EXPERIMENTAL STUDY OF COPPER SLAG STABILIZED CLAYEY SOIL WITH BASALT FIBER

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***Abstract** - In the current study, clayey soil that has been stabilized by compacting it to various densities at specific moisture contents over various curing times with diverse amounts of copper slag and basalt fiber underwent testing for unconfined compressive strength and California bearing ratio. The determination of unconfined compressive strength method was used to cylindrical specimens stabilized with copper slag and basalt fiber. The addition of copper slag and basalt fiber was found to improve the low strength and highly compressible soft clay soils to varying degrees. Overall test results show significant improvement in unconfined compressive strength mixed California bearing ratio, proving that copper slag and Basalt fiber are efficient in stabilizing the soil. If sufficient quantities of credible data are made accessible, a reasonably accurate strength estimate can be obtained from a compilation of the strength. From the test results of unconfined compressive strength method could be easily established for quality control and assurance of stabilization work. The study has been conducted with three different proportions of Basalt fiber as 1%, 2%, 3% and Copper Slag as 10%, 20% and 30%. The reinforced soil where subjected to compaction, California bearing ratio (CBR) and unconfined compressive test (UCS). The experimental results have shown effective increment in compressive strength and shear strength of the soil.*

***Key Words*: Compaction test, CBR, UCS, Copper slag, Basalt Fiber**

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. When safety is taken into account when designing sub-structures like foundations, piles, and other soil-based constructions like sub-grade for pavements, embankments, etc., soil engineering and soil mechanics are the most complicated of all the civil engineering specialties. These constructions require a significantly higher value of safety in comparison to other building materials. Because of this, there is more uncertainty in foundation designs and soil analyses.

To ensure the soil's stability under the weight of the desired structures, the engineering characteristics of the soil are therefore examined prior to any significant construction work. The air and water are found in the empty areas (referred to as voids), while the soil is typically composed of rock particles. It is critical to identify the geological properties impacted by mineral abundance, grain size distribution, and particle size and size distribution. The bulk unit weight, saturated unit weight, dry unit weight, permeability, and porosity of the soil are typically taken into account while analyzing the site characteristics and designing structures. The relative density, properties of soil compaction, permeability, and water content are all examined in a number of laboratory procedures.

2. Literature Review

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 California Bearing Ratio Test (CBR) and the Unconfined Compressive Strength Test (UCS). The purpose of this study is to ascertain the engineering behavior of lime-stabilized clayey soil that contains copper slag.

Das et al. (2016)

The shear strength parameters of unreinforced and reinforced soil with coir fiber were examined. A series of direct shear tests were performed at the standard stresses of 0.5 kg/cm2, 1.0 kg/cm2, and 1.5 kg/cm2. The values of 1%, 2%, and 3% by weight of soil were increased with the coir fiber. It was observed that adding coir fiber to sand would increase the shear strength parameters. The primary reason for the increased shear strength is that whereas the soil exhibits brittle failure in the absence of reinforcement, the soil now exhibits ductile failure because friction between the soil and the reinforced material has now been established.

Peter et al. (2016)

In the study, the behavior of soil that had been stabilized with coir fiber and/or coir pith was examined. The coir fibre percentage ranged from 0.2% to 0.4% to 0.6% to 0.8% to 1%, while the coir pith ranged from 0% to 3%. The maximum dry density was found to decrease with the addition of both coir pith and coir pith, and for OMC, coir fibre was found to initially decrease, which may have been caused by the flocculation of clay particles when coir was added to them, and then increase with the further addition of coir fibre.

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. The load bearing capability of the sub-grade to support pavements and foundations can be improved by stabilizing the soil to raise its shear strength and manage its shrink-swell characteristics. Stabilization methods come in a huge variety. In order to reuse waste materials and provide a cost-effective and environmentally friendly way of soil stabilization, the goal of this report is to investigate the viability of stabilizing soil using rice husk ash and coir fiber.

Pooja et al. (2017)

It was determined through testing the behavior of soil reinforced with Coir fiber with varying percentages from 0.5% to 1.5% by mass that the results from the UCS test for soil samples with fiber content of 0.5%, 1.0%, and 1.5% increased from the value starting from 11.68%, 1.26%, and 0.62% respectively. This led researchers to draw the conclusion that reinforcing soil with fibers can be considered a good ground improvement technique, especially in engineering projects in weak soils where there is a need for increased.

