STUDY ON IMPROVEMENT OF BLACK COTTON SOIL BY USING FINES OF CONCRETE CUBE & BRICK DEMOLITION WASTE

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Abstract: Subgrade soil is a primary part of a road crust which gives considerable strength and support to the whole pavement structure from below. If the subgrade soil exhibits a weak soil then improvement of load-bearing strength properties of that subgrade soil is done by soil-stabilization technique. This project aims to conduct a study to check the improvements in properties of Black Cotton (BC) soil by adding Fines of Crushed concrete cube and Brick waste separately. By varying percentage of Fines of Concrete Cube Waste (FCCW) at 0%, 20%, 40% and 60%, the soil parameters such as Compaction characteristics, CBR and Shear Strength were studied. These values are compared to that of a untreated BC soil. Similarly, the varying percentage of Fines of Brick Demolition Waste (FBDW) at 0%, 20%, 40% and 60%, the soil parameters only considered was Compaction characteristics. The first approach of BC stabilized using FCCW, the Maximum Dry Density increased from 1.504g/cm³ to maximum 1.708 g/cm³, decrease in Optimum Moisture Content and later increase, CBR value increased from 2.05% to maximum 7% and Shear strength increased from 377kN/m² to maximum 1390 kN/m² at 20% FCCW respectively. The second approach of BC stabilized using FBW, the Maximum Dry Density increased from 1.565g/cm³ to maximum 1.702 g/cm³ and decrease in Optimum Moisture Content at 20% FBDW respectively. However, in the light of studies conducted, the 20% of FCCW and 20% of FBDW are considered as the optimum proportion of the FCCW and FBDW resulting in maximum strength and performance as observed from UCS test results in the first approach.

1. Introduction
Concrete cubes are casted and tested during construction of any building structure to check the compressive strength of concrete before the construction has been started. During this more number of concrete cubes is casted and also may be wasted. The crushed concrete cubes are thrown as waste. A lot of money can be saved by reducing the project disposal costs, transportation costs and the cost of new construction materials by recycling old materials onsite. The environmental benefits of recycling construction and demolition waste are considerable.
2. Objectives of the Present Study

The broad objective of the present work is to carry out the experimental studies on the potential use of fines obtained from demolished concrete structures as stabilizing material for improving the strength of the sub grade soil.

In the present study, an effort is made to enhance the strength of black cotton soil by adopting two approaches—

1) Using a concrete cube waste as a soil stabilizer and finding its optimum position with reference to maximum strength.

2) Stabilization of black cotton soil using brick demolition waste in different proportions.

3. Literature Review

Crushed construction demolition waste (CCDW) was added to the clayey soil. CCDW of 0 to 32% by weight of the soil. The conclusion drawn were as follows CCDW content was increased in the un-stabilized soil, increasing the UBC. At 8% CCDW was added to the clayey soil, the UBC strength was 13.78%. At 16% CCDW was added the clayey soil, the UBC Strength is 31.25%. At 24% CCDW was added the clayey soil, the UBC Strength was 43.72%. Fly ash was added to the clayey soil. Fly ash ranging from 9% to 46% by weight of the soil. Based on the results the bearing ratio increases as the thickness ratio increases and it becomes maximum when the ratio is 2:1 within the ranges of the parameters of the study [2]

