AN EXPERIMENTAL ANALYSIS ON THE INFLUENCE OF COPPER SLAG AS STABILISER ON BLACK COTTON SOIL

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Abstract - *In today scenario, lack of stable ground for development of infrastructures is very common. In view of this, construction of buildings on unsuitable ground is unavoidable and making a suitable ground before constructions is real challenging issue for Geotechnical Engineers. To overcome the difficulties experienced with black-cotton soil in geotechnical applications on one side and safe disposal of solid wastes on the other side, an attempt is made in this investigation to explore the possibilities of utilizing solid wastes to improve the engineering behaviour of black-cotton soil. In this, in this present investigation the type of solid waste namely Copper Slag for stabilization is selected to study the effects of same on the index and engineering characteristics of black-cotton soil. The copper slag is mixed with black-cotton soil in various proportions like 5%, 10%, 15% and 20% will be tested and the results are compared with the properties of normal soil. The various tests such as Liquid Limit, Plastic Limit, Specific Gravity of soil by Pyconometer method, Proctor Test, Grain Size Distribution and California Bearing Ratio Test (CBR) were conducted on these proportions and optimized proportion is arrived.*

Key Words: *Soil Stabilisation, Copper Slag, Mohr circle, Proctor test, CBR test.*

1. INTRODUCTION

Soil is one of the most commonly encountered materials in civil engineering. All the structures except some, which are founded on solid rock, rest ultimately on soil. Geotechnical engineers all over the world face huge issues, when structures founded on the soil which is expansive in nature. This expansiveness is imparted to such soils when they contain clay minerals like Montmorillonite, Illite, Kaolinite etc. in considerable amount. Due to the clay minerals, the swelling soils expand on wetting and subjected to shrinkage on drying. These soils are commonly unsaturated.

The problem of instability of structures made on such soil is mainly due to lifting up of the structures on heaving of soil mass under the foundation on saturation during rainy season and settlement as a result of shrinkage during summer season. Due to this cavity formed, leading to loss of contact between the soil and structures at some points. This successively results in splitting of structure and failure due to loss of shear strength or unequal settlement.

1.1. Expansive soil-Origin, Occurrence, Properties & Damage

Expansive soils creates greatest hazard in arid regions. Expansive soils contain clays and fine silts swells and shrinks as their moisture content changes. These expansive soils created problems for the structures, mainly lightweight structures and the structures most commonly damaged are small buildings, roadways, pipelines and irrigation canals.

Clay mineral is that the key component that passes on swelling characteristics to any standard non-swelling soils. Montmorillonite has the utmost swelling potential among many varieties of clay minerals. The origin of such soil is sub aqueous decomposition of blast rocks, or weathering in situ formation of vital clay mineral takes place under alkaline environments. If there is an adequate supply of magnesium of ferric or ferrous oxides and alkaline environments along with adequate silica and aluminum attributable to weathering condition, it will favor the formation of Montmorillonite.

Expansive soils contain clay or other minerals that cause them to expand when absorbing water. These soils often expand by 10% or more during a rainfall. When the soils dry out, they shrink back to their original size.

Causes of Damage:

1. Expanding
2. Contracting

1.2 Objectives

The following are the objectives of the project study. They are:-

- The primary objective of this work is to study the interaction of black cotton soils with Copper Slag.
- To improve the Geo-Technical and Engineering Properties of the Black- Cotton soil.
- To study the behavior of strength gain in black cotton soil using Copper Slag Stabilization.

1.3 Soil Stabilisation

Soil stabilisation in its general meaning considers every physical and chemical method employed to make a soil suitable for its required engineering purpose. In its specific meaning in road engineering, soil stabilisation is a process to improve the soil strength by using additives in order to use as a base or sub base courses and carry the expected traffic and pavement loads.

Types of Stabilisation

There are different types of stabilisation, each having its own benefits and potential problems. The types described below are those most frequently used.

1.3.1 Mechanical Stabilisation

The most basic form of mechanical stabilisation is compaction, which increases the performance of a natural material. The benefits of compaction however are well understood and so they will not be discussed further in this report. Mechanical stabilisation of a material is usually achieved by adding a different material in order to improve the grading or decrease the plasticity of the original material.

1.3.2 Cement Stabilisation

Any cement can be used for stabilisation, but Ordinary Portland cement is the most widely used throughout the world. The addition of cement material, in the presence of moisture, produces hydrated calcium aluminate and silicate gels, which crystallize and bond the material particles together. Most of the strength of a cement-stabilized material comes from the hydrated cement.

1.3.3 Lime Stabilisation

The stabilisation of pavement materials is not new, with examples of lime stabilisation being recorded in the construction of early Roman roads. However, the invention of Portland cement in the 19th Century resulted in cement replacing lime as the main type of stabiliser. Lime stabilisation will only be effective with materials which contain enough clay for a positive reaction to take place. Lime is produced from chalk or limestone by heating and combining with water.

1.3.4 Bitumen or Tar stabilisation

Bitumen or tar are too viscous to use at ambient temperatures and must be made into either cut-back bitumen (a solution of bitumen in kerosene or diesel) or a bitumen emulsion (bitumen particles suspended in water).

1.3.5 Chemical stabilisation

Stabilization of moisture in soil and cementation of particles may be done by chemicals such as calcium chloride, sodium chloride etc.

1.3.6 Geosynthetic stabilisation

Geosynthetic in general can be defined as a generic term which includes geotextiles, geomembranes, geocomposites and these material used by civil engineers to improve soil behaviour.

2.MATERIALS USED

2.1 Copper Slag

Copper slag is an abrasive blasting grit made of granulated slag from metal smelting processes (also called iron silicate). Copper slag is a by-product created during the copper smelting and refining process.

