Influence of Fine Grained Additives on Improvement of Strength Characteristics of Laterite Soils

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Abstract- *Increase in regional growth and development leads to increase in infrastructure like buildings, bridge, tunnel, canal or dam and especially roads. Southern region of India forms a major tropical part, where lateritic soils are used as a road making material and they form the sub-grade of most tropical roads as either natural or formed. Due to presence of clay minerals like kaolinite and in some cases montmorillonite they turned as problematic lateritic soils. Numerous research works have been carried out on stabilization of laterites to make them suitable especially as a material for road construction. It is important to use innovative techniques by utilizing local available industrial waste material for the modification and stabilization of deficient soil. In the process of soil stabilization and modification, emphasis is given for maximum utilization of local material so that cost of construction may be minimized to the minimum extent. The uses of by product such as copper slag have long been established in a number of applications in the civil engineering industry. In order to improve the properties of copper slag stabilized soil certain admixtures such as fly ash, cement, lime etc are added. Silica fume is a mineral admixture cheaper than Portland cement which can be used as an effective material to stabilize clayey soil. This paper presents the laboratory study carried out on the combined influence of copper slag (CS) and Silica fume (SF) in improving the geotechnical properties of lateritic soil. To understand the performance of stabilized soil, its properties like Atterberg's Limits, Compaction Parameters, Swell Parameters and Penetration Parameters were studied.*

Keywords- Lateritic soil, Silica fume, Copper slag, Atterberg's limit test, CBR test, Un confined compression test, maximum dry density and optimum moisture contenttest.

I. INTRODUCTION

Laterite is a soil and rock type rich in iron and aluminum, and is commonly considered to have formed in hot and wet tropical areas. Southern region of India forms a major tropical part, where lateritic soils are used as a road making material and they form the sub-grade of most tropical roads as either natural or formed. Most tropical laterite soils are composed predominantly of kaolinite clay mineral and in some cases they contain swelling clay mineral, montmorillonite. When lateritic soils contain swelling clay mineral type, they are known as problematic lateritic soils. The reason being they have reputation of being problematic in road construction. Numerous research works have been carried out on stabilization of laterites to make them suitable especially as a material for road construction. It is important to use innovative techniques by utilizing local available industrial waste material for the modification and stabilization of deficient soil. In the process of soil stabilization and modification, emphasis is given for maximum utilization of local material so that cost of construction may be minimized to the minimum extent.

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One of the most effective ways in terms of environmental benefits, product-type versatility and cost effectiveness in treating contaminated soils in order to make it suitable for engineering purposes such as the construction of road sub-grade (i.e. the natural foundation which receives load from pavement) is by using industrial wastes. Soil-stabilization is any treatment applied to a soil to improve its strength and reduce vulnerability to water.

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Agriculture serves to be one of the most important sectors of production all over the world. Production of large quantity of agricultural wastes becomes a major problem of waste management. The improper management of such waste cause serious environmental problems like air pollution, water pollution finally influencing the local ecosystems. Disposal of large quantities of industrial by-products as fills on disposal sites adjacent to industries not only require large space but also create many geo-environmental problems. The disposal of the agro industrial wastes Copper slag and silica fume also faces these problems. However, these ashes were found to have pozzolanic properties, therefore have been used as stabilization agent in lateritic soils.

In this research work, the laboratory study carried out on the combined influence of Silica fume andCopper slag in improving the geotechnical properties of lateritic soil. The effects of the ash on geotechnical properties of the soil were investigated.

1.2 OBJECTIVES OF THE STUDY

The objectives of present experimental study are to develop correlations between engineering characteristics of lateritic soil. The study is focused on

- Improvement of locally available soil using some eco-friendly and cheap waste materials.
- Evaluation of strength characteristics of virgin as well as blended soil using Silica fume and Copper slag
- Determination of appropriate Silica fume and Copper slagcontent ratio co achieve the maximum gain in strength of soil.

