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An Investigation on Pavement Shoulder Treatment using Coir Fiber

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ABSTRACT: Pavement shoulder is an integral component of roadway which serves a number of functions in a roadway. It acts as emergency lane and carries a huge number of traffic wheel loads. Also it provides support to the pavement section laterally. But in many roads, pavement shoulders are remained unmaintained and untreated, which leads to different severe pavement failures. A number of rut deflections are observed in the shoulder sections which further leads to a severe shoulder drop. An untreated shoulder reduces the performance of overall roadway. So, it is necessary to strengthening the shoulder section for getting a better road network. In the present study, an attempt is taken to treat the existing earthen shoulder with natural coir fiber. Some laboratory experiments are conducted to evaluate the stability of existing untreated and coir fiber treated shoulder subgrade samples. Soaked and Un-soaked CBR tests are conducted to determine the load carrying capacity of the shoulder samples. Again Wheel Tracking Test is conducted on the treated and untreated shoulder subgrade samples to measure the rut deflection under cyclic wheel load. A huge reduction is observed in rut deflection, by treating the shoulder subgrade section using coir fiber. The subgrade stability can be increase by 24.1% and rut deflection can be minimized by 19.4%, for coir fiber treated shoulder sample.

Keywords: Coir fiber, CBR, Pavement Shoulder, Subgrade, Rut deflection, Wheel Tracking Test.

Abbreviations: MDD, Maximum Dry Density; OMC, Optimum Moisture Content; CBR, California Bearing Ratio.

I. INTRODUCTION

Pavement shoulder plays an important role on overall road performance. It acts as emergency lane, temporary parking plot, pedestrian passage, and also it supports the pavement structure laterally. But in most of the roads, pavement shoulders are not maintained properly. In many roads, there are not enough spaces provided for shoulder which has a vital role on overall road performance. Rodnyansky *et al.,* (2019) explained the poor condition of road network in urban area [18]. They analyzed some theoretical solutions of these problems. Again, it is observed that very often the traffic wheels are moving along shoulder sections and the shoulder materials are failing to carry the wheel loads; and thus severe shoulder drops are forming.

These shoulder drops are further causing edge failures and other types of pavement failures. Pavement edges are deteriorating abruptly, which results a high edge breaking, shoulder drop, surface de-lamination etc. The total bituminous surface layers are damaging which are further reducing serviceability, increasing roughness and causing severe accidents. A no's of researches are found which explains the effect of shoulder section on accident rate [8, 9, 16].

Therefore it is required to minimize these kinds of failures to increase the performance of the roads. In a developing country, it is not possible to construct a paved shoulder in all the roads of the country due to limited financial support. Therefore, a proposal may be place to modify the existing shoulder to a stiff and stable shoulder, and evaluate its acceptability [3,19].

In the present study, subgrades of the shoulder sections are treated with coir fiber, to increase the strength and stability of the shoulder section. Coir fiber is easily available in most of the countries at a very low cost. It exhibits a great tensile strength and act as soil reinforcement and improves the stability of the subgrade soil [7, 15, 20, 24]. 4% coir fiber is considered to add with the existing shoulder subgrade soil sample, after conducting a number of laboratory experiments. The load carrying behavior of the treated and untreated shoulder subgrade samples are evaluated by laboratory soaked and un-soaked CBR (California Bearing Ratio) tests. MDD and OMC values are also determined in laboratory, through standard proctor test.

As the pavement shoulder acts as emergency lane, the shoulder subgrades are subjected to carry a huge traffic wheel load. These wheel loads applied on the shoulder sections, occur a severe rut deflection. So, it is necessary to check the stability of the treated shoulder subgrade samples under wheel load. Different investigations are conducted to mitigate rutting in pavement section [6, 21, 22]. But it is required to reduce rutting in shoulder sections also. In this regard, laboratory Wheel Tracking Test is conducted to evaluate rut deflection for untreated shoulder section. Variations of rut deflection per cyclic wheel loads are also measured for coir fiber treated shoulder subgrade samples. According to the results found from the tests, it is observed that, the stability of the shoulder subgrade may be increase by 24.1% by treating the shoulder section using coir fiber. The rut deformation also decreases by 19.4% for the coir fiber treated the shoulder sections.

