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Improvement in Soil properties of Expansive Soil by using Copper Slag

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Abstract

In this paper, an attempt has been made to study the copper slag – Black cotton soil mix for use in sub-grade improvement in pavements. Copper slag is a by-product formed during the copper smelting process and use of waste materials in construction work has been popular in India. This is particularly necessitated by the problems of disposal associated with it. Otherwise, these materials would cause problems to the environment. Copper producing units in India leave thousands of tons of copper slag as waste every day. As the sub-grade improvement of a pavement is the prime concern when it is constructed over the expansive soil, the stabilization of that expansive soil by the concerning waste material can be referred. A different mix proportion of copper slag and black cotton soil were prepared. The geotechnical properties of different mixes, namely, un-soaked CBR and Direct shear strength were determined. The effects of Soil and copper slag on the above geotechnical properties were investigated. From the present study the 40% Soil+60% copper slag mix was found to be optimum for use for stabilize mix and also use as sub grade improvement in pavements. This will also help in eliminate the disposal problem of waste.

Keywords- *Copper slag (C.S.), Black cotton soil (B.C.), OMC, MDD and CBR test, Direct shear test.*

I. INTRODUCTION

Copper slag is a by product generated during the copper smelting process. Copper slag can be used for a number of applications in the building and to improve soil properties.

A Large amount of waste are generated from various industries and activities of human being. Much of them are not being utilized, but are rather disposed of in the limited disposal sites available which will be exhausted in the near future. Utilization of wastes as construction or geotechnical material has been strongly recommended, and many attempts of geotechnical applications have been undertaken. Various kinds of ground improvement techniques have been widely use to modify the engineering properties of soil. Additionally, copper slag has been applied in soils with copper deficiency. The potential environmental risk by the geotechnical utilization of wastes needs to be avoided. Many waste materials might be contaminated by toxic and hazardous substances and require treatment for safe disposal. Geotechnical waste utilization can serve not only to prevent the negative environmental impact but also to preserve and protect nature.

Weak soil, including soft clays, expansive soil, organic deposits, and loose sand, are often unsuitable for construction due to their poor engineering properties. Site condition can be enhanced through a number of in-situ ground improvement and replacement techniques, but these alternatives are sometimes costly. Recycled materials, such as plastics, carpet waste, construction debris and wood, fly ash, marble chips, cement kiln dust, rice husk ash, wood ash dust at the source etc. can be used to improve soil condition in-situ, stabilize weak or failing embankments, steepen existing slopes, or modify otherwise marginal soils for use as earth fill.

The use of recycled material to improve marginal soils offers a viable alternative from economical, technical, and environmental standpoints. Recycled materials provide an attractive alternative to traditional engineering construction materials such as asphalt, concrete, natural aggregate and others. This is due in part to their suitable engineering properties, which allow them to be used as substitute materials in several transportation and geotechnical applications. Equally important, recycled materials offer both economic and environmental incentives. 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.

II. DETAILS OF MATERIALS

Copper slag: Copper slag was collected from the Birla Copper Industries, Dahej, Gujarat, India.

Table 1. Copper Slag Generation in India

Name of the plant	Copper slag generation/annum in million tonne
Hindustan Copper Limited ICC, Ghatsila	0.07
Hindustan Copper Limited ICC, Rajasthan	0.07
Sterlite Industries India Limited, Tuticorin	0.22
Birla Copper, Gujarat	0.22
SWIL(Jhagadia Copper Limited),Gujarat	0.11

Copper slag is a blackish material similar to coarse sand. The typical physical properties and chemical properties of copper slag are summarized in Table 2.

Table 2. Physical & Chemical Property of Copper Slag

Physical properties	Copper slag
Appearance	Black, Glassy, granulated
Specific gravity	3.51
Bulk density	1.879
Hardness	6 to 7 moh's scale
Moisture content	0.1%

Chemical Composition	Copper slag
Silica (SiO2)	32%
Alumina (Al2O3)	4%
Iron oxide (Fe2O3)	41%
Calcium oxide (CaO)	1.5%
Magnesium oxide (MgO)	1.35%

Black cotton soil: B.C. Soil was collected from near to the college campus.