Black Cotton Soil (BCS), River Sand (SD), Fly Ash (FA) and Marble Dust (MD), was mixed in the varying percentages such as 8%, 12%, 16% and 20%. After finding the optimum mixes for all the combinations i.e. optimum mixes of BCS-SD, BCS-SD-FA, and BCS-SD-FA-MDD. From the results obtained it was concluded that, MDD of BC soil increased from 1.53 to 1.76g/c.c, whereas the optimum water content of black cotton soil decreased from 22.8 to 19%. From XRD technique it was determined that greater strength and lack in swelling nature for the final optimum mixture (BCS-SD-FA-MD::100-30-15-12) due to formation of calcium silicate structure [3]. An experimental study was carried out on Building Demolished Waste Stabilized Expansive Soil (ES) with Potassium Chloride. For conducting the study, soil samples were collected from Amalapuram in East Godavari District, A.P. The Building Demolished Waste (BDW) consisting of Concrete blocks and bricks were separated from demolition waste materials and were crushed using a sledge and laboratory crusher and it was used in the studies. Various experiments like Compaction, Strength and CBR tests were conducted by replacing different percentages of Building Demolished Waste (viz. 0% to 25% with an increment of 5%) and also further stabilizing it with Potassium Chloride (i.e. KCL) as a binder in expansive soil. The percentage of Potassium Chloride was varied from 0% to 10% with an increment of 2.5%. From the results it was observed that Maximum Dry Density (MDD) increased from 1.5 g/c.c (at 0% BDW) to 1.53 (at 25% BDW) g/c.c, Optimum Moisture Content (OMC) decreased from 26.4% (at 0% BDW) to 23.9% (at 25% BDW) and the soaked CBR value was increased from 3.3% to 6.7% (at 80% ES+20% BDW + 2% KCL). Curing (3,7,14 and 28 days) results on the optimum mix of building demolished waste
stabilized expansive soil with potassium chloride were considered and it was seen that there was significant improvement in Cohesion (168 KPa), Angle of internal friction (10°) and Soaked CBR (8.4%) at 80% ES+20% BDW + 1.5% KCL [4]. Use of Cement Kiln Dust (CKD) 0%, 4%, 8%, 12% and 16% by weight of soil, Quarry Fines (QF) only fractions passing through 4.75mm sieve and Black Cotton (BC) soil was used. Results revealed that CBR strength rather than decreasing produced higher strength gains from 4% for the natural soil to 12% as CKD content increased from 0 to 16% (inclusion of 10% QF) for soaked condition. Based on X-Ray Diffraction (XRD) analysis, the mineralogy was dominated by the presence of montmorillonite clay mineral with some amount of kaolinite clay mineral [5].

4. Material used for present study:

4.1 Black Cotton soil (BC Soil) – stock piled in VBIT college laboratory which was brought from MULUGU District. Basic and Strength property of Black Cotton soil are tabulated in Table 1.

4.2 Concrete Cube & Brick Waste - procured from VBIT college Aushapur village, Ghatkesar. The Concrete Cube & Brick Waste passing 425 micron was used in the present project work. Fines of Concrete Cube Waste (FCCW) and Fines of Brick Demolition Waste (FBDW). Specific Gravity and Bulk Density of FCCW is 2.05 & 1.91 g/cc.

Figure 1: Crushing of Concrete Cube to Fine Particles Size, BC Soil-FCCW mix and BC Soil-FBDW mix

5. Experimental investigations of Native soil and Soil stabilized using FCCW & FBDW

The following laboratory tests were conducted on BC soil and Soil stabilized using FCCW & FBDW:

5.1 Grain size analysis:

Wet sieve analysis was conducted on BC soil as per IS 2720 (Part IV) - 1985. Wet sieve analysis [8] results are tabulated in Table 1.

5.2 Consistency Limits and Indices:

Atterberg limits test [9] which includes liquid limit and plastic limit test is carried out on BC soil as per IS 2720 – Part V - 1985. Liquid limit, plastic limit and plasticity index results for BC soil are tabulated in Table 1 and a Liquid limit of BC soil is shown in Graph 2.
Figure 2: Liquid Limit and Plastic Limit test of Black Cotton Soil.

5.3 Standard Compaction Test for Black Cotton Soil & BC Soil stabilized using FCCW and FBDW:
Standard compaction test \cite{11} was carried out on black cotton soil as per the standard procedure mentioned in IS-2720 (Part VIII):1983. The MDD and OMC result for Black cotton soil is tabulated in Table 2 and the compaction curve is shown in Graph 3. Standard compaction test was conducted on soil treated using FCCW at varying percentages of 20%, 40% and 60% and also soil treated using FBDW at varying percentages of 20%, 40% and 60%.

5.4 Soaked CBR Test for Black Cotton Soil & BC Soil stabilized using FCCW:
Native soil: CBR test \cite{10} was conducted on BC soil as per the code specification IS 2720 Part XVI - 1987. The soil specimens were soaked for 4 days prior to testing. BC soil CBR test moulds were prepared for BC soils bended using FCCW at different percentages of 20%, 40% and 60% with a four days soaking in water before testing.

Figure 3: CBR Test with 4- days soaking & Shear Failure of cylindrical specimen in UCS Test.

