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A RESEARCH PAPER ON SOIL STABILIZATION OF BLACK COTTON SOIL USING COPPER SLAG

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ABSTRACT

Stabilization of Expansive soils has been in recent appealing many researchers. The stabilization of Expansive Soils by Copper slag (CS) were tried in the past separately. The authors tried to use both of them together in stabilization of BC soils. Present study was undertaken to evaluate the effectiveness of different percentages of copper slag as soil stabilizers. The tests performed on the mixed proportion of BC soil and Copper Slag and California Bearing Ratio (CBR), Atterberg's limits, and compaction tests. Limited studies have been reported for the combination of copper slag in soil stabilization. The optimum mix was found to be in the proportion of 80% BC + 20% CS. Soil treated with CS decreased steeply from 100 % to 20.4 %. There was a slight change in maximum dry density of the treated soil. The unsoaked CBR test shows that strength of optimum mix was 12.5%. The stabilized soil mixtures have shown satisfactory strength characteristics and can be used for low-cost constructions to build houses and road infrastructure. Laboratory vane shear tests have been carried out under undrained conditions to study the shear strength parameters of the stabilized soil.

KEYWORDS: Black Cotton Soil, Copper Slag, Consistency Tests, California Bearing Ratio, Triaxial Test

Foundations in civil engineering are land-based structures which require a strong base usually provided by soil or rocks. Weak soil including soft clays, expansive soil, organic deposits, and loose sand are often unsuitable for construction due to their poor engineering properties. Black cotton soil is one of the major deposits of India, exhibiting high swelling and shrinkage properties in the presence and absence of moisture content respectively, resulting in deformation of the road surface and reduction of soil-bearing strength. Montimorillonite is a clay mineral, which is mainly responsible for expansive characteristics of the soil. The kaolinite group is generally non-expansive. The mica-like group that includes illites and vermiculites, can be expansive, but generally does not pose notable problems [3].The chief properties of a soil with which the construction engineer is concerned are volume, strength, permeability and durability.A basic decision by a Civil Engineer among the following must, be made whether to:

1) Accept the site material as it is and design to standards, sufficient to meet the restrictions imposed by its existing quality,

2) Remove the site material and replace with a superior material and

3) Alter the properties of existing soil.

Chemical analyses has shown that many new industrial waste sludge is rich in main oxides such as CaO (lime), $Al2O_3$ (alumina), SiO_2 and Fe_2O3 (ferrite).[6]

MATERIALS AND METHODS

Expansive Soil (Black Cotton)

Basaltic rocks are dark black colored rocks solidified from lava and on weathering form black cotton soils. Hence, they are very dark in colour. They develop cracks during the dry period and swell during the wet period hence [1] [4] [5]; they are self-tilling in nature, fertile and can hold water for a long time. This capacity is used for cotton cultivation. Hence, they are also called as Regur or Black Cotton Soil. The Black cotton soil is poorly graded soil. Montimorillonite is the clay mineral responsible for expansive properties of black cotton soil. The black colour in the black cotton soil is due to the presence of titanium oxide in small concentration. These are inorganic clays of medium to high compressibility. The soil sample was collected from a site in local village (Newai), Jaipur at 1.5m depth from the ground level. About 20 kg of soil was used for conducting the experiments.

Copper Slag

Copper slag is the by-product formed during the copper smelting process. Sulphuric acid recovered from the copper smelting process provides a cost-effective by-product and appreciably reduces the air pollution caused by

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the furnace exhaust. Copper slag was collected from Viswakarma industries, jaipur, India. 10 kg of copper slag was used for conducting the experiments, which is passed through 600 microns IS sieve was used in mix proportions of black cotton soil in the range of 0%, 10%, 20% and 30%. It has been estimated that the production of one ton of blister copper generates 2.2 tons of slag [7] [8]. Viswakarma Copper Industries at Jaipur, Gujarat, produces roughly 0.5 million tons of copper slag per year and its captive thermal power plants produce 18,000 tons of fly ash per year [9]. In addition, by mixing it with fly ash, it becomes suitable for embankment fill material. Slag, when mixed with fly ash and lime, develops pozzolanic reactions [17]. The maximum California bearing ratio (CBR) value of 32% was observed for a mix of 80% slag and 20% fly ash when copper slag mixed with different percentages of fly ash [10].