III. RESULTS AND ANALYSIS

Grain Size Analysis

Grain size analysis is primary requirement for classification of any soil. The grain size distribution is obtained by sieving test. The sieve analysis is carried out for grain size distribution analysis of soil & Copper Slag according to the IS: 2720(part 4)-1985. Black cotton soil having Cu =11.4 and Cc = 0.516. It is classified as poorly graded soil as per IS standards. The copper Slag having Cu = 2.83 and Cc = 1.02 is classified as wall graded sand.

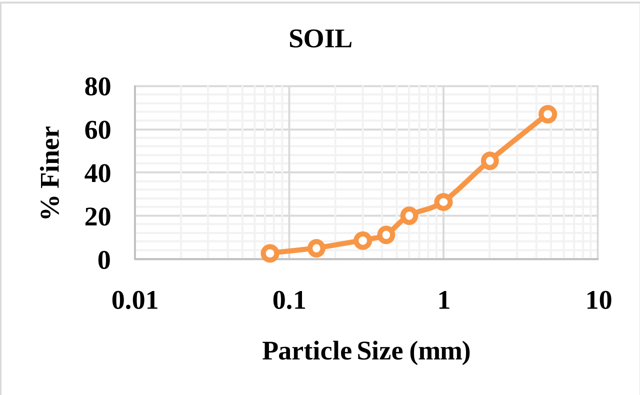

Figure 1. Sieve analysis for B.C. Soil

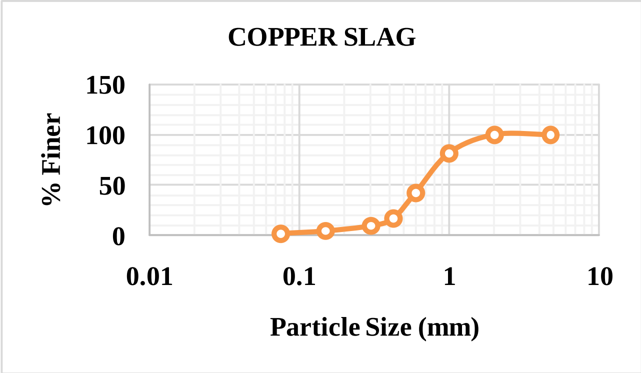

Figure 2. Sieve analysis for Copper Slag

Liquid Limit Test

The liquid limit test was conducted on 100% expansive soil, 90% Soil + 10% Copper Slag, 80% Soil+ 20% Copper Slag, 70% Soil+ 30% Copper Slag & 60% Soil+ 40% Copper Slag using Casagrande's liquid limit apparatus as per the procedures laid down in IS: 2720 part 4 (1970) , liquid limit value ranged between 68.04 % to 39.24%.

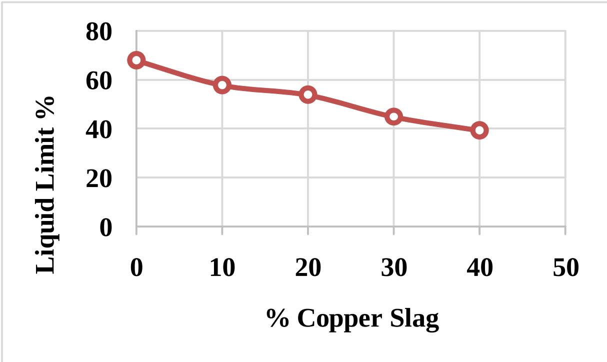

Figure 3. Liquid limit % v/s Copper slag

Liquid limit value decreased as the amount of added copper slag increases addition of 10% copper slag to the soil gave a reduction of 14.96%. The maximum reduction was observed when 40% copper slag was added to the sample which was 42.34%.

Plastic Limit Test

The Plastic limit test was conducted on 100% expansive soil, 90% Soil + 10% Copper Slag, 80% Soil+ 20% Copper Slag, 70% Soil+ 30% Copper Slag & 60% Soil+ 40% Copper Slag using Casagrande's liquid limit apparatus as per the procedures laid down in IS: 2720 part 4 (1970).

