Utilization of Copper Slag as A Reinforcing Material

Sivapriya S.V
Associate Professor
Department of Civil Engineering
SSN College of Engineering, Tamil Nadu

VinothKumar S
Assistant Divisional Engineer,
Engineering Department-Madurai Division
Indian Railways, Tamil Nadu

Nagarajan V
Professor
Department of Civil Engineering
Jansons Institute of Technology, Tamil Nadu

Abstract

Due to rapid development in infra-structure, there is a scarcity of valuable land for construction. There is a shortage in firm land for further construction activity. Hence, construction activity is forced to take place in poor grounded soil. To make the soil stable, stabilization of weak grounded soil is required. Copper Slag (CS) is one of the waste materials that are being used extensively in the civil engineering construction industry. Copper producing units in India leave thousands of tonnes of copper slag as waste every day. Based on U.S. environmental protection agency regulations, governing solid waste characteristics, copper slag can be classified as a non-hazardous material. Granulated copper slag is more porous and therefore, has particle size equal to that of coarse sand. The central pollution control board (CPCB) has recommended usage of copper slag in cement manufacturing process as well as in landfill application. The reuse of waste material is an “STATE – OF – ART”. In view to it, CS is used as a replacement material in stabilizing the soil. To study the influence of CS in shear strength property of soil, laboratory tests were conducted. The physical and geotechnical properties were compared with those of conventional fill materials such as sands. Different percentage of CS is added (0, 10, 20 and 30%) by weight to the soil and their corresponding unit weight and angle of internal friction was found. The obtained values are taken as input parameters to find the stability of slope using Finite Element Analysis. There is linear increase in maximum dry unit weight and angle of internal friction of the soil with increase in replacement of CS till 30%. At 30% replacement of CS with the sand shows significant increase in factor of safety of an unstable slope.

Keywords: CS, Dry unit weight, angle of internal friction, Slope stabilization

I. INTRODUCTION

Due to urbanization, there is a scarcity of valuable land for construction. Hence, the weak soil has to treated and used for the desired construction activity. Reuse of waste material has become the most conventional method in waste management.

Copper slag (CS) is one of the waste materials that are being used extensively in the civil engineering construction industry. Copper producing units in India leave thousands of tonnes of copper slag as waste every day. Large quantities of the accumulated slag is dumped and left on costly land, causing wastage of good cultivable land. It is a byproduct generated during pyrometallurgical process to produce copper. The copper is being produced from the copper concentrate containing around 30 to 35% of copper, iron and sulphur each along with around 12% of silica and 5% of calcium. While producing copper, the slag with rich iron and moderate silica content is also generated this is also termed as ferro sand. This copper slag has a resemblance to natural sand in various aspects of physical properties. Based on U.S. environmental protection agency regulations, governing solid waste characteristics, copper slag can be classified as a non-hazardous material. Granulated copper slag is more porous and therefore, has particle size equal to that of coarse sand. The central pollution control board (CPCB) has recommended usage of copper slag in cement manufacturing process as well as in landfill application.

From the recent studies, CS is used as alternative raw material for iron enhancement in cement, replacement of fine aggregates. Many researchers have proposed the use of CS in the construction industry effectively. Investigated the use of CS as fine aggregate in concrete and found that the mortar strength ratio with cement, slag and water of 1:2:0:55 has higher strength properties [7]. From the life-cycle analysis for the use of industrial waste in CS in road and earth constructions, the effective reuse of waste by-products is studies [3]. It is proposed that 30% of sand size fine aggregates and 4% of silt size materials are required to arrive at the desired gradation in flexible pavement. As copper slag and fly ash are sand and silt size materials respectively, they can be mixed in different proportions to get the specified gradation for Wet Mix Macadam [2]. It is concluded that copper slag as a good interlocking material in pavement [6]. Based on the experimental findings it may be concluded that the mix 30% fly ash + 70% copper slag is suitable for use in the sub-base layers of the flexible pavements [5]. Studies also show the effect of CS as admixture to improve the properties of problematic soils [1].
In our study, the CS is mixed in different proportions with the Sand and their corresponding unit weight and shear strength property was studied. With the obtained values, slope stability analysis was carried out using finite element analysis to check the usage of copper slag in slope stabilization.

II. MATERIAL PROPERTIES

A. Soil:
The naturally available river sand is used for the experiments. The obtained soil is air dried and the organic matters were removed. To classify the soil, dry sieve analysis test was conducted: coefficient of uniformity (cu) is 3.04, coefficient of Curvature (cc) is found as 1.65 and the soil is inferred as well graded sand (SW).

The specific gravity and the unit weight of the virgin soil are found as 2.6 and 17.06 kN/m$^3$ with optimum moisture content as 4.8%. Shear strength value (angle of internal friction, $\phi$) of the soil is found as 33.53$^\circ$.