Table 1: Chemical Composition of Copper Slag

Chemical Composition Copper slag	Percentage of content
Silica (SiO_2)	32%
Alumina (Al_2O_3)	4%
Iron oxide (Fe_2O_3)	41%
Calcium oxide(CaO)	1.5%
Magnesium oxide(MgO)	1.35%

METHODOLOGY

Tests viz., Atterberg limits (liquid limit and Plastic limit tests),Vane shear test, free swell index test, California bearing ratio test and compaction tests were performed as described by the standard protocols IS 2720 (Part 5)-1970,IS 2720 (Part 7)-1980, IS 2720 (Part XL) – 1977, IS 2720 (Part 16)-1987 and IS 2720 (Part 30)-1980. These tests were first conducted on untreated soil (100%) and compared with that of treated soil (with different percentages of BC+CS).

Table 2: Percentage of BC + CS

Test number	Soil (% by weight)	Copper slag (% by weight)
1	100	0
2	90	10
3	80	20

Consistency Limits

Out of 200 gm sample required for conducting the experiment, 88% of soil by weight(105.6gm), 10% CS(12gm) and 2% RHA (2.4gm) was taken that is passed through 425 microns IS sieve and mixed. Distilled water is added to form a uniform paste and a portion of this mix is placed in Casagrande's liquid limit device and spread with the help of a spatula. The mix is trimmed at 1cm depth at the point of maximum thickness and blows are given at two revolutions per second until two halves of the mix come in contact with each other for a length of about 1cm. The number of blows is recorded and a portion of the mix was taken to determine water content and the same procedure is repeated for different moisture contents. Liquid limit value is obtained from the graph plotted between no. of blows and water content. The same procedure is followed for varying percentages of soil (88%, 76% and 64%), RHA (2%, 4% and 6%) and CS (10%, 20% and 30%).

Plastic limit test was conducted as described by the standard protocol IS 2720 part - 5 (1985).

Plasticity index = L.L-P.L = 0.73*(L.L-20)

Compaction Test

Tests were performed as per Indian standard specifications for standard proctor test (IS 2720 part 7-1980). The sample was mixed thoroughly with soil, CS and RHA. Water content is added from 8, 10, 12 and 14% by weight of the sample. Then mix is placed in the mould and compacted in three layers and each layer was compacted using 2.6 kg rammer under a free fall of 310cm. A portion of this compacted mix is taken in a mixing tray and placed in an oven for moisture content determination. The procedure is repeated for the increment of water added and a graph is plotted between dry density and moisture content. Moisture content corresponding to maximum dry density gives the optimum moisture content of the mix

Dry density=weight of compacted soil/Volume of mould * (1+w)

Where w = moisture content of mix.

California Bearing Ratio Test

CBR test is a penetration test for evaluating the strength of sub grades. The unsoaked sample is prepared and compacted as described by IS 2720 part- 16 (1987) with optimum moisture content obtained from compaction tests. The mould is placed on Cbr apparatus and load is applied on the piston so that the penetration rate is about 1.25 mm/min. The load readings at each penetration are noted and the mould is detached from the loading equipment. About 20 to 50 g of this mix from the top 3 cm layer is taken for moisture content determination.

CBR= Test load/ Standard load *100

Triaxial Test

A typical Triaxial test involves confining a cylindrical soil or rock specimen in a pressurised cell to simulate a stress condition and then shearing to failure, in order to determine the shear strength properties of the sample. Most triaxial tests are performed on high quality undisturbed specimens. The samples normally range from 38 mm to 100 mm samples, although samples considerably larger can be tested with the correct equipment. The test specimen most commonly has a height to diameter ratio of 2:1.

