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Investigational Study on the Influence of Polypropylene Fiber and Copper Slag in the Stabilization of Clayey Soil

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Abstract - The use of plastic items, including bottles made of polyethylene (PE) and polypropylene (PP), has expanded dramatically in recent years, which could result in a number of environmental problems. Finding ways to handle these waste products without endangering the environment is crucial. Utilizing plastic waste as materials for soil stabilization is one of these techniques. Polypropylene Fiber (PP) has been used as a fiber in this investigation. Standard laboratory tests were conducted in order to assess the stabilization's impact. Among the tests were the California Bearing Ratio (CBR), unconfined compressive strength (UCS), and standard compaction test. The main purpose of this study is to find the best way to combine clay soil with copper slag and polypropylene fiber. A comparison of virgin soil, soil including copper slag, and soil containing copper slag and polypropylene fiber is made in order to examine engineering properties like liquid limit, plastic limit, maximum dry density, California Bearing Ratio Test, and Unconfined Compressive Strength (UCS). Polypropylene fiber is utilized in varying amounts, such as 1.0%, 1.5%, and 2.0%, in conjunction with three distinct combinations of copper slag at 15%, 20%, and 25%. The UCS and CBR rise as the amount of Copper Slag added to Polypropylene Fiber increases, according to the analysis of these experiments. The highest values of UCS and CBR were found at 1.5% Polypropylene Fiber and 15% Copper Slag. As a reinforcing material, polypropylene fiber intermixed with soil helps to bind soil particles together, and the "bridge effect" of fiber reinforcement in soil prevents stress cracks from spreading further.

***Key Words*:** Compaction test, CBR, UCS, Copper Slag, Polypropylene Fiber

1. INTRODUCTION

Expansive soils are the soils which have high shrinkage and swelling characteristics and lower strength when it came in contact with water. These soils are very sensitive to variations in water content and show excessive volume changes and has high compressibility. This highly plastic soil may create cracks and damage the construction work done above these type of soils.

In India, expansive soil covers nearly about 20% of the land and includes approximately the entire Deccan Plateau. They are mostly black and reddish brown in colour and are generally found with layer thickness between 0.5 m to 10 m below the surface. Because the expansive soil is prone to volume changes when it came in contact with the water by rain or water table capillary action, it will get expand and may cause lifting of the structures built over it. So, these soils are not suitable for construction works until they are properly stabilized which can increase the low bearing capacity of expansive soils.

In India, nearly 46% of total land is covered by Alluvial soil which is the most important soil type of or country. Other soils such as Black cotton soil, desert soil, laterite soil and marine soil are also the important soil groups of India. The Alluvial soil and the black cotton soil mainly consists of clay which is very fine soil and it's the main constituent of expansive soils and due to the cohesive nature of clay, these soils absorb large amounts of water and show swelling characteristics which create problems such as bulging of soil, low bearing strength of soil, and can cause cracks in the foundation.

2. Literature Review

Kashyap Warikoo et al. (2023)

The review begins with soil stabilization basics and additive selection variables. It then examines copper slag and cement as soil stabilizers. Copper slag and cement's impacts on stabilized soils' compaction, strength, permeability, and durability are examined. The paper also discusses laboratory and field investigations on copper slag and cement soil stabilizers. Copper slag and cement improve soil engineering qualities, including load-bearing capacity, settling, and erosion resistance. To successfully deploy copper slag and cement stabilization methods, proper dose, environmental considerations, and long-term performance must be addressed. Different soil types, environmental conditions, and stabilized soil durability need further study. The review concludes that copper slag and cement can stabilize soil. Geotechnical engineering and construction scholars and practitioners benefit from a thorough analysis of their characteristics and soil behavior.

K. Venkata Surya Sandeep et al. (2022)

Stability of any structure depends on strength properties of underground soil on which it is constructed. Structures basically transfer all the loads come on itself directly to the ground. If the underlying soil is not stable enough to support transferred loads then various types of failure occur such as settlement of the structure, cracks and so on. To solve this issue, soil improvement is necessary because it not only lowers the construction cost but also cuts the risk of any damage of structure later on. Numerous improvement methods can be adopted to make ordinary soil stable enough to support the structural loads. In this research work a number of tests may conduct using both ordinary soil and stabilised soil. The stabilising agents are using in this study is Copper Powder. The varying percentage of 5%, 10%, 15%, 20% and 25% added to the expansive soil.

