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Use of Copper Slag and Coir Fibre to Strengthen the Engineering Properties of Clayey Soil

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ABSTRACT: CS and CF were individually tested in the past for stabilizing clayey soil. The current study was conducted to assess the efficiency of various Coir Fibre and Copper Slag percentages as soil stabilizers. The California Bearing Ratio (CBR), Atterberg limits, Unconfined Compression Test (UCS), and compaction tests are conducted on the mixture of clayey soil, copper slag, and coir fibre. The use of Copper Slag and Coir Fibre in soil stabilization has only been the subject of a few research. This study examines the impact of copper slag and copra fibre on the clayey soil's compaction properties, unconfined compression strength, and California Bearing Ratio. The current study aims to evaluate the improvement in the strength and stability qualities of soft subgrade soil by stabilizing it with copper slag and then reinforcing it with core fibre. The samples of reinforced soil are made using the randomly distributed fiber-reinforced soil (RDFRS) approach.

KEYWORD: UCS, RDFRS, CBR.

I. INTRODUCTION

When the factor of safety is taken into account in the design of sub-structures, such as foundations, piles, and other soil-based constructions like sub-grade for pavements, embankments, etc., soil engineering and soil mechanics are the most complex field among all the other civil engineering specialties because they require a significantly higher value of safety in comparison to other building materials. Because of this, there is greater uncertainty in soil analysis and foundation design. To ensure the soil's stability under the weight of the intended structures, the engineering characteristics of the soil are therefore examined prior to any significant construction work. When analyzing the site conditions and designing structures, the bulk unit weight, saturated unit weight, dry unit weight, permeability, and porosity of the soil are typically taken into account. Because of its poor bearing capacity, drainage issues, and other issues like high compressibility, etc., the soil at a certain site sometimes isn't ideal for building structures.

1.1 Clay Soil

Soils that expand or swell when exposed to moisture are exactly what their names imply. These bloated soils frequently contain clay minerals, which pull and absorb water. These deep-colored soils, which account for 15% to 20% of the country's total land area, demonstrate a large volume change in water content. The iron-and-aluminum combination, accumulated humus, colloidal hydrated double ion, and aluminum silicate all contribute to the substance's black appearance.

1.2 Structure of Montmorillonite

Montmorillonite is created when volcanic ash weathers in areas with saltwater and poor drainage. An alumina sheet is placed between two silica sheets to provide the fundamental structural component. The structural components are layered on top of one another. Each structural unit is maintained at a thickness of about 10. The stability of the supporting structure and the road pavement may be substantially jeopardized by the expansive soil's capacity to swell by a significant volume. We, therefore, require methods that would enable us to work on various types of soil as well. Numerous methods, including soil nailing, grouting, stabilizing the soil with different additives, and vibro-compaction, have been developed and are widely used to enhance the geotechnical qualities of the soil. One of these approaches to strengthening the soil is the process of soil reinforcement.

1.3 Soil Reinforcement

Reinforcement agents were first used by Vidal, who also came up with the concept, to strengthen the soil's resilience to shear. The "reinforcing" process, which boosts stability and lessens deformation, involves inserting tensile elements within the soil. To be effective, reinforcement must intersect any potential failure surfaces found in the soil mass. Tensile loads are produced in the reinforcements due to strains in the soil mass, which restrict soil motions and hence increase shear strength. As a result, the shear strength of the composite soil/reinforcement system was much higher than that of the individual soil mass.

1.4 Coir Fiber

Coir Fibre, also known as Coconut Coir, are natural Fibres that are obtained from coconut skin. It is the fibrous layer that a coconut has between its tough internal shell and outside coat. The main benefits of utilizing coconut coir to strengthen soil sub grade are that it is affordable, readily available, and environmentally friendly. The coconut coir used in this study is primarily derived from green nuts.

1.5 Copper Slag

The process of smelting copper produces a byproduct called copper slag. Before it can be used for additional purposes, the countermined copper slag must be carefully cleaned or processed to meet certain recycling requirements. A tonne of copper produces 1.8 to 2.2 tones of copper slag in the manufacturing process. The high concentration of heavy metals in their oxides in copper slag makes it harmful to the environment. By using copper slag for soil stabilization, we can solve a significant environmental issue.

II. RELATED WORK

Manish Kumar Jha et al. (2022) The main objective of this work was to investigate the interactions between GGBS and black cotton soils that include copper slag. for geotechnical and engineering improvements. Black cotton makes up the soil's properties. to look at how Copper Slag and GGBS stabilization affect the behavior of strength enhancement in black cotton soil.