P. Bharath Goud et al. (2018)

The current study was conducted to assess the efficacy of various ratios of copper slag and rice husk ash as soil stabilizers. Vane shear, California Bearing Ratio (CBR), Atterberg limits, free swell index (FSI), and compaction tests are conducted on a mixture of BC soils that includes Copper Slag and Rice Husk Ash. Only a few research have been published on the use of copper slag and rice husk ash together to stabilize soil.

The ratio of 64%BC+30%CS+6%RHA was found to be the ideal blend. The FSI of soil that had been treated with RHA+CS dropped sharply from 100% to 20.4%. The treated soil's maximum dry density changed just a little bit. The strength of the ideal blend was 12.7%, according to the unsoaked CBR test.

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 California bearing ratio test and the unconfined compressive strength of black cotton soil on strengthening. The stabilization process used in this study aims to ascertain the impact of copper slag and polypropylene fiber on the engineering characteristics of black cotton soil. The amounts of polypropylene 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 polypropylene fiber with the dry weight of the soil 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 ground granulated blast furnace slag (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 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.

Adla Prathyusha et al. (2020)

This study aims to determine the appropriateness of locally sourced red soil with basalt fiber addition for highway construction. To the traditional red soil, various amounts of basalt fibers (0%, 0.2%, 0.4%, 0.6%, 0.8%, 1%, 1.2%, and 1.4%) are added by weight of raw soil. In addition to preliminary tests, stabilized soil underwent California bearing ratio (CBR) and proctor compaction tests. The findings of the experiment demonstrate that adding basalt fiber significantly increased the soil's strength. The strength of subgrade soil can be greatly increased by adding basalt fiber at a rate of 0.8% (by soil weight), which also significantly enhances pavement structure design for highways.

Manish Kumar Jha et al. (2022)

The main goal of this research is to understand how GGBS and Copper Slag interact with black cotton soils. Enhance the geotechnical and engineering qualities of the Black Cotton soil. Utilizing GGBS stabilization and Copper Slag to investigate the behavior of strength increase in black cotton soil.

3. Materials

3.1 SOIL

Source of soil

With a wooden hammer, lumps of the site's collected soil were broken up, and it was then allowed to dry in the open air beneath cover. After fully mixing, it was sieved through a 2.35 mm IS sieve.

The needed amount of dirt for each test was removed from polythene bags and dried in an oven at 105°C/5°C for 24 hours. At room temperature, the dirt was allowed to cool.

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 Moisture	13.17 %
5.	Maximum Dry	15.46 kN/m³
6.	Specific Gravity	2.58
7.	CBR (%) (soaked)	3.2 %
8.	CBR (%)	4.4 %
	U.C.S	140.2 kN/m²
10.	Indian Soil	CI

3.2 Copper Slag - The dark, smooth copper slag, which was used in the investigation, was procured from Air Blast Equipment India Pvt. Ltd. in Hyderabad.

Table 2 Chemical Composition of Copper Slag

S.No	Compound	Value (%)
1	SiO_2	25-35
2	Al_2O_3	2-9
3	Fe_2O_3	45-55
4	CaO	1-3.5
5	MgO	1-5
6	So_3	0.11
7	K_2O	0.61

3.3 Basalt Fibre

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

4. EXPERIMENTAL RESULTS

4.1 STANDARD PROCTOR TEST

CLAYEY SOIL, COPPER SLAG AND BASALT FIBRE MIXES

Table no. 3: Results of OMC and MDD for mix proportions of Soil, CS and BF

SOIL:CS:BF	MDD (kN/m³)	OMC (%)
100:0:0	15.46	13.17
94.0:5.0:1.0	16.23	13.47
88.5:10:1.5	16.87	12.93
83:15:2.0	17.62	12.44

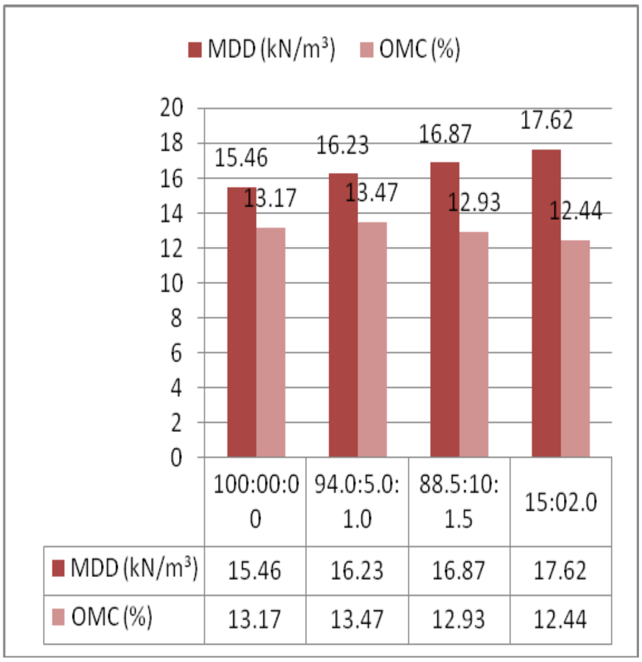

Fig:-1 Showing variations b/w MDD and OMC of Copper Slag, Basalt Fibre & soil with different proportions

