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Use of Recycled Construction and Demolition (C&D) Wastes in Soil Stabilization

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ABSTRACT

With the growing construction sector, there is a constant rise in wastes generated by both construction and demolition activities. According to an estimate by Building Material Promotion Council (BMPTC), 150 million tonnes of construction and demolition (C&D) wastes are generated in India annually. However, the official recycling capacity is a meagre6, 500 tonnes per day (TPD) - just about 1 percent. This paper examines the properties of Black cotton soil and investigates the use of recycled C&D wastes in soil stabilization of black cotton soil. This research focuses on the inexpensive and eco-friendly nature of C&D wastes as an admixture for soil stabilization. The tests were performed using different proportions of recycled C&D wastes in the proportions: 5%, 10%, 15%, 20%, and 25%, to increase the strength of black cotton soil. California Bearing Ratio (CBR) showed an increase from 2% to 18.09%, Maximum Dry Density (MDD) showed a decrease from 2.107 $g.cc^{-1}$ to 1.69 $g.cc^{-1}$, and Optimum Moisture Content (OMC) showed a variation and increased from 15% to 18.09% with the addition of 25% C&D wastes.

INTRODUCTION

Soil is perhaps one of the major factors that affect construction. Everything from a house to a shopping mall is built on soil and therefore, building foundations need to be on stable soil. Since soil ranges in strength, some of them may be able to support a skyscraper, while some may not be able to hold the weight of a human. Black cotton soil is one such soil that requires special methods of construction, soil stabilization being one of them. Soil stabilization is broadly defined as the process of improving the engineering properties of weak soil with the use of stabilizing agents or admixtures. Soil stabilization is mainly carried out in three methods, namely: mechanical stabilization, chemical stabilization, and polymer stabilization. Materials like lime, cement, bitumen, etc. have been used to carry out soil stabilization. Although these materials treat the soil and increase its workability and durability of the soil, it causes harmful effects on the environment, due to carbonation, sulfide attack, etc. Therefore, the main objective of this study is to use recycled C&D wastes for soil stabilization, while reducing the harmful effects on the environment due to illegal dumping, carbonation, and sulfide attacks from using other stabilizers, as well as reduce the need for finite landfill spaces.

There is a substantial history of the use of soil stabilization admixtures to improve poor subgrade soil performance by controlling volume change and increasing strength. Al-sharif et al. (2012) had evaluated the use of burned sludge as a stabilizing agent. The sludge was burnt at 550°C and added to three different samples of clayey soils at different percentages. The results show that the addition of 7.5% burned sludge ash (dry weight) increased the unconfined compressive strength maximum dry density and minimized the swelling pressure of the soil. If more than 7.5% by weight is added, both the maximum dry density and the unconfined compressive strength decrease. Therefore, this study reached the conclusion that burned sludge can be used as a soil stabilizer. Dhananjaya et al. (2019) and Henzinger et al. (2015) has done experiments on the stabilization of black cotton soil using demolition wastes and concluded that CBR values were increasing with an increase in construction wastes.

Shelke (2010) has evaluated the reduction of swelling pressure of expansive soils using EPS geofoam and it was observed from the results of his test that with an increase in EPS geofoam layer, there was a sudden reduction in swelling pressure. Teja et al. (2018) has reviewed on stabilization of expansive soil using brick dust.

