EVALUATION OF STRENGTH CHARACTERISTICS OF CLAYEY SOIL USING BASALT FIBER AND GROUND GRANULATED BLAST FURNACE SLAG

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Abstract - The fundamental requirement of humanity is met by transportation. Everyone has traveled for food or pleasure since the beginning of time. Because there is a direct link between the caliber of a nation's transportation infrastructure and its level of development, everyone has high expectations for these facilities. Today's civil engineers have significant hurdles in creating transportation systems that are analytically sound, economically sound, environmentally benign, socially believable, sustainable, and practicable. The inadequacy of traditional construction techniques in the contemporary environment is generating interest in technologies like ground improvement. The development of the economies of developing nations like India depends heavily on the availability of an affordable road network. When it comes to highways, a weak subgrade layer of the pavement necessitates a thicker pavement, which raises the cost of building the pavement. Because of their weak shear strength, high potential for swelling, and poor bearing capacity, organic soils are not appropriate for construction work. Methods for stabilization and compaction can be used to address these sorts of soils. The major goal of the study in this work is to improve the geotechnical qualities of soil by the effective usage of stabilization utilizing basalt fiber and ground granulated blast furnace slag (GGBS) in varied quantities. The study used 2%, 3%, and 4% of basalt fiber and 5%, 10%, and 15% of powdered granulated blast furnace slag in three different amounts. Compaction and an unconfined compressive test (UCS) were performed on the reinforced soil. The findings of the trial indicated that the soil's compressive strength and shear strength had been effectively improved.

***Key Words*:** Compaction test, CBR, UCS, Basalt Fiber, GGBS

1. INTRODUCTION

The term "complex material" refers to soil. It possesses physical and chemical properties that are crucial for coping with loads and other outside influences. The design of sub-structures such as foundations, piles, and other soil-based structures such as the sub-grade for pavements, embankments, etc. involves taking safety into consideration, making soil engineering and soil mechanics the most challenging of all the civil engineering specializations. Compared to conventional building materials, these projects demand a substantially higher level of safety. Soil analyses and foundation designs are therefore more unclear as a result.

Therefore, the engineering qualities of the soil are assessed prior to any significant building activity to ensure that the soil will be stable under the weight of the required structures. In contrast to the soil, which is normally made up of rock particles, the voids (also known as empty spaces) are where the air and water are found. The geological features impacted by mineral abundance, grain size distribution, and particle size and size distribution must be identified. When studying the site features and constructing structures, it is common practice to take the bulk unit weight, saturated unit weight, dry unit weight, permeability, and porosity of the soil into consideration.

Numerous laboratory techniques are used to look at the relative density, soil compaction characteristics, permeability, and water content.

The soil in a particular area occasionally could not be appropriate for the construction of structures due to its poor bearing capacity, drainage concerns, and other issues like high compressibility, etc. If clayey soil is found to be unsuitable for construction due to its low bearing capacity against the load as a result of its swell-shrink characteristics, it must be improved by altering the properties of such soils by using wastes, such as fly ash, rice husk, etc., having pozzolanic and absorbed properties. This lowers the cost of improvement.

2. Literature Review

Sreekumar and Nair (2013) concentrated on the study of how coir cutting waste from the coir business may be used as a reinforcement material to improve the qualities of stabilized lateritic block. After this pre-stabilized block was formed, it underwent additional stabilization using waste coir fiber and was evaluated for strength and durability. He employed sand and cement to stabilize the soil in his investigation, and after curing the blocks for 28 days with a variety of sand and cement percentages, it was discovered that this combination produced the best results. In order to add coir fiber, this reference was used. The coir fiber content ranged from 0.5% to 1% to 1.50%. Now, the soil-sand-cement-coir block was created and evaluated in the lab for the best outcome.

Jayasree et al. (2015)

used coir waste, which consists of short coir fibers and coir pith, to assess how soil behavior has altered. For the experimental study, six different ratios of short fiber (0.2–1%) and coir pith (0.5–3%) were used. Following the numerous tests, it was discovered that the addition of coir pith and fiber, respectively, lowered the swell index by 95% and 92% and the compression index by 68 and 94%.