II. BACKGROUND STUDY

For a number of years, a number of observations and analyses have been conducting to evaluate pavement failures, to determine pavement performance index, to minimize rutting and creaking on pavement structures, to enhance the stability of pavement structures etc. [2, 4, 5, 13, 14, 17]. Leiva-Villacorta *et al.*, (2017), have explained a number of equations to analyse pavement permanent deformation which depends on several factors like, no of load cycles, ambient temperature, tire pressure materials modulus of resilience etc. They also established an equation to correlate permanent deformation and deflections from various pavement auscultation data [14]. Safwat and Hassan (2014) have predicted rut formation in asphalt concrete under traffic loading. They have used theoretical visco-elastic approach to study rut behavior under wheel load and tire pressure [21].

Several investigations have been going on for years, for improving strength and stability of subgrade soil using different kinds of natural fibers. Upadhyay and Singh (2017) have worked with coir fiber to increase soil stability. They have evaluated the strength parameters of different proportions of coir fiber with a soil sample [24]. Maurya *et al.*, (2015) has used coir fiber to review the, benefits, advantages and applications of coir fiber as soil reinforcement material. They have successfully published some scientific data in support of the above [15].

Most of the literatures are found to study pavement performance only, when pavement shoulder has a great impact on overall road performance [12]. A very few research works are based on pavement shoulder performance. Mohammad. Mohammad and Moahammad (2008) have conducted finite element analysis and Kenlayer computer program to evaluate shoulder thickness and width [16]. Gowda and Shivananda (2018) conducted a case study on maintenance of road shoulder. They have identified some shoulder failures and recommended some maintenance strategies [8]. But these researches are not experimentally justified.

In this paper a new aspect of improving pavement performance is introduced i.e. by modification of pavement shoulder sections using natural fibers. As the shoulder section supports and strengthens the pavement edges laterally, the stiffer sections will provide more stability to the pavement edges. Therefore it may be recommended to modify the shoulder section to improve overall pavement performance.

III. SCOPE AND OBJECTIVES

According to the literatures, it is found that the stability of subgrade soil may be increased by using Coir fiber. Therefore, the recent work focuses on the modification of shoulder section using coir fiber. A treated shoulder will help in increasing the stability of pavement shoulder subgrade, which will further help in increasing the performance of pavement section by reducing edge failure. Based on this scope, following objectives are drawn for this present study.

– To treat the shoulder subgrade using coir fiber.
– To analyze different strength parameters of the treated soil samples.
– To measure the rut deflection under wheel load using laboratory wheel tracking apparatus for the treated and untreated shoulder subgrade samples.
– To compare the stability of treated and untreated shoulder subgrade samples.

IV. MATERIALS OVERVIEW

A. Subgrade Soil

The stability of existing shoulder subgrade is evaluated. The sample is collected from local rural roads. The general physical properties of the existing shoulder subgrade soil samples are evaluated through some laboratory experiments and tabulated in Table 1.

Table 1: Physical Properties of existing shoulder subgrade soil.

Physical properties	Experimental data
Specific Gravity	2.6
Sand Particles (4.75mm-0.075mm, %)	4.79
Silt Particles (0.075mm-0.002mm, %)	38.43
Clay Size (≤0.002mm, %)	56.78
AASHO Classification	A-6
Group	Silty-Clay
Liquid Limit (%)	51
Plastic Limit (%)	28
Plasticity Index (%)	23
Plasticity	High Plastic

B. Coir Fiber

Now a day, coconut coir has become a widely used geo fiber and it has a significant effect on soil subgrade stabilization. They are easily available, cheap, eco-friendly and having a decomposition period of around 20 years. In different countries, a number of construction works are already incorporated with coir fiber in designing flexible pavement. The fibers are fully coated with bitumen to increase their longevity (Fig. 1). General physical properties of the non woven type coir fiber, used in the present work are listed in Table 2.

