properties without additives

Property	Soil 1	Soil 2	Soil 3	Soil 4
Soil Color	Red	Yellow	Black	Brown
Specific Gravity (no unit)	2.27	2.22	2.35	2.41
% of Gravel	1.37	7.07	0.25	0.53
% of Sand	48.60	76.96	42.61	21.70
% of Fines	52.60	14.50	56.75	75.14
Optimum Moisture Content (%)	13.60	12.20	14.20	17.80
Maximum Dry Density (g/cc)	2.46	2.45	2.35	1.80
Soil Type According to USCS	CH	SW	CL	CH

Table 2. Test Results for Soil 1

% of GGBS	0%	2%	4%	6%
Liquid Limit (%)	34.18	48.24	49.26	47.27
Plastic Limit (%)	19.50	25.69	23.35	25.43
Plasticity Index (%)	14.67	22.51	25.91	21.79
Unconfined Compressive Strength (KN/m ²)	128.00	210.00	275.00	270.00
CBR Value (%)	7.69	11.19	11.82	11.68

Table 3. Test Results for Soil 2

% of GGBS	0%	2%	4%	6%
Angle of Internal Friction (°)	33.07	36.75	41.00	38.26
Cohesion (KN/m ²)	26.33	23.47	4.44	2.66
Shear Strength (KN/m ²)	96.46	210.76	221.78	181.81
CBR Value (%)	10.58	16.42	24.82	23.36

Table 4. Test Results for Soil 3

% of GGBS	0%	2%	4%	6%
Liquid Limit (%)	34.95	28.80	38.01	29.54
Plastic Limit (%)	23.88	12.66	20.06	13.56
Plasticity Index (%)	11.07	16.14	17.95	15.98
Unconfined Compressive Strength (KN/m ²)	205.00	261.00	365.00	345.00
CBR Value (%)	6.81	10.22	14.11	9.85

Table 5. Test Results for Soil 4

% of GGBS	0%	2%	4%	6%
Liquid Limit (%)	57.84	66.42	70.31	65.50
Plastic Limit (%)	39.56	29.31	40.21	40.27
Plasticity Index (%)	18.29	37.11	30.10	25.24
Unconfined Compressive Strength (KN/m ²)	260.00	265.00	300.00	180.00
CBR Value (%)	8.91	14.26	17.52	14.10

4. Results and discussion

The above results signify that there is a significant amount of increase in CBR value up to 4% addition of GGBS and 4% is obtained as the optimum result, beyond 4% there is a reduction in CBR value. The variation of CBR for all samples are shown in the Figures below. The Figures 1, 2, 3 and 4 shows the penetration versus load Figure for soil 1, 2, 3 and 4 respectively.

The shear resting property of the soil is also increased with respect to the addition of GGBS and lime. The UCC strength also shows an increase in strength in clay soil samples. Up to 4% addition of GGBS, there is an increases the strength in soil 1, 3 and 4. The unconfined compressive strength of soil 1, 3 and 4 are shown in Figures. The Figure 5, 6 and 7 shows the strain versus stress Figure for soil 1, 3 and 4 respectively.

