A Review on improvement of bearing capacity using industrial waste in Geotechnical Engineering

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***Abstract*— The use of industrial wastes in various engineering projects has been trending in India. This is necessitated by the disposal problems associated with it. Copper slag and Silica fume are the most extensively used waste materials in the construction industry in recent times. Large quantities of these wastes are accumulated and dumped on costly land, causing wastage of good cultivable land. Mixing these wastes with existing soil type without completely removing and refilling with another soil type can be an alternative improvement technique to cement mixing and soil stabilization which are expensive. In this paper, a review of the previous research studies carried out by various researchers on effective usage of copper slag and silica fume is presented.**

Index Terms*— Copper Slag, Silica Fume, Soil Stabilization, Waste Utilization, Properties

I. INTRODUCTION

Soil is a naturally occurring material used for the construction of all except the surface layers of pavements which generally involves concrete and asphalt. Copper slag and silica fume are the industrial wastes with commercial value which improve some engineering characteristics of the soil such as strength, workability, texture and plasticity. The selection of type and determination of the percentage of additive to be used is dependent upon the classification and the degree of improvement in soil quality desired. Copper is one of the basic elements which is often used in construction and electrical industries. It is a by-product of copper extraction by smelting. The other waste which is highly used in soil stabilization is silica fume which is a very reactive pozzolan which is by-product of silicon and ferrosilicon alloy production. It is available in both wet or dry form. Soil containing silica fume can have very high strength and can be very durable. Silica fume and copper slag upon mixing with soil, can be used as an effective stabilizing agent for the improvement of problematic soils for use in sub-grades and sub-bases.

A. Copper Slag

Copper slag (CS) is a waste product which comes out from the smelting of copper. The process of extracting copper slag varies according to the type of ore and the purity of the final product. The unwanted materials are physically or chemically removed to get proper concentration of slag. Copper ore is mixed with powdered coke and sand which is heated at a high temperature in blast furnace. The furnace consists of steel plates lined inside with fire clay bricks. Hot air is introduced from the tuyers near the base of the furnace. The upper layer consists of slag and is removed while the lower layer is called matte which is a mixture of cuprous sulphide and unchanged ferrous sulphide [1].

Fig. 1. Copper slag

The production of one ton of copper generates approximately 2-3 tonnes of copper slag. Utilization of copper slag in soil stabilization can solve a hazardous problem for environment. Copper slag is also widely accepted as embankment and structural fill material [2].

B. Silica Fume

Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide. It is produced in electric furnace. The raw materials are quartz, coal and woodchips. The ash that results from this process is collected and sold as silica fume. It is commonly used as a mineral admixture in concrete. It is grey coloured powder which is similar to Portland cement or flyash.

After environmental concerns necessitated the collection and land filling of silica fume, it became economically justified to use in various geotechnical applications. Flatwork containing silica fume concrete generally requires less finishing effort than conventional concrete. Silica fume concrete with low water content is resistant to penetration by chloride ions [3].

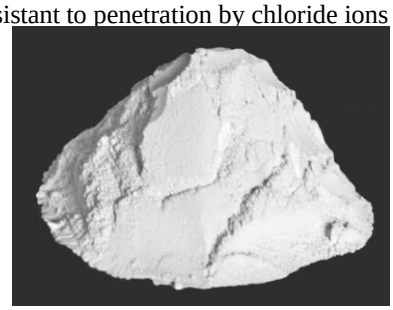

Fig. 2. Silica Fume

II. REVIEW OF RESULTS

The effect of copper slag can be seen by replacing a part of the cement in concrete. The study conducted by CRRI, New Delhi showed that fine sand with copper slag upto 40% can be used as fine aggregate in pavement quality concrete as well as in dry lean concrete [4]. Copper slag mixed with flyash and clayey soil produces effective results in different proportions with suitability in embankment, sub-base and base of a road pavement [5]. Copper slag, when mixed with locally

available soil in a proportion of 30% CS and 70% of soil, the plasticity index of the soil was reduced by 40% [6]. The physical properties of copper slag as obtained from Birla Copper Unit, Hindalco's Industries Ltd, Dahej, Gujarat, India is shown in the table-1.

TABLE I
PHYSICAL PROPERTIES OF COPPER SLAG

Property	Value
Specific gravity	3.51
Plasticity index	Non-plastic
Swelling index	Non-swelling
Hardness, Moh's scale	6-7
Granular shape	Angular, sharp edges
Gravel (%)	1.00
Sand (%)	98.9
Silt + clay	0.05
Colour	Black

The siliceous and silica-aluminous substances available in copper slag are considered pozzolanic. They react chemically with calcium hydroxide in the presence of water at normal temperature to form cementitious products in the form of a gel. Further addition of copper slag to lime or cement form calcium-alumina-silicates which have excellent binding characteristics [7]. A number of studies have been carried out in India as well as abroad to study the impact of copper slag and silica fume as partial replacements of cement and soil stabilizers and the results are encouraging. Mroueh et al carried out life-cycle analysis for the use of industrial waste slag in the construction of road which yielded effective conclusions for the reuse of waste by-products [8]. Improve d soil with 35% Cu slag can be used as a subgrade material and the tensile and compressive characteristics can be improved substantially. The California Bearing Ratio (CBR) value can be increased by more than 50% [9].

Copper slag is also used as a replacement for sand in sand drains and sand piles. Mixing of copper slag with expansive soil has a good potential and economical [10]. Studies show that the behaviour of copper slag is similar to that of medium sands and can be used as construction material in place of sands, such as backfill of retaining walls and landfill for the construction of shallow foundations [11].The chemical composition of copper slag is shown in table-2.

TABLE II
CHEMICAL COMPOSITION OF COPPER SLAG

Property	(% wt)
Iron oxide	42-48
Silica	26-30
Aluminium Oxide	1-3
Magnesium Oxide	0.8-1.5

The addition of silica fume decreases the development of cracks on the surface of compacted clay samples which reduces the width of crack by 75%. The permeability of soil is increased with increase in silica fume content [12]. Silica fume can also be used as a non-traditional stabilizer for black cotton soil which is highly expansive in nature. The chemical composition of silica fume as collected from Shisher Export House, Raipur, Chattisgarh is presented in table-3.

TABLE III
CHEMICAL COMPOSITION OF SILICA FUME

Parameter	Value
Silica	89.9
Total Sulphur Content	0.58
Lime	7.85
Magnesia	4.03
Alumina	-
Iron Oxide	-

Increasing silica fume upto 10% cement content significantly increased the unconfined compressive strength of the samples. Optimal percentage of nanosilica for the stabilization of cemented sand was 10% cement content. The optimum moisture content of cemented sand increased with the increase in nanosilica content.

III. CONCLUSIONS

Copper Slag has the potential to use as admixture to improve the properties of problematic soils. Copper slag is recommended for sub grade, sub-base and bitumen mixes. Utilizing and reusing the industrial waste products like copper slag and silica fume, the wastage of good cultivable land can be avoided. Soil stabilized by silica fume and copper slag can be used for backfilling retaining walls and embankments.

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