AN EXPERIMENTAL STUDY OF CLAYEY SOIL STABILIZED BY COPPER SLAG

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Industrialization extremely demands to the uplift of nation’s economy. However, it causes severe Environmental Pollution due to the generated waste materials. As the non-renewable raw materials for industrial production are dwindling day-by-day, efforts are to be made for conversion of these unwanted industrial wastes into utilizable raw materials, which in turn controls environmental pollution. Copper Slag is one of the waste byproduct produced by ‘Hindustan Copper limited’, Khetri, Rajasthan, India. The production of Copper Slag is 120-130 lakh ton per annum. Expansive soils are a worldwide problem that creates challenges for Civil Engineers. They are considered as potential natural hazard, which can cause extensive damage to structures if not adequately treated. The disadvantages of clay can be overcome by stabilizing with suitable material. This research was done on the engineering behavior of Clay when stabilized with Copper Slag.

Keywords: Copper slag, Expansive soils, MDD and OMC, Tri-axial test, Specific gravity

INTRODUCTION
For developing countries, urbanization and industrialization is a must and this activity extremely demands to uplift nation’s economy and for increase in the living standards of people. However, industrialization on the other hand has also caused serious problems relating to environmental pollution due to the disposal of industrial waste materials. The non-renewable resources which are used as raw materials for industrial production are dwindling day-by-day. Therefore, efforts are to be made for controlling pollution arising out of the disposal of wastes by conversion of these unwanted industrial wastes into utilizable raw materials for various beneficial uses.

Use of industrial byproducts and wastage in the soil stabilization for road and other type of the construction work is been adapted. At the same time, disposal of industrial waste or by-products has become more difficult and expensive as a result of the increasing stringent environmental regulations and shortages of suitable, nearby disposal sites.

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Industrial byproducts also creates environmental hazard as they may be toxic for environment.

Expansive soils are a worldwide problem that poses several challenges for civil engineers. They are considered a potential natural hazard, which can cause extensive damage to structures if not adequately treated (Al –Rawas, 2002). The disadvantages of clay can be overcome by stabilizing with suitable material. This research was done on the engineering behavior of Clay when stabilized with copper slag.

LITERATURE SURVEY

Expansive Soils

Changes in the moisture content of clay soil are generally accompanied by volume changes. On moisture uptake there is generally a volume increase and moisture loss is accompanied by shrinkage. Expansive soils swell when given access to water and shrink when they dry out. Soils containing the clay mineral montmorillonite (a smectite) generally exhibit high swelling properties (Wayne, 1984; komine and ogata 1996). The basic units of which the clay is made are silica (SiO$_2$) tetrahedral sheets and Aluminum (Al) or Magnesium (Mg) Oxide octahedral sheets. These were shown in Figures 1 and 2 (Mitchell and Soga, 2005).

Improving an on-site soil’s engineering properties is referred to as either “soil modification” or “soil stabilization” Ramanatha Ayyar, et al. (2002) carried out tests on coir fiber reinforced clay and found that the discrete fibers of small diameter randomly distributed in soil offer a greater resistance to swelling than the larger pieces placed similarly. Mandal and Vishwamohan have carried out performance studies of expansive clay for three types of clays by conducting California bearing ratio test made use of coir fiber and jute fiber as geo-fabrics placed in layers.

Copper Slag

Copper slag is a by-product formed during the copper smelting process. The countermined copper slag has to be properly treated or washed to meet certain recycling criteria before it can be further used for other
applications. The production of one ton Copper generates, approximately 2-3 tons of Copper Slag. Copper Slag is the toxic for environment because it contains large amount of heavy metals in their oxides. We can solve an important problem for environment by utilization of Copper Slag in soil stabilization (Alpa and Devecia, 2008). The physical properties of copper slag were explained in Table 1 and chemical composition in Table 3. Copper slag was shown in Figure 3.