G. R. Ashwin Kumar et al. (2015)

A form of clay called marine clay is present in coastal areas all over the world. The earth shrinks and loses moisture during dry spells, leaving a space beneath the footings. The house then begins to settle, resulting in warped door and window frames, fractured masonry walls, and interior plaster cracks. Foundations that have moved during dry periods typically return to near their original placements as rainfall replenishes the soil's moisture, causing the soils to swell once more. Wider fissures may develop as a result of the foundation's rebound gradually fading after several cycles.

Dayalan et al., (2016)

In this study, different amount of fly ash and GGBS are added separately i.e. 5, 10, 15 and 20% by dry weight of soil are used to study the stabilization of soil. The performance of stabilized soil are evaluated using physical and strength performance tests like specific gravity, atterberg limits, standard proctor test and California Bearing Ratio (CBR) test at optimum moisture content. From the results, it was found that optimum value of fly ash is 15% and GGBS is 20% for stabilisation of given soil based on CBR value determined.

Rashad et al., (2015) It is vital to make utilization of these wastes as building materials to secure the ecological from degradation. In this paper, the possibility of reusing calcined PG (CPG) as an incomplete substitution of FA in alkali-activated FA (AAFA) glue was considered. FA was halfway changed with CPG at purpose of 0%, 5%, 10% and 15%, by weight. Compressive quality at ages of 3, 7 and 28 days was figured.

The execution of the explored blends subsequent to being presented to 400, 600, 800 and 1000 °C for 2 h was order by measuring the lingering compressive quality.

Parvathy S (2016)

Slag made of copper is employed as an addition in this study. Among the waste products, copper slag is one that is heavily utilized in the civil engineering construction sector. The test will be carried out depending on the clayey soil's clay content and the varied percentages of lime and copper slag. By stabilizing with the right substance, clay's drawbacks can be overcome. The principal laboratory tests are the CBR and the UCS. The aim of this study is to ascertain the engineering behavior of lime-stabilized clayey soil that contains copper slag.

Das et al. (2016)

Unreinforced and reinforced soil with coir fiber both had their shear strength values studied. For a series of direct shear tests, standard stresses of 0.5 kg/cm2, 1.0 kg/cm2, and 1.5 kg/cm2 were used. Coir fiber enhanced the soil's weight values of 1%, 2%, and 3%. Coir fiber was found to improve the shear strength metrics when added to sand. Because friction in the soil and the reinforced material has been developed, the soil now exhibits ductile failure rather than brittle failure, which is the primary source of the enhanced shear strength.

Peter et al. (2016)

The study investigated the behavior of soil stabilized with coir fiber and/or coir pith. In contrast to the coir pith, which ranged from 0% to 3%, the proportion of coir fibre varied from 0.2% to 0.4% to 0.6% to 0.8% to 1%. The addition of both coir pith and coir pith was found to reduce the maximum dry density.

Srikanth et al. (2017)

A crucial factor in the realm of construction is soil stability. Various stabilization techniques can be used on soil that is not sufficiently stable. Stabilizing the soil can increase its shear strength and control its shrink-swell properties, which will improve the subgrade's ability to hold pavements and foundations under stress. There are a wide range of stabilization techniques. The objective of this paper is to examine the practicality of stabilizing soil using rice husk ash and coir fiber in order to repurpose waste materials and give a reasonably priced and ecologically friendly method of doing so.

Pooja et al. (2017)

Testing the behavior of soil reinforced with Coir fiber in percentages ranging from 0.5% to 1.5% by mass revealed that the UCS test results for soil samples with fiber contents of 0.5%, 1.0%, and 1.5% increased from the value starting from 11.68%, 1.26%, and 0.62% respectively. Researchers came to the conclusion as a result of this that adding fibers to the soil might be regarded as a beneficial ground improvement strategy, particularly for engineering projects requiring more support in weak soils.

P. Bharath Goud et al. (2018)

The purpose of the current study was to evaluate the effectiveness of different mixtures of copper slag and rice husk ash as soil stabilizers. The combination of copper slag and rice husk ash to stabilize soil has only been the subject of a small number of studies. It was discovered that the optimal mixture was 64%BC+30%CS+6%RHA. The FSI of soil that has received RHA+CS treatment reduced dramatically from 100% to 20.4%. The maximum dry density of the treated soil changed little. The unsoaked CBR test revealed that the optimal mix had strength of 12.7%.

