

EXPERIMENTAL EVALUATION OF COIR MATS TO ENHANCE THE WEAK SUBGRADE SOIL UNDER REPEATED LOADING CONDITION

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Received 9 November 2017; accepted 5 January 2018

Abstract: The performance and service life of the Low-volume roads (LVRs) largely depends on the properties of the subgrade and sub-base soil. The settlement, compressibility and bearing capacity characteristic of the LVRs associate with subgrade soil strength. The low shear strength subgrade soil poses several problems to the pavement service life. Such soil is known as block cotton (BC) soil. The properties of BC soil are high swelling shrinkage, low bearing capacity and high settlement. The construction of pavement over such soil poses rutting fatigue and reflecting cracks to the pavement. To prevent this problem of pavement many of the conventional techniques were adopted and reported their benefits for improving the service life of the pavement. But these techniques are not possible in all the case, than alternate stabilization methods are introduced by using the geosynthetic in pavement form the past few decades. The stabilization of pavement using the geosynthetics has gained universal promises to improve the service life of the pavement from the last four decades. In the present study, focus on the application of coir geotextile mats to improve the bearing capacity, reduce the settlement characteristic and the maintenance cost of LVRs over the weak subgrade soil.

Keywords: coir geotextile, subgrade, sub-base, reinforcement, separation, wheel tracking test.

1. Introduction

The reinforcement of soil mass in transportation and geotechnical area inserted with the fiber materials to improve its mechanical behavior has become popular. The primary function of reinforcement to the weak subgrade soil is to improving the stability of the pavement, by reducing the settlement and lateral deformation. The reinforcement or stabilization of pavement using the geosynthetics significantly increases the resistance of the pavement in terms of improving the bearing capacity of the weak subgrade soil. The deformation or rutting of the pavement without stabilization

with geotextile significantly increases than compare non-stabilization of weak subgrade. The separation function of geotextile is more significant than the geogrid (Brandon *et al.*, 1996).

The reinforcement of soil elements using the sheets, strips, rubber, and fiber is Asian techniques to stabilization of the weak subgrade to improve the service life of the LVRs. The performance of the pavement improved by insert the tensile element in the form of geotextile, which are abundantly available and widely used in many countries. These materials are locally available with low cost. In the present study, an attempt

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is made to use the coir mats over the weak subgrade to enhance the bearing capacity at suitable position with appropriate sub-base soil to improve the life of the pavement with low maintenance cost.

2. Literature Review

The expansive soil subgrade experience several problems in the form of rutting, heaving and reflection due to their inherent volume change behavior upon wetting and drying condition (Brian *et al.*, 2001; Arafat *et al.*, 2015). Despite favorable properties of geosynthetics for their use in pavement construction, they proved to be cost effective especially for low volume roads (Yang *et al.*, 2007). During past few decades, geosynthetics have gained universal attention across all possible types of soil subgrade either to overcome the subgrade deficiency or to enhance permanent life and performance (Al-Qadi *et al.*, 2011; Ferrotti *et al.*, 2011; Zornberg *et al.*, 2009; Chaple *et al.*, 2013) The study evaluate the reinforcement parameter of the coir geotextile in the laboratory using model tests on square footings supported on highly compressible clayey soil, effects on bearing capacity and settlement of the footing with provision of coir geotextile with adding of coir 0.25%, 0.5%, 0.75% & 1.0% to the thickness of reinforced layer. The study revealed that the provision of coir reinforced layer significantly increase the bearing capacity of clay soil and the ultimate bearing capacity of reinforced section shown the better performance. (Mali and Singh, 2014) an attempt is made in the laboratory to study the behavior of cohesive soils reinforced with coir fibers, polypropylene fibers and scrap tire rubber fiber by the triaxial, direct shear and unconfined compression tests. The results are made

as follows; the optimum fiber content 1%, the shear strength of polypropylene is found to be 0.4%, and optimum fiber length and fiber content are 10 mm and 2% respectively. (Durga Prashanth *et al.*, 2012) conducted study to evaluate the deformation of reinforcement and un-reinforcement of model layer with accelerated pavement test over the problematic soil. Such soil is noticed that the BC soil content clayey and silty. The study found that the provision of coir mats improves the reinforcement, separation, filtration function of pavement. (Jairaj *et al.*, 2013) study is carried out in the laboratory to reinforce the black cotton soils by using the coir geotextile with the help of Undrained triaxial. The present study, concluded that the reinforcement increases peak compressive strength, shear strength, and ductility. Increase in length of coir fiber increases cohesion and angle of internal friction. Increase in the fiber content beyond 2% poses mixing difficulty as soil lumps are formed during mixing this has led to decrease in peak shear strength. The study investigated that the polymeric geocell improves the performance of the unpaved roads over the poor subgrade, quarry dust shown the better performance than the other materials (Pokharel *et al.*, 2011). To Studied the performance of the geo-grid reinforcement, indicates that the use of Geosynthetics in pavement over the poor subgrade soil tends to reduce the Sub Base thickness with increasing traffic volume (Adams *et al.*, 2014). To addressing the problem of pavement, to prevent this problem this study is examine the coir geotextile mats can be effectively serves as reinforcement, separation, drainage materials over the weak subgrade soil for LVRs. The study is conducted under moving loading condition in the laboratory, to correlate the filed study by accelerated pavement test track (APT).