RESULTS AND DISCUSSION

Grain Size Analysis

Sieve Size (mm)	Mass of each Sieve (m_1) in g	Mass of each Sieve + Retained Soil (m_2)in g	Mass of Soil (m_2-m_1) in g	% Retained on each sieve	Cumulative % Retained	Percent finer
4.75	390	723	333	26.667	26.667	73.33
2	320	459	139	11.131	37.798	62.20
1	338	556	218	17.458	55.256	44.7
0.600	282	387	105	8.408	63.664	33.3
0.425	277	369	92	7.367	71.031	28.9
0.300	308	404.7	96.7	7.749	78.78	21.2
0.150	283	420	137	10.971	89.751	42.7
0.090	294	351	57	4.564	94.315	18.9
0.075	283	298	15	1.201	95.516	10.0
0	225	281	281	4.484	100	0

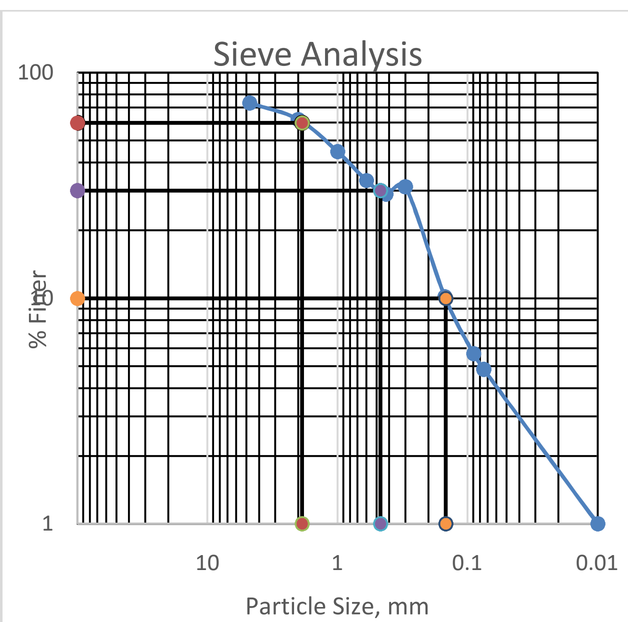

Figure 1

Water Content/Moisture Content

Container No.	1	2	3
Wt. container (W_1) in gram	12	12	12
Wt. of container + Moisture soil (W_2) in gram	61	60	64
Wt. of Container + Dry Soil (W_3) in gram	59	59	63
Moisture content=$\left(\frac{W_2-W_3}{W_3-W_1}\right)$ 100in %	4.255	2.17	1.960

Average Water Content= 2.78%

Liquid Limit

No. Container	1	2	3
No. of Impact	29	35	38
Wt. of Container (W_0) g	13	12	13
Wt. of Container + Wet Soil (W_1) g	23	27	30
Wt. of Container + Dry Soil (W_2) g	20	24	26
Wt. of Water (W_1-W_2) g	3.0	3.0	4.0
Wt. of Oven Dry Soil (W_2-W_0) g	7.0	12	13
Water Content=$\left(\frac{W_2-W_1}{W_3-W_1}\right)$ 100in %	42.85	30.76	25

