International Journal of Innovative Research in Computer Science & Technology (IJIRCST)
ISSN: 2347-5552, Volume-10, Issue-3, May 2022
https://doi.org/10.55524/ijircst.2022.10.3.46
Article ID IRP1194, Pages 276-281
www.ijircst.org

# Behavior of Compacted Clayey Soils Mixed with Copper Slag

**Nausheena Reshi[1], and Er. Ashish Kumar[2]**

[1]M. Tech. Scholar. Department of Civil Engineering. RIMT University Mandi Gobingarh , Punjab, India
[2]Assistant. Professor, Department. of Civil Engineering RIMT University Mandi Gobingarh, Punjab, India

Correspondence should be addressed to Nausheena Reshi; Nausheenareshi1@gmail.com



**ABSTRACT-** As we all know that day by day the dumping of wastes becomes a challenge for civil Engineers. We can't dump wastage at everywhere into the soil but after a lot of research it has been concluded that we can mix the wastage of various elements with the soil in a specified proportion in order to enhance the geotechnical properties of soil. In this thesis work we have taken copper slag and mix it with the soil to stabilize it. We have replaced the soil by copper slag by 10%, 20%, 30% and 40% respectively. After proper sampling we have done three tests on every sample such as CBR Test, Optimum Moisture Content (OMC) & Maximum Dry Density (MDD) Test and Unconfined Compression Test (UC). After the testing we have observed that Optimum Moisture Content decreases continuously with the replacement of soil by copper slag while Maximum Dry Density Increases continuously. Similarly, both soaked and un-soaked CBR test values increase with the addition of copper slag. Unconfined compression test increases rapidly initially but after 20% replacement it increases gradually. The result has been shown both numerically and graphically in this thesis work.

**KEYWORDS-** CBR, OMC, MDD, UC, Oxidation filtration.

## I. INTRODUCTION

### *A. General*

Dirt techniques are suggested by Civil Engineering to cover all naturally occurring, somewhat unconsolidated natural or inorganic soil elements on earth's surface (Ranjan and Rao, 2000). Solid sub-atomic energy holds the stones together as a horde of mineral particles clump together. Whatever the case may be, many hard soils may be described as sensitive stone, and vice versa. Bed shakes and rock fragments, as well as whole stones, are examples of rocks. Civil Engineering's dirt mechanics uses standards of mechanics, hydrodynamics, and physics to deal with soil-related design problems. But rock mechanics is a field of science that uses mechanical standards to study how rock masses behave.

### *B. Soil Formation*

Soil may be separated into two piles based on the arrangement: In the first place, soils that are framed due to the parent rocks' physical and chemical endurance and soil with roots that have grown naturally. The effects and pounding activity of flowing water, wind, ice and separating activity of ice, plants and animals are the causes for the physical endurance of parent rocks. For the most part, parent rocks form the sand and rock that is found on Earth. Oxidation, hydration, carbonation, and filtering by natural acids and water are responsible for the synthetic durability of the parent rocks[2]. Earth and a small amount of sediment make up the bulk of the matter that shapes the parent rocks. Figure 1.1 depicts the many types of soils that have formed as a result of the lasting action of parent rocks on the landscape. The soils that have been formed by the enduring of parent rocks may be divided into two groups: Soil that has been transported and soil that has remained behind are the first and second, respectively. If the products of rock enduring are relocated and re-kept to a different location, the dirt is known as transported soil. If the products of rock enduring are still located where they began, the dirt is referred to as residual soil. The moved soil can be divided into five categories based on the arrangement method: The first is the Alluvial shop, followed by the Aeolian store, the Glacial store, the Lacustrine store, and the Marine store. Alluvial soils are protected from the entanglement caused by the pause in the flow of water.[1] When wind has shifted the soil, it is referred to be Aeolian. It's termed a Glacial shop if the soil was delivered in ice. Lacustrine soils have been preserved by being submerged in lakes' still or fresh water. The suspension of marine soils in ocean water has been avoided.Figure 1shows Various types of soils formed due to weathering of parent rocks.

