International Journal of Structural and Civil Engineering Research

ISSN 2319 – 6009 www.ijscer.com
Vol. 1, No. 1, November 2012

Research Paper

AN EXPERIMENTAL STUDY OF CLAYEY SOIL STABILIZED BY COPPER SLAG

R C Gupta[1], Blessen Skariah Thomas[1*], Prachi Gupta[2], Lintu Rajan[1] and Dayanand Thagriya[1]

*Corresponding Author: **Blessen Skariah Thomas,** ✉ chaprathu44@gmail.com

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.

[1] Malaviya National Institute of Technology, Jaipur, Rajasthan, India.
[2] Aayojan School of Architecture, Jaipur, Rajasthan, India.

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.

Figure 1: A Silica Tetrahedron and a Silica Sheet

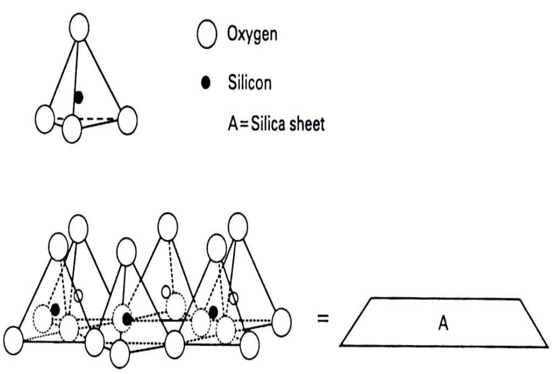
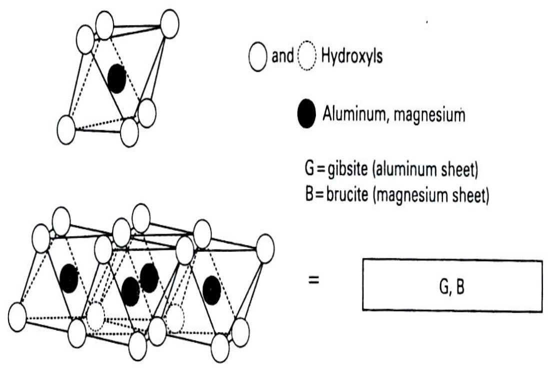


Figure 2: An Octahedron and an Octahedron Sheet



Source: Oweis and Khera (1998)

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 utiliza-tion 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 1: Physical Properties of Copper Slag

S.No.	Physical properties	Value obtained	Test sample Value
1.	Particle shape	Irregular	Irregular
2.	Appearance	Black & glassy	Black & glassy
3.	Type	Air cooled	Air cooled
4.	Specific gravity	2.9-3.9	2.99
5.	Percentage of voids	43.20%	45%
6.	Bulk density	2.08 g/cc	2.08 g/cc
7.	Fineness modulus	3.47	3.86
8.	Angle of internal friction	51o20'	51o20'
9.	Water absorption	0.3 to 0.4%	0.4%
10.	Moisture content	0.1%	0.1%

Brindha et al. (2010)

Figure 3: Copper Slag

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.

Table 2: Physical Properties of Clayey Soil

S. No.	Soil Properties	Values
1.	Specific gravity	2.57
2.	Consistency limit	
	Liquid limit (%)	29.70%
	Plastic limit (%)	16.5%
	Plastic index (%)	10.2%
	Shrinkage limit (%)	16.3%
	Shrinkage index (%)	65.3%
3.	Texture of classification based on plasticity chart	CL
4.	Compaction study Optimum moisture content	18.08 %
	Maximum dry density	1.573 gm/cc

TEST RESULTS

Index Properties

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 sieve analysis (dry process). The particle size distribution curve was shown in Figure 4.

