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Study of the Effectiveness in Improving Montmorillonite Clay Soil by Construction and Demolition Waste

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Abstract : **Black Cotton (BC) soil that change significantly in volume with change in water content is the major cause of distortions to structures in India since it covers around 20 percent of land area. Over the years successful methods have been used to stabilize them. However, it is found very important for engineers to judge the effectiveness and appropriateness of all stabilizers. The present work deals with the modification of BC soil using Construction and Demolition (C & D) waste (concrete and plastering debris) which resulted in soil+10 percent C & D waste optimum mix obtained through standard proctor test. Further, the cohesion (c) and angle of internal friction (ϕ) were evaluated using Direct Shear test and the Safe Bearing Capacity (SBC) of soil was calculated using Terzaghi's equation for BC soil alone, BC+10 % C & D, BC + 12 % C & D and BC + 14 % C & D waste respectively. Based on the experimental investigation conducted it could be seen that optimum addition of C & D waste can effectively contribute in reducing the heaving behavior of black cotton soil by imparting high bearing capacity and strength and hence could be considered as an alternative stabilizer which also promotes the usage of large amount of waste products obtained from construction industries.**

Keywords: Black cotton soil; Construction and Demolition waste; Safe Bearing Capacity.

1. INTRODUCTION

Black cotton soil contain montmorillonite clay mineral that have a tendency to change volume with application of moisture into it which in turn possess various construction and performance problems in site due to swelling and shrinkage behavior [18]. High degree of expansiveness is offered by black cotton soil due to the presence of high percentage of montmorillonite clay mineral resulting in cracks extending till 12" deep [16]. The expansive soils experience periodic swelling and shrinkage during alternative wet and dry seasons causing considerable damage to structures founded on them [17]. The problems posed by expansive soils to the stability of civil engineering structures have received universal attention in view of serious economic losses at national level of many nations [14]. The expansive soil when associated with engineering structure and in presence of moisture show a tendency to swell or shrink causing the structure to experience moments leading to overall structural failure [10]. To prevent all these problems improvement techniques are found very much essential. Apart from mechanical compaction and soil reinforcement other conventional soil stabilizers such as lime, fly-ash, cement, rice husk ash etc. are used to strengthen the soil. Soil stabilization is the modification of one or more soil properties to produce an improved soil system that will remain in place under the design use conditions throughout the design life of project [3]. Well established chemical and mechanical stabilization methods are usually adopted to modify the soil properties.

Several researchers have studied various geotechnical properties of black cotton soil using different stabilizers. Ashango & Patra, 2014 reported higher compressive strength values at optimum mix on addition of rice husk ash and Portland slag cement to black cotton soil. However, the Optimum Moisture Content (OMC) was found to be decreasing with increase in amount of stabilizers. The experimental studies conducted by Yadu & R.K, 2013 indicated that Granulated Blast furnace Slag (GBS) could be used as a stabilizer which significantly improves the physical and strength properties of soil. Also, the OMC decreased with addition of GBS to expansive soil and also the compressive strength of the soil was found to be higher. Cement dust provides substantial and durable benefits when used as a stabilizing agent for BC soil [16]. Lime stabilization of clay is an effective solution for construction in difficult ground conditions which increased the unconfined compressive strength [12]. The compressive strength of the clay soil was enhanced on addition of groundnut shell ash [15]. The strength properties were found to be influenced on addition of natural inorganic stabilizer (RBI-81) additive to black cotton soil [3]. Recently Kamei, et al., 2013 made a similar attempt of stabilizing soft clay soil using gypsum plasterboard which is considered as a major waste obtained from construction and demolition waste in Japan and observed a significant development in strength which inturn enhanced the durability.

Construction Industry is increasing rapidly in India due to improving economic growth; and large amount of wastes are being generated. The concrete debris, plastering slices and bricks are the major wastes creating serious disposal problems by decreasing the area of landfill sites provided for disposal. Researchers are focusing on finding an alternative solution to the use of these wastes in ground improvement projects instead of disposal. In order to facilitate the usage of these wastes as stabilizer, it is essential to determine the durability of the soil stabilized with C & D waste. In the present investigation, the C & D waste were ground into powder form and were added in percentages to BC soil. The primary objectives of the present research included

a) To improve the bearing capacity of black cotton soil on addition of stabilizer.
b) To study the variation of strength of soil at different water content.
c) To study the effect of C & D waste on shear strength of soil.