Sharana Kumar et al. (2018) The goal of the study is to determine the strengthening effects of scattered short polypropylene filaments on the California bearing ratio test and the unconfined compressive strength of black cotton soil. When polypropylene is expanded, a less severe dry thickness and a more suitable dampness material are produced. The stabilizing study looks into the effects of polypropylene fibre and copper slag on the engineering properties of black cotton soil. Different ratios were used depending on the dry weight of the soil after examining the copper slag and polypropylene fibre ratios.

P. Bharath Goud et al. (2018) The study looked at how effective copper slag and rice husk ash were at stabilizing soil. Californian Vane shear One of the investigations involved testing the bearing ratio, atterberg limits, free swell index,

and compaction. The perfect blend, which had 64% BC+30%CS+6%RHA, reduced the free swell index from 100% to 20.4%. The stabilized soil mixtures showed acceptable strength characteristics and can be used for affordable projects like housing and road infrastructure.

Pooja et al. (2017) For soil samples with a fibre content of 0.5%, 1.0%, and 1.5%, respectively, results from the UCS test showed a rise from the value starting from 11.68%, 1.26%, and 0.62%. The study's findings support the idea that adding fibres to soil to strengthen it can be a viable ground improvement strategy, particularly for engineering projects on brittle soils where fibres can be applied in various amounts ranging from 0.5% to 1.5% by mass.

Srikanth et al. (2017) Soil stability is a key element in the construction sector. On inadequately stable soil, a variety of stabilization techniques can be applied. The ability of the subgrade to support pavement and foundation loads can be improved through stabilization, which can increase the soil's shear strength and control its shrink-swell properties. Numerous alternative stabilization techniques exist. The major goal of this report is to determine whether stabilizing soil with rice husk ash and coir fibre is practical. This stabilization technique uses recycled waste products, making them economical and environmentally safe.

Bajaj et al. (2016) This study investigates how sugarcane bagasse ash and core fibre affect soil properties like liquid limit, plastic limit, compaction, and California Bearing Ratio. The project's objective is to strengthen and stabilize soft subgrade soil by stabilizing it with sugarcane bagasse ash and using core fibre as a reinforcing material. The Randomly Distributed Fibre Reinforced Soil (RDFRS) technique is used to prepare reinforced soil samples for simple reinforcement mixing without the need for specialized understanding. For maximizing strength increase, the ideal core fibre content and SCBA ratio will be identified.

Peter et al. (2016) The behavior of soil that had been stabilized with coir fibre and/or coir pith was investigated in the study. 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%. With the addition of both coir pith and coir pith, the maximum dry density was found to drop. For OMC, the initial decrease in coir fibre was also observed, which may have been brought on by the flocculation of clay particles when coir was added to them. With additional coir fibre added, OMC, however, increased once again.

III. METHODOLOGY

Determination of Grain Size Distribution

This test was carried out in two steps to assess the amount of coarse grain soil and fine grain soil:

- Sieve analysis
- Sedimentation analysis

Sand and gravel proportions in the soil sample are determined by sieving, which was done to determine the soil's coarser content. This was done in accordance with IS: 2720 (Part IV)-1985 by conducting a hydrometer test and utilizing different sieves, ranging in size from 40 mm sieve size to 0.075 mm.

Consistency of soil

The amount of water in soil has a big impact on how engineering-friendly fine-grained soils are. Dry soil can exist in four different stages, from solid to semisolid to plastic to liquid, in order of decreasing moisture content. Atterberg's limitations are the water contents that exist at these states' borders. Shrinkage limits exist between solid and semi-solid states, plastic limits exist between semi-solid and liquid states, and liquid limits exist between plastic and liquid states.

There will be three tests in the consistency limits.:

- Liquid limit
- Plastic limit
- Plasticity index

IV. EXPERIMENTAL RESULTS

1. GEOTECHNICAL PARAMETERS OF SOIL

After the soil was oven dried, following basic tests were performed on it:

- Atterberg's limit analysis (IS: 2720 Part V-1985)
- Specific Gravity Test (Pycnometer test) (IS: 2720 Part III-Section I/II-1980)
- Standard proctor test (IS: 2720 Part VII-1980)
- California bearing ratio test (IS: 2720 Part XVI-1987)
- Unconfined compressive strength test (IS: 2720 Part X-1991)

Liquid Limit

The Value of liquid limit of soil was observed as 39%

Plastic Limit

Plastic limit of the soil sample was 23.5%.