5.5 Unconfined Compression Strength Test for Black Cotton Soil & BC Soil stabilized using FCCW:
This test was carried out using a standard procedure with standard dimensions of diameter height in 1:2 ratio \cite{6} were considered while preparing the soil specimen of untreated black cotton soil. The soil specimen of treated black cotton soil by partially replacing the soil specimen of untreated black cotton soil. The soil specimen of treated black cotton soil by partially replacing FCCW at different percentages of 20%, 40% and 60% respectively. The obtained UCS results of treated soil specimens were compared to the untreated black cotton soil for analysis of shear strength.
6. Results and Analysis

6.1 Properties of Black Cotton (BC) Soil

Table 1: Consolidated table for Properties of BC Soil

| Properties                        | Values  |
|-----------------------------------|---------|
| Grain size analysis               |         |
| Gravel (%)                        | 2.17    |
| Sand (%)                          | 1.45    |
| Silt and Clay (%)                 | 96.57   |
| Indian Standard Soil Classification| CH      |
| Specific Gravity                  | 2.16    |
| Liquid Limit (%)                  | 44.82   |
| Plastic Limit (%)                 | 21.95   |
| Plasticity Index (%)              | 22.85   |
| Free Swell Index (%)              | 19.32   |
| Compaction Test-                  |         |
| Standard Compaction               |         |
| MDD, gm/cc^3                      | 1.565   |
| OMC (%)                           | 20.5    |

6.2 Mechanical stabilization of soil by partially replacing the soil using Fines of Concrete Cube Waste (FCCW)

6.2.1 Standard Compaction Test

Table 2: Standard compaction test results of Stabilized BC soil

| Compaction characteristics | BC soil | Percentage of FCCW |
|----------------------------|---------|--------------------|
|                            |         | 20%    | 40%    | 60%    |
| MDD, gm/cc                 | 1.565   | 1.708  | 1.540  | 1.612  |
| OMC, %                     | 20.5    | 19     | 19.5   | 20.3   |

Graph 1: Graphical representation of compaction curve for treated soil
6.2.2 CBR TEST

Table 3: Soaked CBR test results of stabilized BC soil

| Percentage of FCCW | 0%   | 20%  | 40%  | 60%  |
|--------------------|------|------|------|------|
| CBR (%)            | 2.05 | 6.997| 5.497| 4.748|

6.2.3 Unconfined Compression Strength test

UCS (without curing)

Table 4: UCS tests results of native soil and stabilized soils without curing

| Soil specimens               | UCS (kN/m²) |
|------------------------------|-------------|
| BC soil                      | 377.42      |
| BC soil + 20% FCCW           | 1318.55     |
| BC soil + 40% FCCW           | 1266.33     |
| BC soil + 60% FCCW           | 940.88      |

Graph 2: Graphical representation of UCS curve for treated soil.

![Graphical representation of UCS curve for treated soil.](image)

Table 5: Consolidated data of untreated and treated BC soil

| Properties                              | BC soil | Fines of Concrete Cube Waste (FCCW) |
|-----------------------------------------|---------|-------------------------------------|
|                                         | 0%      | 20%       | 40%   | 60%   |
| Standard Compaction Test                |         |           |       |       |
| MDD (g/cm³)                             | 1.565   | 1.708     | 1.540 | 1.612 |
| OMC (%)                                 | 20.5    | 19        | 19.5  | 20.3  |
| CBR TEST                                |         |           |       |       |
| Soaked CBR (%)                          | 2.05    | 6.997     | 5.497 | 4.748 |
| Unconfined Compression Strength Test     |         |           |       |       |
| ZERO-days Shear Strength (kN/m²)        | 377.42  | 1318.55   | 1266.33 | 940.88 |
6.3 Design of flexible pavement:
The design traffic in terms of the cumulative number of standard axles [12] was determined by the following equation:

\[ N = \frac{365 \times \left(1 + r\right)^{n-1} \times A \times F \times D}{r} \]