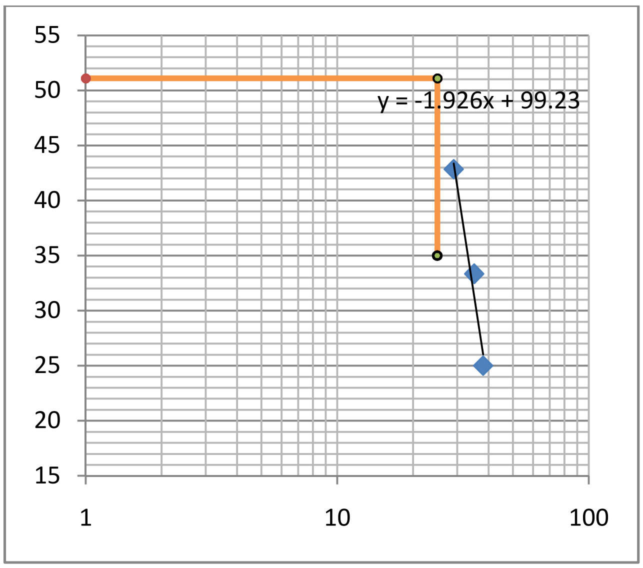

Figure 2

Liquid Limit = 51.08%

Plastic Limit

Container	1	2	3
Wt. of Container (W_0) g	13	12	13
Wt. of Container + Wet Soil (W_1) g	20	18	22
Wt. of Container + Oven Dry (W_2) g	18	17	20
Wt. of Water (W_1-W_2) g	2.0	1.0	2.0
Wt. of Oven Dry (W_2-W_0) g	5.0	5.0	7.0
MC =$\left(\frac{w_1-w_2}{w_2-w_0}\right)$ 100	40	20	28.57

