STUDY ON GEOTECHNICAL PROPERTIES OF SOIL USING WASTE COPPER SLAG

[1]Vanishka,[2]Rajesh Pathak,

[1]PG Student ,[2]Associate Professor,
[2]Department of Civil Engineering,
[2]Thapar Institute of Engineering and Technology, Patiala, India.

Abstract : For the uplift of any nation's economy, industrialisation is a much needed phenomenon. However the pollution caused due to the waste materials generated by the industries is hazardous and inevitable. Copper slag is an industrial by-productwhich is generated during the smelting process of copper production. For every tonne of copper production, around 1.8 to 2.2 tonnes of copper slag is estimated. Its disposal has become a huge problem as it is generally dumped on costly lands and in many cases it causes wastage to the good culturable land. Present paper discusses the results of the laboratory tests done for the improvement of locally available soil when stabilised with different proportions (0%,10%...up to 60%) of copper slag. Effect of granulated copper slag on the liquid limit, plastic limit, plasticity index, MDD, OMC and CBR of the locally available soil are observed and analysed.Granulated copper slag have similar particle size as that of coarse sand. Strength properties of the soil are expected to be increased with increase in the percentage of copper slag.In this paper, an effective usage of copper slag is presented.

IndexTerms: Copper Slag, Liquid limit, Plastic limit, Plasticity index, MDD, OMC, CBR.

I. INTRODUCTION

Soil stabilization becomes essential when the soil which is accessible does not have required geotechnical properties. Since stability of soil plays an important role at the construction site, therefore soil should be feasible enough to follow the design criteria for load, type of foundation and load bearing capacity of subsoil. If the design criteria is not met than there are three alternatives. Either to change the design itself or the soil or to abandon the construction site altogether. But the number of sites to be abandoned is increasing day by day. That is why the soil stabilization methods are incorporated. Soil stabilisation can be categorized in two parts i.e, (1) Stabilization by adding admixture and (2) Stabilization without adding admixture. Also, currently there is a scarcity of natural resources and building materials all over the world due to constant increment in the construction industry. On the other hand, disposal of industrial wastes has become a huge task due to its hazardous effects on environment and the stringent rules and regulations related to it. So the effective usage of industrial wastes is a necessity. Copper slag is a by-product formed during the smelting process of production of copper. In India, round 120 to 130 lakh tonne of copper slag is produced annually which generates thousands of tonnes of copper slag. Granulated copper slag is porous in nature and its grain size is similar to that of coarse sand. It has been researched in the past that copper slag grains have high angularity and have a friction angle of about 52°. Both of these properties leads to increase in stability and load bearing capacity of copper slag. Also it has been found that copper slag particles are free draining and susceptible to frost.

I. OBJECTIVE

The main objective of the present work is to study the physical as well as geotechnical properties of locally available soil (Rajpura, district Patiala, Punjab) when it is replaced with different proportions (10%,20%,..up to 60%) of copper slag by mass.

II. MATERIALS USED

Following are the materials which were used during the experimental programme:

A. LOCAL SOIL

The soil was collected from Rajpura region of Patiala district of Punjab, India. Following table depicts various properties of the soil used.

Table 1 : Soil Properties

S.No.	Property	Value
1.	Liquid limit (%)	24.3
2.	Plastic limit (%)	15.8
3.	Plasticity index (%)	8.5
4.	I.S classification	CL
5.	C.B.R(soaked)(%)	3.41
6.	Maximum Dry Density (kN/m^3)	18.7
7.	Optimum Moisture Content (%)	13.82

B. COPPER SLAG

Granulated copper slag is generated when during the smelting process of production of copper, the slag formed is quenched with water. These angular granules are generally disposed as waste. Copper slag is mainly composed of iron oxides and silicon oxides. It canbe used as a replacement for sand in the production of cement. The granulated copper slag(having particle size less than 3 mm) is insulating in nature. Also it has drainage properties which are helpful in avoiding pavement cracks due to winter frost in the ground. Energy demand is decreased due to reduction in construction depth due to the usage of copper slag. The copper slag used in present work has been collected from SYNCO industries (Jodhpur, Rajasthan, India).Table 2 and Table 3give the physical and chemical properties respectively of the copper slag used.