II. LITERATUREREVIEW

2.1 **Studies on lateritic soil**

Recent research works conducted on stabilization of lateritic soil using different stabilizing agents were referred and their summary was listed below:

The common chemical compositions of laterites according to Gidigasu (1976), Ola (1983) and Osinubi (2003) are silica (SiO_2), sesquioxide of iron (Fe_2O_3) and aluminum (Al_2O_3), and in some few cases, little quantities of manganese (Mn), titanium (Ti), chromium (Cr) and vanadium (V). Though silica is low in most laterite deposits, higher amounts are found in some few laterite deposits where the parent rock contains a lot of quartz.

George R. Otoko presents the experimental study on Soft Soil Stabilization Using Palm Oil Fibre Ash and the analysis shows that the palm ash is classified as class F according to ASTM C618. It is siliceous and aluminous with virtually little or no cementation value. Therefore for pozzolanic reaction it has to be combined into a little lime. An Optimum of 5% lime was obtained for pozzolanic reaction. This combines with 3% optimum palm ash to give best results of soaked and unsoaked CBR. Thus, the palm ash can successfully be used for soil subgrade stabilization

K.S.Gandhi (2012) worked on improving the sub grade soil using gasse ash. Copper slag effectively dries wet soils and provides an initial strength gain, which is useful during construction in wet, unstable ground conditions. Various lab tests were performed with the percentage of Copper slagvarying from 0 % to 10%. It was observed that as proportion of Copper slagincreased in the soil sample, there was notable increment in engineering properties of the subgrade.

M. Chittaranjan et al used agricultural wastes such as Copper slag, rice husk ash and groundnut shell ash to stabilize the sub grade soil. The sub grade soil was treated with these waste materials separately at 0%, 3%, 6%, 9%,12% and 15% and CBR test was carried out for each per cent .The results of tests showed improvement in CBR value with the increase in percentage of waste up to a certain optimum content.

Based on the literature reports, the present is set out to evaluate the combined influence of silica fume and Copper slag in improving problematic lateritic soils. Different combinations of silica fume and Copper slag are added to the problematic soil to determine the optimum mix proportions. Further, the effect of curing period over the improvement in the strength properties is also studied to evaluate the long-term strength profile.

2.2 STABILIZATION

Soil stabilization is the process of altering some soil properties by different methods, mechanical or chemical in order to produce an improved soil material which has all the desired engineering properties. Soils are generally stabilized to increase their strength and durability or to prevent erosion and dust formation in soils.. The properties of soil vary a great deal at different places or in certain cases even at one place; the success of soil stabilization depends on soil testing. Various methods are employed to stabilize soil and the method should be verified in the lab with the soil material before applying it on the field.

3.2 METHODS OF SOIL STABILIZATION

- Mechanical Stabilization.
- Soil Cement Stabilization.
- Soil Lime Stabilization.
- Soil Bitumen Stabilization.
- Thermal Stabilization.
- Chemical Stabilization.

III. METHODOLOGY

3.1MATERIALS USED AND THEIR PROPERTIES

Laterite soil collected from Orissa region at 1.0m depth is used for the study. The lateritic soil was sealed in the air tight plastic bags and transported to the college laboratory for testing. After collecting the soil is dried for 2 weeks.

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.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.

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%.

Silica fume (SF), which is also known as micro-silica, is a secondary product resulting from the reduction of high-purity quartz with coal in electric furnaces during the manufacture of silicon and ferrosilicon alloys. It can be also gathered from other silicon alloys such as ferromagnesium, ferromanganese, ferrochromium and calcium silicon. Silica fume is composed of very fine vitreous particles of around 100 times smaller than the average of cement particles and a surface area of approximately 20,000 m^2/kg

S.No	**Chemical Composition**	**Chemical Composition (%)**
1.	Silica (SiO_2)	98.842
2.	Alumina (Al_2O_3)	00.043
3.	Calcium Oxide (CaO)	00.634
4.	Iron Oxide (Fe_2O_3)	00.035
5.	Potassium Oxide (K_2O)	00.076
6.	Magnesium Oxide (MgO)	00.01

Different laboratory experiments conducted with different combinations of materials. Detailed discussion on the results obtained from various laboratory tests done on untreated and treated lateritic soil are presented in the results and discussions chapter.