Table 4: Results of UCS of Copper Slag and Basalt Fiber with Soil

Clayey Soil :CS:BF	Curing Period (Days)	UCS (kN/m^2)
100:0:0	7	140.21
94:05:01	7	220.17
88.5:10:1.5	7	290.64
83:15:2.0	7	343.71

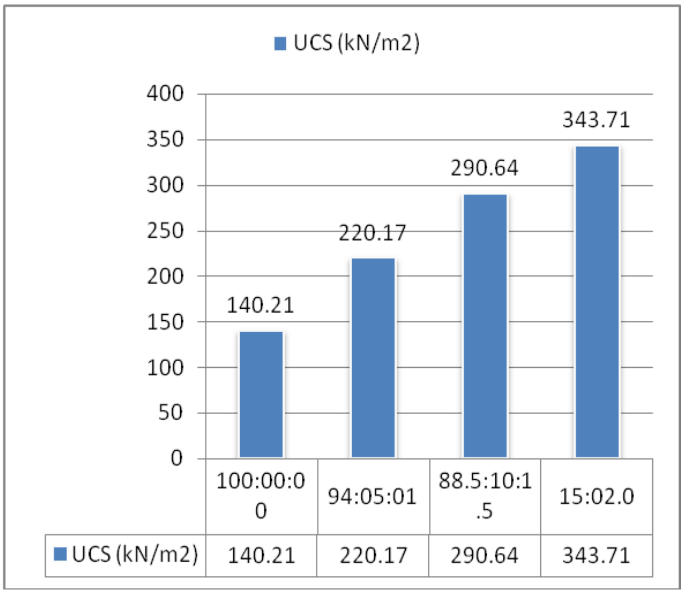

Fig:-2 UCS Graph Copper Slag, Basalt Fibre and soil with different proportions

Table 5: Results of CBR of Soil, Copper Slag and Basalt Fiber

CS:CS:BF	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:0:0	3.20	4.41
94:05:01	5.1	7.6
88.5:10:1.5	6.2	8.7
83:15:2.0	6.9	9.7

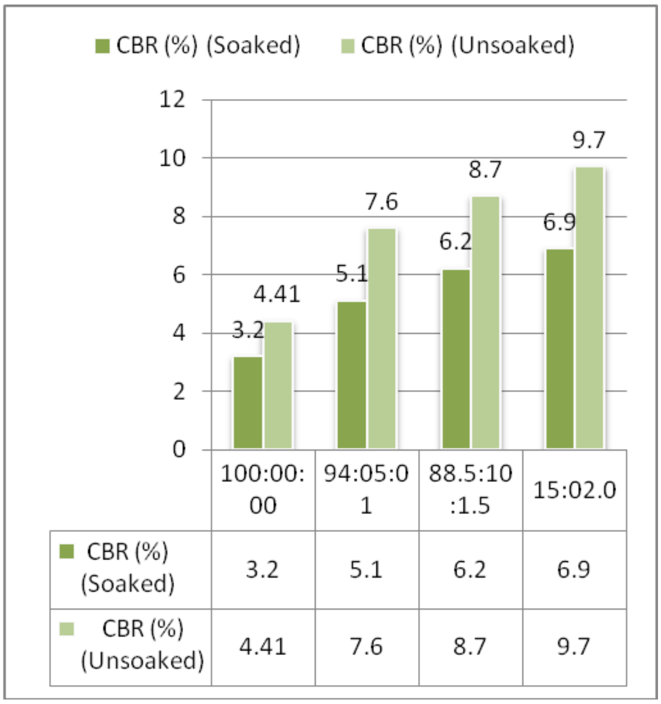

Fig:-3 CBR Graph of Soil, Copper Slag and Basalt Fibre with different proportions

5 DISCUSSIONS

4.5.1 COMPACTION TEST

In this investigation, different amounts of copper slag were used to analyze the soil's compaction characteristics. As the amount of copper slag increased, MDD was seen to decline. This might occur because soil and copper slag have different specific gravities. However, as the amount of Copper slag is increased, the optimal moisture content rises. This might occur as a result of the pozzolanic reaction of copper slag with soil, which needs additional water to complete the cation exchange process. Figures 4.10 and 4.11 below demonstrate the variance in MDD with copper slag and the variation in OMC with copper slag.