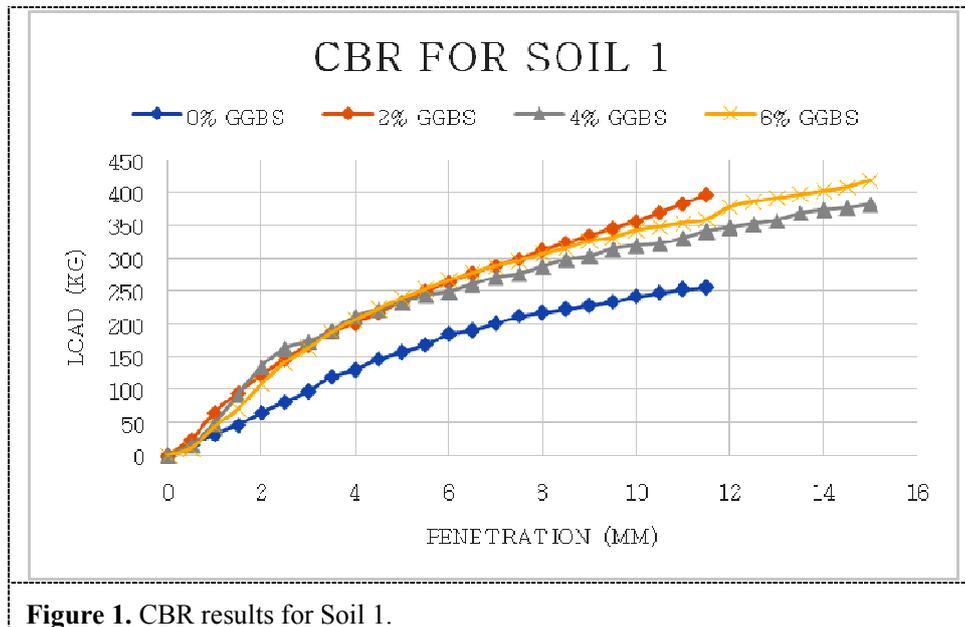


Figure 1. CBR results for Soil 1.

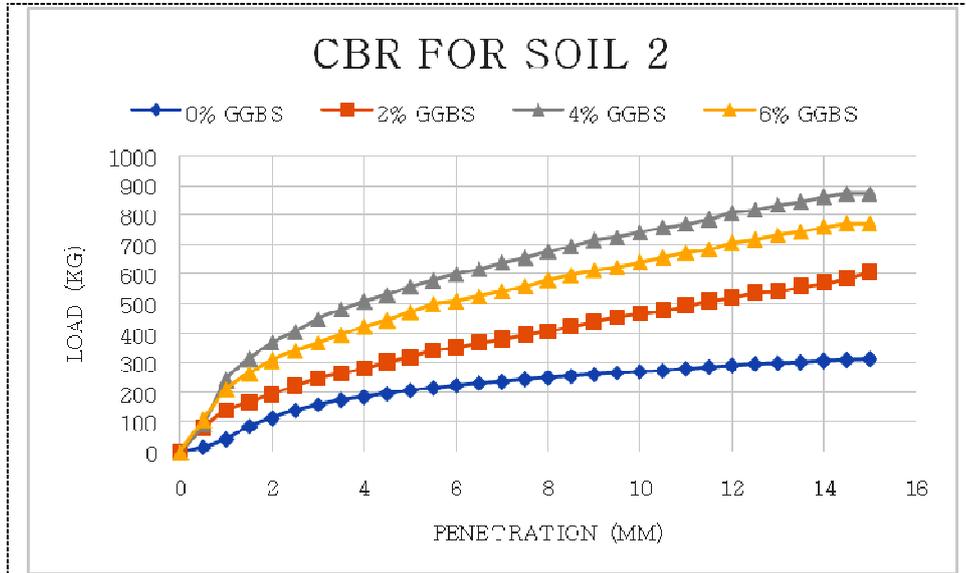


Figure 2. CBR results for Soil 2.

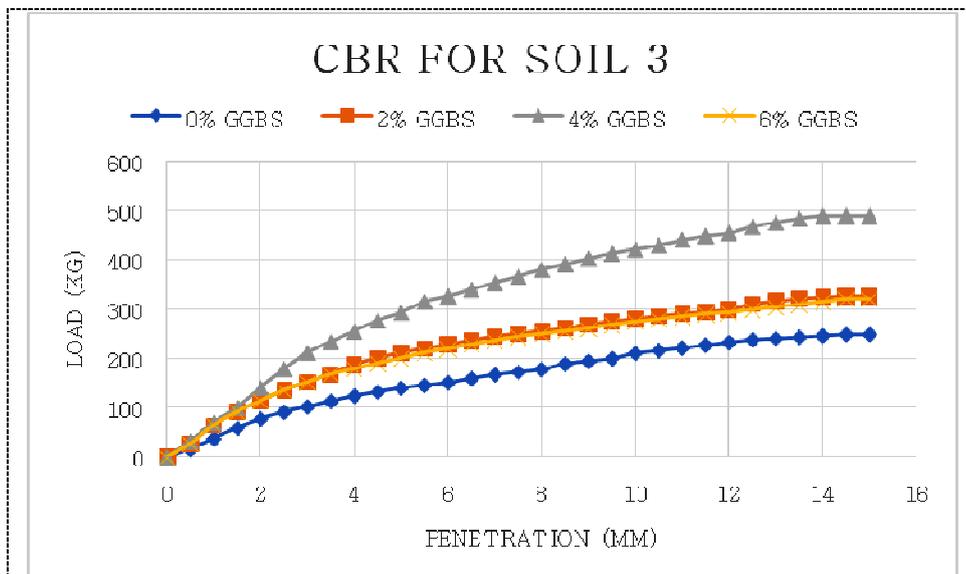


Figure 3. CBR results for Soil 3.

