Construction of Rural Roads using C&D Waste Materials

S. Saravanan1*, C. Venkatasubramanian2, D. Muthu2 and K. Ramakrishnan2

1School of Civil Engineering, Sastra University, Thanjavur - 613401, Tamil Nadu, India; ersaravanan@outlook.com
2Faculty, School of Civil Engineering, Sastra University, Thanjavur – 613401, Tamil Nadu, India; cv@civil.sastra.edu, dmuthu@civil.sastra.edu, ramakrishnan@civil.sastra.edu

Abstract

Objective: Soil is often weak in sustaining heavier loads. In this study, investigations are made to determine the use of C&D (Construction & Demolition) waste materials in geotechnical applications such as formation and strength improvement of rural roads, and to evaluate the effects of powdered waste bricks & prolonged stored cement in the formation of rural roads. Analysis: The results obtained are made towards the effectiveness and usability of reinforcement as a replacement for pavement works used in rural road execution works as a cost effective approach. Findings: By addition of C&D waste materials in the sub-base layer of the road structure, the conventional laterite layer of rural road formation is further strengthened, quantity of utilization of laterite is reduced and thus leads to cost reduction in road laying. Applications/Improvements: Due to the improvement of the strength in the sub-base layer subsequently the water bound macadam layer which is laid on the top of laterite layer will be stabilized further; thus increasing the life of the rural roads to a certain extent.

Keywords: CBR Test, Construction & Demolition Waste, Rural Roads, Soil Stabilization, Soil Tests, Soil Replacement, Soil Tests

1. Introduction

Every road and railway structure needs a stable embankment to support the pavement and shall equally distribute the forces, applied into the road pavement or railway structure, over the subsoil without exhibiting unacceptably large deformations. When constructing an embankment one should take into account a great number of variable properties of both the construction materials to be applied and the subsoil. The stability of the embankment determines the performance of the overlying road pavement or railway structure. As the embankment consists of soil, in road and railway engineering soil is an essential construction material. The stability of the embankment is influenced by many factors1. 8The most common improvements achieved through stabilization include better soil gradation, reduction of plasticity index or swelling potential, and increases in durability and strength. In wet weather, stabilization may also be used to provide a working platform for construction operations the negative effects of other factors can be limited through a solid structural design and an adequate construction of the road or railway. 9The typical behaviour of this soil under different climatic condition has made construction of road over them, due to considerable volumetric change of this soil9. 2The importance of soil as a highway subgrade lines in the fact that it act as an integral part of road pavement. The soil as a highway subgrade serves the following functions:-

1. To provide an adequate support to the road pavement.
2. To provide stability to the road pavement.
3. To provide good drainage of rain water percolating through the road pavement2.
2. Soil Stabilization

Altering the Properties of Soil is known as Soil Stabilization. It is normally performed by mechanical or chemical methods to acquire a soil material with improved and desired engineering properties. Stabilized Soils develop increase in their strength and durability. Formation of dust particles in the soil can lead to erosion which can be ignored. At same place, the properties of the soil show varied values, the achievement in stabilization of soils depends on testing of soil at varied places. Several methods are applied to obtain a stabilized soil and these methods should be asserted in the laboratory before applying it on the field.

2.1 Principles of Soil Stabilization

• Finding out the soil properties of the area under consideration.
• To get the property of soil which needs to be altered to get the design value and choose the effective and economical method for stabilization.
• Calculating the mix sample for Stabilized soil and testing it in the laboratory for intended stability and durability values.

3. Methodology

Here, in this process, stabilization of soil is carried for the local soil. Construction & Demolition waste materials collected & graded to fit into laboratory experimental procedures. Preliminary Tests on the Reinforced Soil are conducted to examine its index properties, as the main motive of this paper emphasis on finding out whether the partial replacement of soil with construction and demolition waste materials is effective for rural road formations, the primary soil is partially replaced with construction and demolition waste materials in 0-25% Proportions. For every 5% Replacement the reinforced soil sample results are studied in comparison with non-reinforced soil (0% Replacement Soil Sample). Direct Shear Test is Carried out to find the shear parameters of the given soil, UCC gives the Compression strength of the given soil, CBR test is Performed to examine the bearing capacity of soil. With the above test results the necessary test parameters are found out using corresponding formulae. The Optimum Percentage of Replacement is observed from Test Results.