Parsons & Kneebone (2004) studied the use of cement kiln dust for the stabilization of soils. Cement kiln dust was added to eight different soils to evaluate the effectiveness of Cement Kiln Dust (CKD) as a stabilizing agent in each soil. The results were then compared with findings from the same type of soils stabilized with lime, cement, and fly ash. Strength and durability tests were conducted. Results showed the effectiveness of CKD as a soil stabilizing agent in each soil. Seda et al. (2007) studied the benefits of using waste tire rubber to mitigate swelling potential in expansive soils. In this paper, the study of the effects of the addition of small particles of waste tire rubber to an expansive soil from Colorado was undertaken. Results showed a significant decrease in the swell percent and swelling pressure with the addition of rubber to the soil sample. Okogbue (2007) had stabilized clay using wood ash. The geotechnical parameters of clayey soil in its native condition, as well as mixed soil with different quantities of wood ash and particle size distribution, specific gravity, Atterberg limits, compaction characteristics, CBR, and compressive strength, were assessed. Results showed a significant improvement in the geotechnical properties of clayey soil, with the best results achieved at the addition of 10% wood ash. However, this study concluded that wood ash cannot completely replace lime as the strength gained lasts only for a short duration. Amadi (2014) assessed the effectiveness of stabilization of combined cement kiln dust and quarry fines on pavement subgrades dominated by black cotton soil. The inclusion of the QF and CKD combination resulted in a significant decrease in the plasticity index, as well as a fall in maximum dry unit weight and an increase in optimum moisture content. It also resulted in a significant increase in CBR, indicating that these two materials can be utilized jointly in soil stabilization.

Karthik et al. and Raut et al. (2014) investigated the use of fly ash in soil stabilization. This study evaluated the effects of fly ash in stabilizing soft fine-grained red soils. CBR and other strength tests were conducted on the soil and a mixture of soil-fly ash prepared at an optimum water content of 9% showed a considerable increase in CBR of the soil. Mudgal et al. (2014) studied the effects of lime and stone dust in geotechnical properties of Black cotton soil and it was concluded that there was an increase in strength and maximum dry density of lime stabilized soil with the addition of 20% stone dust. Henzinger et al. (2015) investigated the use of demolition waste in soil improvement. They had experimented on two treated fine-grained soils, one clay of low plasticity and one of very high plasticity. The geotechnical properties of the two soils were also determined. Results showed this soil treatment was more effective for the clay of low plasticity rather than the clay of very high plasticity and that the improvement capability mostly depends on the water content of the added material. Therefore, the use of dry material was highly recommended.

This paper focuses on the stabilization of black cotton soil by using recycled aggregates from acquired C&D wastes. Various changes in the properties of Black cotton soil are observed with the addition of recycled C&D wastes.

NEED FOR THE PRESENT STUDY

After thoroughly studying the literature reviews, the following gaps and drawbacks were drawn.

(i) Although recycled C&D wastes find their uses as concrete aggregates in soil subgrades and new construction, they can be used to treat soil and increase its durability and stability.

(ii) India produces about 150 million tonnes of C&D wastes out of which only a mere 1% is recycled. Hence, the need for recycling and reusing C&D wastes is a rising concern.

(iii) Since recycling C&D wastes are not always cost-effective, reusing them in new projects may reduce the overall costs of the project. To use recycled C&D wastes as a cheaper alternative for soil stabilization.

(iv) Recycling and reusing C&D wastes will reduce the need for non-renewable resources, thus leading to sustainable development. Using recycled C&D wastes for soil stabilization, will thereby, reduce their overall impact on the environment and finite landfill spaces.

MATERIALS AND METHODS

Figure 1 shown below gives details about the methodology carried out in this research. After procurement of materials, preliminary tests on raw materials were carried out.

The C&D wastes were acquired from a dumping site in Shollinganallur, Chennai, Tamil Nadu. The collected sample went through a process of segregation and a concrete waste sample weighing 5kg was crushed with the help of a rammer.

The addition of the crushed concrete sample to the soil was done in the proportions 5%, 10%, 15%, 20%, and 25%, respectively. The crushed concrete sample was added to the soil sample in different proportions to observe the various changes and find the optimum amount.t. The same tests were conducted for the stabilized soil according to IS 2720. From the results of the test, optimized percentage addition of C&D waste for soil stabilization will be arrived.

Materials Used

This paper focuses on the stabilization of black cotton soil by using recycled aggregates from acquired C&D wastes. Various changes in the properties of Black cotton soil are observed with the addition of recycled C&D wastes. The properties of black cotton soil are given in Table 1.