TABLE 3.1 Properties of Lateritic Soil

Properties of Lateritic Soil		
S. No.	**Property**	**Value**
1	Specific gravity	2.66
2	Differential free swell Index (%)	72
3	Atterberg's Limits	
	i) Liquid limit (%)	30.8
	ii) Plastic limit (%)	17.6
	iii) Plasticity index (%)	13.2
4	Grain Size Distribution	
	i) Gravel Size Particles (%)	35
	ii) Sand Size Particles (%)	26
	iii) Silt & Clay Size Particles (%)	39
5	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.69
	ii) Optimum Moisture Content (%)	16.1
6	Penetration Parameters	
	ii) CBR - Soaked (%)	4.7
7	Unconfined Compressive Strength (UCS) at OMC & MDD (kPa)	113

IV. RESULTS AND DISCUSSIONS

In the laboratory, various experiments were conducted by combination of different percentages of Copper slagand Silica fume in the lateritic soil. Compaction, CBR and UCS tests were conducted with a view to determine the optimum combination of Copper slag and Silica fume. CBR and UCS are conducted for curing studies.

Effect of combination percentages of COPPER SLAG + SILICA FUME in improving the compaction properties of laterite soil:-

By compaction of soil, the particles are mechanically constrained to pack more closely, by expelling part of the air voids. Proper compaction of fills, subgrade, sub-base and base courses are considered essential for proper highway construction. There is optimum moisture content for a soil, at which maximum dry density is attained for a particular type and amount of compaction. To assess the amount of compaction and water content required in the field, compaction tests are conducted. In the present study Standard Proctor Compaction test as per IS: 2720 (Part VII), 1980 was conducted on soil without cement. The test is conducted on soil alone, soil with combination of Silica fume and Copper slag. The compaction test is done immediately after treating it with the stabilizer. The test results of compaction test with soil alone, soil with combination of Silica fume and Copper slag dosages were shown in the graphs in fig 1, 2, 3, and 4.

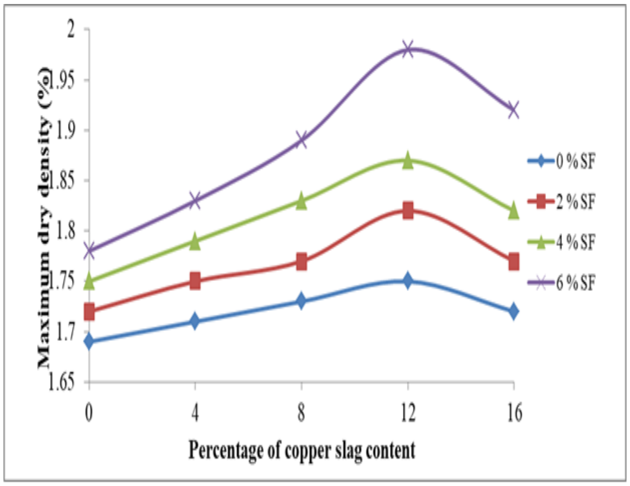

Fig 1 shows the Variation in maximum dry density with percentage of Copper slag content

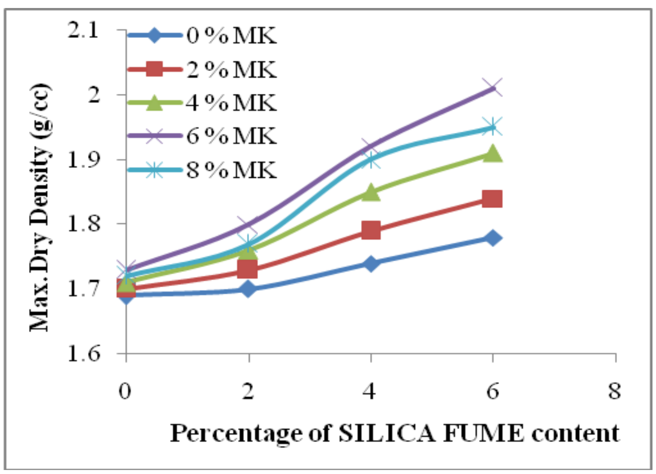

Fig2 shows the Variation in maximum dry density with percentage of silica fume content

