UTILIZATION OF COPPER SLAG TO IMPROVE GEOTECHNICAL PROPERTIES OF SOIL

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Abstract- *The recent development and application in the use of advanced composites in the improvement of soil are increasing on the basis of specific requirements and national needs. The need of efficient stabilization and strengthening techniques of existing soil has resulted in research and development of newer material for improvement. Particularly for the black cotton soils which have high swelling and shrinkage tendencies, demand great deal of attention for stabilization. Varieties of materials are used for improving the soil ranging from wood-ash, acrylic resins, many fiber polymers, lime etc. As a further step toward the innovative material to be used for the stabilization, this study endeavor to use waste material (copper slag) for the soil improvement.*

Copper slag, which is produced during production of copper from copper ore, contains minerals like iron, alumina, calcium oxide, silica, etc. For every tone of metal production about 2.2 tone of slag is generated. Total generation of copper slag is about 24.6 million tones throughout the world. Disposal of such huge quantities of slag cause environmental problems. The utilization of such waste materials in road construction is significant importance in the country. During past decades attempts have been made by several investigators all over the world to explore the possible utilization of copper slag. The bulk utilization of these wastes not only solves the disposal problem of the industries but also protects the environment. The paper discusses the physical and geotechnical properties of copper slag. Copper slag was also mixed with local soil in the different proportion and various geotechnical properties were found.

Keywords- Copper Slag, Soil Stabilization, Utilization Copper Waste, Different Percentage Analysis.

I.Introduction

Weak soils, 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 or 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 earth embankments, steepen existing slops, or modify otherwise marginal soils for use as earth fill. The use of recycled material to improve marginal soils offer 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 material in several transportation and geotechnical application. Equally important, recycled materials offer both economic and environmental incentives. In addition to a lower cost in comparison to traditional materials, their use has potential to alleviate landfill problems as well as avert costs typically associated with their disposal.

Large amounts 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 waste 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 used 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 material 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.

II. NEED OF STUDY

While extensive research has been conducted to investigate the use of Recycled materials in engineering applications, the dissemination of the findings is often limited. The problem is compounded by the lack of a single resource containing relevant engineering and environmental characteristics of each material; the tendency of the researchers to publish their finding in technical reports rather than archived publication; and the wide discrepancies among local and state environmental regulations construction is hindered by the lack of a rational procedure for selection and approving the use of new recycled materials. Among the problems encountered when a new material is proposed are (1) material availability in terms of quantity and price; (2) environmental impact of the proposed material; (3) consistent mixing and construction method; (4) quality control in terms of spatial and temporal variability of the properties of the material; and (5) Consistent design methods.

Since the beginning of the industrial era, slags the glassy materials left over when metals are pyrometallurgically extracted from ores have been considered waste. One such material is copper slag. Copper slag (CS) is a by-product material generated from the process of manufacturing copper. As the copper settles down in the smelter, as it has a higher density, impurities stay in the top layer and then are transported to a water basin with a low temperature for solidification. The end product is a solid, hard material that goes to the crusher for further processing. Slags containing about 0.8% copper are either discovering of metal, production of value added products and disposal in slag dumps or stockpiles. Dumping or disposal of this slag causes wastage of metal values and leads to environmental problems. Rather than disposing, these slags can be used taking full advantage of its physic-mechanical properties.

III. OBJECTIVES AND WORK PLAN

The main purpose of this project is to investigate the use of copper slag in geotechnical and transportation applications, and to classify these materials according to relevant factors such as availability, application, environmental impact, and cost. Specifically, it is concerned with the use of such recycled materials to improve the engineering properties of marginal soils, while maintaining conformance with regulations and practice in terms of the environmental, economical, and practical limitations of such use.

The project involves several components. First, a comprehensive literature review was conducted in order to rather availability information, technical specifications, and parameter data for copper slag. Information was collected on the availability, cost, and earlier performance of the material in order to narrow down the list of potential material which could be implemented for the purpose of improving marginal soils in roadway construction. Data from large-scale field evaluations and other case histories in the literature were also compiled.