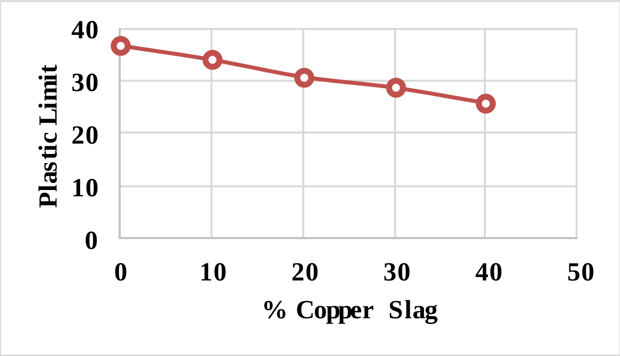

Figure 4. Plastic limit% v/s Copper slag

Addition of 30% and 40% copper slag decreased the plastic limit of the mixtures. Initially decrease in the plastic limit is not so much rapid but it reduces significantly after 30% addition of copper slag to soil. Maximum reduction was observed by addition of 40% stabilizer to the soil.

Plasticity Index

The plasticity properties of soil after mixing with copper slag were altered. The liquid limit of soil mixed with 10% copper slag decreased up to 16%, the liquid limit of soil mixed with 20% copper slag decreased up to 22%, the liquid limit of soil mixed with 30% copper slag decreased up to 35% and the liquid limit of soil mixed with 40% copper slag decreased up to 42% than soil without copper slag. It represents that there is improvement in consistency properties of soil when mixed with different proportion of copper slag.

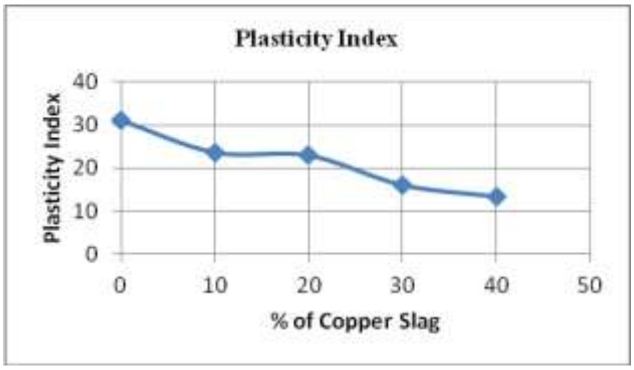

Figure 5. Plasticity v/s Copper slag

Compaction Test

The maximum dry density (MDD) and optimum moisture content (OMC) of B.C. soil is found as 1.54 gm/cm and 25.38 %. The comparative study chart of MDD and percent replacement with different percentage of copper slag is shown in figure 6.9.Preparation of soil sample for proctor's compaction test was done as per IS: 2720 part-6 (1974).

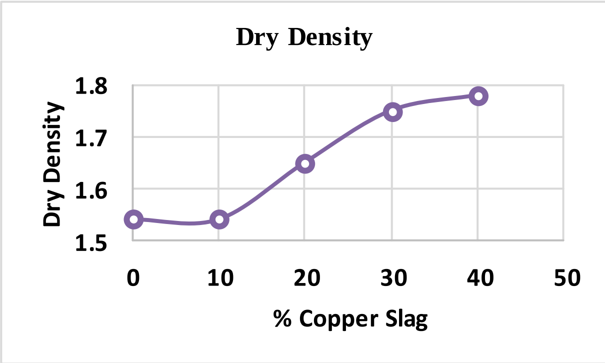

Figure 6. MDD addition of % C.S. with B.C. Soil.

The maximum dry density of soil mixed with 20% copper slag was found as 1.65, which represents that there is 8% increase in maximum dry density, 30% copper slag was found as 1.75, which represents that there is 14% increase in maximum dry density and 40% copper slag was found as 1.78, which represents that there is 16% increase in maximum dry density comparison to the soil without copper slag.

California Bearing Ratio Test

The California bearing ratio test has been performed in Geotechnical laboratory of the all facility with C.B.R apparatus of the proving ring reading is noted for 50 divisions with under a constant strain rate of 1.25mm/min.The samples were tested un-soaked conditions as per IS 2720 part 16 (1979) and loading was continued until 3 (or) more readings are decreasing (or) constant.

The load settlement curve has been plotted for 100% Soil, 90% Soil+10% Copper slag, 80% Soil+20% Copper slag, 70% Soil+30% Copper slag, 60% Soil+40% Copper slag. To calculate the C.B.R values the graph of standard load of C.B.R value has been referred.