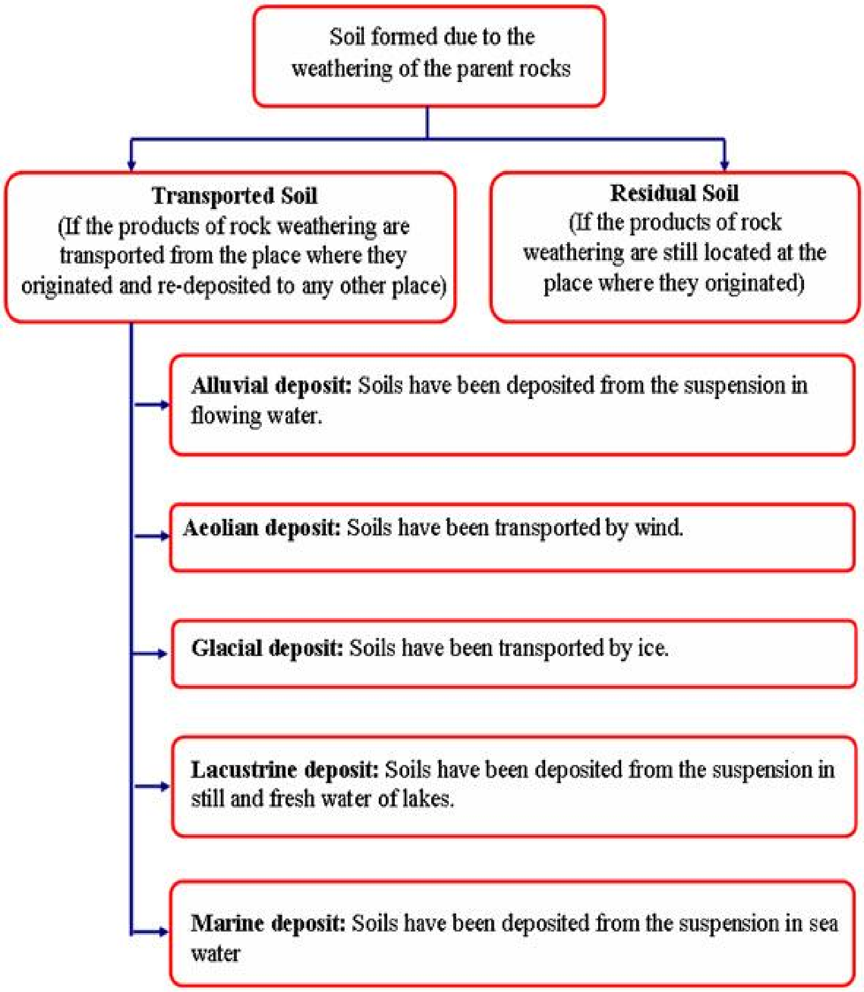


Figure 1: Various types of soils formed due to weathering of parent rocks

### *C. Types Of Soils In India*

The following are some of the most prevalent types of soil in India:

*1) Laterites soils*

- This is a nickname for a Latin term that means "latter" and denotes a brick.
- So fragile while wet, yet quite tough when dry.
- During periods of extreme heat and precipitation.
- Formed because of heavy rains and flooding.
- The dirt will be separated from the lime and silica in the filtration process.
- Microbes will quickly remove organic soil matter due to the high temperature, and plants will quickly take humus up by trees and other types of plants. As a result, the humus's content is deficient.
- Metals found in abundance: Iron and Aluminium
- Nitrogen, Potash, Potassium, Lime, and Humus are all deficient.
- Iron oxide gives the iron a reddish tint.

*2) Black cotton soils*

- Regur suggests cotton as the ideal soil for the growth of the cotton crop.
- Black dirt affects the majority of the Deccan.
- Soil that has grown to maturity.
- Water storage capacity is limited.
- If it gets wet, it will swell up and get sticky.
- Dark soil has a tendency to self-furrow because it dries out with broad gaps.
- Iron, lime, calcium, potassium, aluminium, and magnesium are some of the richest natural resources.
- Natural matter and nitrogen are deficient.
- Shades range from very dark to very bright.
- Clayey is the kind of texture to expect.

*3) Alluvial soils*

- Mostly accessible soil in India (about 43%) which covers a space of 143 sq.km.
- About 43% of India's soil is easily accessible, and it spans an area of 143 square kilometres.
- Common in northern farmland and around waterways.
- They are mostly found in deltas and estuaries in peninsular India.
- It's possible to buy humus, lime, or a natural problem.
- Extremely profitable.
- Examples include the Indus-Ganga-Brahmaputra plain and the Narmada-Tapi plain.
- Depositional soil is that which has been transported and stored by rivers, streams, or other bodies of water.
- Decreases in sand content from the west to the east of the nation.
- There are two names for the new alluvium: Khadar (new) and Bhangar (ancient).
- Tones range from pale gray to dark ash gray.
- Soil or earth texture varies from sand to silty.
- Potash-rich

- Phosphorous deficiency is a major problem.