Fig-1 Copper Slag Material

Physical Properties of Copper Slag:

The following table is the physical properties of copper slag are mentioned:

SNo	Physical Properties	Value	Chemical Property	(% wt)
1	Particle shape	Irregular	Iron oxide (Fe_2O_3)	42-48
2	Appearance	Black & glassy	Silica (SiO_2)	26-30
3	Specific gravity	2.9-3.9	Aluminium oxide	1-3
4	% of voids	43.20%	Calcium oxide	1-2
5	Bulk density	2.08 g/cc	Manganese oxide	0.8-1.5
6	Fineness Modulus	3.47		
7	Hardness, Mohr's scale	7		
8	Moisture Content	0.10%		
9	IS Classification	SP		

2.2 Soil

Fig-2 Clay

Table 2: Properties of Copper Slag

SI No.	Description of properties	Value
1	Shear strength	soaked CBR of only 1.5%
2	Residual strength parameter Φ_r	12°
3	Permeability	10^{-10} cm/sec
4	Liquid limit (Indian subcontinent)	40% ~ 100%.
5	Free Swell index	Sometimes > 50%

3. EXPERIMENTAL METHODOLOGY

The laboratory tests carried out first was on the black cotton soil which includes following tests California bearing ratio (CBR), Liquid limit, Plastic limit, Specific gravity and Proctor test.

3.1 Specific Gravity Test

The appropriate method for determining the specific gravity of the soil is the pycnometer test. Specific gravity of the soil particles is the ratio of weight of given volume of soil solids to the weight of an equal volume of water at 4°c. i.e G = $\gamma s / \gamma w$

3.2 Atterberg Limits

The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. This is the limiting moisture content at which the cohesive soil passes from plastic state to liquid state.

The plastic limit (PL) is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface. The plastic limit is defined as the moisture content where the thread breaks apart at a diameter of 3.2 mm (about 1/8 inch). A soil is considered non-plastic if a thread cannot be rolled out down to 3.2 mm at any moisture.

3.3 Standard Proctor Test

Soil compaction is the process in which a stress applied to a soil causes densification as air is displaced from the pores between the soil grains. It is an instantaneous process and always takes place in partially saturated soil (three phase system). The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density.

3.4 Sieve Analysis

Grain size analysis expresses quantitatively the proportions by mass of various sizes of particles present in the soil. The results of a grain size analysis may be represented in the form of a Grain Size Distribution (GSD) curve/ Particle Size Distribution (PSD) curve/ Gradation curve. The grain-size distribution is universally used in the engineering classification of the soils.

Fig-2 Sieve Analysis Test

3.5 California Bearing Ratio

The California bearing ratio test is penetration test meant for the evaluation of the sub-grade strength of roads and pavements. The results obtained by these are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

Fig-3 CBR Test

4. RESULTS AND DISCUSSION

4.1 RESULTS

The objective of the experimental work is to stabilize the black cotton soil using copper slag in construction. Various tests were performed such as California bearing ratio (CBR), liquid limit, plastic limit, specific gravity and proctor test. The test procedures are followed as per Bureau of Indian standards. In this chapter we are discussing about copper slag were added to the black cotton soil, with the addition of copper slag to the soil strength may increase. The copper slag may add in different proportions i.e. 5%, 10%, 15% and 20%.

Determination of Grain Size Distribution:

Table 3: Sieve Analysis

S.No	IS Sieve Size (mm)	Particle Size D (mm)	Weight Retained (a)	%Weight Retained (b)	Cumulative% Weight Retained (c)	Percentage of Finer % (100 – c)
1.	4.75	4.75	110	11	11	89
2.	2.36	2.36	115	11.5	22.5	77.5
3.	1.18	1.18	275	27.5	50	50
4.	600 µ	0.60	275	27.5	77.5	22.5
5.	425 µ	0.425	170	17	94.5	5.5
6.	300 µ	0.3	15	1.5	96	
7.	150 µ	0.15	15	1.5	97.5	2.5
8.	75 µ	0.075	18	1.8	99.3	0.7
9.	Pan	< 0.075		0.7	100	

Determination of CBR:

Table 4: CBR Test

Mix Proportions of CS	Load (Penetration)		CBR values (Penetration)	
	2.5 mm	5.00 mm	2.5 mm	5.00 mm
0%	52.84	73.36	3.85	3.56
5%	64.10	82.83	4.58	4.23
10%	64.57	92.93	4.79	4.52
15%	73.90	103.53	5.40	5.03
20%	57.67	80.00	4.23	3.92

5. CONCLUSIONS:

Based on the investigation carried out in this study, the following conclusions can be drawn:

From the results of the present study, it is concluded that, the soil stabilization using copper slag is a very effective process for the strengthening of soil. Since copper slag is a low cost material it obtains high strength and makes the structure strong and durable. The test has been conducted on black-cotton soils. Due to stabilization the soil the bearing capacity of the soil gets increasing and any foundation can be construction in the soil.

- The addition of copper slag, increases specific gravity consistently from 2.15 to 2.31, the maximum specific gravity value is obtained at 15% is high with a value as 2.31.
- The addition of copper slag, increases liquid limit consistently from 51.33 to 56.67, the maximum liquid limit value is obtained at 15% is high with a value as 56.67. The liquid limit value is decreased at 20% of copper slag, the value is 52.41.
- The plastic limit value has increased from 36.20 to 43.20, the maximum plastic limit value is obtained at 15% is high with a value as 43.20. The plastic limit value is continuously increased, with increasing of copper slag percentage 5% to 15%.
- The addition of copper slag increases the CBR test consistently from 5.4% to 5.04%.The maximum CBR test value is obtained at 15 %.
- The addition of copper slag increases the dry density value from 1.1 to1.215 g/cc. The maximum dry density value is obtained at 15%.

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