Washed copper slag has a high percentage of iron (Fe) followed by aluminium (Al), calcium (Ca), copper (Cu), Zinc (Zn) and magnesium (Mg) (Alpa and Devecia, 2008).

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Physical properties</th>
<th>Value obtained</th>
<th>Test sample Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Particle shape</td>
<td>Irregular</td>
<td>Irregular</td>
</tr>
<tr>
<td>2.</td>
<td>Appearance</td>
<td>Black &amp; glassy</td>
<td>Black &amp; glassy</td>
</tr>
<tr>
<td>3.</td>
<td>Type</td>
<td>Air cooled</td>
<td>Air cooled</td>
</tr>
<tr>
<td>4.</td>
<td>Specific gravity</td>
<td>2.9-3.9</td>
<td>2.99</td>
</tr>
<tr>
<td>5.</td>
<td>Percentage of voids</td>
<td>43.20%</td>
<td>45%</td>
</tr>
<tr>
<td>6.</td>
<td>Bulk density</td>
<td>2.08 g/cc</td>
<td>2.08 g/cc</td>
</tr>
<tr>
<td>7.</td>
<td>Fineness modulus</td>
<td>3.47</td>
<td>3.86</td>
</tr>
<tr>
<td>8.</td>
<td>Angle of internal friction</td>
<td>51°20'</td>
<td>51°20'</td>
</tr>
<tr>
<td>9.</td>
<td>Water absorption</td>
<td>0.3 to 0.4%</td>
<td>0.4%</td>
</tr>
<tr>
<td>10.</td>
<td>Moisture content</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

*Brindha et al. (2010)*

**MATERIALS USED**

**Copper Slag**

Copper slag is the industrial waste from ‘Hindustan Copper Limited’, Khetri, Rajasthan, India, in dry mode of collection. The uniformity coefficient, Cu was 4.6.

**Expansive Soil**

The soil was used in experimental program and it was classified as plasticity clay (CL) according to Indian standard soil classification system (ISSCS). The physical properties of clayey soil were explained in Table 2.
Index properties were used in discriminating between different kinds of soils. Different properties which fall under the index properties were described below.

**Particle Size Analysis**

The particle-size distribution of Copper Slag is obtained with the help of sieving analysis (dry process). The particle size distribution curve was shown in Figure 4.

**Specific Gravity**

The specific gravity of clay mixed with different percentage of copper slag was decreasing by the increasing amount of clay. The specific gravity of the clay and copper slag used was found to be 2.57 and 2.99 respectively.
Chemical Analysis Report
Copper Slag has maximum amount of silica (71.52%). In comparison with the chemical composition of natural pozzolanas of ASTMC618-99, the summation of three oxides (silica, alumina, iron oxide) in copper Slag is 92.12%, which exceeds the 70% percentile requirement for class N raw and calcined natural pozzolanas. Therefore, Copper Slag was expected to have good potential to produce high quality pozzolanas.

Mechanical Properties
Compaction Characteristics
The maximum dry density and optimum moisture content of the clay are found as 1.573 gm/cm$^3$ and 18.085% and for the copper slag was 1.703 gm/cm$^3$ and 11.92% respectively. The variation in dry density w.r.t. change in moisture in the various combinations of clay and copper slag were shown in Figures 5-15. The values of maximum dry density and optimum moisture content with specific gravity of various combinations were shown in Table 4.
Figure 8: Variation in Dry Density with Moisture in 70% Clay with 30% CS

Figure 9: Variation in Dry Density with Moisture in 60% Clay with 40% CS

Figure 10: Variation in Dry Density with Moisture in 50% Clay with 50% CS

Figure 11: Variation in Dry Density with Moisture in 40% Clay with 60% CS

Figure 12: Variation in Dry Density with Moisture in 30% Clay with 70% CS

Figure 13: Variation in Dry Density with Moisture in 20% Clay with 80% CS
Shear Characteristics

The value of Angle of shearing resistance ($\phi$) and Unit cohesion (c) was determined from the Tri-axial test of clay and copper and its mixture in various proportions, are presented in Table 5 and variations shown in Figures 17 and 18. The absolute maximum value of $\phi$ and absolute minimum value of ‘c’ corresponding value are 48° and 0.01 KN/cm². The variation in MDD with respect to Percentage of copper slag was shown in Figure 16.