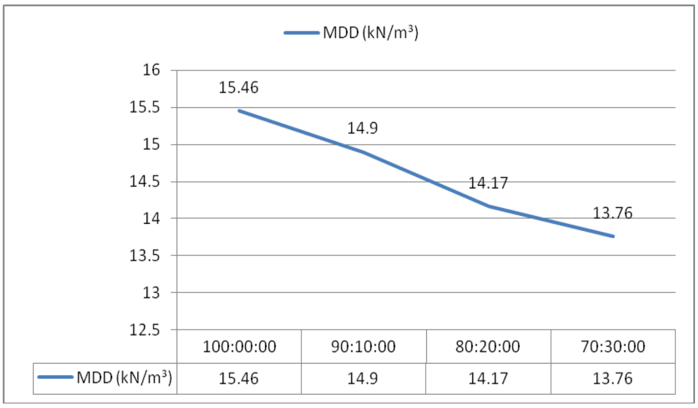

Fig. no. 4.4 Variation in MDD with increase in Copper slag percentage

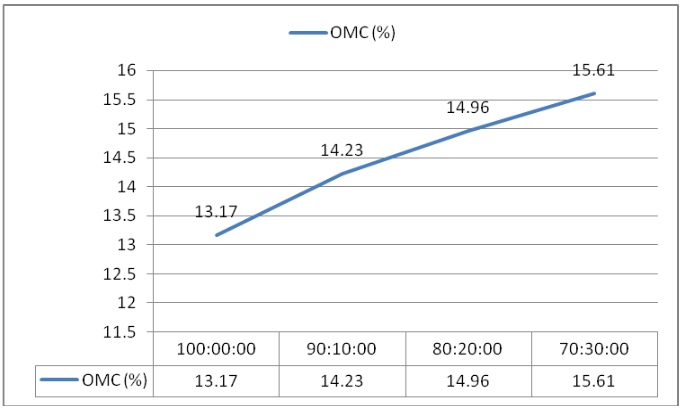

Fig. no. 4.5 Variation in OMC with increase in Copper slag percentage

When soil and slag are combined, MDD rises as the amount of basalt fiber grows with varying copper slag 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.

In figures 4.12 and 4.13 below, the variation of MDD with increasing fiber content and the variation of OMC with increasing fiber content are depicted.

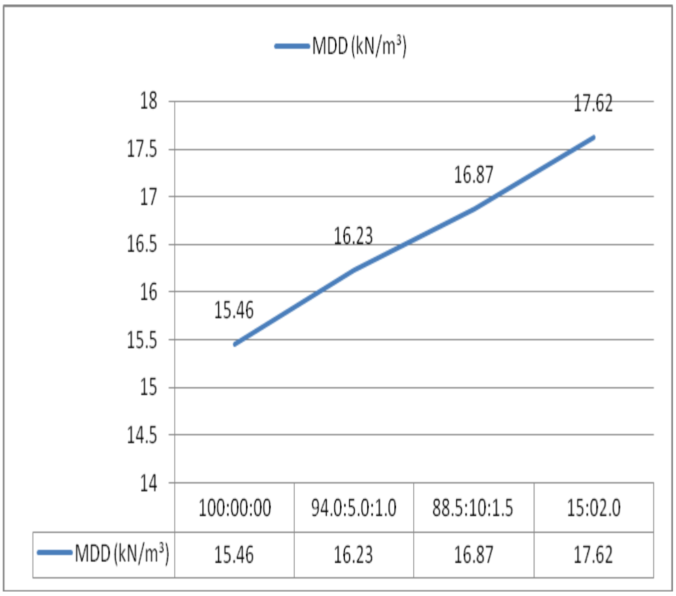

Fig no. 4.6 Variation in MDD with increase in copper slag and Basalt fiber content

