UTILIZATION OF COPPER SLAG FOR IMPROVEMENT OF SUB-SOIL IN PAVEMENT CONSTRUCTION WORKS

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Abstract: Many methods have been used to improve weak subsoil conditions encountered in Road construction works. As a solution, engineers tend to try on mixing materials that can be used with existing soil type without completely removing and refilling with another soil type. Expansive clays 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. 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. In this study, copper slag (CS) with different proportions varying from 45% to 65% was used at optimum moisture content (OMC) with clay soil to investigate the relative strength gain in terms of Unconfined compression strength (UCS) and California bearing ratio (CBR), after curing for 3, 7, 14 and 21 days. Number of tests was carried out to assess the improvement in engineering characteristics of the samples. It was found that copper slag when mixed with the clayey soil results in improvement of strength and CBR value with the increase in percentage of CS which considered as the required characteristics for road construction.

Index Terms – Copper Slag, Sub-soil, Pavement, Unconfined Compressive Strength, California Bearing Ratio.

1. INTRODUCTION

India has a large tracks of expansive soil known as Black cotton soil (B.C. soil), covering an area of 0.8 million square kilometer, which is about 20% of total land area. This type of soil is available up to a depth 3.7 m on an average. B. C soils swells during rainy season and shrinks during summer season. This alternate swelling and shrinkage creates cracks in the B. C soil which are 100mm to 150mm wide and 0.5 to 2 m deep. Swelling creates upward pressure on structure and shrinkage creates downward pull. It results into cracks or damage in the foundations. 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 [1]. Some of the major problems for the engineers in construction on weak soil are poor bearing capacity, high compressibility, and low shear strength. As a solution for that, engineers tend to remove all the weak soil and do refilling with a soil which has better characteristics on the featured required. Alternatively the disadvantages of clay can be overcome by stabilizing with suitable material.

Soil stabilization aims at improving soil strength and increasing resistance to softening by water through bonding the soil particles together, water proofing the particles or combination of the two. This is due to industrial wastes in part to their suitable engineering properties, which allow them to be used as substitute materials in several transportation and geotechnical applications. In addition to a lower cost in comparison to traditional materials, their use has the potential to alleviate landfill problems as well as avert costs typically associated with their disposal. The nonrenewable 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. Industrial byproducts also creates environmental hazard as they may be toxic for environment.

Copper is a soft and ductile metal which is one of the basic chemical elements, known for its high thermal and electrical conductivity and has a reddish-orange surface in its pure state. It is commonly used in electrical, construction and transportation industries. Once the waste materials have been physically removed from the ore, the remaining copper concentrate must undergo several chemical reactions to remove the iron and sulphur. This process is called smelting. Copper slag is a waste product which comes out from the smelting process [2]. Copper producing units in India leave thousands of tons 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. The objective of the present study is to minimize the problem of waste disposal by using copper slag as a stabilizing material and to study the influence of copper slag on soil properties.

II. BACKGROUND INFORMATION

The use of recycled material to improve marginal soils offers a viable alternative from economical, technical and environmental standpoints. Copper slag is a by- product created during the copper smelting and refining process. As refineries draw metal out of copper ore, they produce a large volume of non-metallic dust, soot and rock. Collectively, these materials make up slag, which can be used for a surprising number of applications in the building and industrial fields. Copper slag has also gained popularity in the building industry for use as a fill material. Unlike many other fill materials, it poses relatively little threat to the environment. This means it can be used to build up the earth to support roads, buildings, or other surfaces.

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 [3]. Copper slag is toxic for environment because it contains large amount of heavy metals in their oxides. Washed copper slag has a high percentage of iron followed by Aluminium, calcium, copper, zink and magnesium Utilization of copper slag in soil stabilization can solve an important problem for environment [4]. The range of physical properties and chemical composition of copper slag are given in Table 1 & 2 respectively.