Where,
- \( N \) = Cumulative number of standard axles to be catered for in the design in terms of msa.
- \( A \) = Initial traffic in the year of completion of construction in terms of the number of Commercial Vehicles per Day (CVPD).
- \( A = P \times (1 + r)^x \)
- \( D \) = Lane distribution factor. \{1 single lane\}
- \( F \) = Vehicle Damage Factor (VDF). \{1.5\}
- \( n \) = Design life in years. \{15 years\}
- \( r \) = Annual growth rate of commercial vehicles in decimal. \{7% i.e. 0.07\}

CBR of the soil is 6.997%. Therefore, the design of flexible pavement as per IRC 37:2012 for the CBR value of 7% (maximum) is as follows:

**For Low-Volume Roads, Let \( A = 300 \) CVPD**
- Thickness of conventional flexible pavement layers is, for \( N = 5 \) msa (CBR Value = 2.05%). Total thickness = 670 mm
- Thickness of soil stabilized using Fines of Concrete Cube Waste (FCCW) for Subgrade layers is, for \( N = 5 \) msa (CBR Value = 7%). Total thickness = 505 mm

**For High-Volume Roads, Let \( A = 1964 \) CVPD**
- Thickness of conventional flexible pavement layers is, for \( N = 32.44 \) msa (CBR Value = 2.05%). Total thickness = 808 mm
- Thickness of soil stabilized using Fines of Concrete Cube Waste (FCCW) for Subgrade layers is, for \( N = 32.44 \) msa (CBR Value = 7%). Total thickness = 625 mm

7. DISCUSSIONS AND CONCLUSIONS
7.1 Using Fines of Concrete Cube Waste (FCCW) as Soil stabilizer
7.1.1 Standard Compaction Test

- **Maximum Dry Density (MDD) g/cc**

Graph 3 (a): Graphical representation of effect on Maximum Dry Density of BC soil stabilized using Fines of Concrete Cube Waste (FCCW)
From the above MDD chart, it can be observed that there is an increase and decrease in trend of maximum dry density of BC soil stabilized Fines of Concrete Cube Waste.

- The MDD of BC soil achieved is 1.565 g/cc
- At 20% FCCW it is 1.708 g/cm³ which increased by 13.56%.
- At 40% FCCW the MDD got increased by only 4.52%.

At 60% FCCW the achieved MDD is 1.612 g/cm³ an increase of 7.18%.

b) Optimum Moisture Content (OMC) %

![OMC Chart](attachment:omc_chart.png)

Graph 3 (b): Graphical representation of effect on Optimum Moisture Content of BC soil stabilized using Fines of Concrete Cube Waste (FCCW)

From the above OMC chart, it can be stated that there in substantial increase in the Optimum moisture content of BC soil stabilized with FCCW compared to an unstabilized BC soil.

- The OMC of BC soil is 20.5%, when it is stabilized with increasing percentage of FCCW it showed a gradual decrease in OMC.
- At 20% FCCW the OMC obtained is 19%.
- At 40% Cement it is 19.5%.
- At 60% dosage of FCCW it increased to 20.3%.

7.1.2 CBR Test (%)

![CBR Chart](attachment:cbr_chart.png)

Graph 4: Graphical representation of effect on CBR value of BC soil stabilized using Fines of Concrete Cube Waste (FCCW)
From the above CBR chart, it can be observed that there is an increase and decrease in trend of CBR value of BC soil stabilized Fines of Concrete Cube Waste.

- The CBR of BC soil achieved is 2.05%.
- At 20% FCCW it is 6.997%, which increased by 70.70%.
- At 40% FCCW the achieved CBR is 5.497% an increase of only 62.71%.
- At 60% FCCW the CBR got increased by 56.82%.

7.1.3 Unconfined Compression Strength (UCS) test

**UCS (kN/m²) of 0-days Curing**

| Percentage of FCCW | UCS, kN/m² |
|--------------------|------------|
| 0                  | 377.42     |
| 20                 | 1318.55    |
| 40                 | 1266.33    |
| 60                 | 940.88     |

*Graph 5: Graphical representation of effect on shear strength of BC soil stabilized using Fines of Concrete Cube Waste (FCCW)*

The unconfined compression strength of stabilized soil increases considerably compared to the unstabilized Black Cotton soil as shown in the above UCS chart after zero-days curing of stabilized soil.