2. MATERIALS AND METHOD

2.1. Location of the study

The soil sample used for the study was collected from Vidurashwatha, Gauribidanur Taluk, Karnataka, India. C & D waste was collected from site at Kengeri, Bangalore, Karnataka. The C & D waste consisted in the study were cement plastering, block works, brick works and concrete works.

2.2 Testing methods

Laboratory testing on raw soil included specific gravity, grain size analysis (dry and wet sieve analysis), Atterburg limits, standard proctor test and direct shear test. The engineering properties of the soil were determined according to Bureau of Indian Standard (BIS) [5-7, 9]. Standard compaction tests were conducted on specimens prepared with addition of 2%, 4%, 6% till 4 % C & D waste respectively in interval of 2% [8]. Direct shear test was evaluated at optimum stabilizer content (OSC), OSC+2% and OSC+4% respectively as per IS standards [4].

2.3 Properties of Black cotton soil and Construction and Demolition waste

The properties of expansive soil and C & D waste were evaluated according to BIS standards. The specific gravity of raw soil was found to be 2.66 and the clay content was found to be greater than 70 %. The plasticity index was found to be higher i.e. 24.85%. The group index of raw soil was found to be higher indicating the poor quality of soil and also the soil was classified as per AASHTO soil classification system [2,13] and was found belonging to group A-7-5 indicating that the soils falls below recommendation which requires stabilization. The results of standard proctor test on raw soil and C & D waste has also been reported in Table 1. The specific gravity of C & D waste was found to be 2.75 and was found to be less plastic.

Table 1. Properties of Black cotton soil and Stabilizer.

Soil characteristics	Description
Black cotton soil	
Liquid limit (%)	61.2
Plastic limit (%)	36.4
Plasticity index (PI) (%)	24.8
Maximum Dry Density (MDD)	1.645
Optimum Moisture Content (OMC)	24.8
Specific gravity	2.66
Indian standard classification	A-7-5 (clayey soil)
Construction and Demolition waste	
Maximum dry density (MDD)	1.865 g/cm3
Optimum moisture content (OMC)	16.2 %
Plastic limit	Nill
Specific gravity	2.75

3. RESULTS AND DISCUSSIONS

3.1. Atterburg limits

The liquid limit and plastic limit of the BC soil were calculated as per IS: 2720 (V) [7]. The plasticity index was found to be decreasing with increase in percentage of C & D waste. Figure 1. Indicate the decreasing trend of PI with increase in percentage of C & D. It could be inferred as PI decreases with increase in C & D percentage till around optimum percentage.

3.2. Compaction properties

OMC and MDD for blended mixtures were calculated in accordance with IS: 2720 (VII) [8]. The MDD was found to be increasing with increase in percentage of C & D waste. The reasoning to increase in MDD could be due to the increase in specific gravity of stabilizer as compared to BC soil. The OMC was observed to be decreasing with increase in amount of stabilizer. The reduction in water content could be explained as the decreased clay and silt percentage due to the addition of C & D waste resulting in lesser surface area [18]. The variation in OMC and MDD with different percentages of C & D waste could be seen in Figure 2.

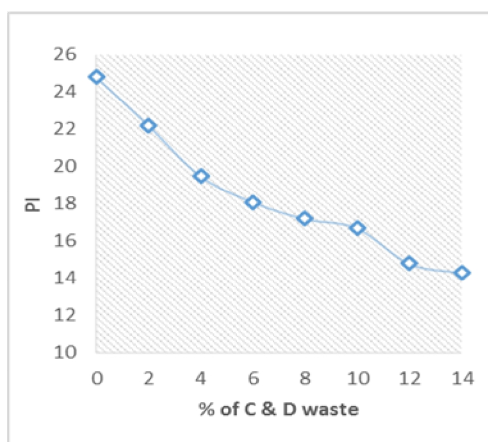

Figure 1. Plasticity index versus different percentage of stabilizer

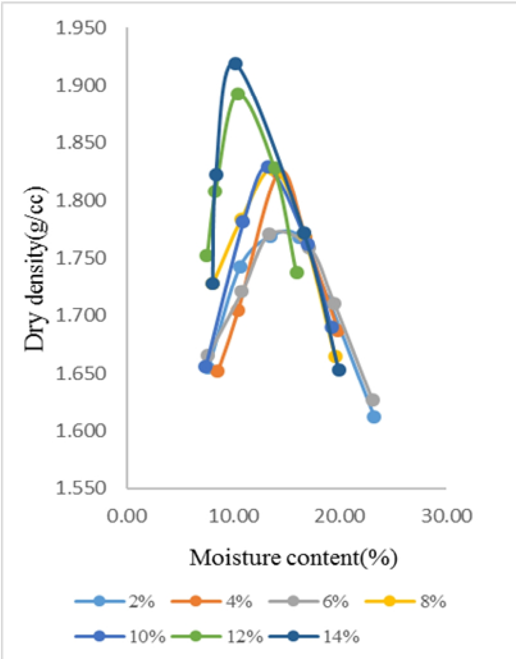

Figure 2. Variation of OMC and MDD with different percentage of C & D waste.