Black Cotton Soil:

Black cotton soil, also known as expansive soil, is amongst the most problematic soils in construction. Generally prevailing in the central and southern parts of India, Black cotton soil is heavy clay soil and varies from clayey to loam, and is generally light to dark grey. When dry, Black cotton soil or expansive soil shrinks, becomes hard-like stone, and has a high bearing capacity; when wet or moist, it expands, becomes very loose, and loses its bearing ability. The ba-

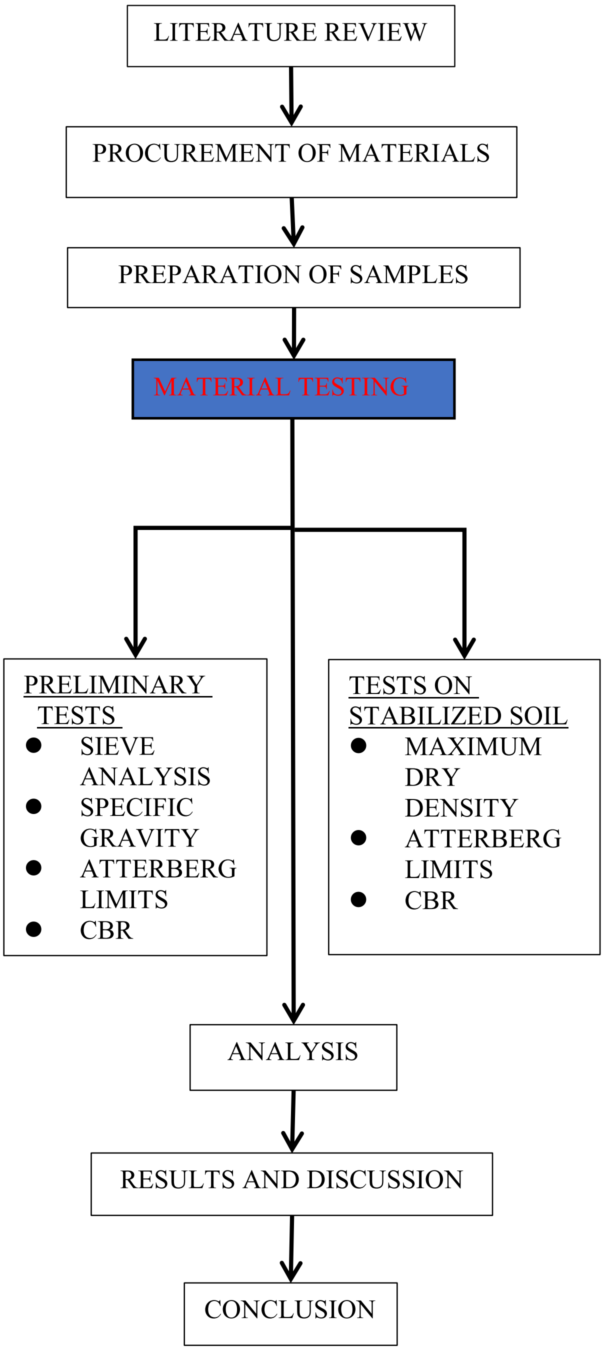

Fig. 1: Methodology for soil stabilization.

sic mineralogical composition of these types of soil has a crucial influence on their swelling behavior, as these soils are typically rich in the minerals montmorillonite and illite.

When it's dry, large cracks form up to 150 mm wide and3.0 to 3.5 meters deep, and when it's wet, the soil increases in volume to about 20% to 30% of the original volume and exerts pressure. The exerted upward pressure is so high that it tends to lift the foundation upwards and this reverse pressure in the foundation causes cracks in the wall above. While the cracks are narrower at the bottom, they get wider as they go up. Because black cotton soil has such unique qualities, construction on it necessitates the use of unique techniques.

Table 1: Properties of black cotton soil.

Sl. No.	Properties	Value
1.	Specific Gravity	2.28
2.	Grain-Size Analysis	
	Gravel	0%
	Sand	17.7%
	Silt	30.4%
	Clay	51.9%
3.	Liquid Limit	51%
4.	Plastic Limit	26.39%
5.	Plasticity Index	30.1%
6.	CBR Value	1.45%
7.	Optimum Moisture Content	15%
8.	Maximum Dry Density	2.107 Gm/CC
9.	UCS Value	1.08%
10.	Swelling Potential	9.47%

Improvisation Materials

Various additives such as lime, cement kiln dust, waste rubber, rice husk ash, burned sludge have been commonly used to stabilize the soil. However, C&D wastes such as soil stabilizers, have been newly introduced, especially the use of recycled concrete aggregates. The C&D wastes used in this study were acquired from a dumping site located in Shollinganallur, Chennai, Tamil Nadu. A typical composition of C&D wastes is demonstrated in the given chart (Fig. 2).