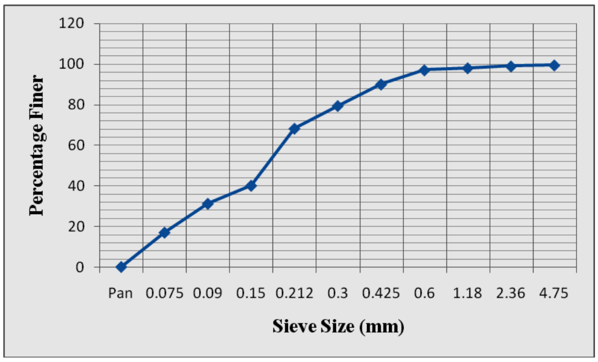
Specific Gravity

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.

Table 3: Chemical Composition of Copper Slag

S. No.	Chemical Tests	Results Obtained by Brindha *et al.* (2010) (%)	Test Sample Result (%)
1.	Loss on ignition(L.O.I.)	-	2.19
2.	Silica(SiO_2)	25.84	71.52
3.	Magnesium oxide(MgO)	-	0.49
4.	Calcium oxide(CaO)	0.15	0.16
5.	Aluminum oxide(Al_2O_3))	0.22	13.96
6.	Iron oxide (Fe_2O_3)	68.29	3.64
7.	Potassium oxide(K_2O)	0.23	1.82
8.	Sodium oxide(Na_2O)	-	4.12
9.	Titanium oxide(TiO_2)	0.41	0.013
10.	Copper oxide(CuO)	1.20	0.32
11.	Manganese oxide (Mn_2O_2)	0.22	0.072
12.	Chloride(Cl^-)	0.018	-
13.	Sulphite (SO_3^-)	0.11	-
14.	Insoluble residue	14.88	-
15.	Sulphide sulphur	0.25	-
16.	SiO_2+AL_2O_3+Fe_2O_3	94.35	92.12

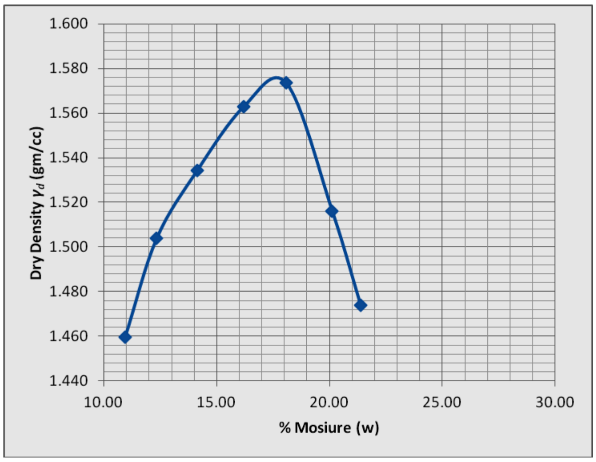
Figure 4: Particle Size Distribution Curve of Copper Slag



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.

Figure 5: Variation in Dry Density with Moisture in 100% Clay



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 6: Variation in Dry Density with Moisture in 90% Clay with 10% CS