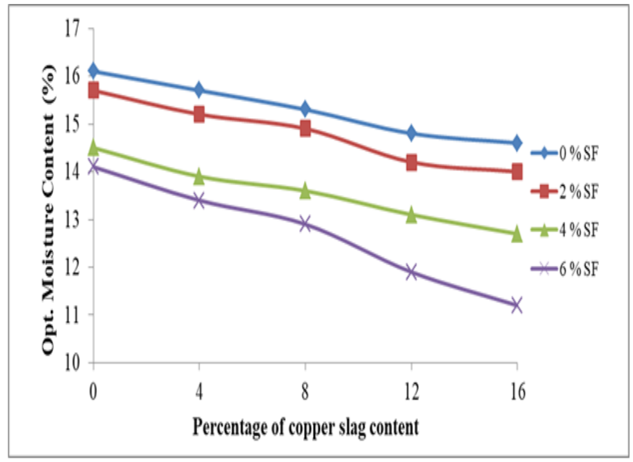

Fig 3 shows the Variation in optimum moisture content with percentage of Copper slag content

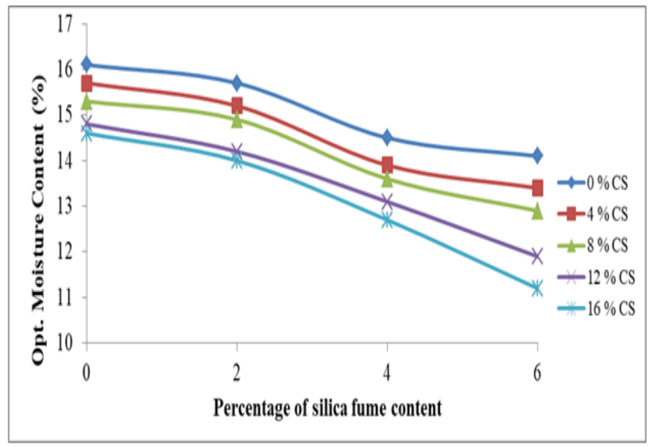

Fig 4 shows the Variation in optimum moisture content with percentage of SILICA FUME content

Effect of combination percentages of COPPER SLAG + SILICA FUME in improving the penetration characteristics of laterite soil

CBR value for untreated soil remained constant for most of the time. When soil treated with silica fume and Copper slagas the combination dosage was increased CBR values also increased for all curing periods. The test is conducted on soil alone, soil with combination of silica fume and Copper slag. The test results of CBR test with soil alone, soil with combination of Silica fume and Copper slag dosages were shown in the graphs in fig 5 and 6.

