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Review on CBR of Lime and Cement Stabilized Copper Slag Cushion Laid over Expansive Soil with 6% and 10%

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Abstract. Expansive soils when subjected to change in water content would undergo commonly swelling and shrinkage a cyclic process seasonally. Cohesive non-swelling method is one of the techniques used to control the swelling and shrinkage behavior of these soils. On the other hand, using of waste materials in the pavement construction especially on clayey sub-grade has been in progress all over the world. Copper slag is one of the waste materials, which is being used for various applications in civil engineering. The laboratory test results related to soaked CBR (California Bearing Ratio) test conducted on a stabilized copper slag cushion-soil system for various thickness ratios ranging from 0.25 to 1.00 and stabilized with lime and cement separately are discussed. The increase in soaked CBR with the addition of lime from 6% and 10% to the copper slag for the thickness ratios of 0.25 to 1.00 was 32% when compared with no cushion, whereas, with the addition of cement from 6% and 10% to the copper slag for the same thickness ratios was noticed as 34%. The results showed that the soaked CBR increases as the ratio of the thickness of cushion to the thickness of the expansive soil bed is increased and with the increase in percentage of admixture.

Keywords: Expansive soil, Copper slag, Cement, Lime.

1.0 Introduction

Copper slag (CS) is a waste by product which comes out from the smelting process. Metal industry slag, mine stone and mining waste are generally suitable for recycling and reuse as alternative materials in buildings, roads and for other geotechnical applications in civil engineering [1, 2, 3, 4]. Life-cycle analysis for the use of industrial waste slag in road and earth constructions produced the results which are technically viable and economically feasible, thus advocating the reuse of waste by-products in construction applications [5].

The CS along with fly ash and lime produces pozzolanic activities upon hydration. CS is reported as one of the effective stabilising agents in the stabilization of expansive soils. CS can be effectively used as stabilizing agent in the construction of highway embankments, subgrades and subbases on swelling soils. Many researchers have reported that fly ash alone is an extensively used material in the embankment and fill constructions [6, 7] on expansive soils.

In general, the size range of CS particles is of medium sand. As non-availability of sand abundantly, utilization of the medium sand sized CS along with other admixtures has gained popularity especially in the road construction works. The CS which is when mixed with calcium products like cement and lime in the presence of water results in development of cementitious compounds and bonding properties which in turn makes the sub base or subgrade system durable and stronger.

Moisture migration from outside the structure to the inside causes uplift of the structure and results in a mound-shaped heave of the floor. Severe cracking might result in the walls of the structure therefore. In pavements, longitudinal cracking may result, due to the migration of moisture from the shoulders to the centre. Techniques like sand cushion [8] and cohesive non-swelling soil (CNS) layer [9] have been tried to arrest heave.

In an expansive soil stratum, development of cohesion in the soil-water system takes place due to its saturation, which helps to arrest heave below a depth of 1.2m [10]. However, the soil in the top 1.2m can undergo heave due to changes in water content. So, if an environment which is free from moisture variations is prevailed within the depth of 1.0 to 1.2 m, then it could be ensured that there wouldn't be any swelling and shrinkage in the soil. Obviously, it is possible to completely arrest the swelling and shrinkage behaviour in soil by altering the soil properties using admixtures. Copper slag cushion admixed with lime or cement, laid on the expansive soil, might be suitable in improving the required strength and other properties as calcium reacts with silica and alumina present in copper slag and develops cementatious products. This helps arrest the heave of the expansive soil beneath it. Similar studies were reported in literature; using copper slag when admixed with lime or cement as a cushion in improving the performance of expansive sub-grades [11].

2.0 Experimental Investigation

2.1 Expansive soil

Expansive soil used in the study was collected from the Nalgonda district in Telangana, India. The basic properties of soil are presented in Table 1. The plasticity index of the soil is high. It has free swell index of 220% which shows a very high degree of expansiveness.

2.2 Copper Slag

Copper slag (CS) was collected from the Sterilite Industries, Tuticorin, Tamilnadu. The physical and chemical properties of the slag are presented in Tables 2 and 3 respectively. From the physical properties of CS it is found that the particle size is equivalent to medium sand. CS is of non-plastic natured material. The cohesion component is zero and angle of shearing resistance is 40o. The California Bearing Ratio (CBR) of CS is 3.5%.