Manish Kumar Jha et al. (2022)

The primary objective of this work is to study the interaction of black cotton soils with Copper Slag and GGBS. To improve the Geo-Technical and Engineering Properties of the Black- Cotton soil. To study the behaviour of strength gain in black cotton soil using Copper Slag and GGBS Stabilization.

Samin et al. (2021)

In this study, PE and PP have been used in the form of fibres. The effect of the stabilisation was evaluated through carrying out standard laboratory tests. These tests have been conducted on natural and stabilised soils with four fibre contents (1%, 2%, 3%, and 4%) of the soil weight. The tests included the standard compaction test, unconfined compressive strength (UCS) test, California Bearing Ratio (CBR) test, and resilient modulus (Mr) tests. In addition, there was a significant improvement in the UCS of soils by 76.4 and 96.6% for both lengths of PE fibres and 57.4% and 73.0% for both lengths of PP fibres, respectively. Results of the CBR tests demonstrated that the inclusion of plastic fibres in clayey soils improves the strength and deformation behaviour of the soil especially with 4% fibre content for both lengths 1.0 cm and 2.0 cm, respectively, to a figure of 185 to 150% for PE and PP, respectively.

P. Bharath Goud et al. (2020)

Present study was undertaken to evaluate the effectiveness of different percentages of rice husk ash and copper slag as soil stabilizers. The tests performed on the mixed proportion of BC soils, Copper Slag and Rice Husk Ash are Vane shear, California Bearing Ratio (CBR), Atterberg limits, free swell index (FSI), and compaction tests. Limited studies have been reported for the combination of copper slag and rice husk ash in soil stabilization. The optimum mix was found to be in the proportion of 64%BC+30%CS+6%RHA. FSI of soil treated with RHA+CS decreased steeply from 100% to 20.4%. There was a slight change in maximum dry density of the treated soil. The unsoaked CBR test shows that strength of optimum mix was 12.7%.

Singh et al. (2019)

The main motive of this research is to investigate the optimal combination of Nano-Silica and Polypropylene fiber with clay soil. The engineering properties such as liquid limit, plastic limit, maximum dry density and unconfined compressive Strength (UCS) are analyzed with virgin soil, the soil with Nano-Silica and combination of soil with Nano-Silica and polypropylene fiber. The Durability test is performed to understand the durability of stabilized soil by analyzing wetting–drying cycles Also, Scanning Electron Microscopy (SEM) test is carried out and images are obtained to understand micro-structural modification towards mixture of Nano-SiO2 and PPF. Four different combinations of Nano-Silica at different percentages 1%, 3%, 5% and 7% are used in integration with polypropylene fiber is used in different percentages such as, 0.1%, 0.4%, 0.7%, 1%, and 1.3%. From these experiments, it has been analyzed that with the increase of PPF content in addition to Nano-Silica, the UCS increases and maximum value of UCS is obtained at 7% of Nano-Silica with 0.7% of PPF. The intermixing of PP fiber with the soil acts as a reinforcing material in binding the soil particles and the 'bridge effect' of fiber reinforcement in soil impedes the further development of tension cracks.

Sharma et al. (2019)

In the present study, therefore we have investigated the influence of waste polypropylene fibers on the resilient modulus of clay soil. Under this investigation, several cyclic CBR tests were performed on soil specimens by reinforcing the clay soil with polypropylene fibers which were added in different percentages i.e. 0.3%, 0.4%, 0.5%, 0.6% by weight of soil. The outcomes show that the experimented technique is very effective to improve the resilient modulus of clay soil. It is found that for the best results, optimum percentage of waste polypropylene fibers to be added is 0.4 % by weight of soil. Finally, it has been concluded that reinforcing the clay soil with polypropylene fibers provides positive influence on resilient modulus of the soil.

Sharana Kumar et al. (2018)

The objective of study is intended to decide the strengthening impact of haphazardly disseminated short polypropylene filaments on the California bearing ratio test and unconfined compressive strength of black cotton soil. The expansion of polypropylene stands brought about increment in Ideal dampness substance and decline in most extreme dry thickness. Copper slag is one of the waste materials that are being used broadly in the structure outline improvement. In this paper the stabilization is done to determine the effect of both polypropylene fiber and copper slag on engineering properties of black cotton soil. Here the dry density, CBR value and unified compression test were carried out. The proportions of copper slag used are (6%, 12%.18% and 24 %,) with respect to dry weight of the soil and also the proportion of polypropylene fiber used are (0.5%.1%, 1.5% and 2 %.) with the dry weight of the dirt. Then by mixing both polypropylene fiber and copper slag with proportion 0.5%, 1%, 1.5%, 2%, And

3%.6%, 9%, 12%, respectively with the dry weight of the soil.