3. Materials Used for the Study

To conduct the study in the laboratory black cotton soil is collected from the lake which

is near to the NIT Warangal and used as a subgrade soil. The basic properties of BC soils are determined in the laboratory and given in Table 1.

Table 1

The Basic Properties of BC Soil

The Property of BC soil	Value
Classification	CH
Liquid limit (%)	58
Plastic limit (%)	27
Plasticity index (%)	34
Specific gravity	2.62
Optimum Moisture Content (%)	17
Max dry density (gm./cc)	1.7
Free Swelling Index (%)	77
Un-soaked CBR value (%)	9
Soaked CBR value (%)	1

Generally morrum soil is commonly used materials in roads construction. The two types of the sub-base soil are considered in

the present study such as morrum soil and uniformly grade sub-base soil. The properties of the sub-base soil are given in Table 2.

Table 2

The Basic Properties of BC Soil

The Properties of sub- Base materials	Sandy Gravel	Morrum
Optimum Moisture Content (%)	8.0	10.0
Maximum Dry Density(MDD)	1.87	1.94
Shear strength parameter (C and ϕ)	0, 31°	5, 34°
Un Soaked CBR (%)	13	21
Soaked CBR (%)	6	9

The coir geotextile is naturally available material extracted from the husk of coconuts. It is strong in the nature and high durability as compared

with other natural material, it can spun and woven into matting. The basic properties of coir geotextile are presented in Table 3.

Table 3*The Basic Properties of Coir Geotextile*

Basic Properties of the coir	Values
Length (mm)	15-20
Density (g/cc)	1.15-1.4
Breaking elongation (%)	30
Diameter (mm)	0.1-1.5
Specific Gravity	1.15
Rigidity modulus (dynes/cm)	1.8924
Swelling in water (%)	5
Young's modulus (GN/m ²)	4.5
Specific heat	0.27

In the present study, three types of coir geotextile mats are used which are shown in Fig. 1. Namely,

CC=Coir Composite, WCM= Woven Coir Mat and NWCM= Non-Woven Coir Mat.

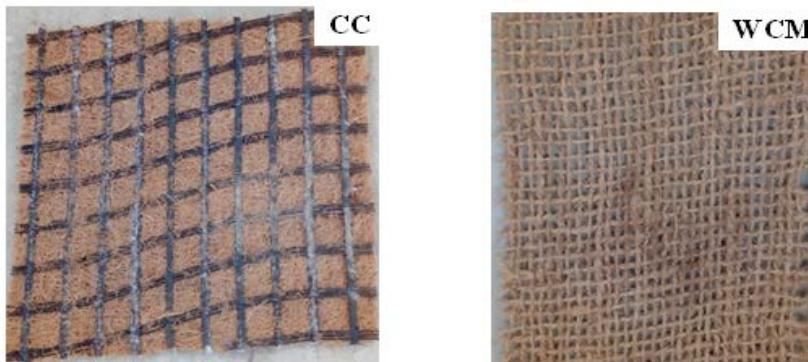


Fig. 1.
Coir Mats used in the Present Study

4. Experimental Setup

The Wheel Tracking Test apparatus (WTT) are used for this investigation with varying contact pressure of moving load to simulate the field condition. It was developed by British National Rail Road Research Institute (generally used for measuring the plastic deformation of bituminous asphalt concrete). The WTT apparatus height of the loading

lever has been raised using the fabricated angle sections. The fabricated angles are controlling the enable to the loading onto pavement model section. The maximum load applied on to the pavement has 55 Kg, through the moving wheel of diameter 200mm, width of 50mm made of solid rubber. To run the wheel over the model section three phase motor with 75kw, 400v power motor is used. The experimental setup is show in Fig. 2.



Fig. 2.
Experimental Setup used for the Study

5. Results and Discussion

The laboratory study is performed using the fabricated mould of size 300mmx300mmx300mm. The fabricated mould was prepared as a two-layer pavement model system as per the modified CBR protocol.