Table 2: Physical properties of copper slag

S.No.	Property	Value
1.	Appearance	Black and glassy
2.	Shape of the particle	Angular, sharp and multifaceted
3.	Grain size analysis	
	Gravel (%)	0.00
	Sand(%)	93.9
	Silt + clay (%)	0.05

Table 3: Chemical composition of copper slag

S.No.	Chemical component	% Chemical component
1.	Silica SiO_2 (combined as silicate)	26-30%
2.	Free Silica	< 0.5%
3.	Alumina Al_2O_3	1 - 3%
4.	Iron Oxide as FeO	42 - 48 %
5.	Calcium oxide,CaO	1 - 2 %
6.	Magnesium oxide , MgO	0.8 - 1.5%
7.	Copper oxide , CuO	0.60 - 0.70 %
8.	Sulphates	0.02 - 0.3 %

(Ref. Synco industries, Jodhpur, Rajasthan)

The chemical analysis report of copper slag depicts that it contains maximum amount of iron oxide (42-48%) and silica oxide (26-30%). The combined percentage of silica, alumina, iron oxide, calcium oxide and magnesium oxide is around 84.5 % which depicts the potential of copper slag as high quality pozzolana. Table 4 gives the designation to the different mixes used in experiments:

Table 4: Mix designation

S.No.	Specimen ID	Sample Specification
1.	C	Base soil
2.	CS10	10% Copper slag + 90% Soil
3.	CS20	20% Copper slag + 80% Soil
4.	CS30	30% Copper slag + 70% Soil
5.	CS40	40% Copper slag + 60% Soil
6.	CS50	50% Copper slag + 50% Soil
7.	CS60	60% Copper slag + 40% Soil

III. RESULTS AND DISCUSSION

A series of tests were done on differentsoil and copper- slag mixes. Below discussed are the experimental investigations carried out on different mixes and the change in geotechnical properties of the soil after the replacement of soil with copper slag in various proportions.

A. Grain size analysis

Sieve analysis (dry process) for both the materials is done for the purpose of analysis of grain size for virgin soil as well as copper slag. The test was performed according to IS:2720 part-IV. The results of this test are as described by the graph below:

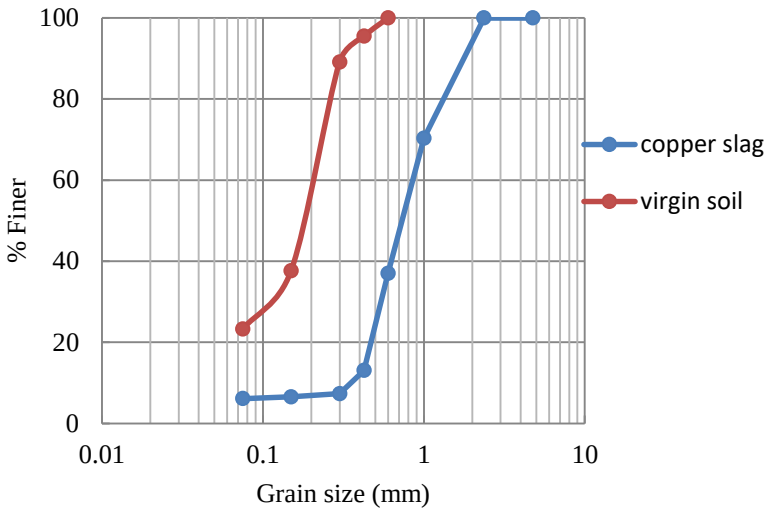

Figure 1: Grain size analysis for copper slag and soil

From the grading curve above, it can be observed that copper slag consists of 93.9% of sandy sized particles and 6.1% of silty and clayey particles. So copper slag used here is coarsely grained.
The D_{10} (effective particle size) of soil from the gradation curve is observed to be 0.029. So according to Indian standard soil classification system, the soil is silty (M) in nature.

B. Tests for Atterberg's limits
Atterberg's limits like liquid limit, plastic limit and plasticity index were routinely determined for each mix. Experimental investigations for these limits were done according to IS:2720 part-V (1970).