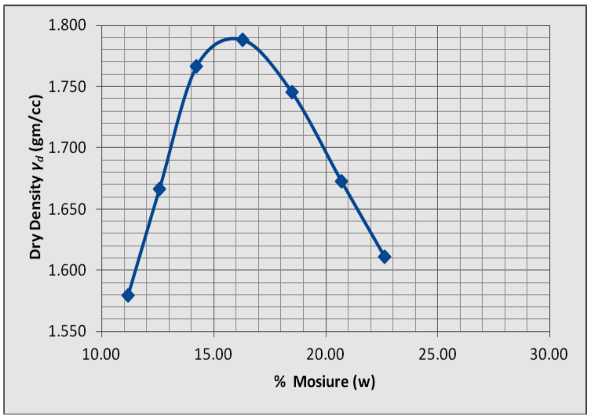


Figure 7: Variation in Dry Density with Moisture in 80% Clay with 20% CS

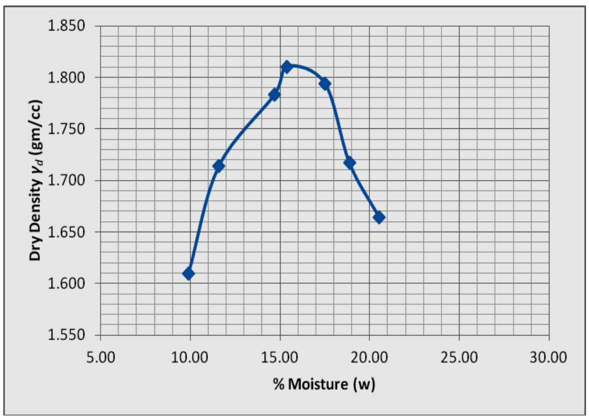


Figure 8: Variation in Dry Density with Moisture in 70% Clay with 30% CS

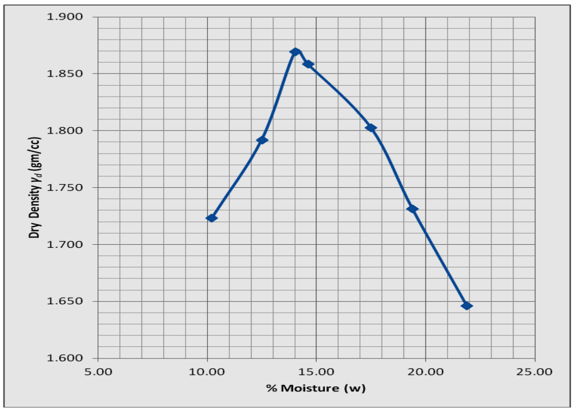


Figure 11: Variation in Dry Density with Moisture in 40% Clay with 60% CS

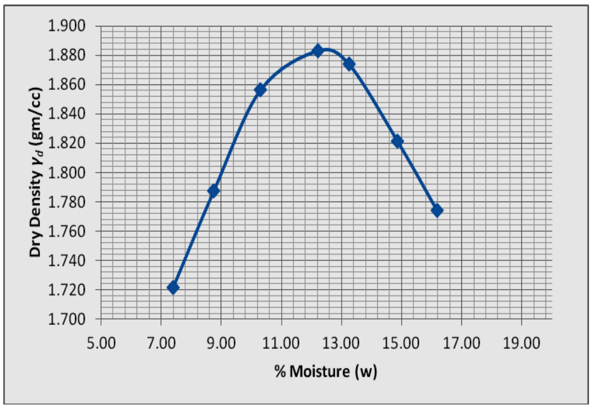


Figure 9: Variation in Dry Density with Moisture in 60% Clay with 40% CS

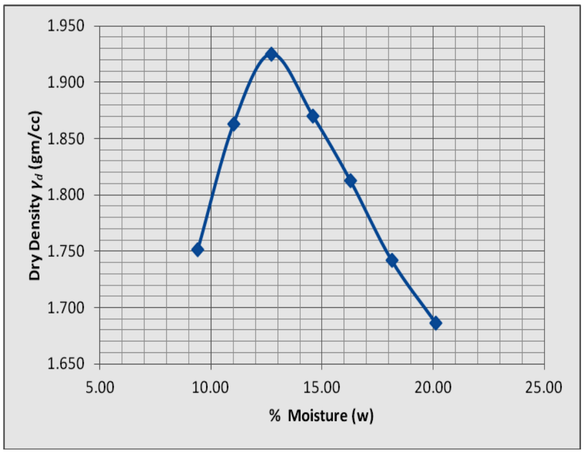


Figure 12: Variation in Dry Density with Moisture in 30% Clay with 70% CS

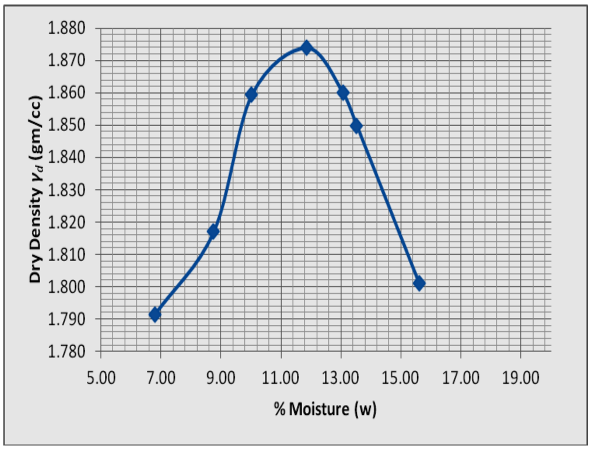


Figure 10: Variation in Dry Density with Moisture in 50% Clay with 50% CS

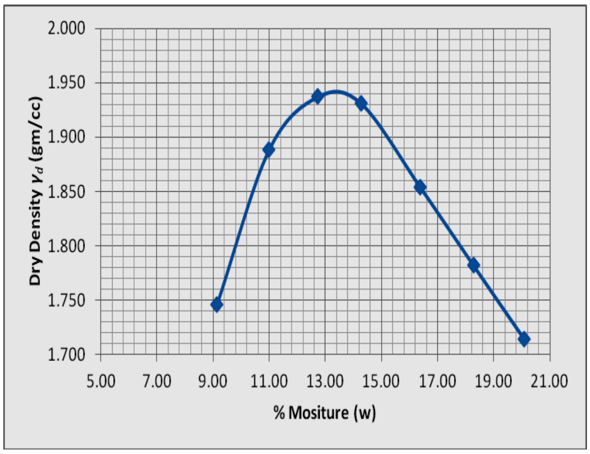


Figure 13: Variation in Dry Density with Moisture in 20% Clay with 80% CS

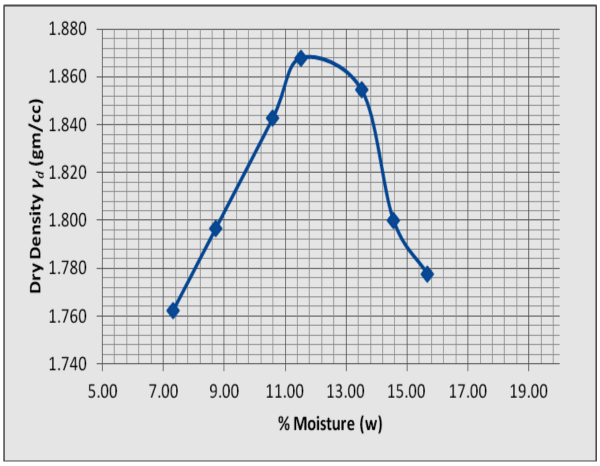