Table 1: Physical Properties of Copper Slag

S. No.	Physical Properties	Values
1	Particle shape	Irregular
2	Appearance	Black and Glassy
3	Type	Air cooled
4	Specific Gravity	2.9 – 3.9
5	Percentage of Voids	43.20%
6	Bulk Density	2.08gm/cc
7	Fineness Modulus	3.47
8	Angle of Internal Friction	$51^{o}21'$
9	Water Absorption	0.4%
10	Moisture content	0.1%

Table 2: Chemical Composition of Copper Slag

S. No.	Constituent	% Weight
1	Silica soil (combined as silicate)	25 – 35 %
2	Free silica	< 0.5 %
3	Calcium oxide	2 – 9 %
4	Aluminum Oxide	2 – 9 %
5	Iron Oxide	45 – 55%
6	Copper Oxide	Up to 0.7 %
7	Manganese Oxide	1 – 5 %
8	Chloride	0.003 %
9	Sulphates	0.2%

Copper slag has the potential to use as admixture to improve the properties of problematic soils. Copper slag with 30% to 50% can be mixed with problematic soils to improve or modify the soil characteristics. Copper slag can also be mixed with fly ash and cement to enhance the strength effectively. Copper slag can be recommended for sub grade, sub base and bitumen mixes. Engineering behavior of expansive soils can be improved by utilizing 40% of the copper slag along with 2% Portland cement for embankment construction, land reclamation and improving sub-grade soil conditions [5].

Lime mixed copper slag in various percentages gives effective and improving results of cohesion when compared to copper slag without any additives. As the percentage of lime increases from 2% to 10% the maximum dry density values are slightly increasing. Copper slag when mixed with lime results increase in cohesion and decrease in angle of internal friction. When lime mixed with CS along with soils may result in beneficial effects in terms of stabilization of clayey deposits [6].

III. MATERIALS AND METHODOLOGY

This research was done on the engineering behavior of clayey soil when stabilized with copper slag. Copper slag for the study was bought from Sri Srinivasa Metalizer, Cherlapally, a local market in Hyderabad and the soil used in experimental program was clayey soil brought from Nalgonda district, Telangana.

In this study, copper slag was mixed with clay soil in various percentages say, 45%, 55% and 65% at optimum moisture content to investigate the relative strength gain in terms of unconfined compression strength and CBR values. The tests have conducted on copper slag-soil mixes after a curing period of 3,7,14 and 21 days.

IV. RESULTS AND DISCUSSIONS

The tests conducted to find the properties of soil are according to Indian standard specifications. The properties of soil used in the study are presented in Table 3.

Table 3: Properties of Clay

S. No.	Properties of Soil	Values
1	Specific Gravity	2.66
2	Liquid Limit	56%
3	Plastic Limit	33%
4	Plasticity Index	23%
5	Maximum Dry Density	1.77gm/cc
6	Optimum Moisture Content	19%
7	P^H	8.2
8	Unconfined Compressive Strength	1.64kg/cm^2
9	Water Content	8.2%
10	C_u	6.16
11	C_c	1.3
12	CBR	1.04

Figure 1 shows the variation in UCS values with percentage of copper slag at different curing periods. It may be seen from the figure that the strength of soil increases with increase in percentage of copper slag as well as with curing period. Figure 2 shows the variation in UCS values with curing period at different percentages of copper slag.

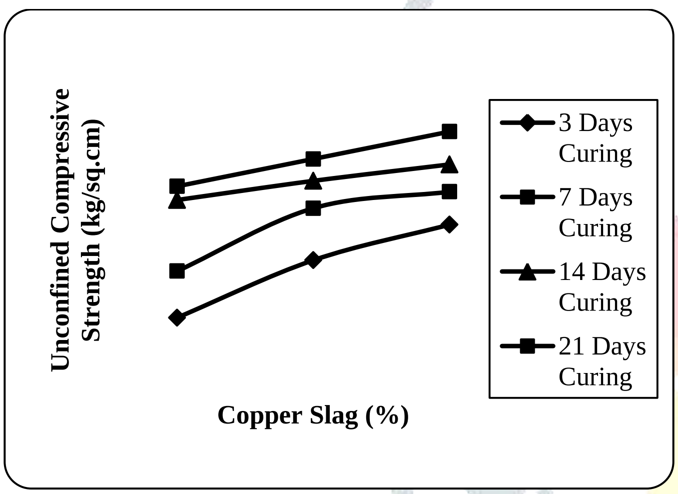

Figure 1: Variation in UCS values with percentage of copper slag at different curing periods