4. Results and Discussions

4.1 Specific Gravity

Table 1. Specific Gravity of the Sample

| Sample Number | 1   | 2   | 3   |
|----------------|-----|-----|-----|
| Weight of empty bottle in kg (w1) | 0.39 | 0.387 | 0.39 |
| Weight of bottle + dry soil in kg (w2) | 0.635 | .660 | .696 |
| Weight of bottle + soil + water in kg (w3) | 1.173 | 1.193 | 1.218 |
| Weight of bottle + water in kg (w4) | 1.040 | 1.044 | 1.052 |
| Specific Gravity | 2.18 | 2.20 | 2.18 |

Average Specific Gravity=2.19

4.2 Standard Proctor Test

Table 2 Standard Proctor Test of the Sample

| Description | Trial 1 (8% WC) | Trial 2 (10% WC) | Trial 3 (12% WC) |
|-------------|----------------|-----------------|-----------------|
| Weight of the mould with the compacted Soil(g) | 5.654 | 5.724 | 5.654 |
| Weight of the Compacted Soil(g) | 2.536 | 2.606 | 2.536 |
| Weight of (Container+ Soil) (g) | 27.45 | 32.36 | 31.21 |
| Weight of empty container (g) | 14.49 | 17.57 | 18.75 |
| Weight of the Soil (g) | 12.69 | 14.79 | 12.46 |
| Maximum Dry Density (g/cc) | 2.12 | 2.204 | 2.08 |

4.3 Particle Distribution Analysis of the Sample

Inferences from Specific Gravity, Standard proctor Test and Sieve Analysis
### Table 1. Particle Distribution of the Sample

| Sieve Size | Mass of Soil Retained (g) | Percentage on each Sieve Retained | Cumulative Percent Sieve Retained | % finer |
|------------|---------------------------|----------------------------------|-----------------------------------|---------|
| 1          | 258                       | 25.8                             | 25.8                              | 74.2    |
| 2          | 164                       | 16.4                             | 42.2                              | 57.8    |
| 3          | 220                       | 22                               | 64.2                              | 35.8    |
| 4          | 148                       | 14.8                             | 79                                | 21      |
| 5          | 142                       | 14.2                             | 93.2                              | 6.8     |
| 6          | 50                        | 5                                | 98.2                              | 1.8     |

**Figure 1.** Direct Shear Test Tabulation with Powdered Brick.

**Figure 2.** Direct Shear Test Sample replaced with Prolonged Cement.
### 4.4 Direct Shear Test

**Table 3. Direct Shear Test Inference**

| Description                              | Powdered Brick                      | Prolonged Cement                  |
|------------------------------------------|-------------------------------------|-----------------------------------|
| For 0% Replacement (160g Soil)           | Unconfined Compressive Strength-93.639<br>Undrained Shear Strength-46.815 | Unconfined Compressive Strength-93.639<br>Undrained Shear Strength-46.815 |
|                                          |                                     |                                   |
| For 5% Replacement (152g Soil+8g Filler) | Unconfined Compressive Strength-70.431<br>Undrained Shear Strength-35.215 | Unconfined Compressive Strength-109.36<br>Undrained Shear Strength-54.68 |
|                                          |                                     |                                   |
| For 10% Replacement (144g Soil+16g Filler)| Unconfined Compressive Strength-157.17<br>Undrained Shear Strength-78.59 | Unconfined Compressive Strength-166.38<br>Undrained Shear Strength-83.19 |
|                                          |                                     |                                   |
| For 15% Replacement (136g Soil+24g Filler)| Unconfined Compressive Strength-122.95<br>Undrained Shear Strength-61.475 | Unconfined Compressive Strength-159.6<br>Undrained Shear Strength-79.8 |
|                                          |                                     |                                   |
| For 20% Replacement (128g Soil+32g Filler)| Unconfined Compressive Strength-97.25<br>Undrained Shear Strength-48.63 | Unconfined Compressive Strength-128.99<br>Undrained Shear Strength-64.5 |
|                                          |                                     |                                   |
| For 25% Replacement (120g Soil+40g Filler)| Unconfined Compressive Strength-97.25<br>Undrained Shear Strength-48.63 | Unconfined Compressive Strength-128.99<br>Undrained Shear Strength-64.5 |