P. Bharath Goud et al. (2018) Present study was undertaken to evaluate the effectiveness of different percentages of rice husk ash and copper slag as soil stabilizers. The tests performed on the mixed proportion of BC soils, Copper Slag and Rice Husk Ash are Vane shear, California Bearing Ratio (CBR), Atterberg limits, free swell index (FSI), and compaction tests. Limited studies have been reported for the combination of copper slag and rice husk ash in soil stabilization. The optimum mix was found to be in the proportion of 64%BC+30%CS+6%RHA. FSI of soil treated with RHA+CS decreased steeply from 100% to 20.4%. There was a slight change in maximum dry density of the treated soil. The unsoaked CBR test shows that strength of optimum mix was 12.7%. The stabilized soil mixtures have shown satisfactory strength characteristics and can be used for low-cost constructions to build houses and road infrastructure Laboratory vane shear tests have been carried out under undrained conditions to study the shear strength parameters of the stabilized soil.

Srikanth et al. (2017) Soil stability is an important criteria in the field of construction. For soil which lacks sufficient stability, various stabilization techniques can be adopted. Stabilization can increase the shear strength of soil and control the shrink-swell properties of soil, thus improving the load bearing capacity of the sub-grade to support pavements and foundations. A vast diversity of stabilization techniques exist. The focus of this report is to study the feasibility of stabilizing soil by using rice husk ash and coir fiber, thus re-using waste materials and providing an economical and eco friendly method of soil stabilization.

Parvathy S (2016) In this study copper slag is used as an additive. Copper slag is one of the waste materials that are being used extensively in the civil engineering construction industry. The test will be conducted based on the varying percentage of lime and copper slag with the clayey soil. The disadvantages of clay can be overcome by stabilizing with suitable material. Main laboratory tests include Un-confined compressive strength test (UCS), California bearing ratio test (CBR). This study is done to find out the engineering behavior oflime stabilized clayey soil with Copper Slag.

Ajit kumar et al. (2016) The study is an experimental investigation on the use of HDPE (High Density Polyethylene) mixed with a CL-ML soil. The HDPE sheets were cut into 5mm wide strips and then into three aspect ratios as 1, 2 and 3. Such strips were then randomly mixed in the soil in different proportions (0.5%, 1.0%, 1.5% and 2%) by dry weight of soil. The paper reports results obtained on dry density and CBR behaviour of the soil. A decrease in the dry density of soil with increasing aspect ratio as well as percentage of HDPE content was obtained. On the other hand, CBR value is found to increase with increase in aspect ratio, the maximum CBR value obtained at 1.5% HDPE content. Increasing HDPE to 2%, resulted in reduction of CBR. In view of HDPE, being relatively less expensive as compared to other reinforcing materials; the results find application in designing base material for highway construction and reducing compressibility of soil. Also, it will certainly lead to safe disposal of the waste in eco-friendly manner.

3. Materials

3.1 SOIL

Source of soil

The soil is alluvial in nature and contains high amounts of clay. The total quantity of soil collected is about 120 Kg. All the soil that is used is sieved using 4.75mm sieve before start of the tests. The soil is oven dried for 24 hours before use to eliminate presence of any moisture in the soil. Firstly, Virgin soil without any admixture is tested for its properties and strength value and after that it is tested along with the addition of various proportions of Copper slag and Polypropylene Fiber.

Table no. 1 Properties of soil used in the study

S.No.	Properties	Result
1.	Liquid limit (%)	46
2.	Plastic limit (%)	27
3.	Plasticity Index (%)	19
4.	Specific Gravity	2.55
5.	Maximum Dry Density (KN/m³)	17.10
6.	Optimum Moisture Content (%)	13.45
7.	Soil Classification	CI (Intermediate Compressive Clay)
8.	CBR (%) (soaked)	3.1
9.	CBR (%) (Unsoaked)	5.2
10.	UCS (kN/m²⁾	190.52

3.2 COPPER SLAG

Copper slag was collected from the Air blast equipment India Pvt. Ltd. Hyderabad the shade of the copper slag is dark, smooth, utilized as a part of the examination. Copper slag is a residue that is produced as a secondary product during high-temperature smelting processes. Its major constituents are iron and silica oxides, and it also contains small amounts of Al, Ti, Ca, and Mg, and other elements. The production of one ton of refined copper is typically accompanied by the generation of 2.0–3.0 tons of copper slag. The global annual production of copper is approximately 17.0 million tons, and the production of copper slag amounts to 37.7 million tons. Due to its low comprehensive utilization rate, a significant portion of copper slag accumulates in open stockpiling, resulting in substantial resource wastage and environmental pollution.

