Study on Influence of Coir Geotextile and Bitumen Content on Shear Resistance of Bituminous Overlays

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Abstract - An experimental program was designed to study the effects of coir geotextiles in shear resistance characteristics of asphalt overlays. The objective of this study was to quantify the effects of coir geotextiles inclusion as inter layer in improving shear resistance of contact layers. Flexible pavements are complex structures consisting of several layers of asphalt and granular materials. This pavement layers including overlays are subjected to tangential force and there is a chance of slipping of layers and which will induce parabolic crack and heaving. This is predominant especially in the case of braking, overtaking zones, intersections and grade separations. Non-linear mechanical behaviour of the pavement materials combined with the randomness in traffic and environmental conditions complicate the issue. Coir geotextiles introduced at the interface of existing damaged surface and overlay found to improve the adherence between layers. The shear resistance is also sensitive to amount of tack coat content. Research also revealed inclusion of coir geotextiles as interlayer in the overlay showed increase in shear resistance and is also dependent on the type of geotextiles and quantity of tack coat content.

Index Terms – bituminous overlay, coir geotextiles, shear resistance, adherence, displacement ratio, optimum tack coat, shear stress ratio

1. INTRODUCTION

One of the major problems associated with the use of thin overlays is lack of proper bond or adherence between existing layer and newly laid overlay. Modern pavement design, realize the significant role of geosynthetics in reduction of various pavement distress. Geosynthetics prove to be a cost effective tool to prolong pavement life and reduce maintenance cost. The geotextiles used in mitigating propagation of reflective cracking. It used as stress absorbing and reinforcing layer also. The geosynthetics showed improved performance as base reinforcement with respect to surface deformation and also to mitigate reflective cracks [1,2,3]

In an agriculture country like India lack of availability of synthetic geotextiles, high cost, stringent environmental concern and shortage of power lead the researchers to explore possibility of natural geotextile in place of synthetic petroleum based material. [4]

Coir is a natural material obtained as a by product of coconut husk is most durable natural fibre because of its lignin content [5,6]The coir fibers are twisted to form coir yarns, which is used to make mesh mattings known as coir geotextiles of different mesh size and different density measured in mass per square meter. It is of two type woven and non woven. Woven type coir geotextiles are available in different aperture characterized by combination of longitudinal and transverse yarns (warp and weft yarns).In nonwoven geotextiles coir fibres are randomly arranged and stitched in position .
The properties of coir geotextiles varies considerably with the properties of coir fibre such as its origin, opening size, weight per unit area etc.

Coir geotextiles are extensively used for many geotechnical applications such as strengthening sub grade, soil stabilization, erosion control in embankments and cuttings. Many researchers studied the shear resistance mechanism of sand coir geotextile interaction [7,8].The use of geosynthetics at the interface found to improve the durability and check reflective cracking. But the introduction of geosynthetics causes layer separation. The proper bonding between layers is also important and to be ensured during laying in the field. The pavements are subjected to lateral or tangential force and the pavement likely to slip due to lack of bonding and friction especially in braking and overtaking zones and lead to parabolic fracture and cut shot life of pavement. Many pavements, which are considered to be structurally sound after the construction of an overlay, prematurely exhibit a cracking pattern similar to that which existed in the underlying pavement.

Lack of bonding destroy continuity, decrease structural strength, and allow water to enter sub layers. Thus, the problems that weakened the old pavement are extended up into the new overlay. The cracking in the new overlay surface is due to the inability of the overlay to withstand shear and tensile stresses created by movements of the underlying pavement. This movement may be caused by either traffic loading (tire pressure) or by thermal loading (expansion and contraction).
When Geotextile introduced in between two pavement layers will reduce bond (adherence) between the layers. But adherence between layers can be ensured by proper selection of materials and quality of binder content. Shear resistance slightly increased at higher temperature. [9]
Earlier researcher [10] had developed a new procedure which enable the measurement of adherence and analyze adherence between two layers of bituminous mix when geosynthetic material placed between them as a function of type of geotextiles quality and quantity of binder used.
Very few studies found in literature to explore the potential of coir geotextiles as interlayer in flexible overlays to improve the performance. No relevant study has been reported in literature on shear resistance of coir geotextiles when placed in bituminous overlay interface. In this background this paper focuses on the study of effectiveness of coir geotextiles in improving the shear resistance (adherence) of bituminous layers and the parameters affecting the performance.