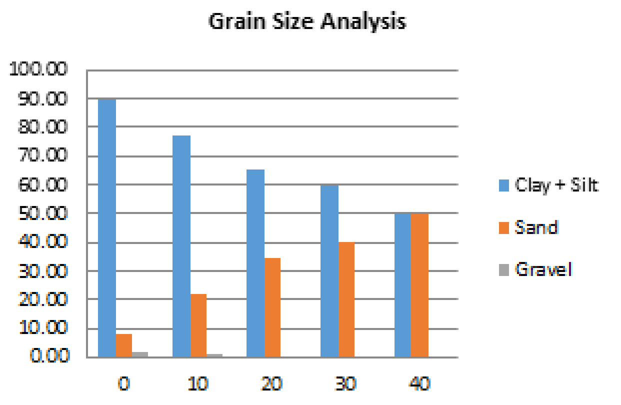
IV. PROBLEM DEFINATION

From reading the literature and speaking with engineering professionals, it is apparent that a quality control mechanism must be in place if the goal of recycled materials implementation is to be achieved. Perhaps the most expeditious method to achieve it is through source control. By ensuring that a material comes from the same source and is processed in a consistent way, many of the variables associated with engineering performance and environmental impact can be at least partially controlled. The wide range of engineering parameters especially for unit weight, internal friction angle, permeability, and compressive strength emphasize the need to test materials at the local level from a controlled source using specified sampling procedures. Once consistency can be established, and more importantly assured at the local level, the use of recycled materials will be greatly facilitated. High up-front costs associated with quality control through testing should lead to lower costs in the future. The flow charts shown in Figure 1.6.1 is prepared to facilitate the decision making process regarding whether or not a particular material can be approved for use.

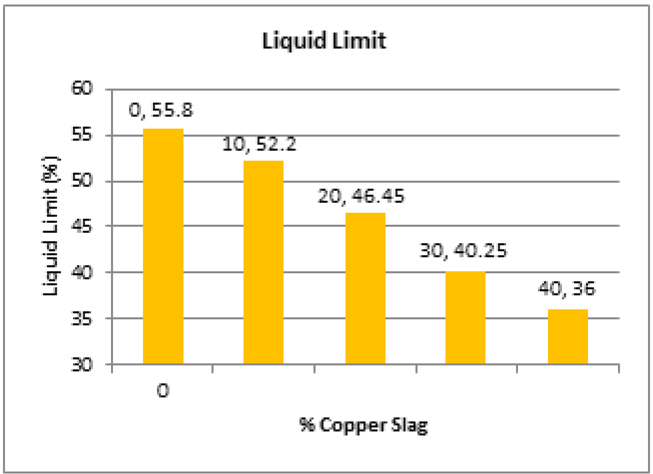
At all steps, suppliers and providers of recycled materials must be informed from the early stages that the use of recycled materials in highway and roadway applications, particularly for improving the properties of marginal soils, does not provide and should not be approached as an avenue to dispose of the material. Instead, the proposed material and process must provide mechanical improvement to the soil, economic advantages, and must comply with environmental regulations.

It should also be noted that samples used for testing and demonstrations are generally selected from a few batches and may therefore not be representative of the material as a whole. Care should be taken by personnel as different recycling and post-processing methods. Therefore, results for the tests on a sample obtained from a different supplier might be very different from the results presented in this report or provided by a supplier due to variations in methods collection and processing. Other states often have different methods and regulatory requirements that yield different results and the case studies must be unique to the material of concern at the location it is being recycled and marketed.