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 POLYPROPYLENE FIBER

Source of Polypropylene fiber

The Polypropylene fiber used in this study was obtained from Jindaram Exports, Sirsa. Polypropylene fiber is a natural fibre having greater tensile strength and can be used as an effective reinforcing material in soil stabilization. The properties and composition of Polypropylene fiber are discussed in table no. 3.

Table 3:- Properties of Polypropylene fiber

S. No	Property	Value
1	Colour	White
2	Specific Gravity (Kg/m^3)	910
3	Water Absorption (%)	110
4	Length of fibre (mm)	12
5	Diameter of propylene fibre (mm)	0.034
4	Tensile Strength(MPa)	350
5	Modulus of elasticity (GPa)	3500

4. EXPERIMENTAL RESULTS

4.1 STANDARD PROCTOR TEST

Table no. 4: MDD and OMC for soil– Copper Slag – Polypropylene Fiber mix

SOIL:PPF:CS	MDD (kN/m³)	OMC (%)
100:00:00	17.10	13.45
93.5:1.5:05	17.50	12.90
88.5:1.5:10	16.80	13.50
83.5:1.5:15	16.20	14.10

Fig:-1 Variations b/w MDD and OMC of Copper Slag – Polypropylene Fiber & soil with different proportions

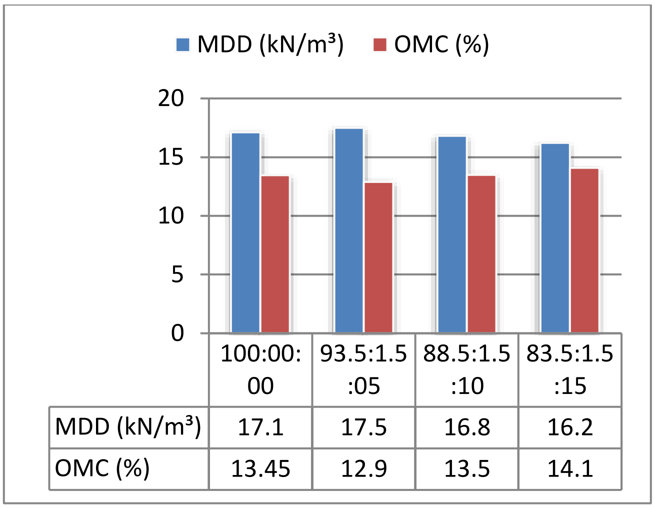

Table 5: Results of UCS of Copper Slag – Polypropylene Fiber Mix with Soil

SOIL:PPF:CS	Curing Period (Days)	UCS (kN/m^2)
100:00:00	7	191
93.5:1.5:05	7	280
88.5:1.5:10	7	340
83.5:1.5:15	7	410

Fig:-2 Variations b/w UCS Values of Clayey soil, Copper Slag & Polypropylene Fiber with different proportions