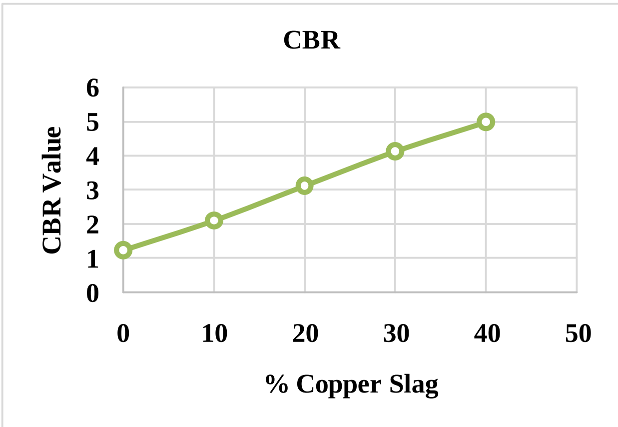

Figure 7. CBR v/s % of copper slag

The CBR value goes higher up to 4.98 with the addition of 40% copper slag in soil. It represents that the copper slag may be better admixing material for expansive soil and can be acceptable for sub grade improvement during embankment construction.

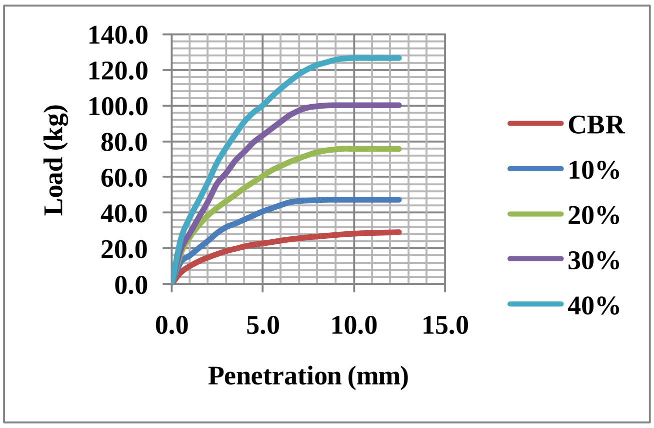

Figure 8. CBR of different proportion of C.S. in Soil

Direct Shear Test

The value of angle of shearing resistance (Ø) and unit cohesion (c) are determined from the direct shear test. Direct shear test were carried out on 60 mm × 60 mm × 20 mm samples. The samples for direct test were prepared by compacting the samples at the required density and moisture content directly into the shear box after fixing the two-halves of the shear box together by means of the fixing screw. Copper slag has high angle of internal friction.

Table 3. Value of C and Ø

Proportion	C – Value	Ø – Value
100 Soil	0.57	9°
90 Soil + 10 Copper Slag	0.46	11°
80 Soil + 20 Copper Slag	0.44	12°
70 Soil + 30 Copper Slag	0.42	16°
60 Soil + 40 Copper Slag	0.37	22°

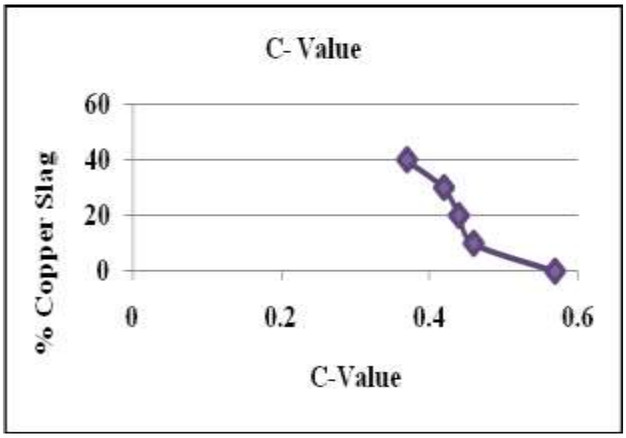

Figure 9. Variation in Ø-Value respect to % of C.S. in Soil

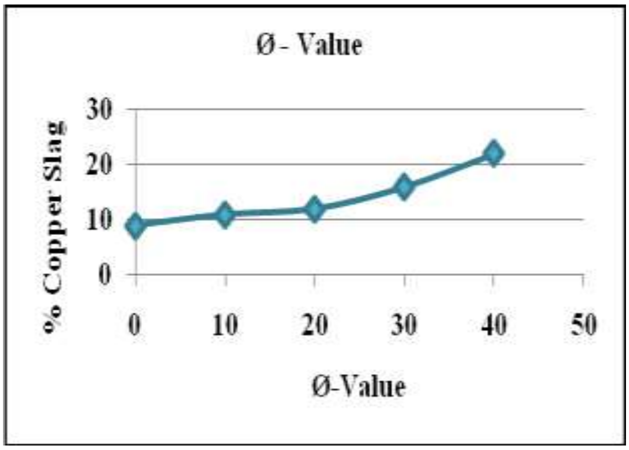

Figure 10. Variation in Ø-Value respect to % of C.S. in Soil

The samples were tested on Direct Shear Apparatus as per IS 2720 and the readings of 60% soil + 40% Copper slag is 0.37 for C-Value & 22° for Ø-Value.

