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A Study on the Effect of Copper Slag on Lime Stabilized Clay

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***Abstract*: Soil stabilization is a method employed for modifying the properties of a soil to improve its engineering performance. This paper investigates the improvement in the properties of clayey soils stabilized with copper slag and lime. Lime has been used for several decades as stabilizing agent in deep stabilization of soft soil and it is used to improve the strength parameters. Lime soil blend were reported to have developed substantial tensile strength. In order to improve the properties of lime stabilized soil certain industrial wastes such as fly ash, copper slag, marble dust etc are added. In this study copper slag is used as an additive. Copper slag is one of the waste materials that are being used extensively in the civil engineering construction industry. The test will be conducted based on the varying percentage of lime and copper slag with the clayey soil. The disadvantages of clay can be overcome by stabilizing with suitable material. Main laboratory tests include Un-confined compressive strength test (UCS), California bearing ratio test (CBR). This study is done to find out the engineering behavior of lime stabilized clayey soil with Copper Slag.**

Keywords: Copper slag, UCS, CBR, Lime, Stabilization

I. INTRODUCTION

With increasing scarcity of river sand, soil and natural aggregates across the country, there is a need to replace soil and sand with alternate materials which are stable and economical. For developing countries, urbanization and industrialization is a must and this activity extremely demands to uplift nation's economy and increase 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 [2]. Methods of stabilization may be grouped under two main types a) Modification or improvement of a soil property of the existing soil without any admixture. b) Modification of the properties with the help of admixtures. The properties of soft soils can be improved by either of the above mentioned methods [5].

Soil stabilization is the process of the alteration of the geotechnical properties to satisfy the engineering requirements. Soil stabilization is basically done on expansive soil because expansive soil swell on imbibition of water during monsoon, reduce in density and become slushy. But in dry seasons, they shrink because of evaporation of water, and become hard due to increase in density. The alternate swelling and shrinkage causes distress to civil engineering structures built on these soils are severely damaged. Numerous kinds of stabilizers were used as soil additives to improve its engineering properties. Lime has been found to be the most effective and economical of all additives. Addition of lime to expansive soils reduces swell potential and increases workability and strength. Lime stabilization improves the compressibility characteristics of clayey soil and helps to reduce plasticity index, increase optimum moisture content and decrease maximum dry density [6].

Industrial waste like Copper slag, fly ash, blast furnace slag, steel slag etc is also used for soil stabilization along with or without Lime. Copper slag (CS) is a waste product which comes out from smelting process, the production of copper slag is 120-130 lakh ton per annum and copper producing units in India leave thousands of tons of copper slag as waste every day, granulated copper slag is more porous and, therefore has particle size equal to that of coarse sand [1]. Various studies were carried out by researchers on utilization of copper slag in expansive soil results for good soil stabilizations also copper slag has high angularity and friction angle (up to 520) of aggregates contribute to the stability and load bearing capacity. Also copper slag aggregates tend to be free draining and are not frost susceptible. Copper slag can be recommended for sub-base, Sub-grade, bitumen mixes [7]. Copper slag is a good backfill material than sand and it can be used as backfill in retaining walls [8].

II. MATERIALS AND METHODS

The experimental work was undertaken to archive the objective of the study. Laboratory tests were conducted on nature soil and after treatment with copper slag and lime.

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Materials

1. Soil

Fig.1. Kuttanad clay

The soil used for the study was Kuttanad clay. Kuttanad clays are dark brown colored medium sensitive alluvial deposits spread over the Kuttanad region in the state of Kerala in India. The dominant mineral constituents in this clay are kaolinite and illite. These clays are characterized by high compressibility, low shear strength and high percentage of organic matter, which are unfavorable from the geotechnical point of view.

TABLE I. GEOTECHNICAL PROPERTIES OF KUTTANAD CLAY

Properties	Value
Specific Gravity	2.4
Liquid Limit (%)	46
Plastic Limit (%)	36.2
Plasticity Index	9.8
Silt (%)	50
Clay (%)	42
Sand (%)	8
Optimum Moisture Content (%)	30
Maximum Dry Density (g/cc)	1.42

2. Lime

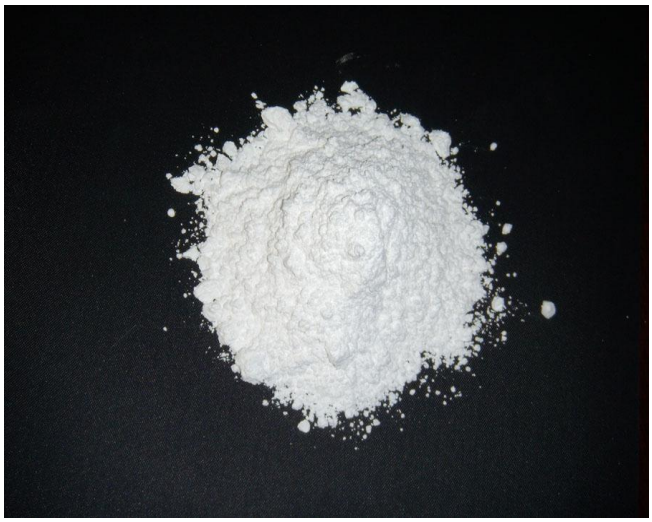

Fig.2. Lime

Lime treatment can produce high and long-lasting strength. Lime in the form of quicklime (calcium oxide – CaO), hydrated lime (calcium hydroxide – Ca [OH] 2), or lime slurry can be used to treat the soils. Hydrated lime is created when the quicklime chemically reacts with water. It is hydrated lime that reacts with particles of clay and permanently transforms them into a strong cementious matrix.