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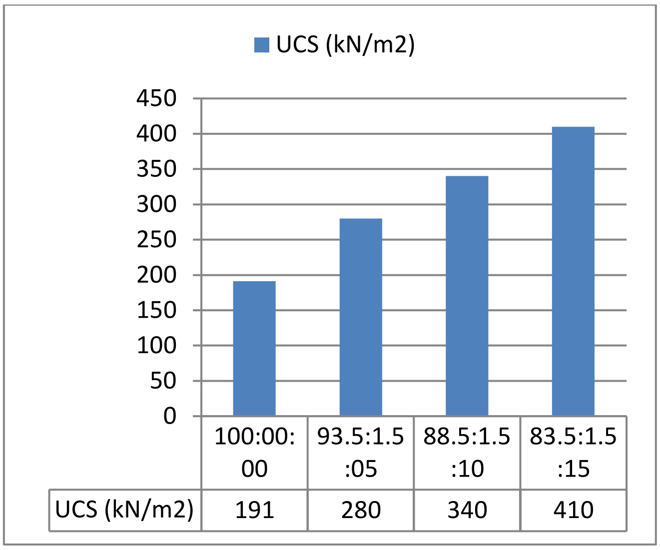
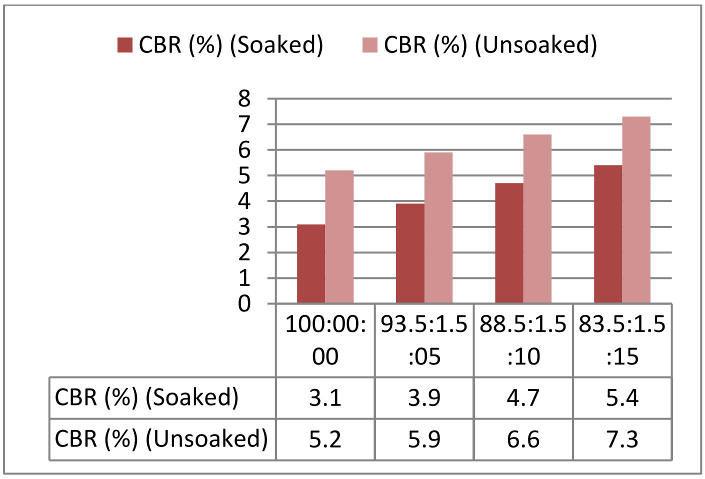


Table 6: Results of CBR of Copper Slag – Polypropylene Fiber Mix with Soil

SOIL:PPF:CS	CBR (%) (Soaked)	CBR (%) (Unsoaked)
100:00:00	3.1	5.2
93.5:1.5:05	3.9	5.9
88.5:1.5:10	4.7	6.6
83.5:1.5:15	5.4	7.3

Fig:-3 Variations b/w CBR Values of Clayey soil, Copper Slag & Polypropylene Fiber with different proportions



5. DISCUSSIONS

5.1 STANDARD PROCTOR TEST:

- There is an also increase of OMC from 12.90 to 14.10% and decrease of MDD from 17.50 to 16.20% when the percentages of Copper slag vary from 05, 10 and 15% and Polypropylene Fiber is fixed at 1.5%.

- There is a decrease in MDD of modified soil with increase in percentage of copper slag, due to the higher specific gravity of copper slag as compared to the unmodified soil and OMC of modified soil is increase as the percentages of copper slag increases, due to the increase in pozzolanic properties of soil. Additionally, it helps to reduce soil plasticity and potential for swelling and shrinkage.

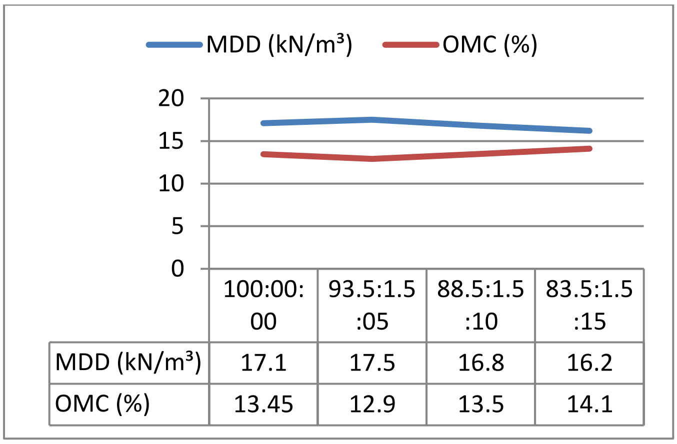


Fig:-4 Variations b/w MDD and OMC values of Copper Slag & Polypropylene Fiber Mix with Soil

5.2 CBR TEST:

- The CBR value of untreated soil is 3.1 and it increases to 1.58 times with addition of 25% copper slag when observed in soaked conditions.
- The CBR value of untreated soil is 3.1 and it increase to 1.74 times when copper slag 15% and Polypropylene Fiber 1.5% is added to untreated soil.
- This enhancement in CBR may be because of the gradual formation of hydration compounds in the soil due to the reaction between the stabilizers and the

essentials particle present in the soil and due to the increase in pozzolanic properties of soil.

