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Influence of Varied Cushion Thickness Ratio of Lime Stabilized Copper Slag Laid Over Expansive Soil Bed

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Abstract
Use of waste materials in transportation has been in development all over the world for quite a time and particularly because of the disposal problems associated with it. Copper slag is one of the waste materials that is being used for various applications in civil engineering. Granulated copper slag is more porous and has particle sizes equal to that of medium sand. Also, due to the scarcity of sand, copper slag along with an admixture can be used as an alternative material to sand in road construction. Expansive soils are associated with volume changes when subjected to changes in water content. CNS (cohesive non-swelling) and sand cushion are some of the techniques that have been used to reduce the volume changes and which were originally in practice, bristle with a few disadvantages. The present paper discusses the laboratory test results of soaked CBR (California Bearing Ratio) conducted on a stabilized copper slag cushion-soil system for various thickness ratios of ranging from 0.25 and 0.50 when stabilized with various percentages of lime. The results showed that the soaked CBR increases as the ratio of the thickness of the cushion (h_c) to the thickness of the expansive soil bed (h_s) is increased and with the increase in percentage of admixture.

Key words: Expansive soil, Copper slag, Lime.

INTRODUCTION

Expansive clays are related with volume changes that are closely associated with changes in water content. The change in water content is mostly due to seasonal changes. During monsoon, expansive soils imbibe water from outside and during summer, shrinkage occurs due to the evaporation of water. Moisture migration from outside to inside causes uplift of the structure and results in a mound-shaped heave. In pavements, longitudinal cracking may result, due to the migration of moisture from the shoulders to the center. Montmorillonite is the clay mineral having the highest potential to swell by virtue of its structure and illite also swells though not as much as montmorillonite, but it undergoes greater swelling than kaolinite, which is non-swelling in nature. Techniques like CNS (cohesive non-swelling) [1] cushion and sand cushion [2] have been tried to arrest such heave. Copper slag is one of the waste materials being used in Civil Engineering practice. It has particle size equal to that of medium sand. Also, due to the scarcity of sand, copper slag along with an admixture can be used as an alternative material to sand in pavements. If the copper slag is mixed with calcium-based compound like cement or lime in the presence of water, the silica and alumina present in it will react chemically on hydration and the resulting product may be used for the improvement of sub-grades and subbases. Metal industry slag, mine stone and mining waste are generally suitable for recycling or reuse and the use of these inorganic wastes as alternative materials in buildings, roads and for other geotechnical applications have been reported [3, 4, 5, 6, 7, 8]. Life-cycle analysis for the use of industrial waste slag in road and earth constructions produced effective results, thus advocating the reuse of waste by-products [9].

By mixing expansive soil with copper slag, it can be used as an effective stabilizing agent for the improvement of problematic soils in highways, embankments, sub-grades and sub-bases. Also, by mixing it with fly ash, it becomes suitable as embankment fill material. Slag, when mixed with fly ash and lime, develops pozzolanic reactions [10]. Fly ash has been widely accepted as embankment and structural fill material [11, 12]. It has been felt that the same copper slag when admixed with lime or cement can be used as a cushion in improving the performance of expansive sub-grades. Similar studies using fly ash and blast furnace slag with lime and cement were carried out earlier [13, 14, 15, 16].

The present paper discusses the results of observed soaked CBR (California Bearing Ratio) values conducted on the cushion-soil system with various percentages of lime as an admixture added to the copper slag. The soaked CBR value with the addition of various percentages of lime (2% to 10%) to the copper slag was from 3% to 25% for the various thickness ratios used, ranging from 0.25 to 1.00.

EXPERIMENTAL STUDY

Expansive soil

Expansive soil used in the present investigation was collected from the Nalgonda district in Andhra Pradesh. 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.

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/m^3)	14
OMC (%)	21
CBR (%)	1

Copper Slag

Copper slag was procured from Sterilite Industries, Tuticorin, Tamilnadu. Copper slag is having an angle of internal friction of 40^0 and it is non-plastic and non-swelling.

Admixtures

Lime is used as an admixture with the copper slag. Hydrated lime, which consists of 95% of calcium hydroxide was procured from the local market and is used in the present study.

Tests performed

Soaked CBR tests were performed for the copper slag mixed with lime which was laid on the expansive soil bed as a cushion. The copper slag and the admixture were mixed in dry condition and then, water corresponding to the desired percentage of water was added to it. Samples were prepared for different thickness ratios. The ratios of the thickness of the cushion (h_c) to the thickness of the expansive soil bed (h_s) used in the study were 0.00, 0.25 and 0.50. Laboratory California Bearing Ratio (CBR) tests were conducted on the samples as per IS code procedure (I.S.2720 (Part 16):1987 second revision). The cushion-soil specimen system in the CBR mould consists of expansive soil bed at the bottom and copper slag cushion on its top. This specimen was kept for soaking after placing the surcharge weights and the dial gauge to read the swelling, for 96hrs. 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. Both the soil bed and the admixture-mixed copper slag were compacted in the CBR mould at their respective OMC values.