Sharana Kumar et al. (2018)

The study's goal is to determine the impact of short polypropylene filaments that have been randomly distributed on the CBR test and the UCS of black cotton soil on strengthening. The stabilization process used in this study aims to ascertain the impact of Slag and fiber on the engineering characteristics of black cotton soil. The amounts of fiber used are 0.5%, 1%, 1.5%, and 2% relative to the dry weight of the soil, and the amounts of copper slag utilized are (6%, 12%, 14%, and 24%). Next, combine copper slag and As a percentage of the dry weight of the soil, polypropylene fiber should be added in the following amounts: 0.5%, 1%, 1.5%, 2%, and 3.6%, 9%, and 12%, respectively.

G. Ramachandran et al. (2019)

The major goal of this study is to improve the geotechnical qualities of soil, which is why basalt fiber and GGBS in varied quantities are used in this work to examine effective stabilization. The study used 1%, 2%, and 3% of basalt fiber and 3%, 6%, and 9% of powdered granulated blast furnace slag in three different amounts. Compaction and UCS test were performed on the reinforced soil. The findings of the trial indicated that the soil's compressive strength and shear strength had been effectively improved.

Adla Prathyusha et al. (2020)

The purpose of this study is to evaluate the suitability of red soil from a nearby source with the addition of basalt fiber for highway building. Basalt fibers are added to the conventional red soil in varying proportions (by weight of the raw soil, 0%, 0.2%, 0.4%, 0.6%, 0.8%, 1%, 1.2%, and 1.4%). Proctor compaction tests and California bearing ratio (CBR) testing were performed on stabilized soil in addition to the preliminary tests. The experiment's results show that strengthening the soil by adding basalt fiber was greatly enhanced. By adding basalt fiber to subgrade soil at a rate of 0.8% (by soil weight), it is possible to dramatically boost the strength of the soil, which also has a positive impact on the design of highway pavement structures.

Manish Kumar Jha et al. (2022)

This study's primary objective is to comprehend how GGBS and Copper Slag interact with black cotton soils. The geotechnical and engineering properties of the Black Cotton soil should be improved. Investigating the behavior of strength increase in black cotton soil using Copper Slag stabilization and GGBS.

3. Materials

3.1 SOIL

Source of soil

The soil used for the experiment purpose, which is clay soil (CI) was taken from the local area near Jammu. The amount of soil that was taken for the experiment purpose was around 130 kg, including the impurities in the soil (like hard particles, pebbles, organic impurities etc.). After bringing the soil to the working area, the lumps and the organic impurities in the soil were removed by using tools like Hoe and Rake.

Table no. 1 Properties of soil used in the study

S.NO.	PROPERTIES	RESULTS
1.	Liquid Limit	36 %
2.	Plastic Limit	21.5 %
3.	Plasticity Index	14.5 %
4.	Optimum	12.23 %
5.	Maximum Dry	14.47 kN/m³
6.	Specific Gravity	2.58
7.	CBR (%) (soaked)	2.9 %
8.	CBR (%)	3.7 %
9.	U.C.S	167.4 kN/m²
10.	Indian Soil	CI

3.2 GROUND GRANULATED BLAST FURNACE SLAG

A courier was used to deliver the ground-granulated blast furnace slag from Delhi.

Table 2 Chemical composition of Blast furnace slag

S. No	Name of constituent	Percentage
1	SiO_2	33.67
2	$Al_2O_3 + Fe_2O_3$	19.18
3	Calcium Oxide (CaO)	36.2
4	Magnesium oxide (MgO)	8.18
5	SO_3	0.2
6	Na_2O	0.14
7	P_2O_5	0.05

3.3 Basalt Fiber

In the test, 6mm Basalt Fiber of various lengths will be used. The basalt fiber is equally distributed throughout the clay soil sample prior to dispersion. The filamentous Basalt Fiber is. bought online from Delhi.