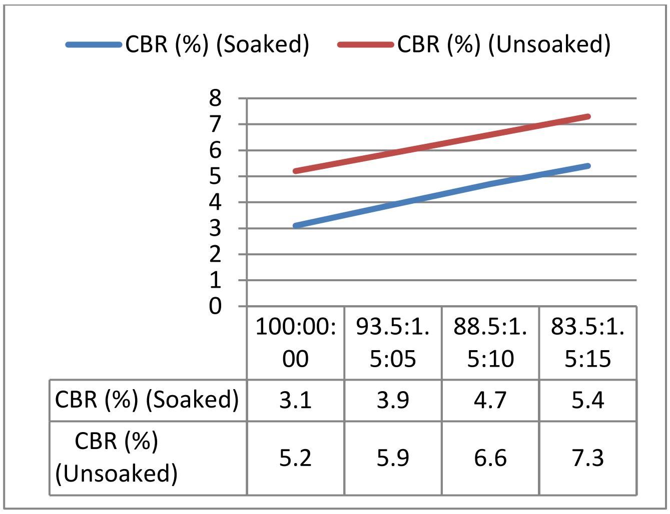


Fig:-5 Variations b/w CBR Values of Copper Slag & Polypropylene Fiber Mix with Soil

5.3 UCS TEST:

- The UCS values of untreated soil also improve considerably with expansion of copper slag 15% and Polypropylene Fiber 1.5%. The value increases from 191kN/m² to 410kN/m² with addition of copper slag and Polypropylene Fiber.
- The reason behind of this when copper slag and Polypropylene Fiber comes in contact with water, Because copper slag wraps the outer surface of the fiber and hence form better bond between the soil particles and the fiber surface which results in improving soil characteristics. It also increases the soil bearing capacity and reduces its swelling potential and due particle size reduction can improve soil structural integrity and stability.

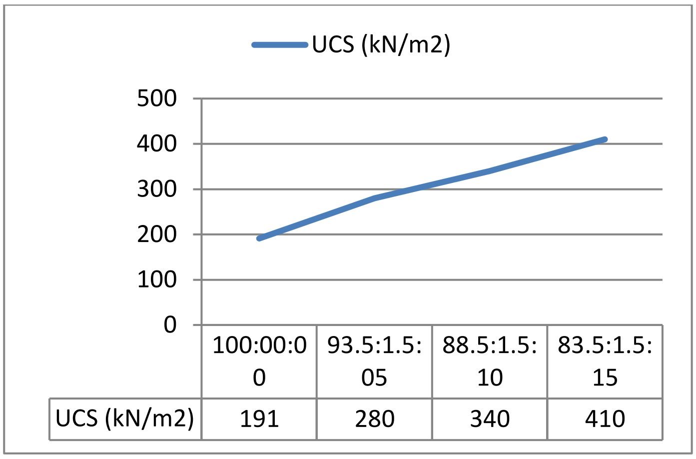


Fig:-6 Variations b/w UCS Values of Copper Slag & Polypropylene Fiber Mix with Soil

6. CONCLUSIONS

On the basis of above-obtained experimental results and discussions, the following conclusions can be drawn;

- In this study, a series of standard Proctor test, unconfined compression strength test and the California Bearing Ratio test was carried out to calibrate the effect of two stabilizers additives namely Copper Slag and Polypropylene Fiber on the clayey soil sample. The results showed that Copper Slag and Polypropylene Fiber could improve the UCS, California Bearing Ratio of clayey soil sample.
- The different percentages of Copper Slag and Polypropylene Fiber used in this study were 15%, 20% & 25% and 1.0%, 1.5% & 2.0%. Finally, the value of Copper Slag varies from 15 to 25% at the interval of 5% with the fixed quantity of Polypropylene Fiber 1.5% to clayey soil.
- Addition of Copper Slag with clayey soil decreases maximum dry density and increases the optimum moisture content of the soil sample.
- Addition of Polypropylene Fiber with clayey soil increases the value maximum dry density and decreases the value of optimum moisture content.

- The addition of the fixed quantity of Polypropylene Fiber 1.5% with changing the content of Copper Slag increase the value of optimum moisture content and decreases the value of maximum dry density.
- The optimum value of Polypropylene Fiber used in this research was 1.5% because the maximum value of UCS was found at 1.5% Polypropylene Fiber.
- The UCS value increases with an increase of Copper Slag content along with a fixed quantity of Polypropylene Fiber. It increased 2.14 times from the untreated soil.
- Based on the unconfined compression strength test results, the value of UCS increases from 191kN/m² to 410kN/m² with addition of copper slag and Polypropylene Fiber.
- The Maximum value of California Bearing Ratio test was found at copper slag 15% and Polypropylene Fiber 1.5%.
- Hence, the addition of Copper Slag and Polypropylene Fiber makes the soil mixes durable, economical and effective for soil stabilization process if these two materials are easily available near to the site.

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