Fig. 1. Bitumen coated coir fiber sample.

Table 2: Physical Properties of coir fiber.

Properties	Coir Fiber
Diameter (mm)	0.2 mm
Length (cm)	2 cm
Specific Gravity	1.32
Density (gm/cc)	1.55 gm/cc
Water absorption (%)	61%

V. LABORATORY EXPERIENTS ON TREATED AND UNTREATED SHOULDER SUBGRADE SAMPLES

The load carrying behavior of the pavement shoulder materials are evaluated through laboratory experiments and the quantity of materials to be added with existing soil sample is also calculated by some experimental process. Standard proctor test is conducted as per ASTM D698-07 to determine MDD and OMC values of the treated and untreated shoulder subgrade samples [1]. Soaked and Un-soaked CBR test is conducted as per IS: 2720 (Part-16)-1979 to evaluate the bearing capacity of the treated and untreated shoulder subgrade samples [10]. It is experimentally found that coir fiber is required to add by 4% of total weight of existing soil sample, to obtain the optimum stiff and stable mix sample. The graphs of soaked and un-soaked CBR tests of the bitumen coated coir fiber mixture and are presented in Fig. 2 and 3. The average values of MDD; OMC; Soaked and Un-soaked CBR test, observed for three sets of each tests are tabulated in Table 3.

Table 3: Experimental Results of Treated and Untreated Samples.

Subgrade Samples	Untreated Sample	Treated Sample
MDD (gm/cc)	1.6	1.52
OMC (%)	16.9	19.4
Soaked CBR (%)	4.5	7.35
Un-soaked CBR (%)	8.25	11.92

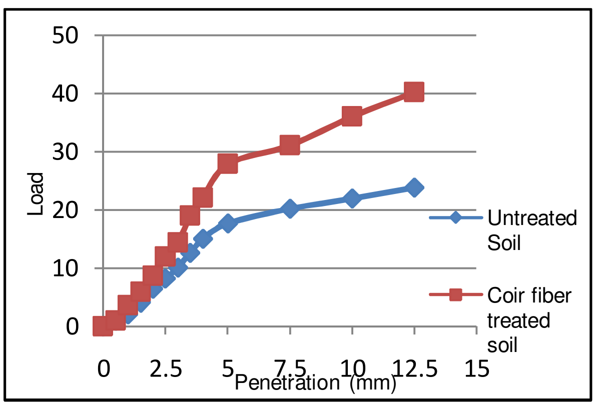

Fig. 2. Variation in Un-soaked CBR Test for treated and untreated subgrade samples.

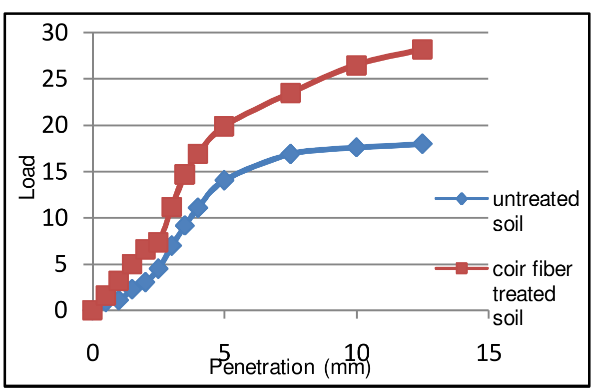

Fig. 3. Variation in Soaked CBR Test for treated and untreated subgrade samples.

VI. WHEEL TRACKING TEST ON TREATED AND UNTREATED SHOULDER SUBGRADE SAMPLES

The rut deformations are evaluated for all samples using laboratory wheel tracking apparatus. The wheel load having 0.7 KN, which simulates 0.56 MPa, is passed on the sample surface. The wheel is passed at a speed of 52 rpm. Each sample is subjected to 10000 wheel passes and corresponding rut deformations are recorded. Here one load cycle represents two passes on the wheel in Wheel Tracking Apparatus. Thus total 5000 cycles are operated through the instrument.