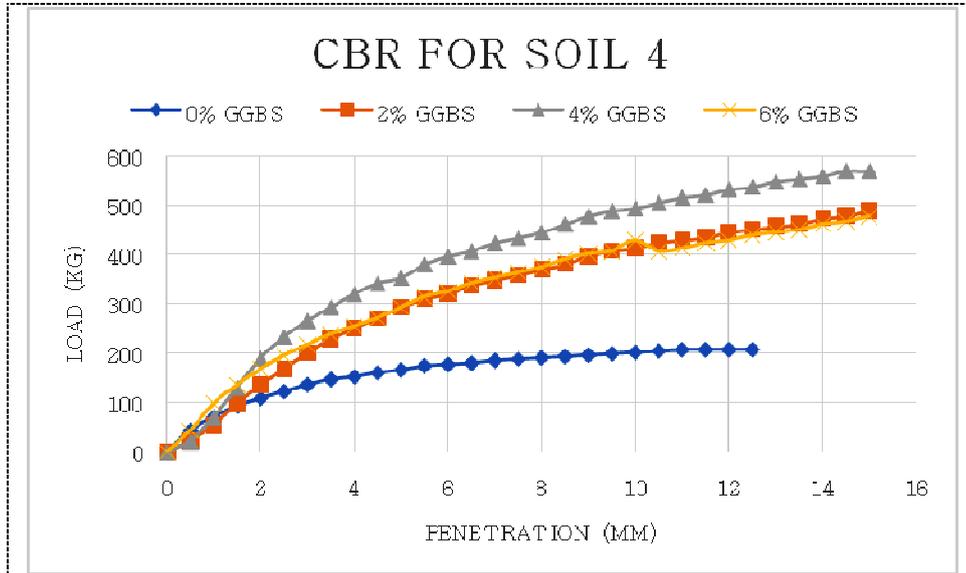


Figure 4. CBR results for Soil 4.

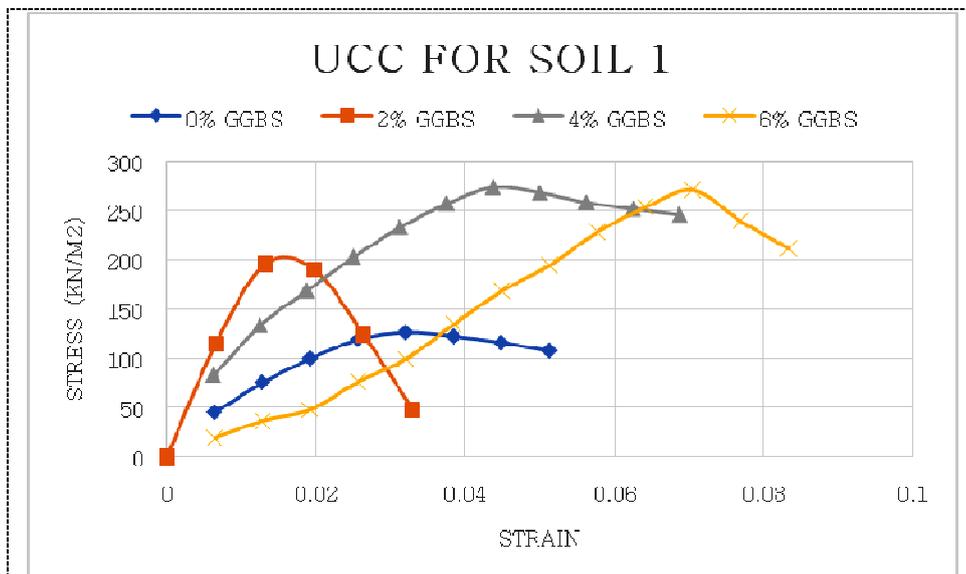


Figure 5. UCC results for Soil 1.