DISCUSSION

Sieve Analysis

The average size of aggregate in the Copper Slag was 0.46 mm.
Table 5: Variation in Shearing Resistance, $\phi$ and Unit Cohesion, $c$ With Respect to Change in % of Copper Slag in Clay

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Combinations (%)</th>
<th>Angle of Shearing Resistance $\phi$ (°)</th>
<th>Unit Cohesion, $c$ (N/cm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>100% Clay</td>
<td>26</td>
<td>0.15</td>
</tr>
<tr>
<td>2.</td>
<td>90% Clay with 10% Copper slag</td>
<td>39</td>
<td>0.13</td>
</tr>
<tr>
<td>3.</td>
<td>80% Clay with 20% Copper slag</td>
<td>42</td>
<td>0.11</td>
</tr>
<tr>
<td>4.</td>
<td>70% Clay with 30% Copper slag</td>
<td>46</td>
<td>0.03</td>
</tr>
<tr>
<td>5.</td>
<td>60% Clay with 40% Copper slag</td>
<td>48</td>
<td>0.01</td>
</tr>
<tr>
<td>6.</td>
<td>50% Clay with 50% Copper slag</td>
<td>47</td>
<td>0.13</td>
</tr>
<tr>
<td>7.</td>
<td>40% Clay with 60% Copper slag</td>
<td>40</td>
<td>0.25</td>
</tr>
<tr>
<td>8.</td>
<td>30% Clay with 70% Copper slag</td>
<td>35</td>
<td>0.25</td>
</tr>
<tr>
<td>9.</td>
<td>20% Clay with 80% Copper slag</td>
<td>32</td>
<td>0.3</td>
</tr>
<tr>
<td>10.</td>
<td>10% Clay with 90% Copper slag</td>
<td>21</td>
<td>0.33</td>
</tr>
<tr>
<td>11.</td>
<td>100% Copper slag</td>
<td>19</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Chemical Composition

Copper Slag has maximum amount of silica (71.52%) and very less amount of CaO (0.16%). The summation of silica, alumina and iron oxide in copper Slag was 92.12%. So it has good potential to produce high quality pozzolanas.

Specific Gravity

Specific gravity of the Copper Slag was 2.99. Then the weight density of the copper Slag is...
higher compared to Clay because specific gravity of clay was only 2.57.

**Variation in MDD and OMC**

Increasing the percentage Copper Slag in clay increases the MDD up to 50% combination (1.937 gm/cm$^3$) and further it tends to decrease.

**Variation in Unit Cohesion and Angle of Shearing Resistance**

As the percentage of Copper Slag increases, the Angle of shearing resistance increases up to certain limit (48°) at 40% of combination and further it tends to decrease.

**CONCLUSION**

On the basis of this study and observations made, the conclusions are as follow.

1. The absolute maximum dry density was 1.937 gm/cm$^3$ for the combination of 50% Clay and 50% Copper slag. The maximum dry density was higher than 1.87 gm/cm$^3$ for the combination of 70% Clay with 30% Copper slag to 30% clay with 70% copper slag.

2. In the Tri-axial test, the angle of shearing resistance ($\phi$) was 48° for the combination of 50% Clay and 50% Copper slag. The angle of shearing resistance ($\phi$) higher than 40° for the combination of 80% Clay with 20% Copper slag to 40% clay with 60% copper slag.

3. The combination of 70% Clay with 30% Copper slag to 30% clay with 70% copper slag was most satisfactory combination to get good soil stabilizations.

**REFERENCES**

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Steel Slag”, *American Society for Testing and Materials*, USA.