1.1 Objectives of the study

1. To determine the optimum tack coat content for highest shear resistance
2. To study the variation of shear resistance with different types of coir geotextiles
3. To identify the type of geotextiles which offer maximum shear resistance
4. To analyse the variation of performance of geotextiles with variation of tack coat content

Test setup was designed based on earlier study [10] to quantify adherence at the interlayer. The variation of shear resistance at the interface when different type of coir geotextiles used in between existing layer and overlay and variation in bond stress with variation in tack coat content was also studied.

This study is limited to shear stress characteristic of

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bituminous concrete mix modified with coir geotextiles only. The tests were carried out in special manner based on earlier study similar to double shear test setup by applying static load through Universal testing machine. The limitation of the study was all tests were carried out at room temperature (30 ± 1ºC).

2.EXPERIMENTAL PROGRAM

2.1 Material Used for the Study

Coir is natural fibre obtained from coconut husk, used to manufacture geotextiles. Coir geotextiles collected from local source used for the study.Fig.1.to Fig.5. Shows different types of geotextiles used for the study Table 1. Shows the properties of coir geotextiles used for the study.
Physical properties of Bitumen VG30 used for study given in Table 2. Aggregates which possess sufficient strength, hardness, toughness, specific gravity and shape were chosen the gradations of aggregates selected as per Indian Road Congress, Ministry of Surface Road Transport and Highways, (MORTH) Govt. of India.The physical properties of aggregates given in Table 3.

Fig.1 coir stitched blanket

Fig.2 CCM 400 woven coir geotextiles

Fig.3 CCM 700 woven coir geotextiles

Fig.4 CCM 800 woven coir geotextiles

Fig.5 CCM 900 woven coir geotextiles

Table 1 Properties of coir geotextiles

Particulars	Unit	Woven type				Non-Woven
		CCM 400	CCM 700	CCM 800	CCM 900	CSB 400-450
Mass/unit area	g/m2	390	800	810	820	420
Thickness	Mm	6.96	7.56	8.01	8.66	6.97
Tensile strength						
Warp	kN/m	5.40	9.94	10.34	11.97	2.70
Weft	kN/m	4.00	8.90	9.01	7.61	2.15
Failure strain						
Warp	%	24.16	28.70	26.18	21.06	30
Weft	%	21.30	30.06	28.11	27.63	25

Table 2 Properties of Bitumen

Properties	Values	Standard values
Penetration value	64	60-70
Softening point	53.5	40-65
Ductility	89cm	>75
Specific gravity	1.012	0.97-1.02
Viscosity	2600 Cp	3000 ± 600

Table 3 Physical Properties of Aggregate

Test description	Coarse aggregates	Standard values
Combined flakiness and elongation index (%)	29	<30
Specific gravity	2.758	2.6-2.9

Los Angeles abrasion value (%)	28	<30
Crushing value(%)	27	<30
Impact Value %)	22	<30
Angularity number	10	0-11
Specific gravity fine aggregate	2.514	

2.2 Specimen Preparation and Test Setup

The specimens for shear resistance test were prepared by filling the hot bituminous mix in three layers of thickness 5cm in a cubical mould of size 15 X 15 X 15 cm. Each layer compacted as per wheel tracking test procedure. The optimum percentage of bitumen used for the mix was 5.5 % by weight of the mix obtained from Marshall Stability Test.

After proper batching the aggregates, it is heated to a temperature of 140ºC and 5.5% of bitumen by weight of mix was added, mixed and heated to a temperature of 160ºC. The mix is then poured into the cubic mould and compacted to a layer thickness of 5 cm. It is then cooled to room temperature and tack coat applied , over that geotextile spread. Over this again the second layer of hot mix poured and compacted. After cooling to room temperature second tack coat is applied at specified rate and geotextiles placed over it. Over this geotextiles, third tack coat is applied in the same manner and last layer of hot mix poured and compacted to get three layered specimen. After cooling, the mould is removed and the sample is allowed to cool for 24 hours.