*4) Desert soils*

- Observed in arid and semi-arid regions throughout the world.
- Wind workouts are the primary means of depositing this material.
- Excessive use of salt.
- Lack of moisture and Humus are two important factors to consider.
- A lot of Kankar or impure calcium carbonate restricts water's ability to permeate.
- There is a deficiency in Nitrogen, and phosphate is the norm.
- Sandy is the texture type.
- Red to brown in color.

*5) Red Soil*

- The species is mostly found in areas with little rainfall.
- Also referred to as an omnibus get-together.
- Porous and flimsy appearance.
- lime and kankar are not available because of this (debased calcium carbonate).
- Deficient in lime, phosphate, manganese, nitrogen, humus, and potassium.
- Color: Ferric oxide gives this red hue. The underside of the skin has a rosy yellow or a pale-yellow coloration.
- Surface: ranging from sand to earthy loam.

### *D. Soil Reinforcement*

Using geo-engineering methods, soil support is a common approach for increasing the strength and stability of the soil. As a result, the soil is better equipped to deal with more stress. However, this antiquated technique didn't provide a high return and needed sufficient time for the ground to recover, thus it was abandoned many years ago. With the help of mineral and soil supplement circulation, soil health is maintained and restored.[3] The support of soil is critical in geotechnical design, especially on unstable terrain. Territories with delicate soil typically use soil support methods, as the latter do not provide adequate assistance to any structure or development. As a result, these soils are very vulnerable to changes in regular and natural variables such as shear strength and high compressibility. Over 5000 years ago, the concept of soil support was already well-established. In order to enhance the overall strength and capacity to sustain heavier loads, soil support is made up of braided reeds and branches and other plant strands mixed with mud and straw. Several examples of earth fortification date back to the construction of the Great Wall of China (utilizing parts of trees as pliable components). Currently, Henri Vidal is widely credited with developing the concepts and standards for soil support. He demonstrated that the sheer blockage of a medium increases when construction components are presented in a dirt mass.

### *E. Copper Slag*

As a byproduct of copper extraction and processing, copper slag is created. Contaminations turn into slag, which floats on top of the liquid metal during refining. Extinguishing slag in water yields exact granules that may be disposed of as trash or put to good use. Generally, iron oxides and silicon oxides are found in the slag from metals that have been carefully focussed before refinement.[4]

### *F. Applications Of Copper Slag*

*1) Coarseness Blasting*

Surface impact cleaning is where copper slag shines. Using rough impact, metal, stone, concrete, and other materials may be cleaned and shaped on their exteriors. During this cycle, a swarm of grating grains known as coarseness is drawn toward the workpiece. Rough coarseness may be achieved using a variety of materials, including copper slag. For example, the amount of time it takes to use coarseness, how much residue is generated, and surface finishing quality may all be affected by the choice of coarseness material. The shown media is produced in accordance with ISO 11126 all around the world. Copper slag-based impact media are less harmful to people and the environment than sand. The product satisfies the most exacting standards of health and naturalness.[5]

*2) Development*

Copper slag may be used as a partial replacement for sand in solid construction. Copper slag is formed into blocks and used as a structural material. If you're thinking about England, think of places like St Helens and Cornwall where tin was refined. Granulated copper slag from the Boliden copper smelter is used as a roadway development material in Sweden (Skellefte area). During the winter, the granulated slag (with a size division of about 3 mm) may be used to keep ground ice away, which helps prevent the asphalt from cracking. As well as decreasing the usage of necessary resources, using this slag reduces the depth of development, lowering energy interest in construction. The granulated slag may be used as a filler and protective material in cold-climate residential buildings for similar reasons. A slag-protected establishment is used to work on a number of homes in the same neighbourhood.[6]

## II. LITERATURE REVIEW

- Kalkan et al. (2020), A large volume shift in water content was found to be associated with sweeping soil volume changes. Because of the sporadic variations in moisture content, these sands are subjected to antagonistic volume and pressure-driven conductivity shifts. The tremendous expanding pressure that these dirts provide has a significant impact on lightweight structures. Developments built on vast soils must have their design characteristics enhanced to avoid damage.[7]
- Jarad et al. (2019), Some designing uses, such geothermal wastes and atomic waste stockpiles, may expose Clayey soil to heated cycles. These changes in temperature may influence the way soil solidifies. About the solidification behaviour of wet compacted soil, this study investigates how temperature affects solidification behaviour. For strain rates ranging from 0.002 to 0.02 percent/min, a temperature-controlled pedometric cell has been developed that performs CRS union tests consistently throughout a temperature range of 5°C to 70°C.[8]
- Tang et al. (2019), During drying up measures, clayey soils' shrinkage capacity overwhelms their volumetric twisting and minute breaking behaviour and has substantial practical implications. They use a noninvasive technique combining X-beam registered geography (CT) and computerized picture handling strategy to evaluate the evolution of the drying up break network in compacted clayey soil. Desiccation crack designs are evaluated for morphological progress by using agent mathematical