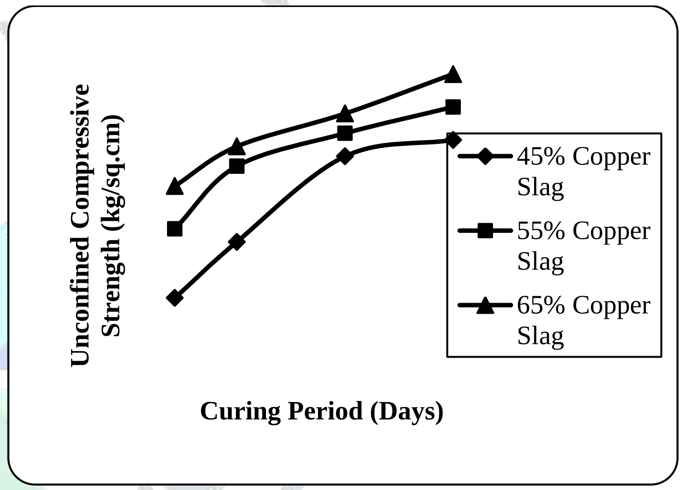

Figure 2: Variation in UCS values with curing period at different percentages of copper slag

Figure 3 shows the variation in CBR values with percentage of copper slag at different curing periods. It may be seen from the figure that the strength of soil increases with increase in percentage of copper slag as well as with curing period. Figure 4 shows the variation in CBR values with curing period at different percentages of copper slag.

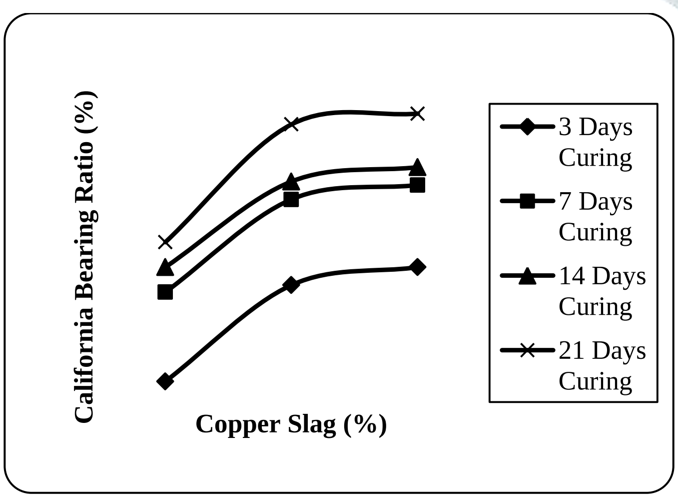

Figure 3: Variation in CBR values with percentage of copper slag at different curing periods

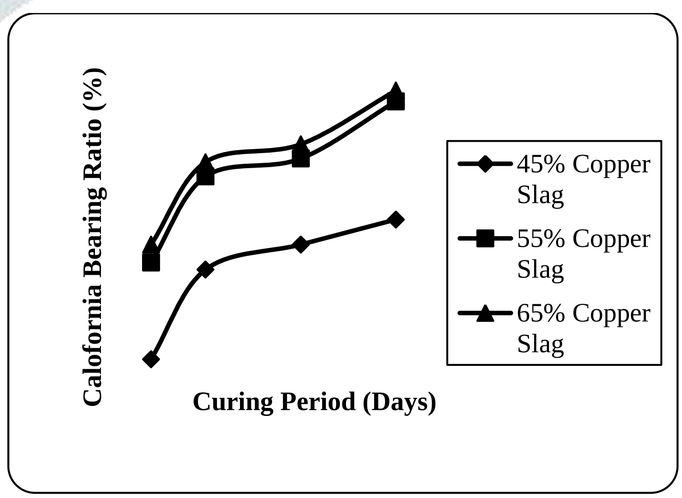

Figure 4: Variation in CBR values with curing period at different percentages of copper slag

V. CONCLUSIONS

Based on the tests performed in this study, the following conclusions/suggestions can be drawn.

1. Copper slag has the potential to use as admixture to improve the properties of problematic soils like B. C. Soil.
2. The study proved that mixing of stabilizing agent can significantly modify B. C. Soil from a weak material to strong one for construction.
3. Compressive strength and CBR values increase with increase in percentage of copper slag and also with curing period.
4. By utilizing and reusing the industrial waste product, namely, copper slag, wastage of good cultivable land can be avoided otherwise large quantities of the accumulated slag is dumped and left on costly land.
5. Further investigations are necessary in order to obtain comprehensive understanding that would provide an engineering base to allow the use of copper slag in soil stabilization.

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