Table 3 Properties of Basalt Fiber

Density	2.65g/cm^3
Elastic modulus	85.9Gpa
Elongation at break	3.12%
Tensile at strength	2611Mpa
Length	6mm

4. EXPERIMENTAL RESULTS

4.1 STANDARD PROCTOR TEST

CLAYEY SOIL- GGBS AND BASALT FIBER MIXES MIXES

Table no. 3: Results of OMC and MDD for mix proportions of GGBS and Basalt Fiber

SOIL:GGBS:BF	MDD (kN/m³)	OMC (%)
100:0:0	14.47	12.23
84.0:15:1.0	15.10	11.87
83.5:15:1.5	15.86	11.41
83:15:2.0	16.61	10.97

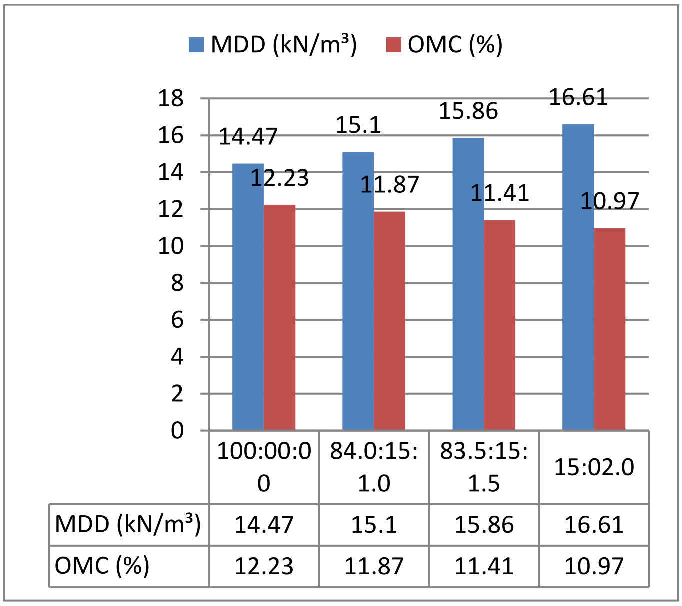


Fig:-1 Differences b/w MDD and OMC of GGBS and Basalt Fiber in various ratios

Table 4: Results of UCS of GGBS and Basalt Fiber

Clayey Soil :GGBS:BF	Curing Period (Days)	UCS (kN/m²)
100:0:0	7	167.4
84.0:15:1.0	7	315.21
83.5:15:1.5	7	367.27
83:15:2.0	7	411.62

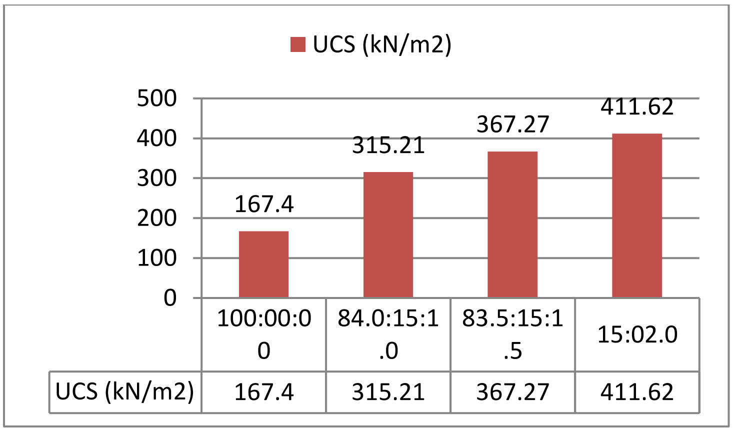
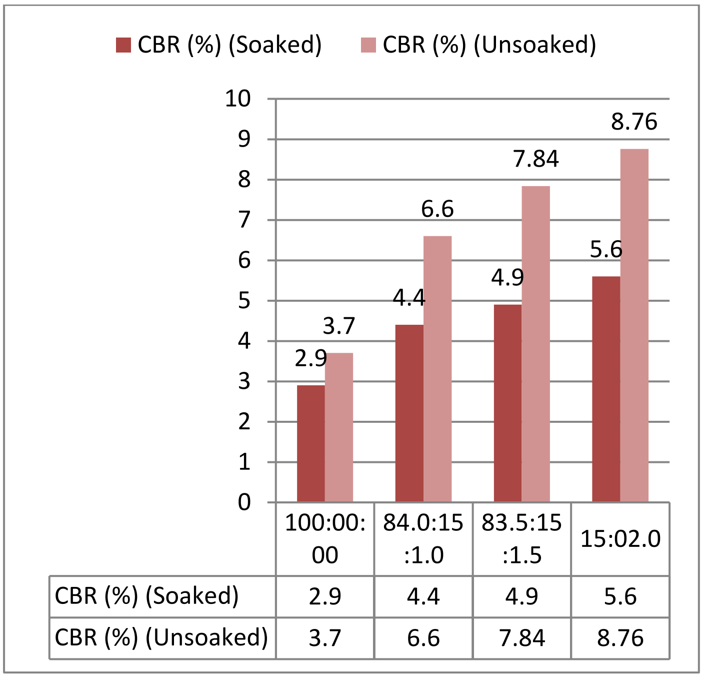