Tests

Crushed concrete was added to the Black cotton sample in the proportions of 5%, 10%, 15%, 20%, and 25%. After the addition of crushed concrete, the following tests were conducted to observe and understand the behavior of Black cotton soil (expansive soil).

- Liquid limit test
- Plastic limit test
- California Bearing Ratio test

RESULTS AND DISCUSSION

Engineering properties of soil w.r.t liquid limit, plastic limit, plasticity index, maximum dry density, and moisture con-

Table 2: Final results for Black Cotton soil.

Engineering property	Black cotton soil	5% of C&D Wastes	10% of C&D Wastes	15% of C&D Wastes	20% of C&D Wastes	25% of C&D Wastes
Liquid limit [%]	51%	58.68%	56.85%	51.46%	50.87%	49.21%
Plastic limit [%]	26.39%	29.41%	26.53%	24.65%	23.39%	22.54%
Plasticity index [%]	30.1%	29.27%	33.12%	26.81%	27.48%	27.67%
Maximum dry density [$g.cc^{-1}$]	2.107	1.932	2.083	1.827	1.738%	1.689%
Optimum moisture content [%]	15%	21.5%	19.3%	18.23%	19.19%	18.09%
CBR [%]	2%	4.8%	9.7%	14.35%	16.3%	18.99%

tent for an addition of 5% to 25% C&D wastes in soil are tabulated in Table 2.

From table 2 it was observed that the values of Liquid limit was varying between 49% to 58% and plastic limit between 22 % to 29% for an addition of 25% to 5% addition of C&D waste. Plasticity index and dry density were high for an addition of 10% addition of C &D wastes. Moisture content was 21.5%, 19.3%, 18.23%, 19% and 18.1% for percentage increase of C&D wastes from 5% to 25% addition.

Fig. 3 represents the effects of recycled C&D wastes on Black Cotton soil in the proportions of 5%, 10%, 15%, 20%, and 25% respectively. From Table 2 and Fig. 3, we can observe a steady decrease in the liquid limits and plastic limits of the soil, as we keep increasing the percentages of C&D wastes. The liquid limit of the soil changed from 51% to 49.21% with the addition of 25% recycled C&D wastes, while the plastic limit changed from 26.39% to 22.53%.

Fig. 4 represents a variation in the optimum moisture content with the addition of different percentages of C&D wastes in the proportions of 5%, 10%, 15%, 20%, and 25% respectively. The optimum moisture content of the Black Cotton sample was 15% and increased to 18.09% with the addition of 25% C&D wastes. For the addition of 5%, 10%, 15%, and 20 % C&D wastes, OMC increased to 21.50%, 19.30%, 18.23%, and 19.19% respectively. As observed from Fig. 3, there is a significant increase in the optimum moisture content of Black cotton soil, thus proving that the addition of C&D wastes improves the OMC of black cotton or expansive soils.

Fig. 5 represents the variation in CBR values for different percentages of C&D wastes added and the effect of C&D

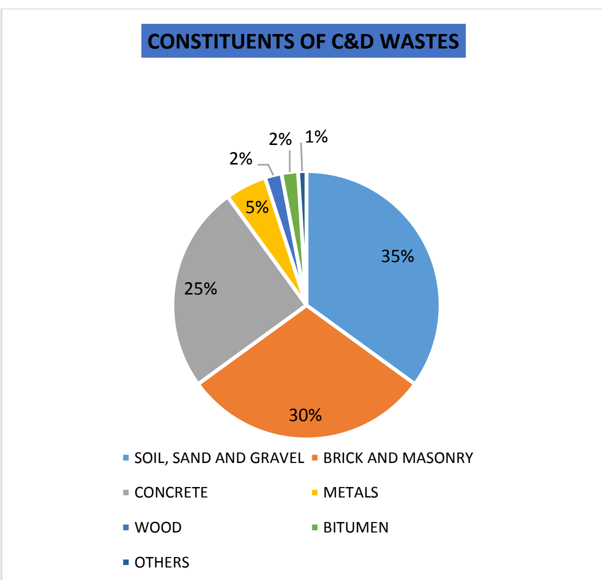

Fig. 2: Constituents of C&D wastes.