It is observed that, the amount of deflection under same wheel load is more for the existing untreated shoulder subgrade condition and it decreases by 19.4% for coir fiber stabilized subgrade soil sample. Similarly stability value also increases by 24.1%, for the treated shoulder sections. The result is shown in the Table 4 and the graphs representing the deflection vs. number of cycles are shown in Fig. 4.

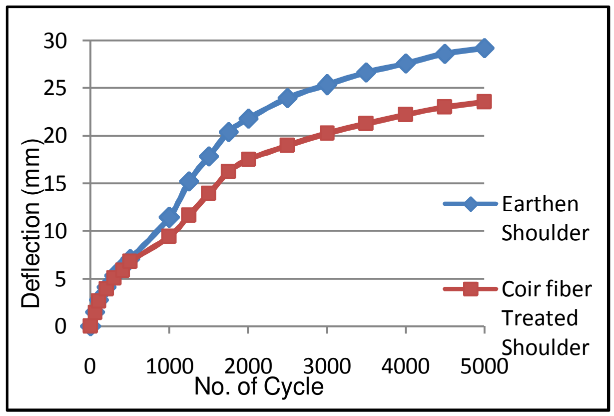

Fig. 4. Wheel Tracking Test.

Table 4 : Variation in rut deflection for treated and untreated shoulder subgrade samples.

Time (min)	Cycle	Rut Deflection (mm)	
		Untreated Shoulder	Treated Shoulder
0	0	0	0
0.5	50	1.515	1.41
1	100	2.73	2.595
2	200	4.14	3.885
3	300	5.31	5.055
4	400	6.21	5.865
5	500	7.08	6.78
10	1000	11.4	9.405
15	1250	15.18	11.655
20	1500	17.82	13.905
25	1750	20.4	16.2
30	2000	21.81	17.49
35	2500	23.91	18.96
40	3000	25.32	20.22
45	3500	26.61	21.24
50	4000	27.54	22.2
55	4500	28.56	22.98
60	5000	29.19	23.52
Reduction in Deflection		—	19.4%
Stability (passes/mm)		342.58	425.17
Increase in Stability		—	24.1%

VII. DISCUSSION

It is known to all that, pavement shoulder provides emergency lane to the road users and also it provides lateral stability to pavement structures. As per IRC: SP:20:2002, shoulder section should be compacted and maintained as same as pavement section [11]. But, due to improper maintenance of the shoulder section, a huge number of rut deflections are observed in the shoulder sections [23]. Often the wheel track is dislocating from the pavement black top portion and directly applying loads on shoulder subgrade section causing a severe shoulder drop which is forming a support-free, pavement section. Consequently, when the wheels are passing through these free edges repeatedly, the lateral thrust makes the edges weaker and after a certain period the edges collapses [16]. In the present analysis, the shoulder sections are modified with coir fiber, which acts as soil reinforcement and increases the load carrying capacity of shoulder subgrade section. Therefore, the stability under wheel load is found to be increased for the coir fiber treated shoulder subgrade samples.

VIII. CONCLUSION

Pavement shoulder sections are treated using coir fiber to make it more stiff and stable and to minimize rut deflection under wheel load, in shoulder section and also to increase overall pavement performance. Therefore, the concluding remarks may be drawn as, to replace the existing untreated pavement shoulder with coir fiber treated shoulder. As per laboratory cyclic wheel load test, the surface deflection can be minimized by 19.4% after treating the shoulder structures using 4% bitumen coated coir fiber. Again, the stability is increased by 24.1% for this treated sample.

IX. FUTURE SCOPE

Some future recommendations of this present work may be suggested as per the following points:

– The strength parameters of the treated shoulder can be evaluated by means of some dynamic cyclic load.

– The present work can extend for overall improvement in the performance of a road.

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Conflict of Interest. Nil.

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