Specific Gravity Test

$$\text{Specific Gravity} = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

W ₁ = weight of empty Pycnometer bottle	187.4
W ₂ = weight of Pycnometer bottle half filled with soil sample	212.36
W ₃ = weight of Pycnometer bottle half filled with sample and rest with water	303.61
W ₄ = weight of Pycnometer bottle filled with water	287.37

$$\text{Specific Gravity} = \frac{(212.36 - 187.4)}{(212.36 - 187.4) - (303.61 - 287.37)} = 2.862$$

Specific Gravity of the soil sample was **2.86**

2. STANDARD PROCTOR TEST

2.1 Untreated Soil and Copper Slag Mix

Table 2.1: Results of OMC and MDD for untreated soil and CS mix

SOIL:CS	MDD (kN/m ³)	OMC (%)
100:0	16.15	18.45
90:10	15.25	17.37
80:20	14.90	18.11
70:30	14.37	18.67

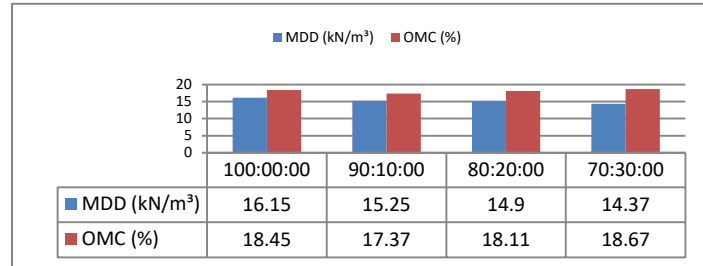


Fig:-2.1 Variations b/w MDD and OMC of CS & soil with different proportions

2.2 CLAYEY SOIL AND COIR FIBRE MIXES

Table no. 2.2: Results of OMC and MDD for mix proportions of Soil and Coir Fibre

SOIL:CF	MDD (kN/m ³)	OMC (%)
100:0:0	16.15	18.45
99.0:1.0	15.10	18.87
98.5:1.5	14.62	19.43
98.0:2.0	13.84	19.87

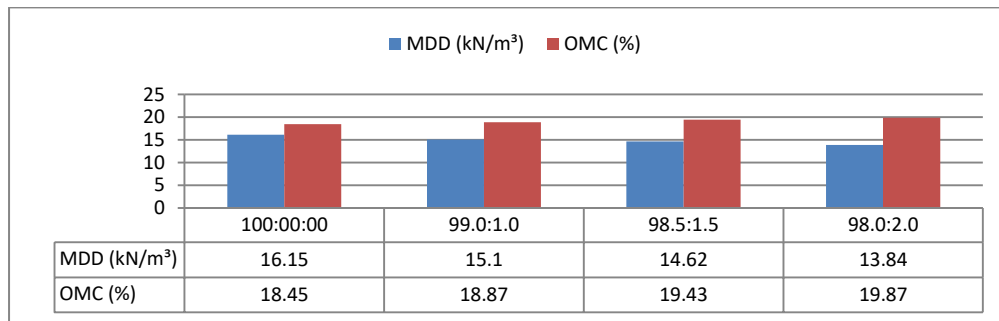


Fig:-2.2 Variations b/w MDD and OMC of Coir Fibre & soil with different proportions

2.3 CLAYEY SOIL, COPPER SLAG AND COIR FIBRE MIXES

Table no. 2.3: Results of OMC and MDD for mix proportions of Soil

SOIL:CS:CF	MDD (kN/m ³)	OMC (%)
100:0:0	16.15	18.45
94:5:1.0	15.62	19.10
88.5:10:1.5	16.22	19.77
83:15:2.0	16.84	20.26

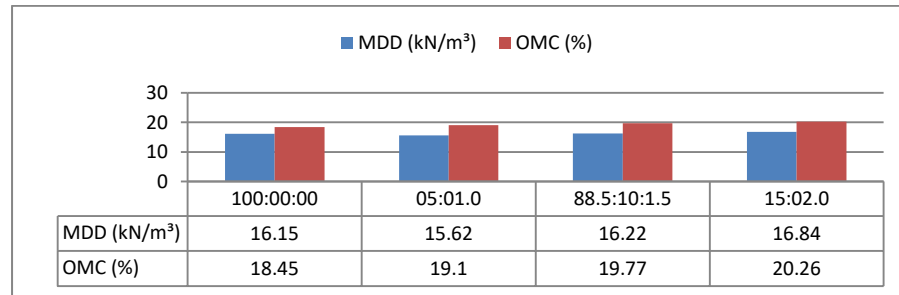


Fig 2.3:- Variations b/w MDD and OMC of Copper Slag, Coir Fibre & soil with different proportions