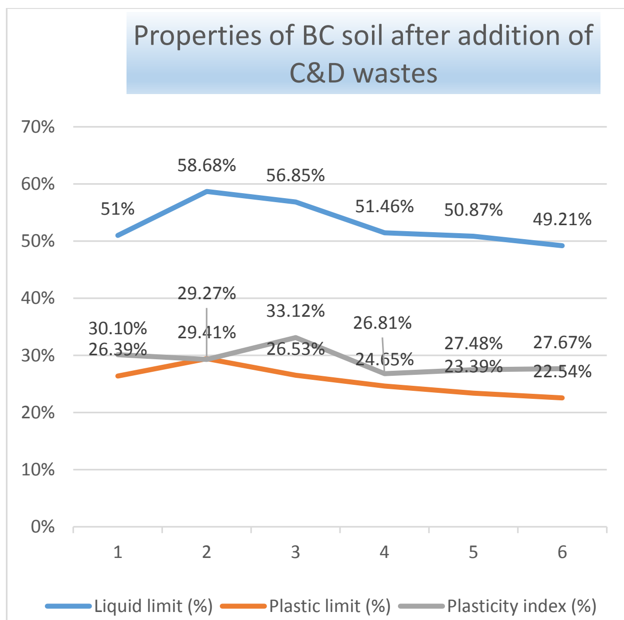

Fig. 3: Atterberg limits of initial and after addition of C&D wastes to black cotton soil.

wastes over CBR values. From the above figure, we can observe a significant increase in the CBR values of Black cotton soil with the consequent increase in the proportions of recycled C&D wastes. With the addition of 5%, 10%, 15% and 20% C&D wastes, CBR values increased to 4.80%, 9.70%, 14.35% and 16.30% respectively.

With the increase in the percentage of C&D wastes added, CBR values increased from the initial 2% to 18.095 for 25% C&D wastes added.

Fig.6 represents a variation in the maximum dry density of the soil sample with the addition of different percentages of C&D wastes. As the amount of C&D wastes is increased, we can see a decrease in the maximum dry density of the Black cotton soil sample. As we increase the quantities of recycled C&D wastes in the Black cotton soil sample, the values of maximum dry density gradually decrease. With the addition of 5%, 10%, 15%, and 20%. C&D wastes, MDD values changed to 1.932, 2.083, 1.827, and 1.740 ($g.cc^{-1}$), respectively. At the addition of 25% C&D wastes, maximum dry density showed a decrease from 2.10 $g.cc^{-1}$ to 1.69 $g.cc^{-1}$.

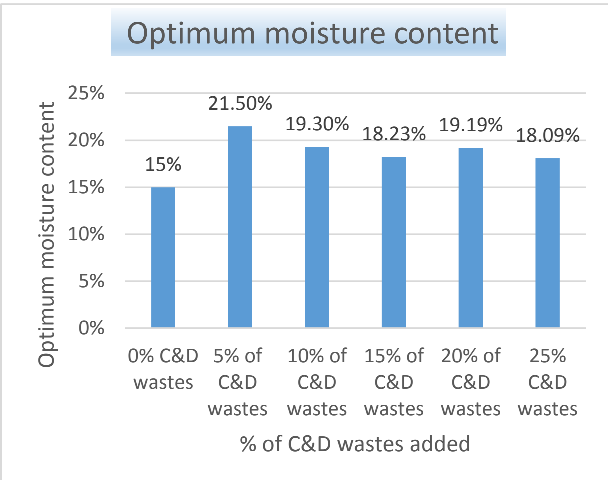

Fig. 4: Optimum moisture content of black cotton soil after adding recycled C&D wastes.