- The initial compression strength of BC soil is less as 377.42 kN/m², so to improve the shear strength of Black Cotton soil it is been stabilized with FCCW of varying percentages.
- It is seen that there was increase in UCS value as the percentage of FCCW increased and later decrease for zero-days curing period.
- At 20% of FCCW the UCS value is 1318.55 kN/m².
- At 40% & 60% it is increased to 1266.33 kN/m² & 940.88 kN/m² respectively.
- Due to increase of particle to particle interaction, there was substantial increase observed in the UCS values of BC soil stabilized with FCCW, but decreased as the percentage of FCCW was increased.

7.2 Using Fines of Brick Waste (FBW) as Soil stabilizer

7.2.1 Standard Compaction Test

a) Maximum Dry Density (MDD) g/cc
Graph 6 (a): Graphical representation of effect on Maximum Dry Density of BC soil stabilized using Fines of Brick Waste (FBW)

From the above MDD chart, it can be observed that there is an increase and decrease in trend of maximum dry density of BC soil stabilized Fines of Brick Waste (FBW).

- The MDD of BC soil achieved is 1.565 g/cc
- At 20% FBW the MDD got decreased by 13.2%.
- At 40% FBW it is 1.538 g/cm³ which decreased by only 2.26%.
- At 60% FBW the achieved MDD is 1.62 g/cm³ an increase of 7.71%.

b) Optimum Moisture Content (OMC) %

Graph 6 (b): Graphical representation of effect on Optimum Moisture Content of BC soil stabilized using Fines of Brick Waste (FBW)

From the above OMC chart, it can be stated that there in substantial decrease and later increase in the Optimum moisture content of BC soil stabilized with FBW compared to an unstabilized BC soil.

- The OMC of BC soil is 20.5%, when it is stabilized with increasing percentage of FCCW it showed a gradual decrease in OMC.
- At 20% FBW the OMC obtained is 19.5%.
- At 40% Cement it is 19%.
- At 60% dosage of FBW it increased to 20%.
8. Conclusions:
From the above discussions made, the following can be concluded

1. The first approach to improve the strength property of Black Cotton soil by adding Fines of Concrete Cube Waste (FCCW) with Black Cotton soil was achieved.
2. The density of the Black Cotton soil also increased with increase in the proportion of FCCW and later decrease. At 20% of FCCW the density was 1.708 g/cm$^3$ and at 40% of FCCW the density was 1.540 g/cm$^3$.
3. The Optimum Moisture Content (OMC) of BC soil was slightly decreased with increase in the proportion of FCCW and later increase.
4. The CBR of Black Cotton soil was 2.05% it is increased to maximum 7% when stabilized the BC soil at 20% of FCCW.
5. The Shear Strength of Black Cotton soil was 377 kN/m$^2$, it is increased to 1318.55 kN/m$^2$ when stabilized the BC soil at 20% of FCCW.
6. However, in the light of studies conducted, the 20% of FCCW is considered as the optimum proportion of the FCCW resulting in maximum strength and performance as observed from UCS test results.
7. The second approach is to improve the strength property of Black Cotton soil by adding Fines of Brick Demolition Waste (FBDW) with Black Cotton soil was evaluated only based compaction characteristics.
8. The density of the Black Cotton soil also increased with increase in the proportion of FBDW and later decrease. At 20% of FBDW the density was 1.702 g/cm$^3$ and at 60% of FBDW the density was 1.62 g/cm$^3$. The Optimum Moisture Content (OMC) of BC soil was slightly decreased with increase in the proportion of FBDW and later increase.
9. However, in the second approach, the 20% of FBDW is considered as the optimum proportion of the FBDW resulting in maximum strength.
10. The design of flexible Pavement approach was evaluated based on IRC: 37-2012 Standards for low-volume traffic and high-volume traffic with respect to the improved CBR value (7%) and observed a reduction in the Thickness of whole pavement structure by 165 mm and 183 mm respectively.
11. The reduction in the Thickness of whole pavement structure will be cost saving.

9. Future Scope:

1. Conducting plate load test on black cotton soil stabilized using concrete and brick waste to determine the performance of sub-grade soil.
2. X-ray Diffraction test to be carried out to know the presence of the mineral montmorillonite in the black cotton soil and calcium mineral in soil stabilized using concrete and brick waste.
3. Upon arriving at the required strength of weak soil, the cost assessment should be carried out for treated soil and compared with untreated soil.
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