boundaries such as soil mass region, shrinkage strain, fracture proportion, normal fracture width, and total fracture length and fracture number. These boundaries are derived from picture investigation results.

- M.Kavisri et ol. (2018) using modern result copper slag and Ground Granulated Blast Furnace Slag (GGBS) to balance out the soil with high expanding property, and this test is used to recognize the ideal level of copper slag and GGBS for increasing clayey soil strength's expanding property, which causes serious damage to structures based on it. GGBS and copper slag are combined in three distinct parts (10%, 20% and 30%), and the results are compared to Indian Standards for determining the design properties of soil like Maximum Dry Density (MDD), Optimum Moisture Content (OMM), and California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS).
- Li et al. (2018), An study of the volumetric behavior of two compacted soils (Boughrara and Châtaignier muds) using controlled drying-wetting attractions and oedometric experiments is presented in the article under review. It is possible to plot the progressions in void proportion, level of immersion, and water substance of two different materials against the logarithm of pull during pressure-driven stacking (drying-wetting tests), providing generally complete test results to approve late experimental connections on the wetting way and to determine the attraction yield bend on the drying way.
- Arumoy Chatterjee and Joyanta Maity (2018): The Clayey soils are weak and will result in a helpless asphalt backing and short life span. Clayey soils also have an effect on the asphalt's design and development, resulting in higher development costs and early dissatisfaction with the asphalt.
- Amandeep Varma and Avtarpreet Singh (2017) To increase soil strength is to also improve the soil's other characteristics. Fly debris and marble dust are two examples of waste items used to enhance the soil. Nuclear power plants burn pummelled coal, which creates fly debris. Larger amounts of marble dust are being delivered by marble companies.

## III. MATERIALS AND METHODOLOGY

### A. General

Clay soil and copper slag waste were utilized in this investigation. The soil samples were from the northern Indian region of Srinagar (Kashmir). These waste materials were incorporated into the clay soil to help keep it stable.

### B. SOIL

This study's soil came from the Srinagar region. A sample was collected after the top 0.5m of soil was removed. After that, it was filtered through a 4.75mm IS sieve to remove any remaining debris. The soil in question was subjected to a wide range of tests. Table 1Shows Properties of soil

The results of the following tests were broken down as follows:

### C. Properties Of Soil

Table 1: Properties of soil

| S. No | Property | Value |
|---|---|---|
| 01 | Specific gravity | 2.55 |
| 02 | OMC | 17.950% |
| 03 | MDD | 1.566 g/cc |
| 04 | Liquid limit | 29.75% |
| 05 | Plastic limit | 16.25% |
| 06 | Plasticity index | 13.50% |
| 07 | Shrinkage limit | 15.70% |

Index properties and engineering properties are the two main types of soil properties, and they are both discussed below:

## IV. METHODOLOGY

After cutting the top 0.5m of a nearby site in the Srinagar region of Kashmir, I first collected soil samples. After that, I bought 10 kg of copper slag from Sharad Enterprises through India Mart, an internet supplier. After collecting soil and copper slag trash, I tested the materials at the civil engineering lab of the Islamic University of Science and Technology, Srinagar, in different ways, as I've described above. Afterwards, I prepared five samples, each with a different combination of soil and copper slag, and called them S1, S2, S3, S4, and so on for each test. In this thesis, the findings of each test are presented both mathematically and visually.