2.4 UNCONFINED COMPRESSION STRENGTH TEST

Table 2.4: Results of UCS Test of virgin soil

Clayey Soil	Curing Period(Days)	UCS(kN/m ²)
100 : 00	7	65.51

Table 2.4.1: Results of UCS of Copper Slag

Clayey Soil : CS	Curing Period (Days)	UCS (kN/m ²)
100 : 00	7	65.51
90:10:0	7	130.59
80:20:0	7	182.87
70:30:0	7	172.72

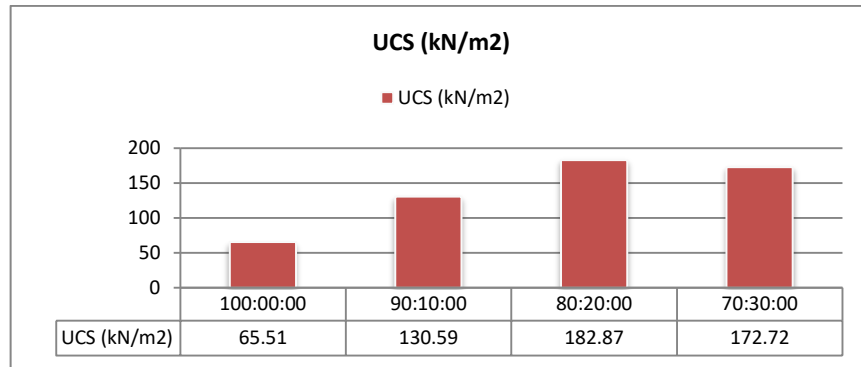


Fig:-2.4.1 UCS Graph of Fly Ash & soil with different proportions

Table 2.4.2: Results of UCS of Coir Fiber

Clayey Soil : CF	Curing Period (Days)	UCS (kN/m ²)
100 : 00	7	65.51
99.0:1	7	110.72
98.5:0:1.5	7	146.73
98.0:0:2.0	7	177.31

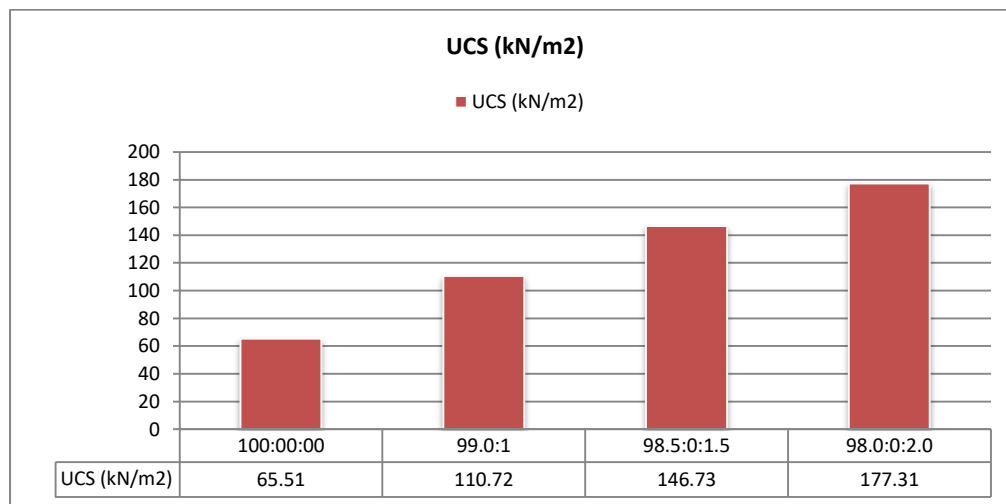


Fig:-2.4.2 UCS Graph Coir Fiber & soil with different proportions

Table 2.4.3: Results of UCS of Copper Slag and Coir Fiber with Soil

Clayey Soil :CS:CF	Curing Period (Days)	UCS (kN/m ²)
100:0:0	7	65.51
94:05:01	7	116.51
88.5:10:1.5	7	156.32
83:15:2.0	7	193.81