Geotextile is placed at one third and two third positions in the sample at layer interface for this study. Fig.6 shows the schematic diagram of test sample. Fig 7 shows schematic diagram of test.

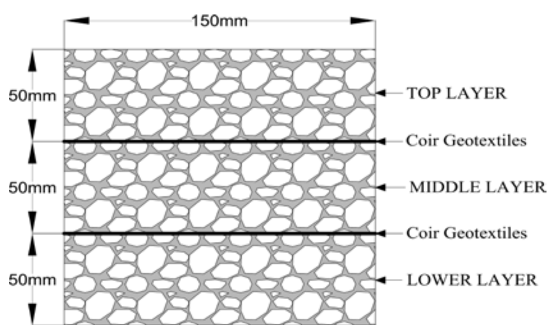

Fig.6 Schematic diagram of test sample

Table 4 Summary of test condition

Surface to which load is applied	75sqcm
Area of adherence of each face	150 * 150 mm
Condition temperature of test piece	Room temperature

Table 5.Tack coat Contents and geotextiles Used in the Study

Type	Sample ID	Tack coat content (kg/m2)
Coir stitched blanket	1	0.30–0.50–0.70–0.90-1.1
CCM 400 Coir geotextiles	2	0.30–0.50–0.70–0.90-1.1
CCM 700 Coir geotextiles	3	0.30–0.50–0.70–0.90-1.1
CCM 800 Coir geotextiles	4	0.30–0.50–0.70–0.90-1.1
CCM 900 Coir geotextiles	5	0.30–0.50–0.70–0.90-1.1
Reference material	6	0.30–0.50–0.70–0.90-1.1

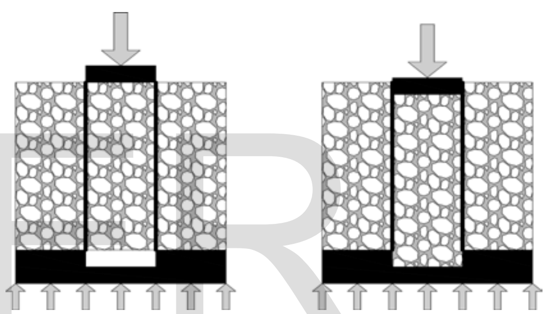

Fig.7 Schematic diagram of test

Specimens were tested from each category and the results averaged. The result is then compared with that of the control sample without geotextiles. One type non-woven geotextiles (CSB400-450) and four types of woven geotextiles designated as (CCM400, CCM700, CCM800, CCM900) were used for the study. The tack coat content was varied from 0.3 to 1.1 kg/m^2 incrementing with 0.2 kg/m^2 for all type of geotextiles and control sample. The test condition and the test scheme are shown in Table 4 and Table 5 respectively.

3.TEST SETUP

The test was conducted at an effective temperature level of 30 ± 1ºC. The load applied on the middle layer of specimen parallel to the plane of geotextiles (parallel to the interface). The load applied at uniform rate and deformation noted by extensometer attached at lower plate of UTM at each 25 KN load interval. During loading the central layer gradually slip through the outer layers. The load at failure is noted. Load verses displacement for different tack coat content and geotextiles plotted as shown in fig.8 to fig.13. It can be seen from fig 8 to 13 that 0.9 kg/m² bitumen content gives max load for a given displacement and for next increment 1.1 kg/m² the load was found decreasing. So the optimal tack coat content of 0.9 kg/m² was used for further study. For control specimen also the same trend was observed. From the study it is evident that the influence of geotextiles is predominant.