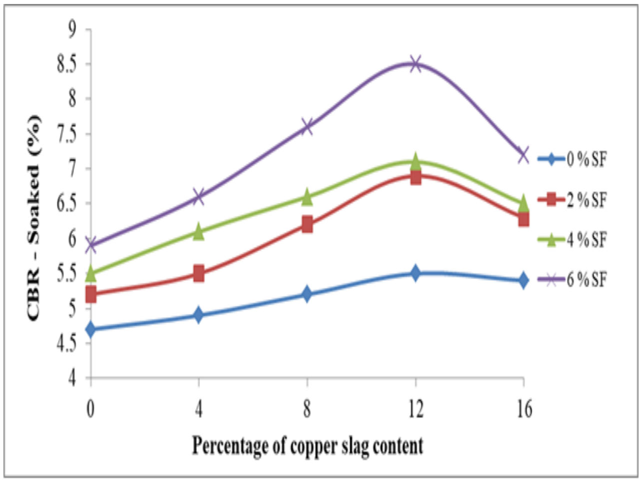

Fig 5 shows the Variation in CBR Values with percentage of Copper slag content

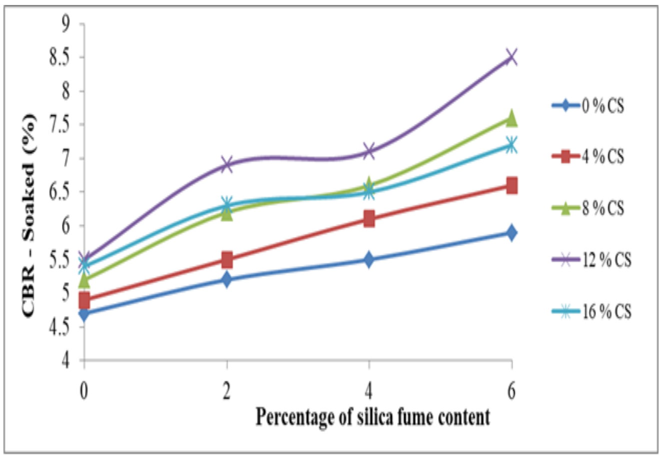

Fig 6 shows the Variation in CBR Values with percentage of silica fume content

Effect of combination percentages of COPPER SLAG + SILICA FUME in improving the unconfined compressive strength of laterite soil

Figure 7 and 8 shows the change of unconfined compressive strength with different percentage of combination of Silica fume and Copper slag. It is found that the unconfined compressive strength increases as we add on Copper slag and silica fume in combination and decreases after a particular percentage combination addition of Copper slag and silica fume.

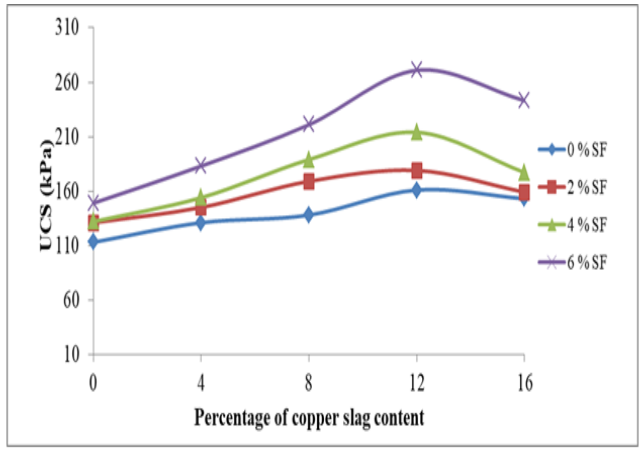

Fig7 shows the Variation in UCS Values with percentage of Copper slag content

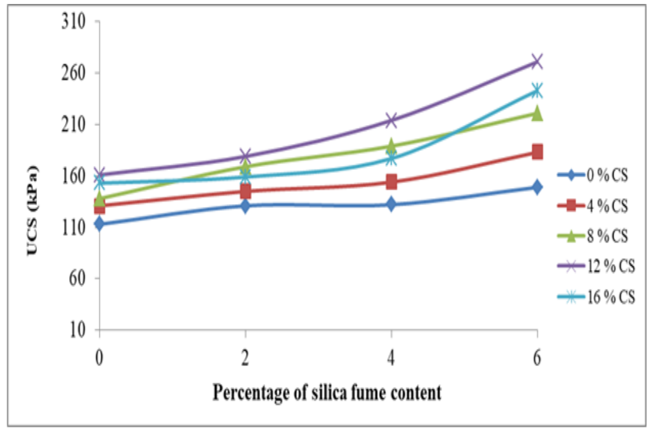

Fig 8 shows the Variation in UCS Values with percentage of silica fume content

From the above results the Combined Optimum Content of SILICA FUME + COPPER SLAG for improving the Weak Laterite Soil (WLS) is 6% SILICA FUME + 12% COPPER SLAG. Since the CBR requirement as per IRC 37-2012 which is Soaked CBR of 8% is not achieved for the optimum combination, the Curing study was done on the optimum combination samples.

Effect of curing on samples prepared with 6% Silica fume + 12% Copper slag

Figure 10 and 11 shows the variation of penetration and shear characteristics for different curing periods. From above figures we can conclude that laterite soil when cured with 28 days had shown more pronounced improvement about 32.72% and 46.2% for CBR and UCS respectively.