Table5: Variation of liquid limit, plastic limit and plasticity index with % CS

S.No.	Specimen ID	Liquid limit(%)	Plastic limit(%)	Plasticity index
1.	C	24.3	15.8	8.5
2.	CS10	20	12.125	7.875
3.	CS20	21.4	14.49	6.91
4.	CS30	13.58	6.75	6.83
5.	CS40	9.665	16.405	6.74
6.	CS50	12.2	5.63	6.57
7.	CS60	12	10.415	1.585

Following chart shows the variation of LL,PL and PI with change in percentage copper slag in the mix:

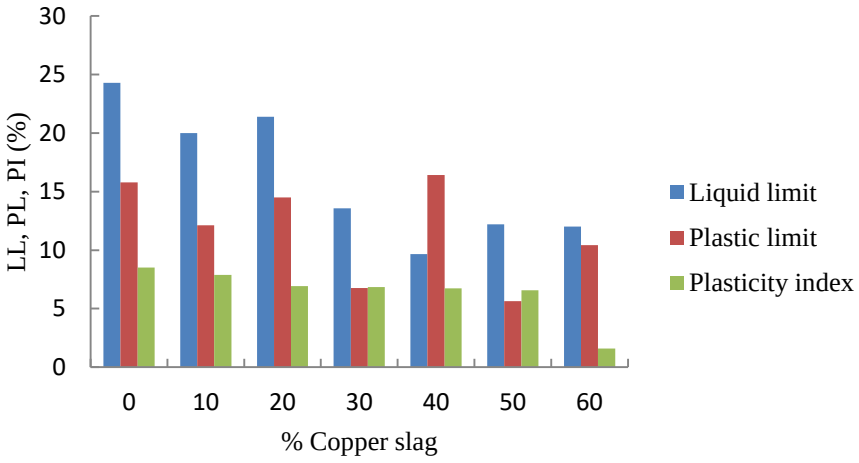

Figure 2: Variation of LL,PL,PI with change in % copper slag

In the mix, the fine soil particles have the capability to attract and hold the water molecules or ions due to electro-chemical forces. Those particles are polar in nature due to an unbalanced negative charge on them such that electric fields are created around them. Therefore water molecules which are dipolar in nature get attracted towards the negatively charged soil particles. The addition of

coarsely grained copper slag reduces the amount of negatively charged soil particles due to which the Activity of the mix gets reduced.

The addition of copper slag as well as the reduction in activity results in the lowering of the concentration of ions and hence the reduction of unbalanced charge near the surface of soil particles in the mix. All this leads to the reduction in affinity for water resulting in the gradual reduction of the liquid limit. As it can be observed from the graph above the plasticity index of the mix is linearly decreasing as the percentage of copper slag in the mix is increasing from 0% to 60%.

C. Compaction tests

The standard proctor test was performed on different mixes in accordance with IS:2720 Part-VII. The maximum dry density of local soil is 18.7 kN/m^3. The compaction curves for different mixes are shown by the following graphs:

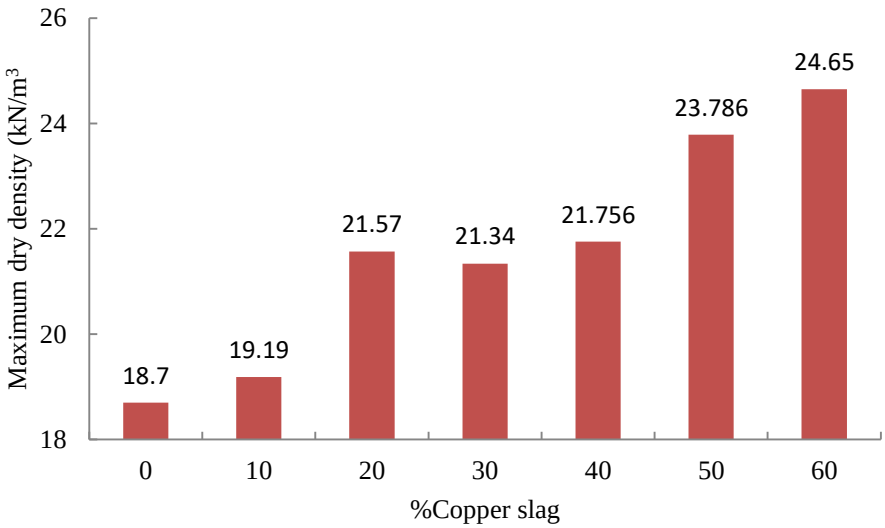

Figure 3 : Variation of MDD with % copper slag

From the chart above it is clear that MDD is increasing with increase in percentage copper slag in the mix. The reason behind this is the usage of granulated copper slag which consists of coarser particles as compared to the size of soil particles used. Addition of copper slag leads to the creation of large voids in the mix which further are appropriately filled with the fine soil particles and hence leading to better interpacking of particles and increase in density. Due to an increase in the copper slag content in the mix, the proportion of sandy sized particles have increased which has reduced the dependence of mix on water. So OMC is found to be constantly decreasing with increase in copper slag content.