Table 1. Basic Properties of Soil

Property	Value
Grain Size Analysis	
Gravel (%)	4
Sand (%)	33
Silt & Clay (%)	63
Consistency Limits	
Liquid Limit (%)	75
Plastic Limit (%)	35
Plasticity Index (%)	40
IS Classification	CH
Free Swell Index (%)	220
MDD (kN/m³)	14
OMC (%)	21
CBR (%)	1

Table 2. Physical Properties of Copper Slag

Property	Value
Hardness, Moh's Scale	6.5 – 7.0
Specific Gravity	3.6
Plasticity Index	Non-Plastic
Swelling Index	Non-Swelling
Granule Shape	Angular, Sharp edges
Grain Size Analysis	
Gravel/Size (%)	1
Sand/Size (%)	98.9
Silt & Clay/Sizes (%)	0.05
MDD (kN/m^3)	23.5
OMC (%)	6
Direct Shear test	
Cohesion (kN/m^2)	0
Angle of internal friction (degree)	40
Permeability(cm/sec)	15.43×10^{-3}
CBR (%)	3.5

(***Courtesy:***Sterilite Industries Ltd, Tuticorin, Tamilnadu, India)

Table 3. Chemical Composition of Copper Slag

Property	(% wt)
Iron Oxide, Fe_2O_3	55 – 60
Silica, SiO_2	28- 30
Aluminium Oxide, Al_2O_3	1 – 3
Calcium Oxide, CaO	3– 5
Magnesium Oxide, MgO	1.0– 1.5

(***Courtesy:***Sterilite Industries Ltd, Tuticorin, Tamilnadu, India)

2.3 Admixtures

Lime and Cement are used as admixtures separately with the copper slag. Hydrated lime, which consists of 95% of calcium hydroxide and 53-Grade Ordinary Portland Cement are procured from the local market.

2.4 Tests Conducted

California Bearing Ratio (CBR) test is a penetration test planned to measure the sub-grade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to find out the thickness of pavement and its constituent layers. This test is most extensively used for the design of flexible pavements.

Soaked CBR tests were conducted for the copper slag mixed with various percentages of lime and cement separately and laid on the expansive soil bed as a copper slag cushion. The percentages of admixture used were 6% and 10%. The copper slag and the admixture were mixed in dry condition in various percentages and then, water corresponding to the desired percentage of water was added to it. Samples were prepared for different thickness ratios (t_c/t_s) ratios such as 0.25, 0.50 & 1.00.

Laboratory California Bearing Ratio (CBR) tests were conducted on the samples as per IS code procedure [12]. The cushioned – soil specimen in the CBR mould consists of expansive soil bed at the bottom and copper slag cushion on the top of the soil bed. This specimen was kept for soaking after placing the surcharge weights and the dial gauge to read the swelling. The overall thickness of the soil bed and the cushion prepared in the CBR mould for testing was 127 mm and its diameter 150 mm.

3.0 Results and Discussion

3.1 Test Results

Figs. 1 and 2 present the soaked CBR results of the cushion-soil system with 6% and 10% lime in the copper slag respectively. Fig 1 presents the soaked CBR results of the cushion-soil system with 6% lime in the copper slag. From these curves, it can be noticed that the increase in the soaked CBR corresponding to a penetration of 2.5mm with the addition of 6% lime to the copper slag for the thickness ratios of 0.25, 0.50 and 1.00 was about 67% when compared with no cushion.