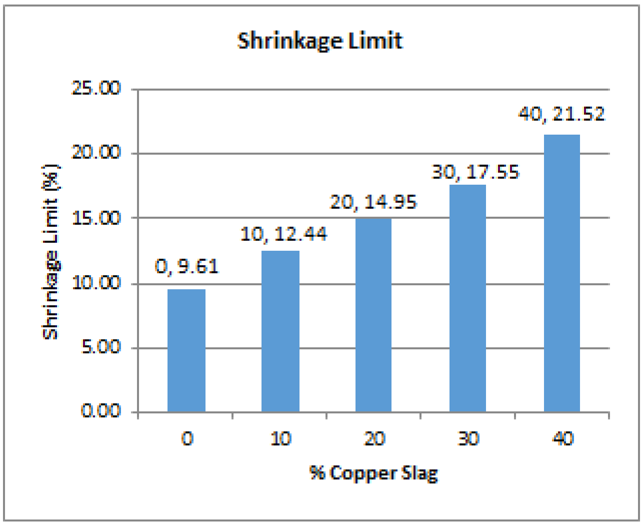
V. ANALYSIS WITH DIFFERENT PERCENTAGE OF COPPER SLAG



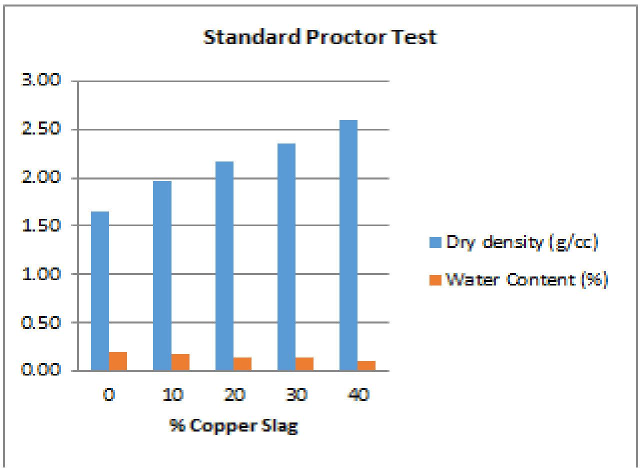
		Local Soil + Copper Slag			
Soil	**0**	**10**	**20**	**30**	**40**
Clay + Silt	90.00	77.00	65.29	59.70	50.08
Sand	8.00	22.00	34.30	39.95	49.92
Gravel	2.00	1.00	0.41	0.35	0.00
Total	100.00	100.00	100.00	100.00	100.00

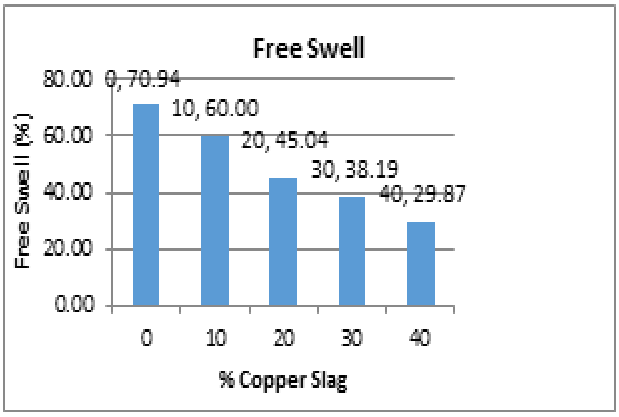


% Copper Slag	**0**	**10**	**20**	**30**	**40**
Liquid Limit (%)	55.8	52.2	46.45	40.25	36
% Decreased in Liquid Limit	0.00	6.45	16.76	27.87	35.48