RESULTS AND DISCUSSION

Test Results

Soaked CBR values were determined on the cushion-soil system when admixed with various percentages of lime to the copper slag for various thickness ratios. Soaked CBR for the black cotton soil was less than 1% whereas for the copper slag without any admixtures it was 3.5%. Figure 1 & 2 shows a typical soaked CBR test results of the cushion-soil system with 4% and 10% lime in the copper slag for different (h_c/h_s) ratios. From these curves, it may be noticed that the soaked CBR value increases as the ratio of the thickness of the cushion (h_c) to the thickness of the expansive soil bed (h_s) is increased. Also, an increase in the soaked CBR value corresponding to an increase in percentage of lime added to the copper slag as an admixture. Similar figures were observed with cushions with 2%, 6% and 8% lime also. The increase in the soaked CBR with the addition of lime by varying percentages from 2% to 10% to the copper slag overlying the expansive soil bed for thickness ratios of 0.25 and 0.50 were from 4 to 24 times more when compared to that with no cushion.

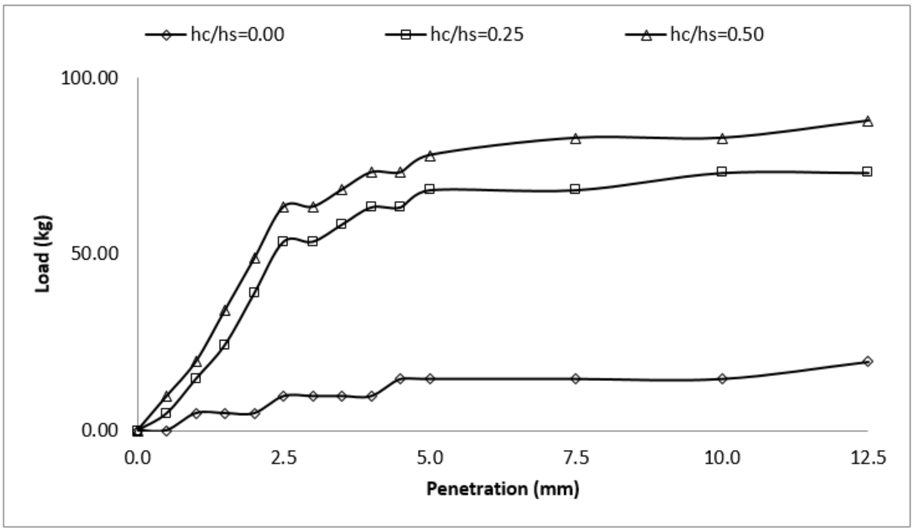

Fig. 1 CBR of cushion-soil system with 4% lime in the cushion after soaking

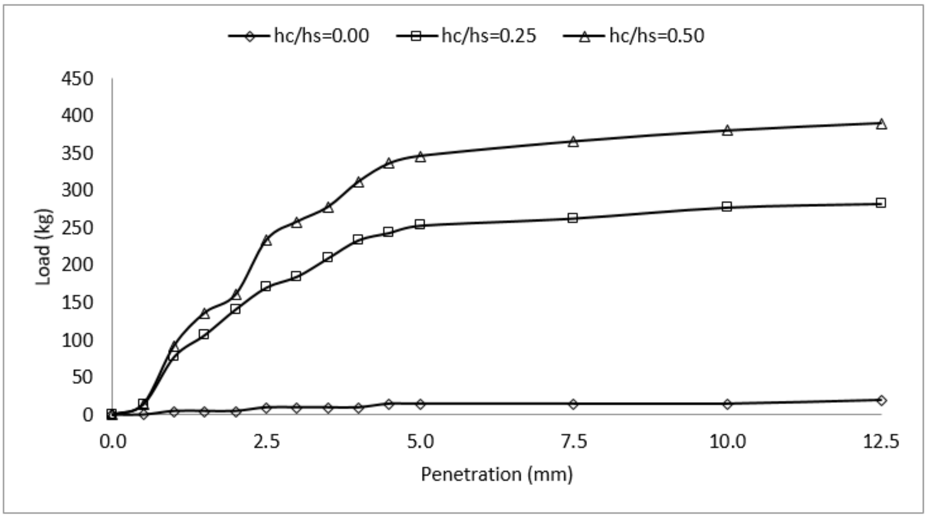

Fig. 2 CBR of cushion-soil system with 10% lime in the cushion after soaking

The results of soaked CBR as given in Table 2 show that, soaked CBR values using lime-stabilized copper slag cushions are more with the increase in cushion thickness.

Table 2 Soaked CBR (%) of cushion-soil system with lime in the copper slag cushion

% Lime	Soaked CBR (%)	
	h_c/h_s=0.25	h_c/h_s=0.50
2	3.05	4.06
4	3.91	4.63
6	8.12	9.14
8	12.18	16.24
10	12.45	17.08

CONCLUSIONS

From the results, it was noticed that there is a marked improvement in the soaked CBR value of the cushion-expansive soil system when the cushioning material was added with lime. It was noticed that the increase in the soaked CBR with the addition of 2% to 10% lime to the copper slag for the thickness ratios from 0.25 and 0.50 was about 4 to 24 times more when compared with the expansive soil with no cushion. Studies indicate that with the addition of lime in the copper slag cushion, the value of soaked CBR increases and also with the increase in the thickness ratio of the cushion to that of the expansive soil bed.

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