Average Plastic Limit=29.523%

Specific Gravity

Average Specific Gravity, Gs=2.55 g/cm^3

Compaction

Normal Soil

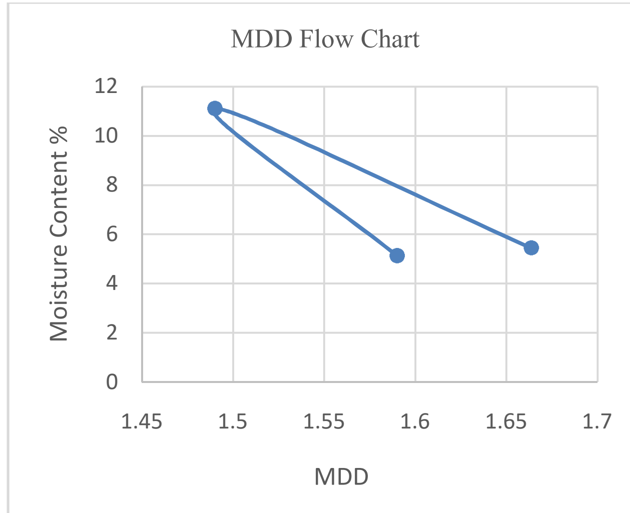

Figure 3

California Bearing Ratio Test

Variation of Penetration and Load Intensity

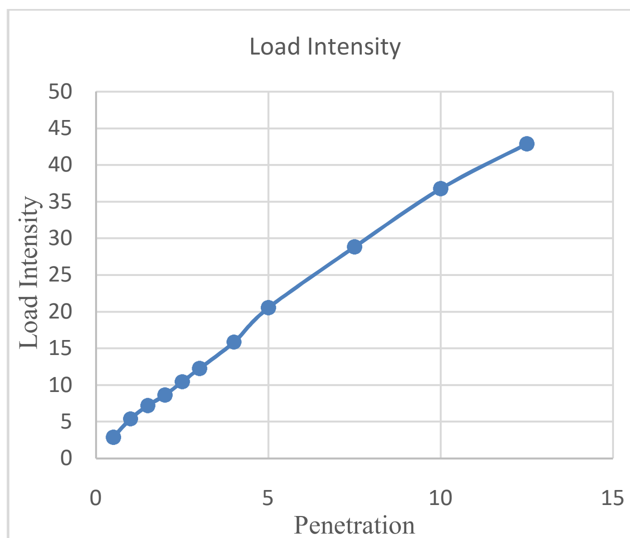

Figure 4

Table: Variation in CBR Values

Description	Unsoaked CBR Values (%)
90%BC+10%CS	12.33
80%BC+20%CS	12.7

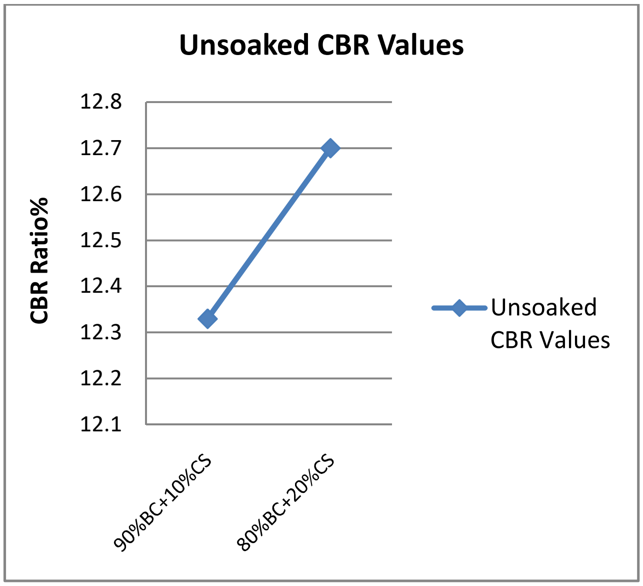

Figure 5

CONCLUSION

All the tests were conducted in the laboratory. The study results gives that copper slag can also be used as an additive to stabilize the Expansive soil. Free swelling of the soil is decreased with the addition of Copper slag. Mixing of Copper slag decreased the liquid limit, plasticity index and optimum moisture contents of the expansive soil used. Copper slag also significantly increased the plastic limit, unconfined compressive strength, maximum dry density and unsoaked CBR of the soil when mixed up to 8-10 % of the soil weight, but further increase in the slag content can decrease the Triaxial and CBR of Copper slag mixed soil as evident from the tests. The unconfined compressive strength of black cotton soil increased significantly with increase in the curing period. Change in soaked CBR value is insignificant with addition of Micro-fine slag as compared to the un-soaked CBR value of the soil. The swell potential of soil is reduced from medium to very low. The effects of slag treatment very much depend upon the amount of Copper slag that is mixed with the black cotton soil. The optimum amount of Copper slag was found to be approximately 10-20 % by the weight of the soil.

REFERENCES

M.A. Qureshi, H.M. Mistry and Patel V.D. “Improvement in Soil properties of Expansive Soil by using Copper Slag.” International Journal of Advance Research in Engineering, Science & Technology (IJAREST), vol. 2(7), pp.125-130, 2015.

Thomas Rukenya karatail, James wambua kaluli, Charles kabubo and George thiong’o. “Soil Stabilization Using Rice Husk Ash and Natural Lime as an Alternative to Cutting and Filling in Road Construction.” Journal of construction engineering and management, ASCE, vol. 143, pp. 04016127-1 to 04016127-5, 2017.

Nelson, J. D., and Miller, D. J. “Expansive soils, problems and practice in foundation and pavement engineering.” Wiley, New York, 1992.

Jinka Chandrasekhar, Timir A chokshi and Dharsha V Chauhan. “A review on utilization of waste material “copper slag” in geotechnical applications.” International journal of innovative research in science and technology (IJIRST), vol. 1, pp. 246250, May 2015.

R.C. Gupta, BS Thomas, Gupta P, Rajan L and Thagriya D. “An experimental study of clayey soil stabilized by copper slag.” International Journal of Structural and Civil Engineering Research (IJSCER), vol. 1(1), pp. 110-119, 2012.

Pranshoo Solanki, Naji Khoury and M. M. Zaman. Engineering Properties and Moisture Susceptibility of Silty Clay Stabilized with Lime, Class C Fly Ash and Cement Kiln Dust.” Journal of Materials in Civil Engineering, ASCE, Vol. 21, pp. 749–757, No. 12,December 1, 2009.

Jinka Chandrasekhar, Timir A chokshi and Dharsha V Chauhan. “A review on utilization of waste material “copper slag” in geotechnical applications.” International journal of innovative research in science and technology (IJIRST), vol. 1, pp. 246250, May 2015.

Lavanya, C, Rao, A.S. and Kumar N.D. “A review on utilization of copper slag in geotechnical applications.” In Proceedings of Indian

Geotechnical Conference. New Delhi, India, paper no. H-212, pp. 445-448, 2011.

Chu, S.C. and Kao, H.S. “A study of Engineering Properties of a clay modified by Fly ash and Slag, Proceedings, Fly ash for Soil Improvement,” AmericanSociety of Civil Engineers, Geotechnical Special Publication, No. 36, pp 89 – 99, 1993.

Patel. S, Vakharia P P and Raval S. M. “Use of copper slag and fly ash mix as subgrade and embankment fillmaterial.” J. Indian Highways, pp. 17–22, 2007.