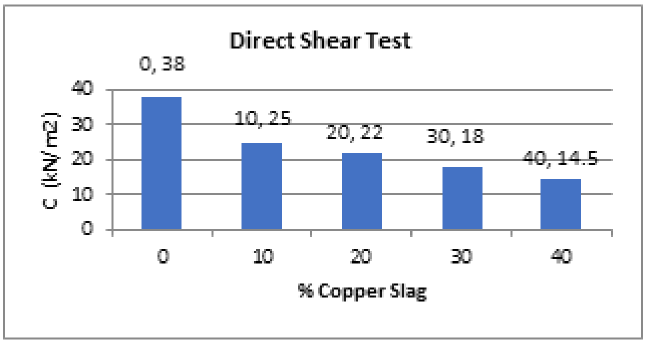


% Copper Slag	0	10	20	30	40
Shrinkage Limit (%)	9.61	12.44	14.95	17.55	21.52
% Increased in Shrinkage Limit	0.00	29.44	55.47	82.50	123.78

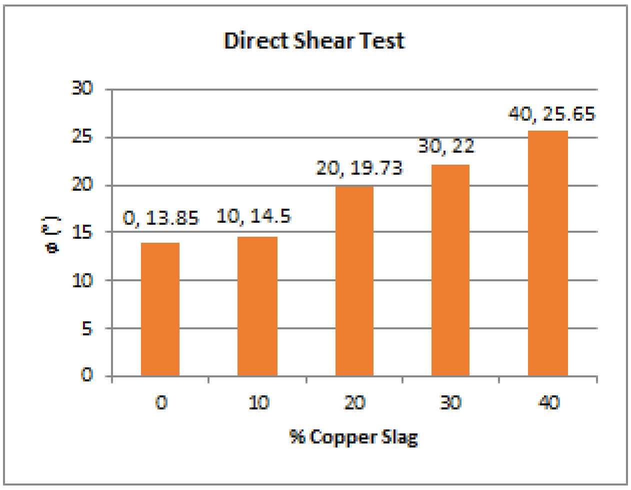




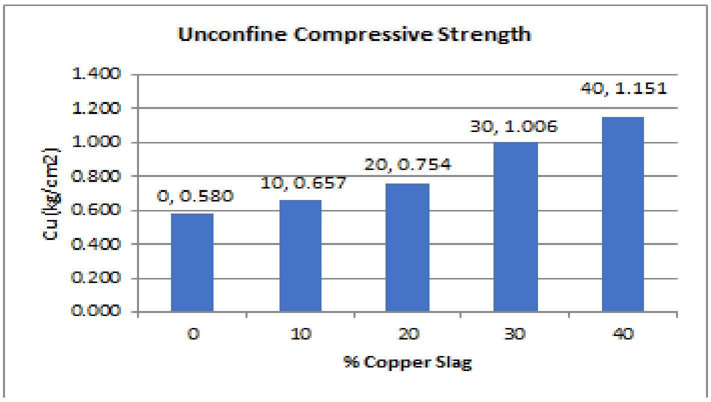
% Copper Slag	0	10	20	30	40
Dry density (g/cc)	1.64	1.96	2.17	2.35	2.59
% Increased in Water Content	0.00	19.62	32.55	43.59	58.08
Water Content (%)	0.21	0.18	0.15	0.13	0.11
% Decreased in Dry density	0.00	14.28	28.04	35.00	48.02



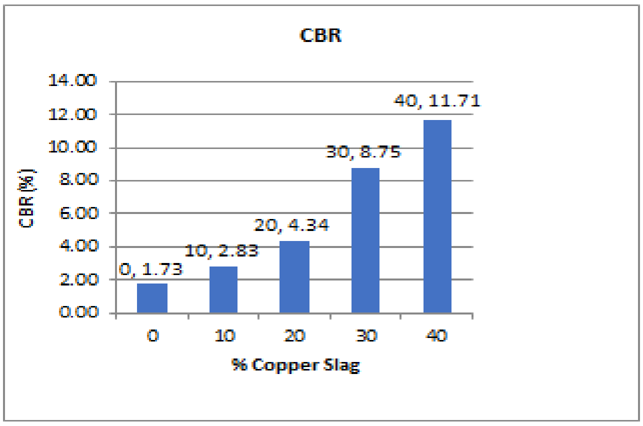
% Copper Slag	0	10	20	30	40
Free Swell (%)	70.94	60.00	45.04	38.19	29.87
% Decreased in Free Swell	0.00	15.42	36.51	46.16	57.89