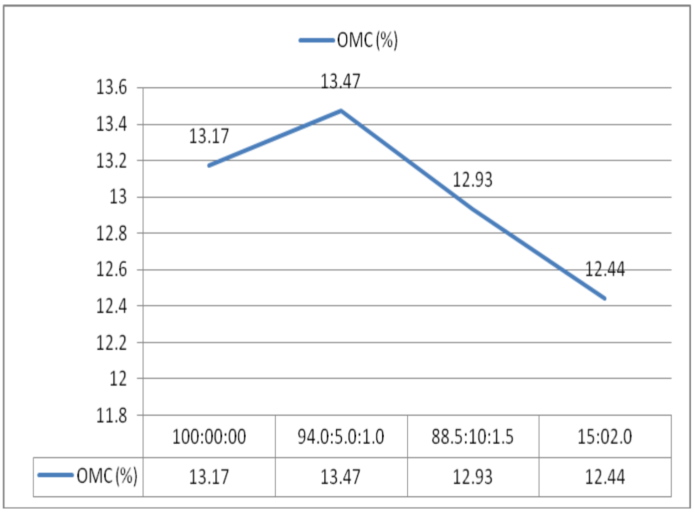

Fig no. 4.7 Variation in MDD with increase in copper slag and Basalt fiber content

4.5.2 CALIFORNIA BEARING RATIO TEST

Addition of copper slag somewhat raises the soil sample's soaking CBR values. Copper slag (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 Copper slag, 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. Figure 4.14 depicts the correlation between CBR value, copper slag content, and basalt fiber content.

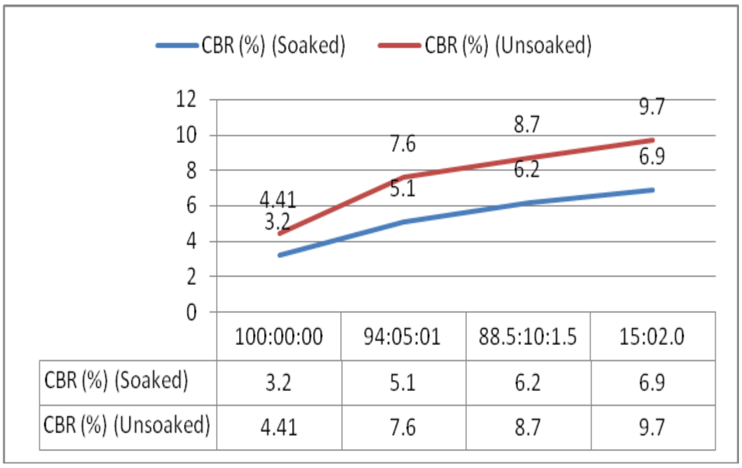

Fig. no. 4.8 Variation in CBR value with increase in CS and BF content

1.5.3 UNCONFINED COMPRESSION STRENGTH TEST

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

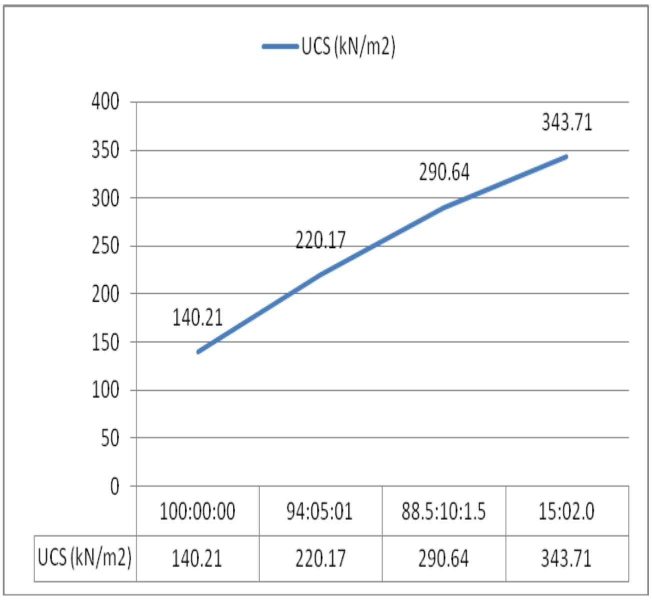

Fig. no. 4.9 Variation in UCS value with increase in CS and BF content

CHAPTER 6

CONCLUSIONS

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

1. Copper slag is a waste product that can be utilized to stabilize soil because of the cementitious qualities that aid to increase the soil's strength.
2. Basalt fibre on the other hand is a cheaply available material which can be added to soil in less quantities to make big changes in its strength parameters.
3. Since the value of C.B.R. is discovered to be at 20% when Copper Slag is added to soil, Copper Slag was used at 20% value for this project.
4. The C.B.R value rises as basalt fiber and a predetermined amount of copper slag are added. From the untreated soil, it multiplied by 2.15.
5. The ideal percentages of basalt fiber and copper slag needed to stabilize soil are 2.0% and 20%, respectively, of the soil's weight.
6. Unconfined compressive strength improves with more basalt fiber and a constant amount of copper slag. When compared to untreated soil, the unconfined compressive strength is 2.45 times higher.

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