D. CBR tests (4 days soaked)

California bearing ratio tests were performed in accordance with IS: 2720 Part 16 (1979). The sample preparation was done by compacting the mixes at their respective optimum moisture contents. The specimens were then soaked for 4 days. The outcomes of CBR tests at various proportions of copper slag in the mix are as depicted in Figure 4. .It was observed that the value of CBR increases with increase in the percentage of copper slag in the mix.

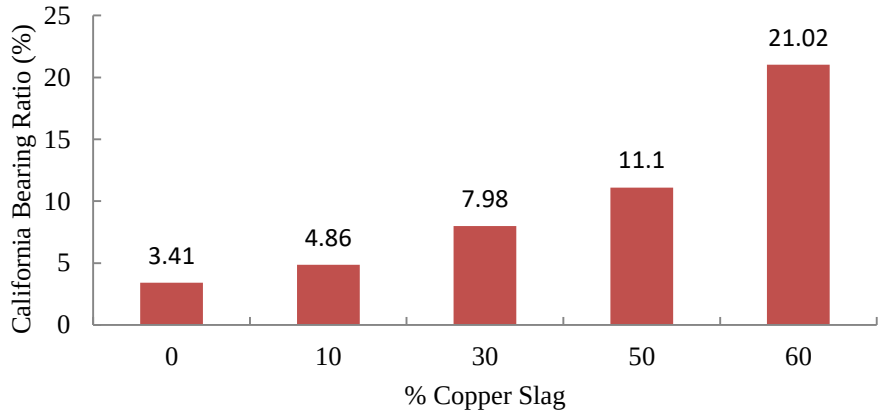

Figure 4: Variation of CBR with % copper slag

The larger voids created by the addition of copper slag get filled by the smaller and finer soil particles and also due to addition there is a presence of particles of all sizes which provides a good skeleton for resistance of loads resulting in increase in CBR value. There is an increase in interlocking forces due to which movement of particles and sample swelling is prevented which clearly reflects in the increased value of CBR.

E. Bearing ratio index :

Bearing ratio index is a dimensionless property which can be defined as the ratio of CBR value of reinforced material (CBR_r) to the CBR value of unreinforced material (CBR_u). The BRI value for different mixes are given below in table.

Table 6: BRI for different mixes

S.No.	Specimen ID	BRI
1.	C	3.41/3.41= 1
2.	CS10	4.86/3.41= 1.425
3.	CS30	7.98/3.41= 2.34
4.	CS50	11.1/3.41= 3.255
5.	CS60	21.02/3.41= 6.164

BRI value has increased from 1 for unblended soil to 6.164 for 60% copper slag in the mix.

V.CONCLUSION

Based on the test results it is concluded that :

1. With variation in the copper slag content from 0% to 60% in the soil, the plasticity index of the soil has decreased from 8.5 % to 1.585%. The percentage decrease in PI is 81.353 %.
2. With increase in copper slag content in the mix, the maximum dry density value has increased from 18.7 kN/m^3 to 24.65 kN/m^3. There is a percentage increase of 13.82 % in the value of maximum dry density. Along with it, the optimum moisture content has decreased from 13.82% to 6.25%. The percentage decrease in the OMC value is 54.77%.
3. Addition of copper slag has led to increase in the CBR value from 3.41% to 21.02%. Percentage increase in CBR value is 516.42%.

Copper slag has the potential to be used in the form of admixture for problematic soils in areas like land reclamation, embankment construction and for the improvement of subgrade soil. Since the gradation properties of copper slag is similar to the medium sand, therefore it can be effectively used in backfill for retaining walls and shallow foundations. Also, by utilising and reusing the copper slag, wastage of cultivable land is avoided which gets wasted during the dumping of the slag.

Since there has been an increase in the CBR value, therefore copper slag can be used for subgrades in road construction. Copper slag can be economically used as stabilizing admixture near the areas of slag source. This leads to the reusing of copper slag without harming the environment.

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