% Copper Slag	0	10	20	30	40
Angel of Internal Friction: ø (°)	13.85	14.5	19.73	22	25.65
% Increased in Angel of Friction	0.00	4.69	42.45	58.84	85.20



% Copper Slag	0	10	20	30	40
Cu (kg/cm^2)	0.580	0.657	0.754	1.006	1.151
% Increased in UCS	0.00	13.33	30.00	73.33	98.33



% Copper Slag	0	10	20	30	40
CBR (%)	1.73	2.83	4.34	8.75	11.71
% Increased in CBR	0.00	63.55	150.67	405.13	575.75

VI RESULT

MIXES AND THEIR DESIGNATION

Mix Designation	Mix
10:90	10 % Copper Slag + 90 % Local Soil
20:80	20 % Copper Slag + 80 % Local Soil
30:70	30 % Copper Slag + 70 % Local Soil
40:60	40 % Copper Slag + 60 % Local Soil

GEOTECHNICAL CHARACTERISTICS OF STABILIZED MIXES

Property		Local Soil	10 : 90	20 : 80	30 : 70	40 : 60
Grain size analysis	Silt + Clay (%)	90.00	77.00	65.29	59.70	50.08
	Sand (%)	8.00	22.00	34.30	39.95	49.92
	Gravel (%)	2.00	1.00	0.41	0.35	0.00
Atterberg limit test	Liquid limit: W_L (%)	55.8	52.2	46.45	40.25	36
	Plastic limit: W_P (%)	27.27	26.96	25.78	24.09	20.57
	Plasticity Index: I_P (%)	28.53	25.24	20.67	16.16	15.43
	Shrinkage limit: W_S (%)	9.61	12.44	14.95	17.55	21.52
Compaction test	Maximum Dry Density: MDD (gm/cc)	1.64	1.96	2.17	2.35	2.59
	Optimum Moisture Content: OMC (%)	0.21	0.18	0.15	0.13	0.11
Swelling test	Free swell index (%)	70.94	60.00	45.04	38.19	29.87
Direct shear test	C (kN/m^2)	38	25	22	18	14.5
	Ø (°)	13.85	14.5	19.73	22	25.65
CBR (soak) (%)		1.73	2.83	4.34	8.75	11.71
UCS(kg/cm^2)		0.580	0.657	0.754	1.006	1.151

CONCLUSION

The grain size distributions of the soil tested are altered by the addition of copper slag. The silt & clay size particles decreased whereas sand size particles increased with increasing amount of copper slag.

1. Copper slag is blackish granular material similar to coarse sand having specific gravity of 3.29.

2. The moisture-density curve for copper slag is observed to be flat similar to sandy soils. It is granular material with high angle of friction (ø=25.65°) and CBR value (11.71).

3. The mix of copper slag and local soil (40:60) has CBR value 11.71%. For sub grade minimum CBR value requirement is 2%. So, this mix can be use as a sub grade material.

4. Copper slag local soil mix (40:60) has a low free swelling index (11.71%). By utilizing this mix, we can avoid the problems of swelling and shrinkage of expansive soil. This can prove economically viable and alternative solution for road construction.

5. Due to non cohesive and non plastic characteristics of copper slag, care shall be taken during the construction of such mix.

6. The bulk utilization of copper slag in the road construction solves the disposal problems of the industries.

7. On the basis of this research study copper slag can be recommended as effective stabilizing agents for improvement of soils for highway embankments, sub grade and sub base. The use of copper slag as stabilizing agents can be economically attractive in regions near to the areas where these waste by-products are obtained. Utilization of copper slag in this manner also has the advantage of reusing industrial waste by-product without adversely affecting the environment or potential land use.

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