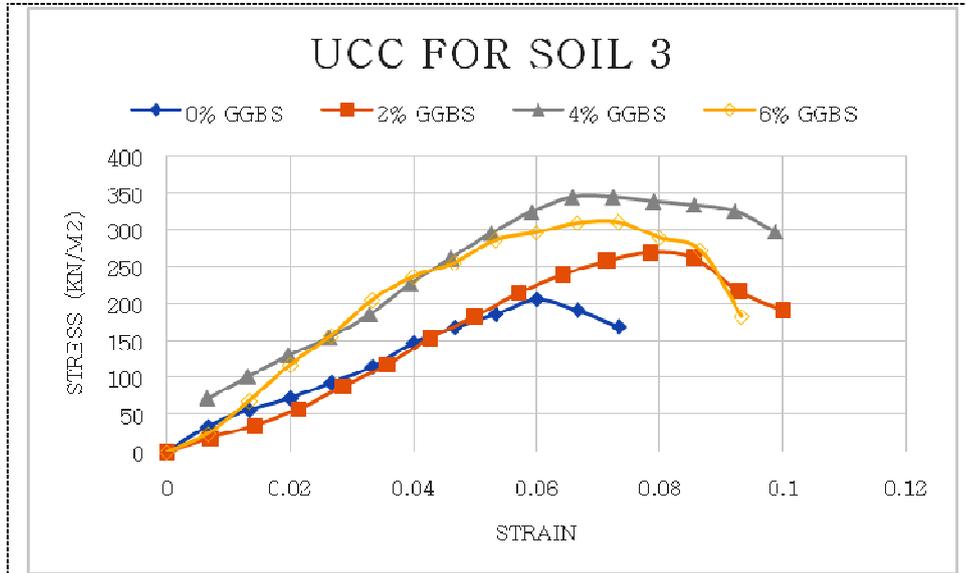


Figure 6. UCC results for Soil 3.

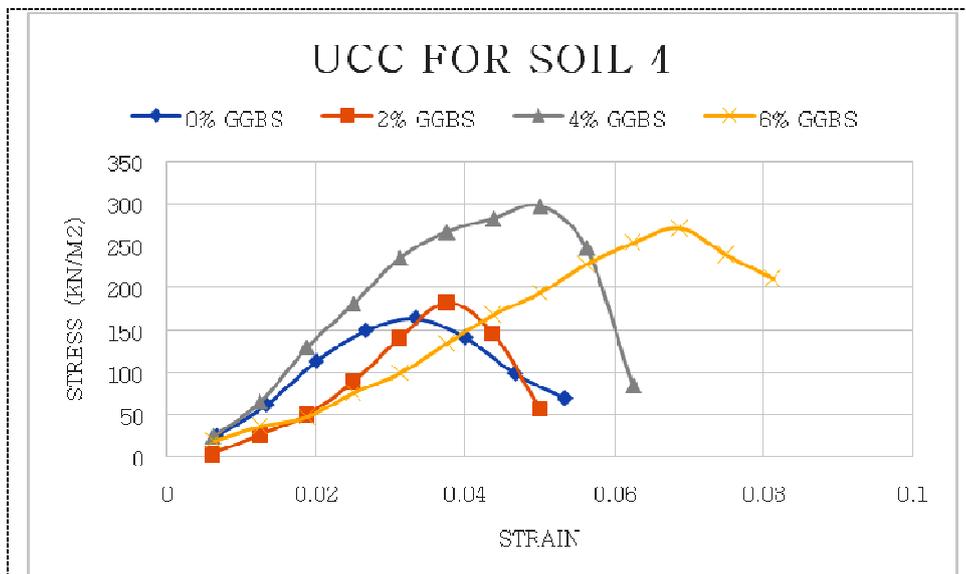


Figure 7. UCC results for Soil 4.

5. Conclusions

Based on the above analysis it has been concluded with,

1. Effective stabilisation is obtained with an addition of 4% of GGBS by dry weight of soil.
2. CBR value increases constantly with an addition of up to 4% of GGBS and 1% of lime to the soil.
3. The addition of GGBS beyond 6% will have no significant effect on soil than 4% addition, beyond that 6 % there is a slight reduction in strength on soil has been visualised.

4. The addition of a small quantity of lime of 1%, increases the strength and alters the index property of soil and reduces the plastic property of soil. The addition of GGBS and lime shows a better result in sandy soil than clay soil.
5. The unconfined compressive strength of clay soils, with a mix of maximum 4% GGBS and 1% lime shows a reasonable increase in shear strength of soil. The shear strength of sandy soil is increased with addition of up to 4% of GGBS and 1% of lime.
6. Plastic index of the soil is reduced with the increase in GGBS addition, after 4% there is notable decrement has been found out.
7. This addition of waste material for soil subgrade, considerable cost reduction is achieved in formation of roads. Therefore, subgrade for roads in Thanjavur region can be stabilized using GGBS and lime to achieve improved strength.

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