## V. RESULTS AND DISCUSSIONS

### A. Sample Preparation

For each test, different soil and copper slag proportions are mixed for various samples and the samples are presented as Sample 1 with 0% copper slag that is 100% clayey soil. Sample 2 is with 10% copper slag and 90% clayey soil. Sample 3 is with 20% copper slag and 80% clayey soil.
Sample 4 is with 30% copper slag and 70% clayey soil. Sample 40% copper slag and 60% clayey soil. Table 2 Shows Sample preparation

Table 2: Samples preparation

| Sample Name | Proportions |
|---|---|
| S1 | 100% clay |
| S2 | 90% clay + 10% copper slag |
| S3 | 80% clay + 20% copper slag |
| S4 | 70% clay + 30% copper slag |
| S5 | 60% clay + 40% copper slag |

### B. Standard Proctor Test Results

It is clearly seen that a maximum dry density rises constantly when the optimum moisture content decreases due to the replacement of copper slag. The maximum dry density rises by .60% when copper slag replaces only 10% of soil whereas, if we replace 40% of soil with copper slag it rises to 23.18% as shown in Table 3 , Fig 2 & Fig 3

Table 3: Standard Proctor Test Results

| Sample Name | OMC (%) | MDD (g/cc) |
|---|---|---|
| $S_1$ | 17.950 | 1.566 |
| $S_2$ | 16.184 | 1.779 |
| $S_3$ | 15.272 | 1.813 |
| $S_4$ | 13.992 | 1.872 |
| $S_5$ | 12.636 | 1.929 |

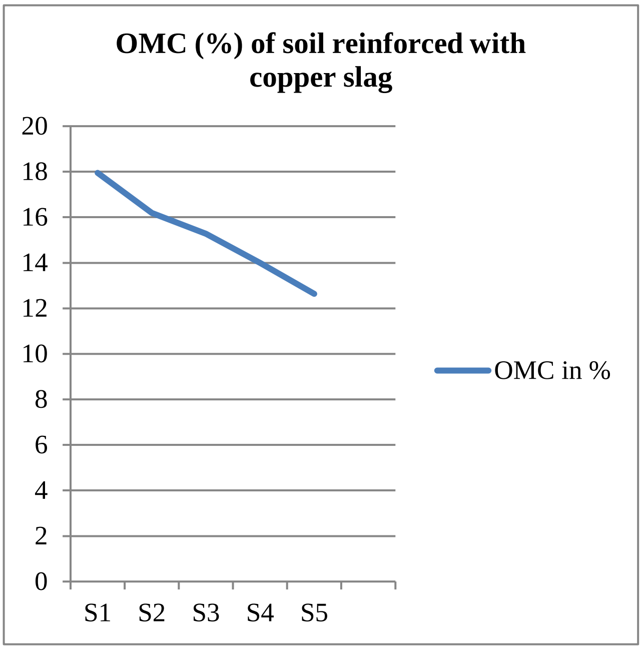


Figure 2: OMC test results of soil with copper mine waste

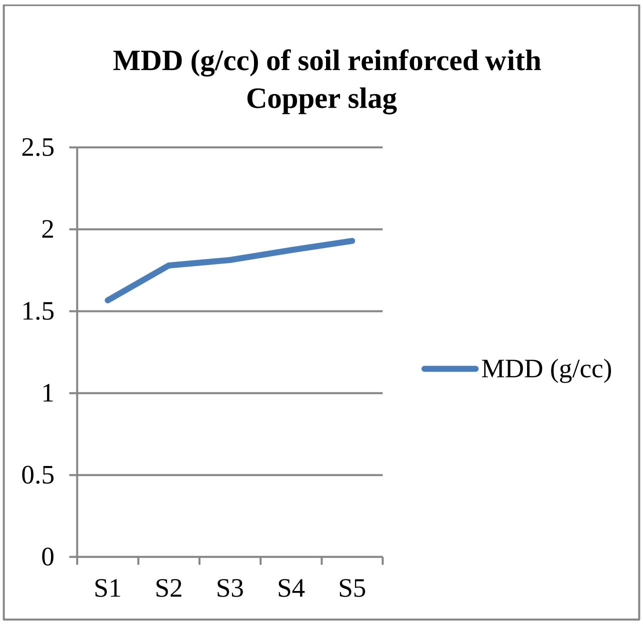


Figure 3: MDD test results of soil with copper slag

### *C. CBR Test Results*

Initially there is a quick rise in CBR value but on replacement of soil with copper mine waste the CBR value for both soaked and unsoaked value increases gradually. It has been observed on replacement of 10% of soil with copper slag soaked CBR value rises to 95.62% while unsoaked value rises to 192.05%. Finally, when copper slag replaces 40% soil soaked CBR value rises by 150.88% and unsoaked by 272.18%. as shown in Table 4 & Fig 4.