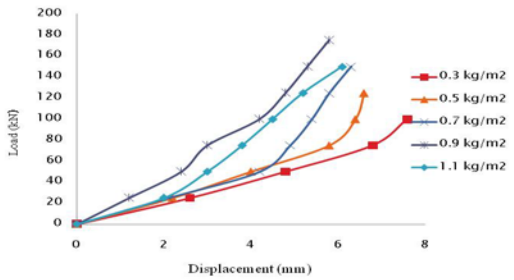

Fig.8 Load Vs Displacement graph for control specimen

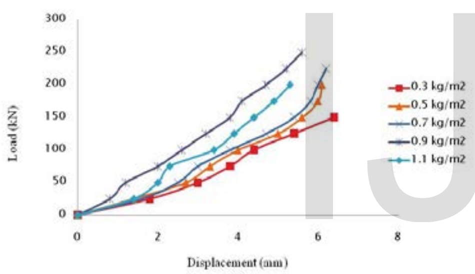

Fig 9 Load Vs Displacement graph for coir stitched blanket 400-450

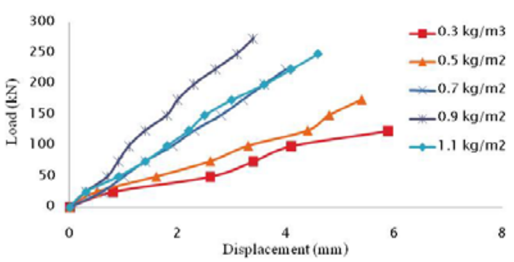

Fig.10 Load Vs Displacement graph for CCM 400 woven coir geotextiles

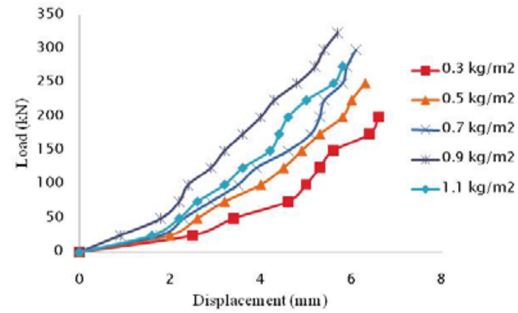

Fig.11 Load Vs Displacement graph for CCM 700 woven coir geotextiles

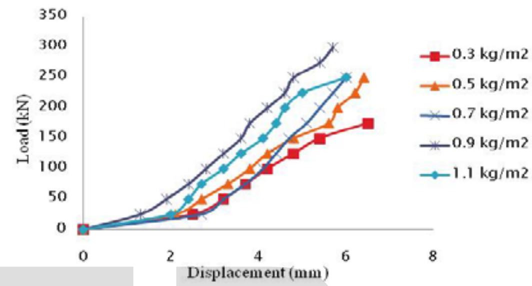

Fig.12 Load Vs Displacement graph for CCM 800 woven coir geotextiles

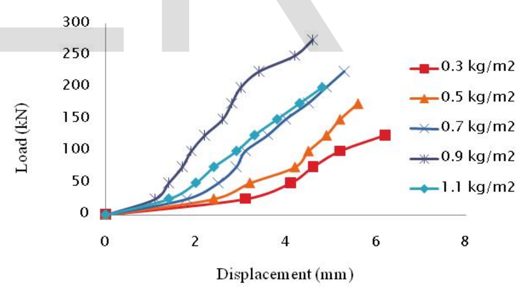

Fig.13 Load Vs Displacement graph for CCM 900 woven coir geotextiles

4. DISPLACEMENT RATIO

Displacement ratio is defined as the ratio of displacement at a particular stress level to depth of sample. The stress Vs displacement ratio graph for different tack coat content is plotted and is shown in fig.14 to fig.18. Here for displacement ratio of 0.01 and 0.02, the maximum stress was taken for comparison of result. The result showed maximum shear stress for CCM400 type coir Geotextiles, followed by CCM900 but CSB400-450 showed minimum shear resistance. The least value was obtained for the control sample. Same trend was seen for all tack coat content.