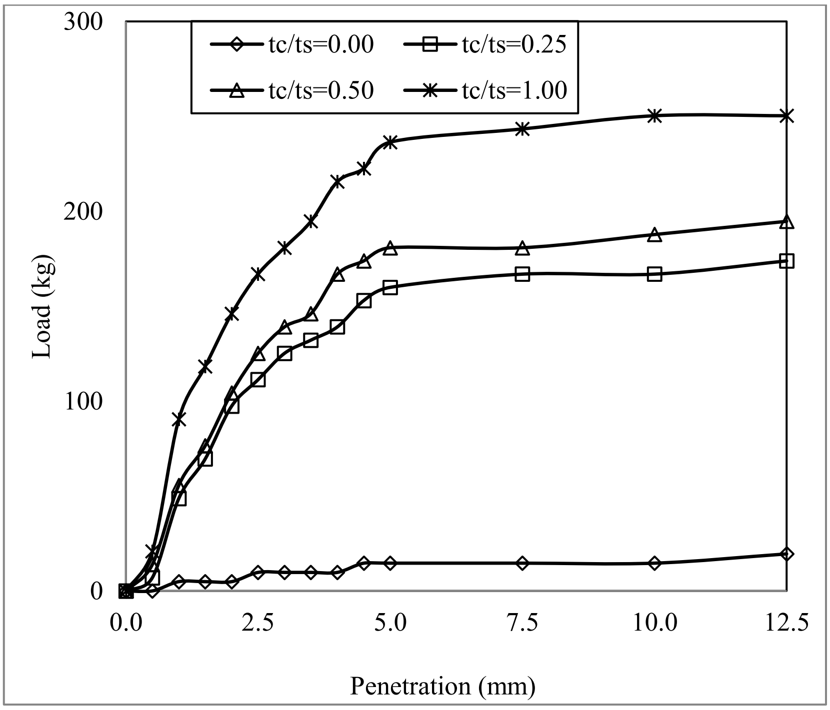

Fig. 1. CBR of cushion-soil system with 6% lime in the cushion after soaking

From Fig 2, it can be noticed that the soaked CBR is increasing as the ratio of thickness of the cushion (t_c) to the thickness of the expansive soil bed (t_s) increases. The increase in the soaked CBR corresponding to a penetration of 2.5mm with the addition of 10% lime to the copper slag for the thickness ratios of 0.25, 0.50 and 1.00 was about 49% when compared with no cushion.

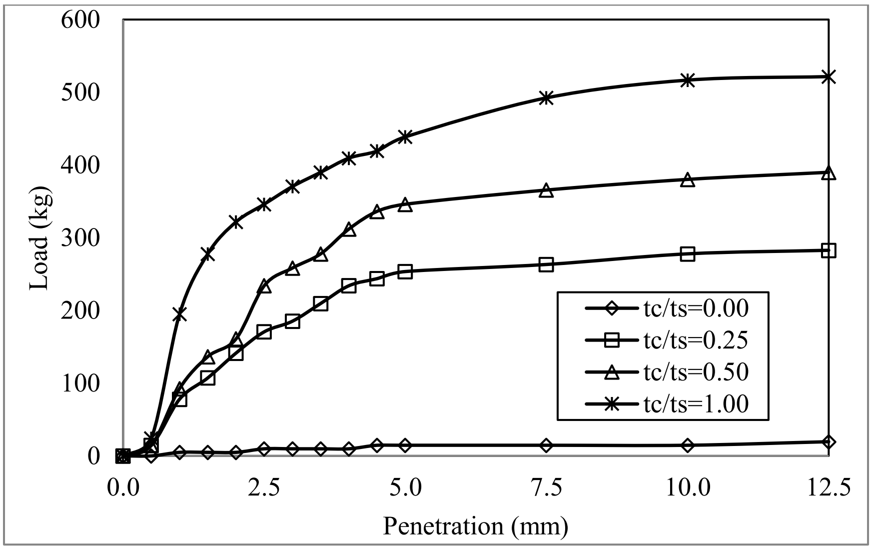

Fig. 2. CBR of cushion-soil system with 10% lime in the cushion after soaking

Figs 3 and 4 presents the soaked CBR test results of the cushion-soil system with 6% and 10% cement respectively in the copper slag after subjecting them to soaking period of 96 hours. It can be noticed that the soaked CBR is increasing as the ratio of thickness of the cushion (t_c) to the thickness of the expansive soil bed (t_s) increases.

From Fig 3, it can be noticed that there is a increase in the soaked CBR corresponding to a penetration of 2.5mm with the addition of 6% cement to the copper slag for the thickness ratios of 0.25, 0.50 and 1.00 and was about 55% when compared with no cushion.