B. Copper Slag:
Copper Slag (CS) is a by-product material produced from the process of manufacturing copper. The chemical composition of the slag has 30 - 35% of copper, iron and sulphur each along with around 12% of silica and 5% of calcium with high density.

The CS has cu as 1.65 and cc as 0.75 from sieve analysis and has a major proportions of medium sand size say 55%. CS posses’ specific gravity as 3.6 and the angle of internal friction is 50$^\circ$. Figure 1 shows the sieve analysis results for both sand and the CS.

![Sieve Analysis](image)

Fig. 1: Sieve Analysis

III. LABORATORY TESTING

Laboratory tests such as proctor and direct shear tests were carried out with different proportions say 10%, 20%, 30% and 40% of CS by weight with sand.

A. Proctor Compaction Test:
Standard proctor compaction test was carried out with 0%, 10%, 20% and 30% sand by copper slag as replacement. With increase in percentage of CS the unit weight of the mixture increases linearly (Figure 2). The increase in percentage of CS for 10% by weight shows only 2.5% increase, 20% of CS shows 5% and 30% of CS shows 6.9% of increase in unit weight. This shows the unit weight increases marginally with the increase in percentage of CS.
B. Direct Shear Test:

The angle of internal friction of the soil and CS is found as 33.53° and 46° respectively. Direct Shear Test is done for Virgin Sand (i.e. 0%), 10% Replacement of Sand by CS, 20% Replacement of Sand by CS and 30% Replacement of Sand by CS for normal Stress of 0.05, 0.3 and 0.8 kg/cm². Figure 3 shows the direct shear test results of 20% replacement of soil by copper slag.

The angle of internal friction obtained for 20% replacement of soil by copper slag is 36.02°. The variation of angle of internal friction with respect to the replacement of soil by copper slag is shown in the Figure 4. There is a small increase in angle of internal friction to a maximum of 6.9% till 20% replacement, whereas for 30% replacement the increase in angle of internal friction is 17.4%. This is mainly due to the friction contributed by the copper slag.

With the obtained test result, a slope stability analysis was carried out to find the influence of the CS replacement in the stability analysis.
IV. ANALYSIS

The Slope Model is generated in the Plaxis for the Slope Stability analysis with the values obtained from the results of Proctor Compaction and Direct Shear test. The medium mesh is generated for the model with 15 nodded model. The Analysis is done in two phases: First Phase: In-Situ stresses are generated under plastic analysis. Second Phase: “c – ø” reduction. In which the factor of safety of the soil is computed. A Problem is referred from the text book Soil Mechanics and Foundations by Muni Budhu, 2011[4]. It is validated (Figure 5) in the Plaxis Software and the values are found. Factor of Safety obtained by method of slices by the author is 1.05 and the value obtained from Plaxis 1.09. The Error in the value is 3.66%, which is permissible.

The Properties of the soil in the validated problem are as follows, Youngs Modulus (E) is 35MPa, Poissons Ratio(µ) is 0.33, Coefficient of Permeability (kx = ky) is 0.001 m/day, Cohesion(c) is 0.1 kPa, Condition is Drained, Unit Weight(γ) is varied in kN/m³ and the Angle of Internal Friction is also varied.

Slope Stability Analysis is done for the Virgin Sand for the Slope of 1:1.57. Initially the type of failure is observed as bas failure with 0% replacement of CS. With the increase in percentage of CS as replacement, the factor of safety increases and the type of failure is observed as toe failure. This is mainly due to the resisting force given by the soil mass. For 20% replacement of sand by copper slag, the factor of safety obtained is 1.464. The Stress distribution of 20% replacement is shown in Figure 6 and type of failure observed to be of toe failure. The Factor of Safety for different proportions is computed and the Variation is tabulated in Table 1.
Table – 1
Variation - Factor of Safety

<table>
<thead>
<tr>
<th>CS added in %</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.09</td>
</tr>
<tr>
<td>10</td>
<td>1.37</td>
</tr>
<tr>
<td>20</td>
<td>1.464</td>
</tr>
<tr>
<td>30</td>
<td>1.67</td>
</tr>
</tbody>
</table>

V. CONCLUSIONS

The influence of Copper Slag is studied by means laboratory experiments such as proctor and direct shear test. With the obtained results, analysis was carried and the following observations are made:

- The Maximum Dry Density increases with increase in the percentage of CS from 1.706g/cc to 1.833g/cc for 0% replacement to 30% replacement respectively.
- The Angle of Internal Friction varied from 33.53˚ to 40.60˚ for 0% replacement to 30% replacement respectively.
- Slope Stability Analysis shows, with 30% replacement of Sand by CS has stabilized the ground.

REFERENCES