The coir mats are placed between the subgrade and sub-base at a height of H/2, H/3 and H/4 position. The two types of the coir mats were used as reinforcement material. The model layer as compacted as subgrade and sub-base of BC soil and sandy gravel soil respectively, tested by using the WTT apparatus.

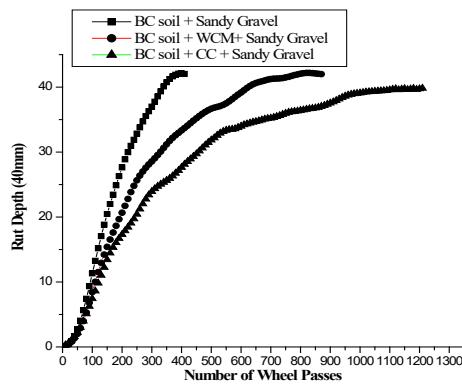


Fig. 3.
Rut Depth along with Number of Wheel Passes at H/2 Position

The laboratory study is conducted, in order to determine the deformation of reinforced and un-reinforced model layer at H/2 position of fabricated mould. The unreinforced model layer higher deformation occurs at lower repetition than the reinforced model layer. The higher repetition (1250) is

noticed with CC materials at H/2 position. The un-reinforcement pavement layer showed the 350 repetition. In that case higher the thickness of sub-base material is placed over the coir mats. The rut depth along with the number of wheel passes at H/2 is shown in Fig. 3.

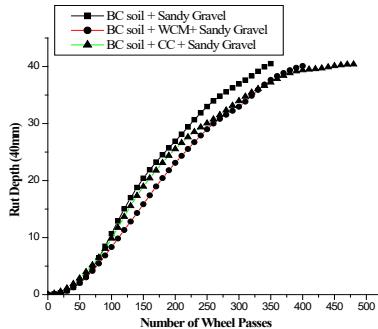


Fig. 4.

Rut Depth along with Number of Wheel Passes at H/3 Position

In this case, the coir mats are placed in between the subgrade and sub-base at a height of H/3 position with reducing the thickness of sub-base soil than the H/2 position. At this particular location the failure are noticed in sandy gravel sub-base soil, due to its lower shear strength C and ϕ are 0 and 31°

respectively. The strength of the sub-base soil greatly influences the load distribution over the subgrade. The maximum repetition are 480 occurs at this position with the CC materials higher than the WCM. The rut depth along with number of wheel passes at H/3 position shown in Fig. 4.

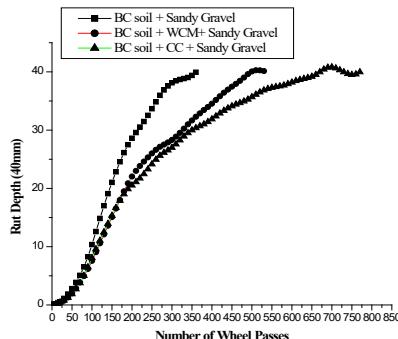


Fig. 5.

Rut Depth along with Number of Wheel Passes at H/4 Position

The fabricated mould was prepared with provision of coir mats at H/4 position while reducing the sub-base soil thickness and measured the deformation of the prepared mould. The 40mm deformation is noticed for maximum repetition 840 of CC coir mats at H/4 position. The reinforce model layer repetition are more significant than the un-reinforced model layer. In this case the provision of coir mats acts as more effective in tension member and transferred towards the edge of the pavement. The provided coir mats at H/4 position near to the wheel load is more significant to transfer the load coming from the top of the sub-base layer. Due to this phenomenon, the load and stress over the over the weak subgrade is

reduced and improved the repetition and performance of the LVRs. The rut depth and number of wheel passes at H/4 position given in Fig. 5.

Similarly, the fabricated mould was prepared with inclusion of coir mats at H/2, H/3 and H/4 position in between subgrade and sub-base soil. The test is performed in the laboratory, to determine the appropriate placement position of coir mats with suitable types of sub-base soil. The pavement model layers were prepared with the BC soil as subgrade and morrum soil as sub-base with and without reinforcement of coir mats. The deformation of the fabricated mould is noticed along with their wheel passes.