Figure 14: Variation in Dry Density with Moisture in 10% Clay with 90% CS

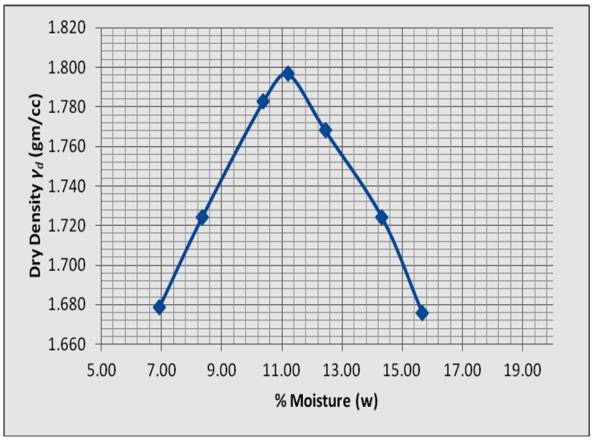


Figure 14: Variation in Dry Density with Moisture in 100% CS

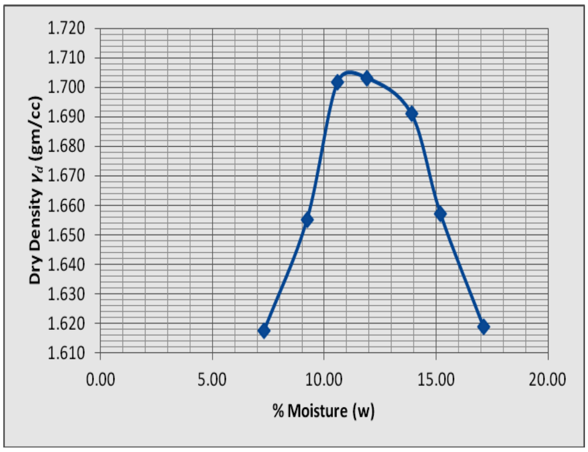


Table 4: Peak Value of OMC and MDD, Specific Gravity

S. No.	Combinations (%)	OMC (%)	Maximum Dry Density	Specific Gravity
1.	100% Clay	18.085	1.573	2.57
2.	90% Clay with 10% Copper slag	16.272	1.788	2.60
3.	80% Clay with 20% Copper slag	15.379	1.811	2.65
4.	70% Clay with 30% Copper slag	14.036	1.87	2.70
5.	60% Clay with 40% Copper slag	12.716	1.925	2.76
6.	50% Clay with 50% Copper slag	12.735	1.937	2.82
7.	40% Clay with 60% Copper slag	12.212	1.883	2.87
8.	30% Clay with 70% Copper slag	11.844	1.874	2.91
9.	20% Clay with 80% Copper slag	11.511	1.868	2.94
10.	10% Clay with 90% Copper slag	11.196	1.797	2.97
11.	100% Copper slag	11.916	1.703	2.99

Shear Characteristics

The value of Angle of shearing resistance (ϕ) 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 ϕ and absolute minimum value of 'c' corresponding value are 48° and 0.01 KN/cm^2. 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, ϕ and Unit Cohesion, c With Respect to Change in % of Copper Slag in Clay

S.No.	Combinations (%)	Angle of Shearing Resistance ϕ (°)	Unit Cohesion, c (N/cm²)
1.	100% Clay	26	0.15
2.	90% Clay with 10% Copper slag	39	0.13
3.	80% Clay with 20% Copper slag	42	0.11
4.	70% Clay with 30% Copper slag	46	0.03
5.	60% Clay with 40% Copper slag	48	0.01
6.	50% Clay with 50% Copper slag	47	0.13
7.	40% Clay with 60% Copper slag	40	0.25
8.	30% Clay with 70% Copper slag	35	0.25
9.	20% Clay with 80% Copper slag	32	0.3
10.	10% Clay with 90% Copper slag	21	0.33
11.	100% Copper slag	19	0.35