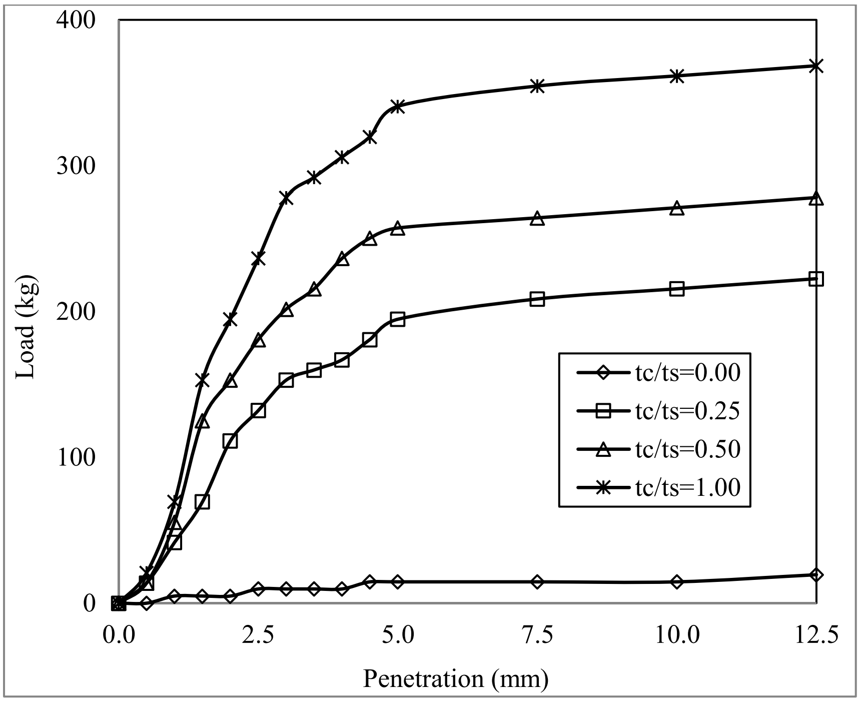

Fig.3.CBR of cushion-soil system with 6% cement in the cushion after soaking

Fig 4 shows soaked CBR results of the cushion-soil system with 10% cement in the copper slag. The increase in the soaked CBR corresponding to a penetration of 2.5mm with the addition of 10% cement to the copper slag for the thickness ratios of 0.25, 0.50 and 1.00 was about 60% when compared with no cushion.

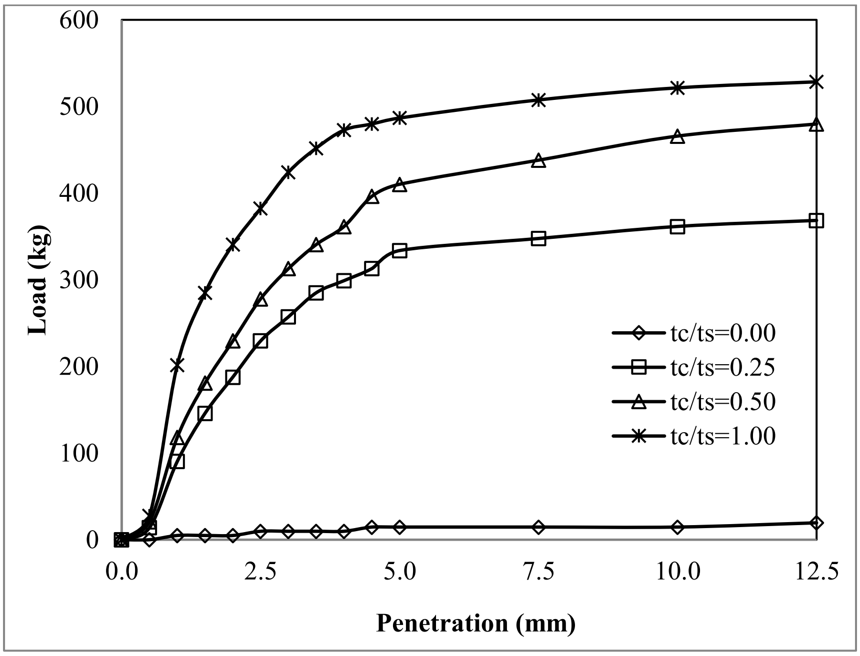

Fig. 4. CBR of cushion-soil system with 10% cement in the cushion after soaking

Figs. 5 and 6 show the comparison of soaked CBR values of the lime, cement cushion-soil system respectively. From these figures it can be noticed that the soaked CBR value increasing as the ratio of the thickness of the cushion (t_c) to the thickness of the expansive soil bed (t_s) is increased. Also, the increase in CBR is noticed with an increase in percentage of lime and cement.

The results of soaked CBR as given in Table 4 shows that the soaked CBR values of cement stabilized copper slag cushions are more than those of lime stabilized copper slag cushions. At lower values of the additive (lime or cement) and under smaller cushion thicknesses, the CBR values noticed are low for the stabilized copper slag as cushioning material.

Since the minimum value of soaked CBR recommended for any material for use as sub-base, when used for 2Million Standard Axle loads (2msa) is 20%, appropriate value of copper slag cushion thickness and additive content may be chosen accordingly. Since the general practice in pavement construction is to cure the material after laying, upon which the strength would further increase, lower values of copper slag cushion thickness and additive content can also be used for getting the required value of CBR. This may be verified by conducting a field CBR test.