3. Copper Slag

Fig.3. 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. Copper slag for this study is collected from AARUSH Enterprise Madurai.

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TABLE II. CHEMICAL PROPERTIES OF COPPER SLAG

Properties	Value
Particle shape	Irregular
Appearance	Black and Glassy
Specific gravity	3.6
Bulk density g/cc	2.08
Moisture content %	<.01

TABLE III. PHYSICAL PROPERTIES OF COPPER SLAG

Properties	Value
Iron Oxide(Fe_2O_3)	42-48
Silca($Si0_2$)	26-30
Aluminium Oxide (Al_20_3)	1.0-3.0
Calcium Oxide(CaO)	1.0-2.0
Manganese Oxide(MgO)	.8-1.5

A. *Methods*

Unconfined Compressive Strength Test, California Bearing Ratio Test and Scanning Electron Microscope were conducted.

1. *Unconfined Compression Strength (UCS) Test*

UCS test was performed according to IS: 2720(Part X)-1991. Test was conducted on Soil alone, Soil-Lime mix and Soil-lime- Copper slag mix. The Lime-Soil sample and Lime-Soil-Copper slag samples were sealed in air tight polythene bag for different curing period (7, 14 & 28 Days). Cylindrical specimens were subjected to a gradually increased axial compression load until failure.

2. *California Bering Ratio Test (CBR)*

Test was conducted as per IS 2720 (Part XVI) 1979 on optimum mix. After compaction CBR samples were sealed in air tight polythene and cured. The samples were then soaked in water for 4 days prior to testing.

3. *Scanning Electron Microscope*

To observe the influence of lime and copper slag addition on the soil was done using scanning electron microscope (SEM). After UCS testing, the tested samples were dried for SEM. Small specimens of both untreated and treated clay samples were prepared and the fractured surfaces of the specimens were coated with gold before scanning.

III. RESULTS AND DISCUSSION

A. *Unconfined Compression Strength (UCS) Test*

Unconfined compression test was conducted on Soil-Copper slag mix, Soil-Lime mix and Soil-Lime-Copper slag mix.

TABLE IV. UCC TEST RESULT FOR VARYING PERCENT OF COPPER SLAG IN SOIL

Sl No	Mix Proportion	UCC (KN/m^2)
1	Soil	33.12
2	Soil + 2% of CS	35
3	Soil + 4% of CS	38.15
4	Soil + 6% of CS	44.48
5	Soil + 8% of CS	36.80
6	Soil + 10% of CS	33.36

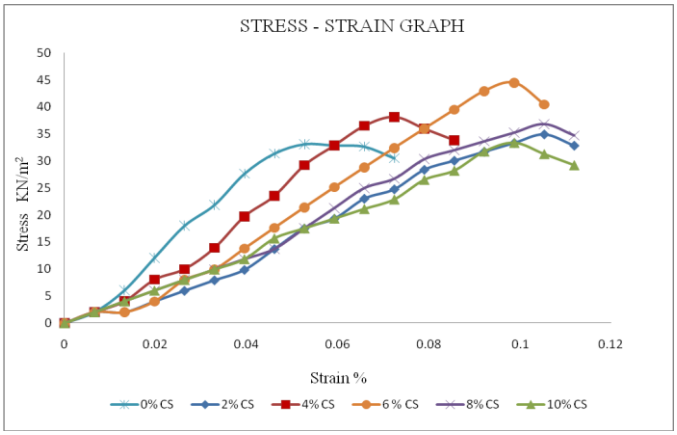

Fig.4. Variation of Stress Strain curve of Soil-CS mix

TABLE V. UCC TEST RESULT 6%CS AND VARYING % OF LIME

Sl No	Mix Proportion	UCS (KN/m^2)		
		7 Day curing	14 Day curing	28 Day curing
1	Soil	33.12	33.12	33.12
2	Soil+6%CS+2%L	54.93	77.66	197.35
3	Soil+6%CS+4%L	70.3	98.5	304.22
4	Soil+6%CS+6%L	90.92	102.28	306.06
5	Soil+6%CS+8%L	56.11	88.38	274.72
6	Soil+6%CS+10%L	74.4	82.4	220.17