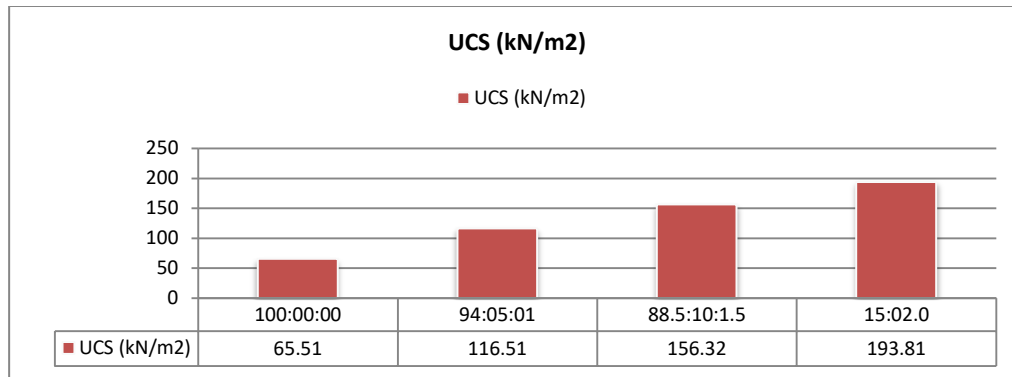


Fig:- 2.4.3 UCS Graph Copper Slag, Coir Fiber and soil with different proportions

2.5 CALIFORNIA BEARING RATIO TEST

Table 2.5: Results of CBR value for clayey soil sample

Clayey soil	CBR (%)
100:00:00	3.87

Table 2.5.1: Results of CBR of Copper Slag

Mix Proportions (CS:CS)	CBR (%)
100:00:00	3.82
90:10:0	4.51
80:20:0	5.10
70:30:0	4.70

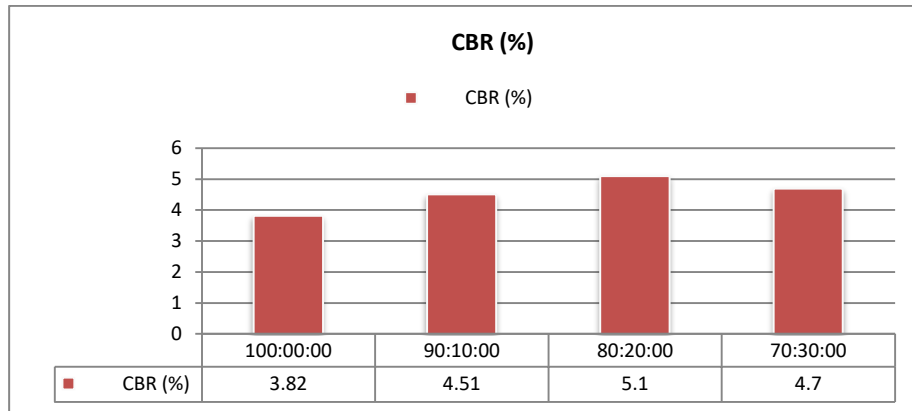


Fig:-2.5.1 CBR Graph of Soil and Copper Slag with different proportions

Table 2.5.2: Results of Soil and Coir Fiber

Mix Proportions (CS:CF)	CBR (%)
100:00:00	3.87
99.0:0:1.0	4.44
98.5:0:1.5	4.98
98.0:0:2.0	5.39