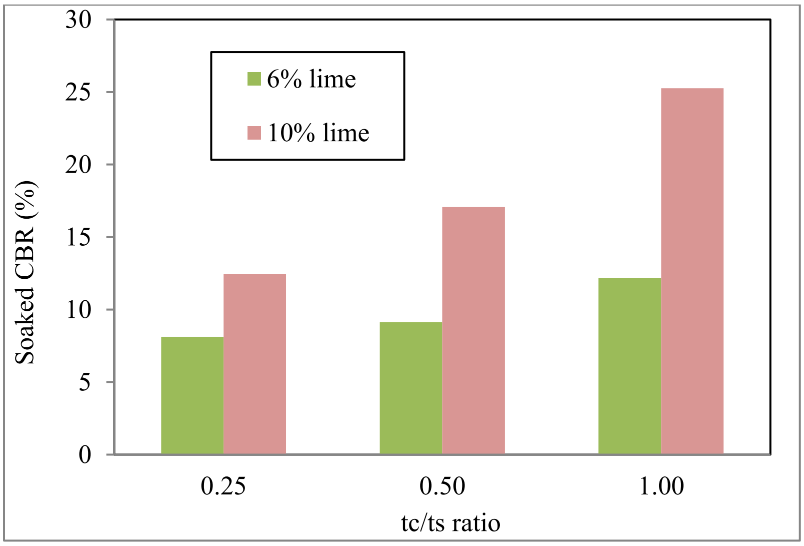

Fig. 5. Comparison of Soaked CBR values of the cushion-soil system with 6% and 10% of lime added to the copper slag cushion

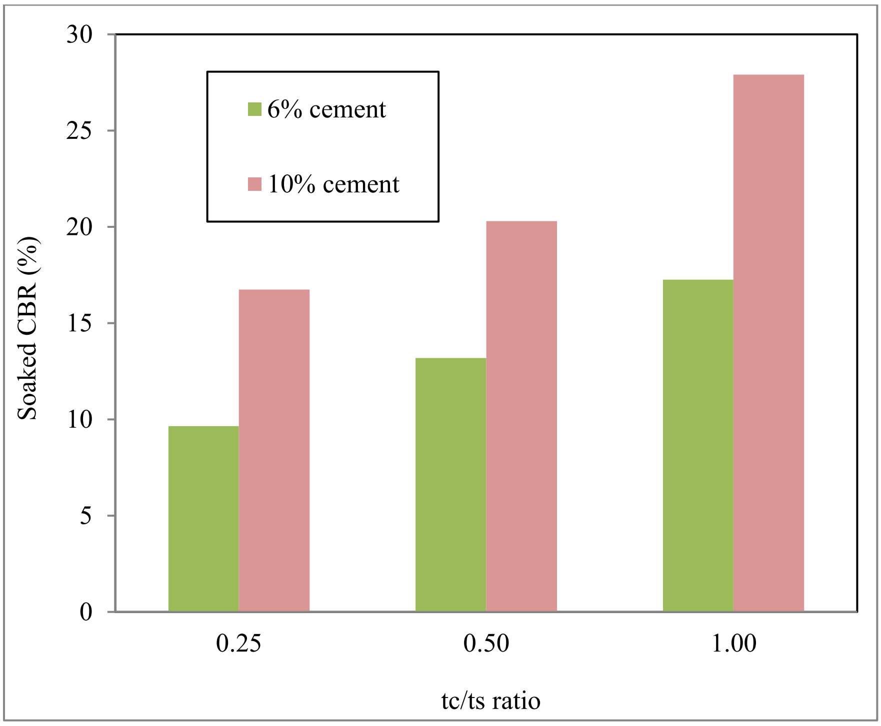

Fig. 6. Comparison of Soaked CBR values of the cushion-soil system with 6% and 10% of cement added to the copper slag cushion

Table 4. Soaked CBR (%) values of cushion-soil system with different percentages of lime/cement in the cushion

Thickness ratio/ Admixture	tc/ts=0.25	tc/ts=0.50	tc/ts=1.00
6% Lime	8.12	9.14	12.18
6% Cement	9.64	13.20	17.26
10% Lime	12.45	17.08	25.26
10% Cement	16.75	20.30	27.91

4.0 Conclusions

- From the results, it was noticed that there is a clear improvement in the soaked CBR value of the cushion-expansive soil system when the cushioning material was mixed with lime or cement as an additive.
- From the soaked CBR test results, it may be noticed that the increase in the soaked CBR value with the addition of lime from 6% and 10% to the copper slag for the thickness ratios of 0.25, 0.50 and 1.00 is 32%, whereas with the addition of cement, this improvement is noticed as 34%, when compared with the soil bed with no cushion.
- Studies indicate that cement is more effective than lime for a soaked CBR value of an expansive soil bed when copper slag cushion is laid over it.

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