Fig:-2 various ratios of GGBS and Basalt Fiber are shown in the UCS graph.

Table 5: Results of CBR for GGBS and Basalt Fiber

Clayey Soil :GGBS:BF	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:0:0	2.9	3.7
84.0:15:1.0	4.4	6.6
83.5:15:1.5	4.9	7.84
83:15:2.0	5.6	8.76



	100:00:00	84.0:15:1.0	83.5:15:1.5	15:02.0
CBR (%) (Soaked)	2.9	4.4	4.9	5.6
CBR (%) (Unsoaked)	3.7	6.6	7.84	8.76

Fig:-3 CBR Graph of GGBS and Basalt Fiber with various ratios

5 DISCUSSIONS

5.1 STANDARD PROCTOR TEST:

1. In this investigation, different amounts of GGBS were used to analyze the soil's compaction characteristics. As the amount of GGBS increased, MDD was seen to decline. This might occur because soil and GGBS have different specific gravities. However, as the amount of GGBS is increased, the optimum moisture content rises. This might occur as a result of the pozzolanic reaction of GGBS with soil, which needs additional water to complete the cation exchange process.
2. When soil and slag are combined, MDD rises as the amount of basalt fiber grows with varying GGBS ratios. Because basalt fiber is more easily added because it is circular in shape and lighter in weight, MDD may rise as a result of this behavior. However, OMC rises as fiber content rises because fiber absorbs a lot of water.

5.2 CBR TEST

1. Addition of GGBS somewhat raises the soil sample's soaking CBR values. GGBS (15%) and basalt fiber (2.0%) were added, which increased the soaked CBR value. The rise in CBR value might be brought about by the reaction between the pozzolonic compounds of soil-available CaOH and GGBS, which create cementitious compounds in the soil. Basalt fiber should be used in the optimal amount, 15% Copper Slag. This could be the result of the fact that stabilized soil gains strength as its fiber content rises, increasing the soil's ability to withstand applied stresses.

5.3 UCS TEST:

With the addition of 15% GGBS and 2% basalt fiber, the UCS value of virgin soil also significantly increases. When GGBS and basalt fiber are added, the value rises. The cause of this is that during the curing process, pozzolanic reactions occur when GGBS and basalt fiber come into touch with water.

CHAPTER 6

CONCLUSIONS

Following conclusions can be inferred on the basis of the experiments performed:

1. Due to its cementitious properties, which help to strengthen the soil, GGBS is a waste product that can be used to stabilize soil.
2. In contrast, basalt fiber is an inexpensive material that may be applied to soil in little amounts to significantly alter its strength characteristics.
3. Since adding GGBS to soil is found to increase C.B.R. by 15%, GGBS was utilized at a 15% value for this project.

4. When basalt fiber and a set quantity of GGBS are added, the C.B.R value increases. It multiplied by 1.93 from the virgin soil.
5. The appropriate proportions of GGBS and basalt fiber to the weight of the soil are 2.0% and 15%, respectively, in order to stabilize the soil.
6. Increasing the amount of basalt fiber and maintaining the same level of GGBS improves unconfined compressive strength. The UCS is 2.45 times higher in treated soil than in untreated soil.

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