Figure 16: Variation in MDD with Respect to % of Copper Slag in Clay

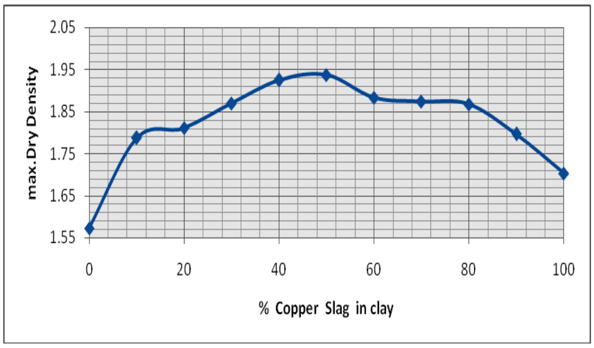


Figure 17: Variation of Angle of Shearing Resistance to % Copper Slag in Clay

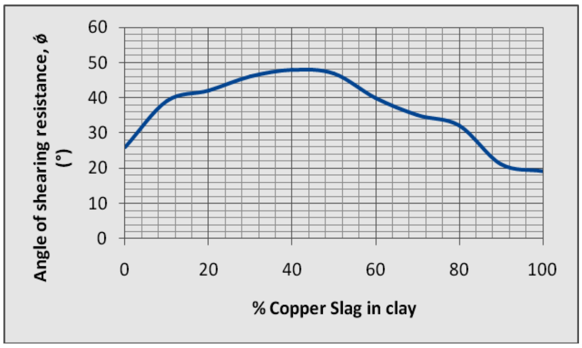
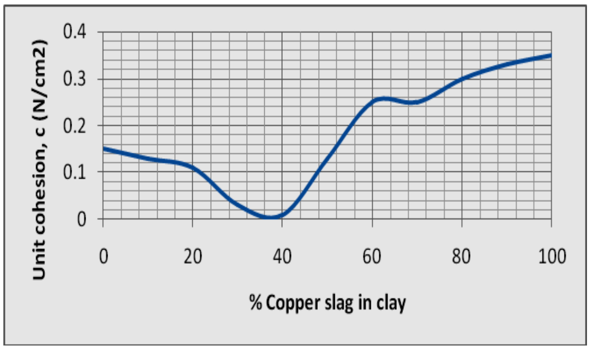


Figure 18: Variation Unit Cohesion with Respect to % Copper Slag in Clay



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 (ϕ) was 48° for the combination of 50% Clay and 50% Copper slag. The angle of shearing resistance (ϕ)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

1. Alpa I, Devecia H and u¨ ng ¨unb H S (2008), “Utilization of flotation Wastes of Copper Slag as Raw Material in Cement Production”, Karadeniz Technical University, Department of Mining Engineering, 61080 Trabzon, Turkey.
2. Al-Rawas A A, Taha R, Nelson J D, Al-Shab T B and Al-Siyabi H (2002), “A Comparative Evaluation of Various Additives Used in the Stabilization of Expansive Soils”, *Geotechnical Testing Journal*, Vol. 25, No. 2, pp. 199-209.
3. Bipra Gorai and Jana R K Premchand (2003), “Characteristics and Utilization of Copper Slag: A Review”, *Resources, Conservation and Recycling*, Vol. 39, pp. 299-313.
4. Brindha D, Baskaran T and Nagan S (2010), “Assessment of Corrosion and Durability Characteristics of Copper Slag Admixed Concrete”, *International Journal of civil and structural Engineering*.
5. Blessen Skariah Thomas, Anoop S and Sathish Kumar V (2012), “Utilization of Solid Waste Particles as Aggregates in Concrete”, in Procedia Engineering, Elsevier, Vol. 38, pp. 3789-3796.
6. Chaudhary R and Rachanan M (2006), “Factors Affecting Hazardous Waste solidification/stabilization: A Review”, in *Journal of Hazardous Materials,* Vol. B137, pp. 267-276.
7. Dayanand Thagriya (2011), M.Tech. Thesis Entitled “Use of copper Tailing for clay soil stabilization” Submitted to Malaviya National Institution of Technology, Jaipur, India.
8. David H and Poh Y (1997), “Soil Stabilization Using Basic Oxygen (BOS)

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

9. Jouko Saarela (1997), "Recycling of Industrial by-Products for Soil Constructions In Finland", Finnish Environment Institute, Helsinki, Finland.

10. Ramanatha Ayyar T S, Ramachandra Nair C G and Balakrishnana Nair N (2002), "Comprehensive reference book on Coir Geotextiles", Published by Centre for Development of Coir Technology (C-DOCT), Trivandrum, India.

11. Oweis I S and Khera R P (1998), *Geo-technology of Waste Management*, 2nd Edition, PWS Publishing Company, Boston.

12. Vimal Kumar, Gulab Singh and Rajendra Rai (2005), "Flyash: A Material for Another Green Revolution", Fly Ash Utilization Programme, TIFAC, DST, Government of India, New Delhi 110 016.

13. Wayne A C, Mohamed A O and El-Fatih M A (1984), "Construction on Expansive Soil in Sudan", *Journal of Construction Engineering and Management*, Vol. 110, No. 3, pp. 359-374.