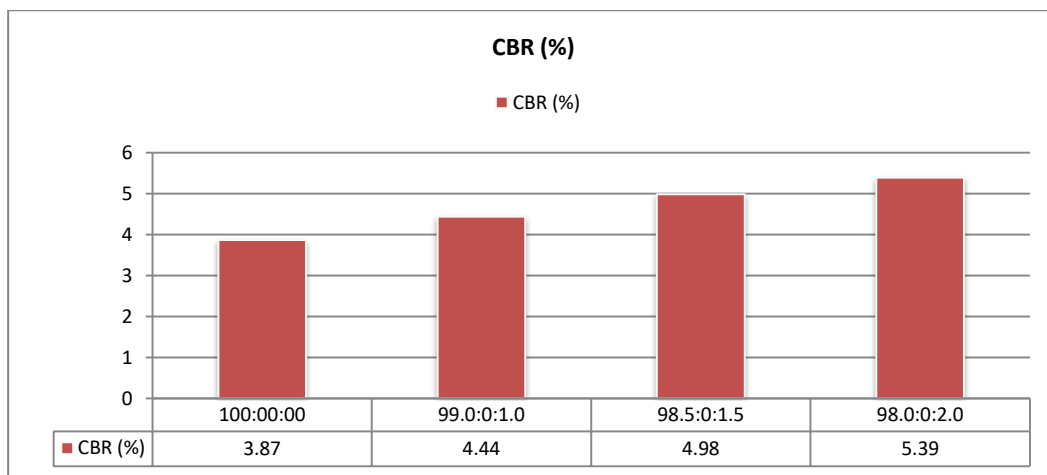


Fig:-2.5.2 CBR Graph of Soil and Coir fiber with different proportions

Table 2.5..3 : Results of CBR of Soil, Copper Slag and Coir Fiber

CS:CS:CF	CBR (%)
100:0:0	3.87
94:05:01	4.22
88.5:10:1.5	4.67
83:15:2.0	4.92

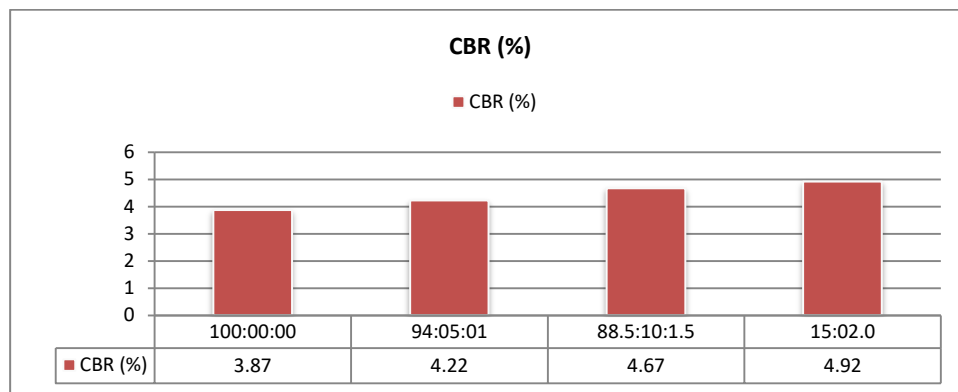


Fig:-2.5.3 CBR Graph of Soil, Copper Slag and Coir Fibre with different proportions

V. DISCUSSIONS

1. COMPACTION TEST

This study used various copper slag content percentages to analyze soil compaction characteristics. Higher Copper slag percentages were associated with a reduction in MDD, probably as a result of reduced specific gravity. The pozzolanic reaction and higher moisture needs for thick packing, however, led to an increase in the ideal moisture content that was seen. The differences in MDD and OMC with Copper Slag are shown in Figures 1 and 2.

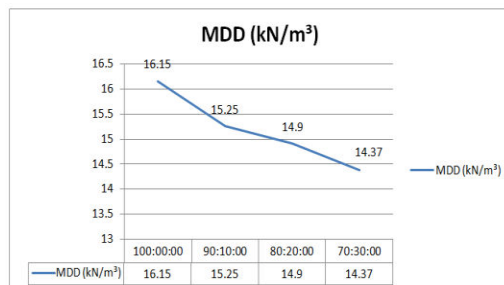


Fig. no. 1 Variation in MDD with increase in CS percentage

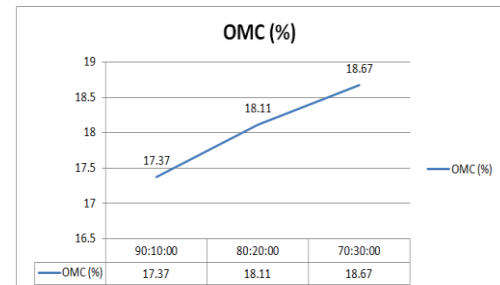


Fig. no. 2 Variation in OMC with increase in CS percentage

MDD increases with increasing Coir fiber content in soil-slag mixtures due to lighter weight and circular shape, causing more void spaces. OMC increases with fiber content due to high water absorption. Figures 3 and 4 display variations in MDD and OMC.