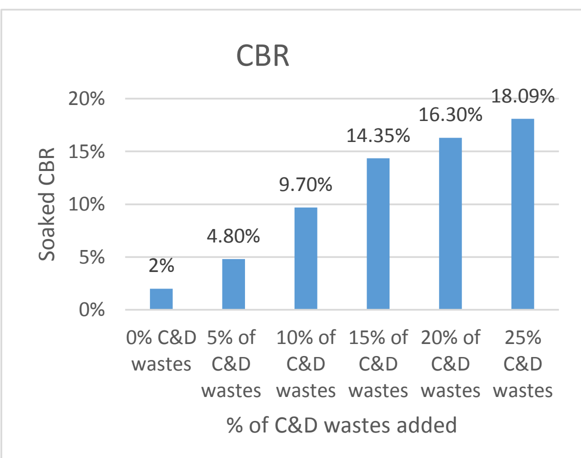

Fig. 5: Values of CBR values before and after addition of C&D wastes.

CONCLUSION

The purpose of this research was to enhance the engineering properties of Black cotton soil, reduce its swelling potential land increase its load-bearing capacity at the same time. Previous research has studied the effect of various additives such as lime, Rice husk ash, cement kiln dust, etc., for soil stabilization but most of these resulted in excessive heaving and pavement failures. The use of C&D wastes as a soil stabilizer has been studied before and the results obtained in this research are similar to the results of other research studies, which goes to proves that C&D wastes can be used as soil stabilizers.

In this study, we tried to improve the engineering properties of Black cotton soil with the addition of recycled C&D wastes. The following results were achieved.

- Optimum moisture content(OMC)values of the soil sample varied with the addition of C&D wastes and changed from the initial15% to 21.50%, 19.30%, 18.23%, 19.19% and18.09%, respectively.
- CBR values saw a significant increase from 2% to 4.89%, 9.70%, 14.35%, 16.30% and 18.09%, with the addition of C&D wastes in the proportions of 5%, 10%, 15%, 20% and 25%, respectively.

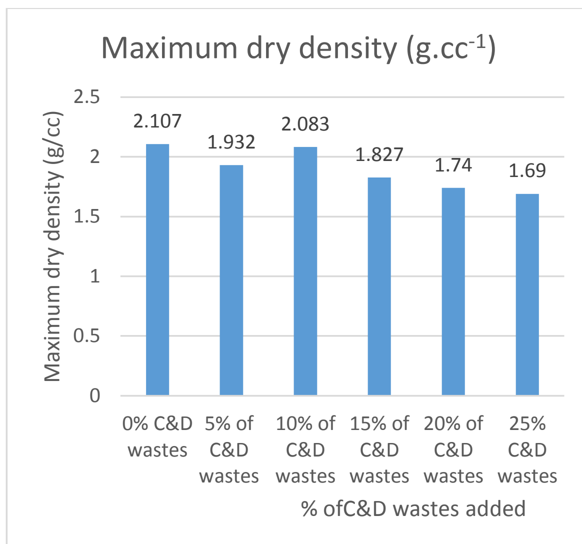

Fig. 6: Values of maximum dry density ($g.cc^{-1}$) before and after addition of C&D wastes.

- Maximum dry density(MDD) of the soil decreased from 2.107g.cc^{-1} to 1.932,2.083,1.827, 1.74and1.69g. cc^{-1} with the addition of 5%, 10%, 15%, 20% and25% C&D wastes, respectively.

From the above observations, we can conclude that there is a significant improvement in the engineering properties of Black cotton soil.

With the use of C&D wastes as a soil stabilizer, the problems of Black cotton soil in construction can be tackled. In addition, the rising problems caused by the massive C&D wastes generation such as pollution of water bodies, green areas, public spaces, and the biggest one among them being the depletion of finite landfill spaces can be curbed. The use of C&D wastes as a soil stabilizer will not only improve the engineering properties of soil, it will also reduce the costs of the overall project and negate the impact on the environment, thus leading to a more sustainable way of construction.

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