3.3. Cohesion and frictional properties (c and ϕ)

From the compaction characteristics curve obtained 10 % C & D waste blended soil was considered to be optimum. Further, Direct shear test as per IS standard [4] was conducted for only BC soil, optimum, optimum+2, optimum+4 percentage of blended soils. The cohesiveness of the soil decreased and angle of internal friction increased with increase in percentage of C & D as shown in Figure 3. The rough and angular surface of individual C & D particles could be considered as the reason for increase in angular friction. However, further research on particle shape and size of individual particles add up to the above drawn conclusion.

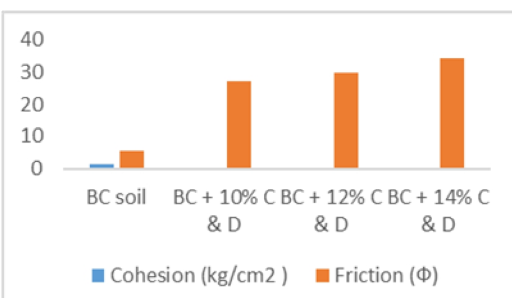

Figure 3. Variation in cohesion and angle of internal friction with change in blend %.

3.4. Safe Bearing Capacity

Based on the 'c' and 'ϕ' values obtained the SBC of expansive soil alone, 10 %, 12 % and 14 % blended soil respectively were calculated using Terzaghi's bearing capacity equation as given in equation-1. Table 2. indicate Terzaghi's Bearing capacity factors for different values of angle of internal friction. Calculations were made by assuming Circular footing with two different diameters and three different depths. The results given in Table 3. indicate that the SBC of the soil significantly improved on addition of 10 % C & D as when compared to BC soil alone i.e. from 1411 to 2148 kN/m^3. However no much improvement in bearing capacity was observed on further addition of C & D waste to the expansive soil. Therefore, 10 percent C & D waste could be considered as the optimum mix percentage required to improve the soil properties.

$$Q^F = 1.3cN_c + \gamma DN_q + 0.3\gamma BN_\gamma$$

Where c= cohesion in kg/cm^2, N_c, N_q, N_γ are known as bearing capacity parameters, γ= dry density kN/m^3, D= depth of footing (m), B= diameter of footing (m).

Table 2. Terzaghi's bearing capacity factors [13]

ϕ	N_c	N_q	N_γ
0	5.7	1.0	0.0
5	7.3	1.6	0.5
10	9.6	2.7	1.2
15	12.9	4.4	2.5
20	17.7	7.4	5.0
25	25.1	12.7	9.7
30	37.2	22.5	19.7
34	52.6	36.5	35.0
35	57.8	41.4	42.4
40	95.7	81.3	100.4
45	172.3	173.3	297.5
48	258.3	287.9	780.1
50	347.5	415.1	1153.2

Table 3. Safe bearing capacity of soil and soil mixtures in kN/m^3

Depth\ soil	BC soil	10% blended soil	12% blended soil.	14% blended soil
1m diameter				
1.0m	1411.40	1805.12	1639.00	1524.34
1.5m	1425.07	1957.80	1847.57	1782.78
2.0m	1438.69	2005.95	2056.15	1941.23
1.5m diameter				
1.0m	1412.80	1843.09	1693.78	1543.47
1.5m	1426.42	1995.77	1902.36	1838.92
2.0m	1440.04	2148.46	2110.94	1947.37

4. CONCLUSIONS

The potential usage of construction and demolition wastes in stabilizing the Black cotton soil has been studied here. The soil has higher GI value belonging to A-7-5 subgroup as per AASHTO soil classification systems [13] which indicate a poor quality of soil and recommend stabilization. The physical and strength parameters have been evaluated for raw and blended soils. The experimental results indicate that addition of C & D waste significantly affects the properties of soil. The plasticity index of the soil decreased with increase in amount of stabilizer. The MDD increased and OMC decreased with increase in the content of stabilizer. Based on the strength test 10 percent of C & D waste is considered to be optimum and also the SBC of the soil significantly improved on addition of 10 percent stabilizer i.e. from 1411 to 2148 kN/m^3.

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