Table 4: CBR Test results

| Sample Name | Soaked CBR (%) | Un-soaked CBR (%) |
|---|---|---|
| S1 | 5.70 | 7.55 |
| S2 | 11.15 | 22.05 |
| S3 | 13.45 | 24.40 |
| S4 | 14.16 | 27.95 |
| S5 | 14.30 | 28.10 |

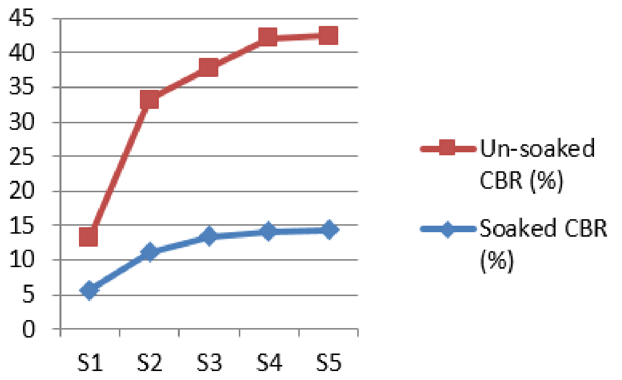


Figure 4: Soaked and Un-soaked CBR Test Results

### *D. Unconfined Compression Test Results*

It is observed Unconfined compressive strength rises when soil is replaced with a corresponding amount of copper waste. It is seen when 30% and 40% of the soil is replaced by copper slag there is increases in the strength to 196.67% and 209.17% respectively as shwn in Table 5 and Fig 5

Table 5: Unconfined Compression Test results

| Sample Name | UCC (kg/cm2) |
|---|---|
| S1 | 1.20 |
| S2 | 1.85 |
| S3 | 2.66 |
| S4 | 3.56 |
| S5 | 3.71 |

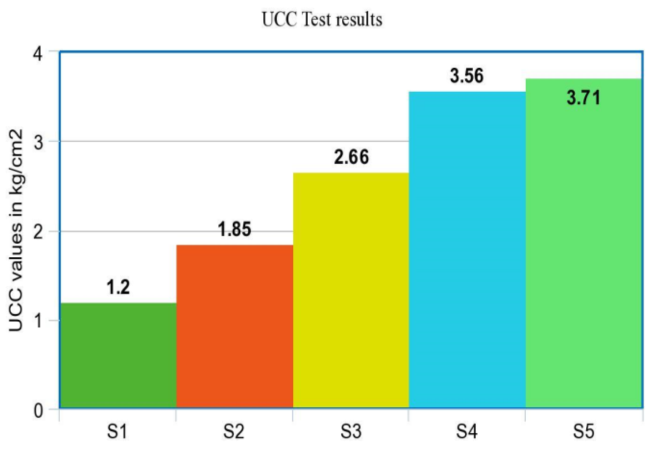


Figure 5: Unconfined Compression Test results

## VI. CONCLUSIONS

There were a few key findings that emerged from this research, which are described below

- As more soil is replaced with copper slag, the optimum moisture content drops. The value drops from 9.84% to 14.92% when just 10% of the soil is replaced, and it drops from 22.05% to 17.95% in the final sample when we mix 70% of soil and 30% copper slag.
- The Maximum Dry Density (MDD) rises constantly when the Optimum Moisture content (OMC) decreases due to the replacement of Copper Slag. The MDD rises by 13.60% when copper slag replaces only 10% of the soil. If we combine 80% soil with 20% copper slag, it rises by 15.77%. If we replace 30% of the soil with copper slag, it rises by 19.54%. And if we replace 40% of the soil, it rises by 23.18%.
- Unconfined Compressive Strength rises when soil is replaced with a corresponding amount of copper waste. The strength rises quickly at first, but after a 30% replacement, it gradually increases again. The UC strength rises by 54.16% when 10% of the soil is replaced with copper slag, 121.67% when 20% of the soil is replaced, 196.67% when 30% of the soil is replaced, and 209.17% when 40% of the soil is replaced with copper waste, respectively.
- It rises quickly initially, but with subsequent replacement it increases gradually with replacement of soil by copper mine waste, both wet and unsoaked values of the CBR test increase. Those that have not been soaked grow more than values that have. By adding 10% more topsoil, saturated CBR values rise by 95.62%, while unsoaked values increase by 192.05%. Finally, copper mine waste replaced 40% of the soil, increasing soaked values by 150.88% and unsoaked values by 272.18% over soil.

## ACKNOWLEDGMENT

I would like to convey my heartfelt appreciation to my supervisor, Er. Ashish Kumar, Assistant Professor of Civil Engineering at RIMT University MandiGobindgarh, for launching an engaging project, his personal dedication, stimulating debate, and invaluable advise. He has been a constant source of encouragement and useful direction and oversight throughout the project.

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