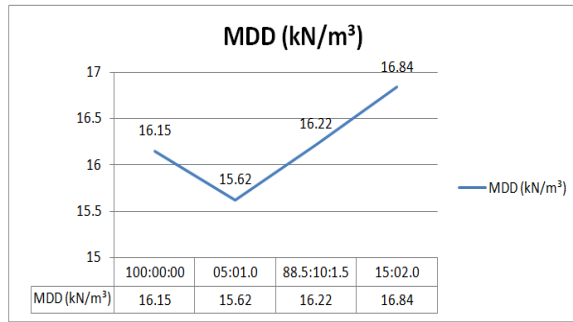


Fig no. 3 Variation in MDD with increase in CS and CF content

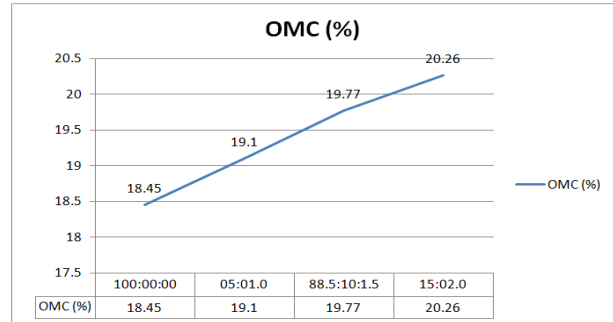


Fig no.4 Variation in MDD with increase in CS and CF content

1.2 CALIFORNIA BEARING RATIO TEST

With the addition of copper slag (15%) and coir fibre (2%) soil sample CBR values slightly increase. The development of cementitious chemicals in the soil may be the cause of this enhancement. CBR increases to 4.92% with 15% Copper slag and 2% Coir Fibre. This is caused by a combination of enhanced load-deformation actions, greater friction caused by an increased contact area between soil particles and fibres, and increased strength and force resistance. Figure 1.2 depicts the link between CBR value, copper slag, and the fraction of coir fibre.

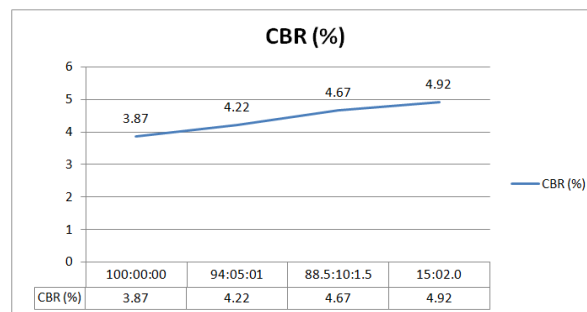


Fig. no.1.2 Variation in CBR value with increase in CS and CF content

1.3 UNCONFINED COMPRESSION STRENGTH TEST

Virgin soil UCS values improve significantly with expansion of 15% Copper slag and 2% Coir Fiber, resulting from pozzolanic reactions during curing.

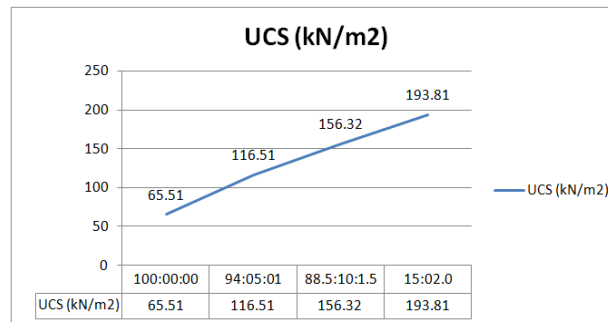


Fig. no.1.3 Variation in UCS value with increase in CS and CF content

VI. CONCLUSION

THE RESULTANT REPRESENTATIONS CAN BE DRAWN FROM THE EXPERIMENTS CONDUCTED:

1. Copper slag is a waste product that, because to the qualities of its cementations, can be employed efficiently in the stabilisation process of soil.
2. On the other hand, coir fibre is an inexpensive substance that may be added to soil in little amounts to significantly alter its strength properties.
3. The ideal amount of copper slag utilised for this project was 20% since adding copper slag to soil increases C.B.R to its ideal level, which is 20%.
4. With an increase in Coir Fibre and a constant amount of Copper Slag, the C.B.R value rises. Compared to the untreated soil, it grew 1.27 times.
5. The ideal amounts of Coir Fibre and Copper Slag for stabilizing soil are 2.0% and 20% of the soil's weight, respectively.
6. With a constant amount of Copper Slag and an increase in Core Fibre, Unconfined Compressive Strength rises. In comparison to untreated soil, the value of unconfined compressive strength has increased by 2.95 times.

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