Geotechnical Characteristics of Stabilized Mixes

In the present study, Copper slag was mixed with soil in different proportions. Important geotechnical properties namely; compaction plasticity characteristics CBR & shear strength parameter was investigated for various mixes. Result are summarized in Table 4.

Table 4. Geotechnical characteristics of stabilized mixes

Property	Type of Mix (S+C)				
	100+0	90+10	80+20	70+30	60+40
L.L.(%)	68.04	57.86	53.84	44.87	39.24
P.L. (%)	36.87	34.18	30.87	28.81	25.87
I.P. (%)	31.17	23.68	22.97	16.06	13.37
MDD (gm/cm³)	1.54	1.54	1.65	1.75	1.78
OMC (%)	25.38	24.73	22.61	21.39	20.6
Cohesion C (kg/cm²)	0.57	0.46	0.44	0.42	0.37
Angle of Friction Ø (°)	9°	11°	12°	16°	22°
CBR (%)	1.22	2.09	3.11	4.12	4.98

Comparison of Results with Codal Provision

The CBR value of 60:40 mix was found to be 4.98% this mix was compared with the relevant codal provision for the usefulness in highway construction (Table 5)

Table 5. Comparison of Result with the relevant IS code (MORT&H & IRC 37)

Sr No.	Property	Specification of Relevant IS Code	Result of 60:40 Mix
1	Liquid Limit (%)	< 70 %	39.24
2	Plastic Limit (%)	< 45 %	25.87
3	Plasticity Index (%)	< 50 %	13.37
4	MDD (gm/cm³)	> 1.76 gm/cm³	1.78
5	CBR (%)	≥ 2 %	4.98

IV. CONCLUSION

The use of recycled material in the stabilization of marginal soils must not be conceived as an avenue for the supplier to dispose of their waste. To the contrary, the use of such materials in highway construction must provide a clear advantage in terms of improvement of the engineering properties of the foundation, subgrade, sub-base, embankment materials.

The summaries of conclusions determined from detailed laboratory investigations are given below:

- As per the Schedue-1 of the Hazardous Wastes (Management and Handling) **Amendment Rules, 2003of the Ministry of Environmental and Forests**, copper slag is not listed as the Hazardous waste. So, it can be beneficially use as a recycled geotechnical material.
- Copper slag is blackish granular material similar to course sand having specific gravity of 3.40. The high specific gravity may be due to presence of high iron content (41%).
- The CBR value of this proportion is increase up to 4.12 as compare to black cotton soil and satisfied the criteria for use in road pavement.
- It was absolved on the bases of experimental work that CBR value of combination of 60% B.C. soil with 40% C.S. is increases and further it tends to decrease.
- High value of CBR is 4.98 in combination of 60% B.C. + 40% C.S. satisfied the criteria for use in sub grade/sub base layer of road pavement.
- This combination (60+40) was found most satisfactory combination to get good soil stabilization.
- The utilization of this mix in pavement construction will solve many problems with one effort.
- The bulk utilization of copper slag in the road construction solves the disposal problems of the industries as well as reduces the waste management cost.
- On the basis of this research study copper slag can be recommended as effective stabilizing agents for improvement of soils for highway embankments, subgrade and sub-base.
- It reduces the construction cost of land reclamation due to saving in material cost.
- It reduces the environmental impact due to quarrying and aggregate mining.

Table 6. Property of 60%+40% Mixture

Property	Result of (60+40) mix
Liquid limit	39.24 %
Plastic limit	25.87 %
MDD (gm/cm³)	1.78 gm/cm³
OMC (%)	20.6 %
Cohesion (C)	0.37 kg/cm²
Angle of friction (Ø)	22 °
CBR (%)	4.98 %

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