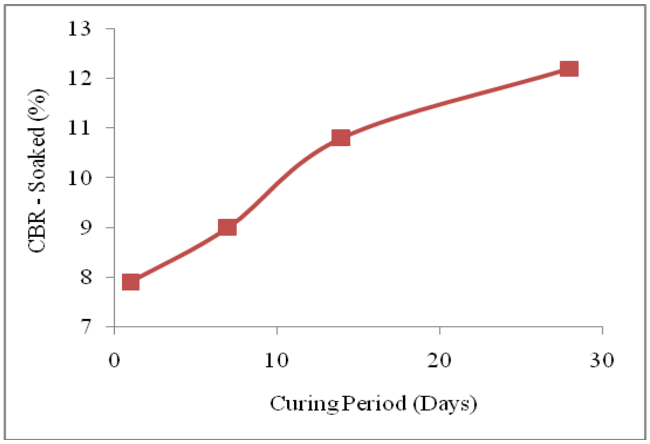

Fig9 shows the Variation in CBR Values with different curing periods

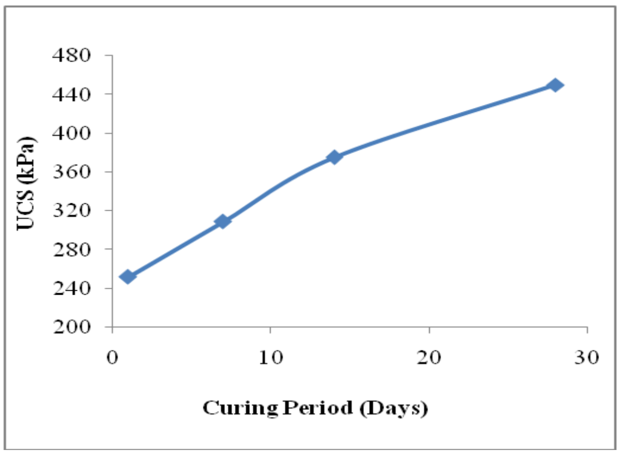

Fig10 shows the Variation in UCS Values with different curing periods

From the above results the outcome revealed that the potentiality of treated lateritic soil was established as a sub-grade soil with a combined optimum dosage of 6% Silica fume and 12% Copper slag.

Finally from the above discussions, it is clear that there is improvement in the properties of laterite soil stabilized with copper slag + silica fume. It is evident that the addition of Copper slag and silica fume to the laterite soil showed an improvement in plasticity, compaction and strength properties. It can be summarized that the materials Copper slag and silica fume had shown promising influence on the properties of laterite soil, thereby giving a two-fold advantage in improving problematic laterite soil and also solving a problem of waste disposal.

V. CONCLUSIONS

An experiment was undertaken to investigate the effects of Copper slag and silica fume stabilised lateritic soil. The following conclusions can be drawn from the results of the study.

- From the studies, it is observed that the laterite soil chosen was a problematic soil.
- Copper slag is a blackish granular material similar to coarse sand with a specific gravity of 3.8. The high specific gravity may be due to high iron content (41%).
- It is noticed that additives like silica fume improved strength of copper slag stabilized clayey soil and made the stabilized mix more durable.
- It was observed that the soil with a combined optimum dosage of 6% Silica fume and 12% Copper slag has improved the properties of laterite soil.
- The maximum dry density of the soil increased with increase in combination of silica fume and Copper slag contents.
- It can be inferred from the graphs, that there is a gradual improvement in the maximum dry density by an amount of 15.84 % and it was about 78.12% for Soaked CBR and 139 % for UCS respectively.
- From the results the Combined Optimum Content of silica fume + Copper slag for improving the Weak Laterite Soil (WLS) is 6% silica fume + 12% Copper slag.
- Since the CBR requirement as per IRC 37-2012 which is Soaked CBR of 8% is not achieved for the optimum combination, the Curing study was done on the optimum combination samples.
- Curing studies done on the Copper slag and silica fume modified laterite soil. The optimum mix proportion blended with lateritic soil when cured for 28 days had shown more pronounced improvement about 32.72% and 46.2% for CBR and UCS respectively.
- Finally it can be summarized that the materials Copper slag and silica fume had shown promising influence on the properties of laterite soil, thereby giving a two-fold advantage in improving problematic laterite soil and also solving a problem of waste disposal.

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