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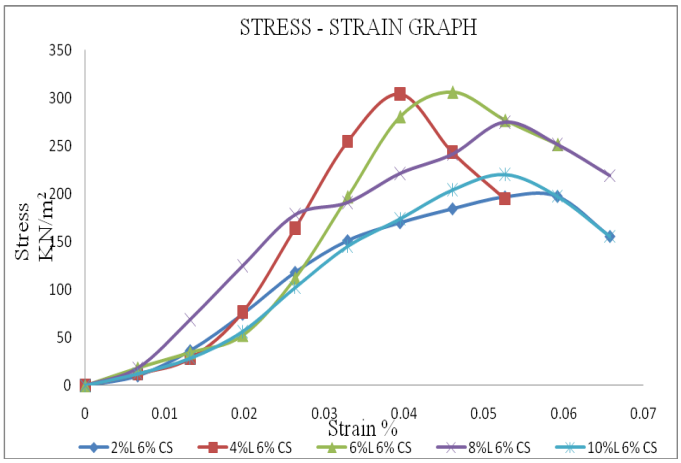

Fig.5. Variation of Stress Strain curve of Soil-CS-Lime mix (28Day)

B. California Bering Ratio Test (CBR)

CBR test is conducted on Soil-Lime-CS mix and optimum value was obtained at Soil - 6% Lime - 6% CS mix proportion. Soaked and Unsoaked test was conducted and maximum strength was seen in unsoaked The CBR value of the soil is 2.12 it gets improved when treated with lime and copper slag. The unsoaked CBR value for 7 day curing was 40.76 and that of soaked was 18.38. There is reduction in swelling characteristic and increase in density results in an increase in CBR value.

C. Scanning Electron Microscope

The scanning electron microscopes of the two samples are done The SEM micrographs confirm the formation of cementitious material for the treated soil samples. Reduction in pore spaces can also be observed indicating the change in microstructure of the soil on addition of stabilizer as in Figure 7. Figure 6 shows the structure of untreated soil with flaky and pores surface

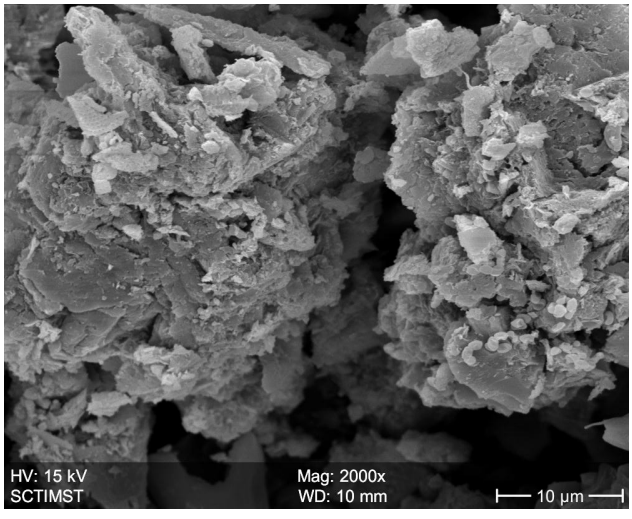

Fig.6. SEM of Soil

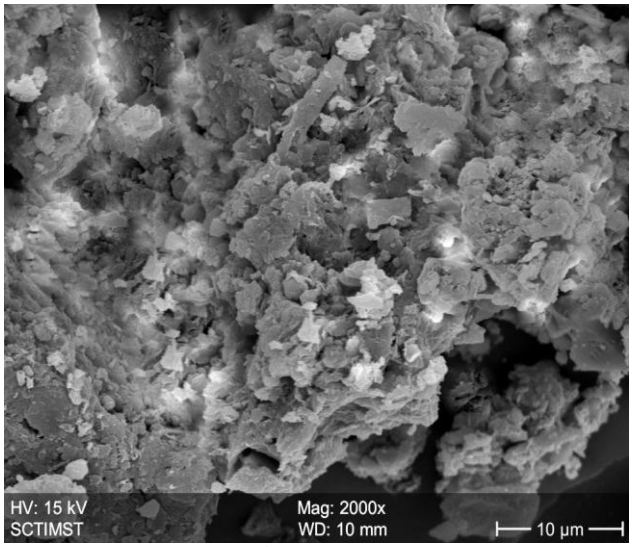

Fig.7. SEM of Soil+Lime+Copper Slag

IV. CONCLUSION

- Copper slag can be used as an admixture to improve the properties of problematic soils.
- Engineering behavior of soil can be improved by utilization of 6%CS along with 6% Lime which was most satisfactory combination to get good soil stabilization.
- The compressive strength (UCS) increases with copper slag content up to 6% and decreases thereafter. The mix 6% CS - 6% Lime may be considered as optimum, The UCS value increases with increase in curing period. The increase in strength is 25 times that of soil alone.
- Maximum CBR value is obtained for Soil - 6% Lime - 6% CS mix proportion. The CBR value of the soil is 2.12 it gets improved when treated with lime and copper slag. The unsoaked CBR value for 7 day curing was 40.76 and that of soaked was 18.38.
- The results obtained from SEM are in agreement with the results obtained from unconfined compressive strength test.
- Copper slag and Lime can enhance the strength effectively.

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