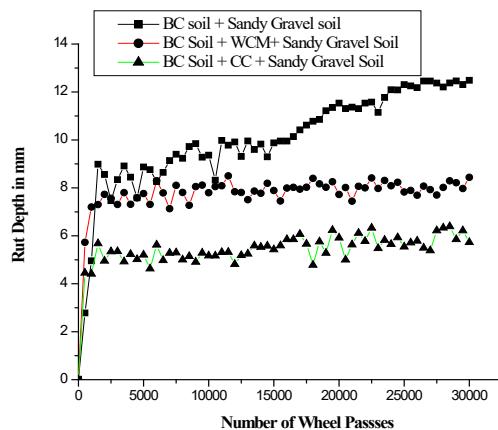


Fig. 6.
Rut Depth and Number of Wheel Passes at H/2

The study was carried out in the laboratory in the form of two-layer model system. The pavement layer, the coir mats are placed at H/2 position with morrum soil sub-base. The deformation of the reinforced and unreinforced model layer noticed for T1 traffic categories ($T1=30,000$). During the study it was noticed that the provision of coir mats

with well graded morrum soil increase the repetition and reaches up to T1 traffic categories. The deformation or rut depth of the un-reinforced sample is 15mm and the reinforced sample 4mm was noticed. The provided CC mats reduce the deformation up to 11mm. The rut depth and number passes at H/2 position is shown in Fig. 6.

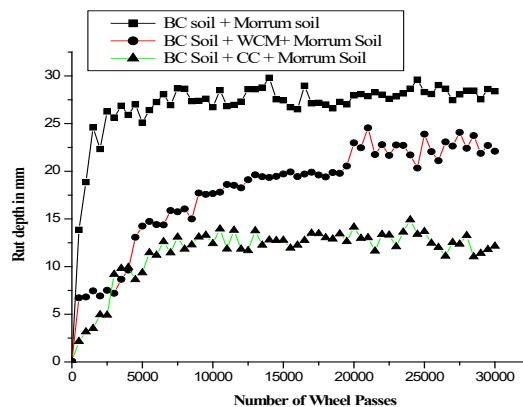


Fig. 7.
Rut Depth and Number of Wheel Passes at H/3

From the test it was observed that the maximum and minimum rutting of unreinforcement two-layer model section occurs at a position of H/3 position are 27mm and 8 mm respectively. The reinforcement pavement model layer with CC mats at H/4 with reducing the thickness of the morrum sub-base soil reduces the deformation and increases the repetition.

The minimum rut depth of coir mats are occurs at h/4 position with CC. In case of morrum as a sub-base soil, the provision of CC, WCM and NWCM mats are shown the less rutting when compared with sandy gravel soil. Increasing the thickness of the sub-base soil materials reduce the rut depth. Rut depth and number of wheel passes at H/3 at position is shown in Fig. 7.

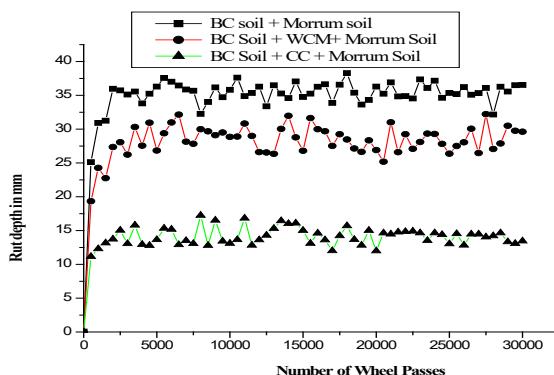


Fig. 8.
Rut Depth and Number of Wheel Passes at H/4

The two-layer model pavement system was prepared in order to reduce the thickness of the sub-base soil and the coir mats are provided at H/4 position. The maximum and the minimum rut depth of reinforced and un-reinforced model layer deformation are noted as 37mm and 11 mm respectively. The un-reinforced model layer rut depth at H/4 position shown in Fig. 8. The inclusion of coir mats in between subgrade and sub-base with sub-base as a morrum soil showed the better performance than compared with the sandy gravel soil. From experimental study were concluded that the higher thickness of coir mats helps to settle the pavement section slowly. The placement of the coir geotextile mats with well-graded soil increases the performance and service life of the pavement structure.

6. Conclusion

In the laboratory, the comparison study between the two types of fabricated mould with two types of varying thickness of sub-base has been down. The following conclusions are drawn from the study.

- The maximum repetition were found with morrum soil with reinforcement of coir composite mate with minimum deformation 13mm with reducing the sub-base thickness at H/4 position;
- The reinforcement and un-reinforced pavement model layer reaches the T1 traffic categories with morrum soil with varying deformation, which not occur in case of sandy gravel soil with increasing the sub-base thickness due its low shear strength parameter C and ϕ ;
- The coir composite material acts as reinforcement and separation material in both the case of soil, the WCM gives the less reinforcement than the CC and also fails in provide the separation function;

- The coir geotextile are need to place near to wheel load so that it can carry the maximum load and transferred away from the subgrade. It can reduce the subgrade deformation and improved the pavement service life.

The observation made as a part of this work will have an important to use the naturally available materials for the construction of LVRs over weak sub-grade soil. The coir mats can be effectively used since the fiber allows pore water pressure to dissipate easily when subjected to overburden pressure.

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