### 4.5 Unconfined Compression Test

**Table 4. UCS Test Result of the Samples**

| Description                              | Powdered Brick                      | Prolonged Cement                  |
|------------------------------------------|-------------------------------------|-----------------------------------|
| For 0% Replacement (160g Soil)           | Cohesion-1.2<br>Angle of Internal Friction-60°15′ | Cohesion-1.2<br>Angle of Internal Friction-60°15′ |
|                                          |                                     |                                   |
| For 5% Replacement (152g Soil+8g Filler) | Cohesion-1.8<br>Angle of Internal Friction-60°15′ | Cohesion-2.7<br>Angle of Internal Friction-68°11′ |
|                                          |                                     |                                   |
| For 10% Replacement (144g Soil+16g Filler)| Cohesion-6<br>Angle of Internal Friction-45° | Cohesion-5.2<br>Angle of Internal Friction-65°33′ |
|                                          |                                     |                                   |
| For 15% Replacement (136g Soil+24g Filler)| Cohesion-10<br>Angle of Internal Friction-55°15′ | Cohesion-6<br>Angle of Internal Friction-60°15′ |
|                                          |                                     |                                   |
| For 20% Replacement (128g Soil+32g Filler)| Cohesion-6<br>Angle of Internal Friction-60°15′ | Cohesion-3<br>Angle of Internal Friction-61°23′ |
|                                          |                                     |                                   |
| For 25% Replacement (120g Soil+40g Filler)| Cohesion-0.8<br>Angle of Internal Friction-33°41′ | Cohesion-0.7<br>Angle of Internal Friction-30°15′ |
• For Specific gravity of range <2.6, Soil will be of Organic type.
• And so our sample is an Organic Soil.
• For Coefficient of Uniformity Cu>5.5 and Coefficient of Curvature<3, According to ISSCS, Sample is Well Graded.
• From the Standard Proctor Test, the maximum density of 2.204 g/cc is achieved at 10% of Moisture Content.

4.6 California Bearing Ratio Test Results

For the Sample without any Replacement,
CBR of the sample at 2.5mm
Penetration = 2.7%
CBR of the sample at 5mm
Penetration = 2.3%
CBR of the sample = 2.7%

For the Sample with 10% Replacement with Powdered Brick,
CBR of the sample at 2.5mm
Penetration = 3.5%
CBR of the sample at 5mm
Penetration = 3.6%
CBR of the sample = 3.6%

For the Sample with 10% Replacement with Prolonged Cement,
CBR of the sample at 2.5mm
Penetration = 22.22%
CBR of the sample at 5mm
Penetration = 23.84%
CBR of the sample = 23.84%

6. References

1. Soil Stabilization. Available from: http://www.citg.tudelft.nl/fileadmin/Faculteit/CiTG/Over_de_faculteit/Afdelingen/Afdeling_Bouw/_Secties/Sectie_Weg_en_Railbouwkunde/-_Leerstoelen/Leerstoel_Wegbouwkunde/-_Onderwijs/-_College_Dictaten/doc/CT3041_UK_Hoofdstuk_1.pdf. Date accessed: 05/04/2016
2. Functions of Soil. Available from: http://civilengineeringtraining.blogspot.in/2012/12/what-is-soil-functions-of-soil-subgrade.html. Date accessed: 05/04/2016
3. The need for soil stabilization. Available from: http://www.contracostalandscaping.com/the-need-for-soil-stabilization/. Date accessed: 09/04/2011
4. Methods of soil stabilization. Available from: http://www.engineeringtraining.tpub.com/14070/css/14070_424.htm. Date accessed: 24/12/2010
5. Sen A, Kashyap R. Department of Civil Engineering, National Institute of Technology Rourkela. Soil Stabilization Using Waste Fiber Materials.
6. Rafalko SD, Brandon TL, George M. Filz. Virginia Polytechnic Institute and State University Blacksburg, Fiber Reinforcement for Rapid Stabilization of Soft Clay Soils. 2006 Nov.
7. Aalok D, Sakalkal GD, Kedar Dhawale RS. Experimental Study On Stabilization Of Black Cotton Soil By Fly Ash, Coconut Coir Fiber & Crushed Glass. International Journal of Emerging Technology and Advanced Engineering. 2014 Nov.
8. Ramaji AE. School of Civil Engineering, Universiti Sains Malaysia, 14300 Nibong Tebal. A Review on the Soil Stabilization Using Low-Cost Methods, Penang, Malaysia. Journal of Applied Research. 2012; 8(4):2193–6, ISSN 1819-544X.
9. Zafar Eqyaabal AMD, Ambica A. Construction of a Road in the Black Cotton Soil Using Fly Ash. Indian Journal of Science and Technology. 2015 Nov; 8(32).