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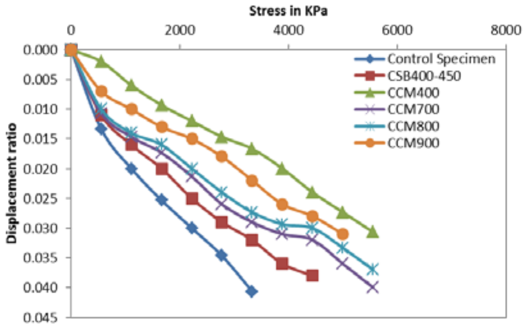

Fig.14 Stress Vs Displacement ratio for 1.1kg/m²

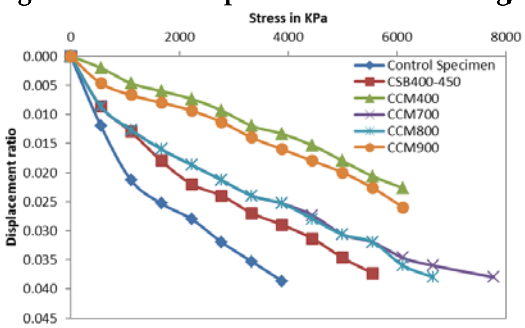

Fig.15 Stress Vs Displacement ratio for 0.9kg/m²

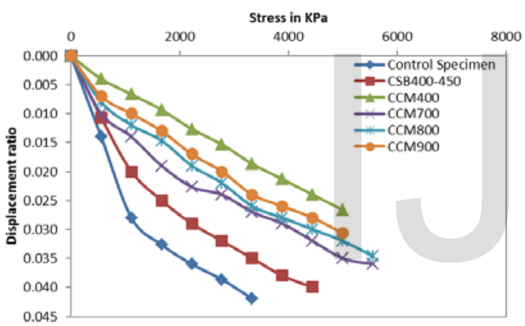

Fig. 16 Stress Vs Displacement ratio for 0.7kg/m²

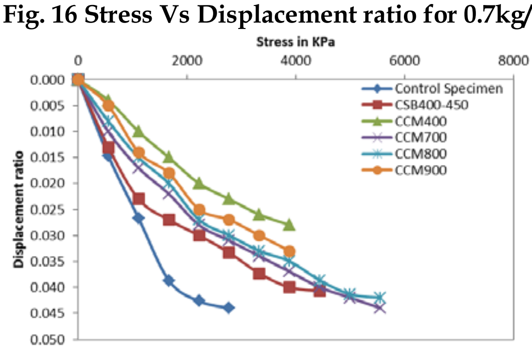

Fig.17 Stress Vs Displacement ratio for 0.5kg/m²

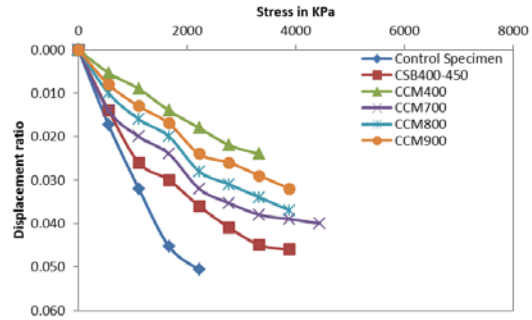

Fig.18 Stress Vs Displacement ratio for 0.3kg/m²

5.SHEAR STRESS RATIO

Improvement in the adherence stress of a coir geotextile reinforced pavement layer was defined by Shear Stress Ratio (SSR) and it was determined using equation 1;

$$SSR = q_r / q \qquad (1)$$

Where q_r is the stress for reinforced sample at a specified displacement and q is the stress for unreinforced sample or the control specimen, at the same displacement.

Based on SSR the improvement in percentage of adherence (shear stress) with 0.9 kg/m² tack coat content is shown in the fig.19. The maximum improvement in adherence stress was obtained for CCM 400 type coir Geotextiles(800%) and the least value was obtained for CSB 400-450 coir Geotextiles (200%) which was a non-woven type for a stress ratio 0.02.

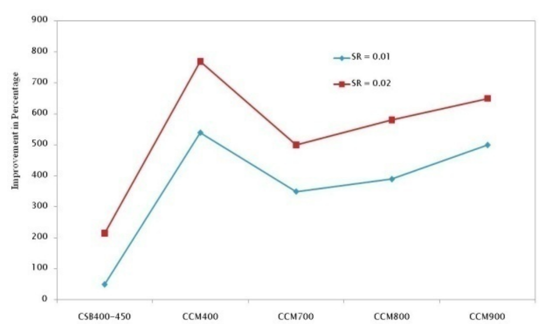

Fig.19 Improvement in % of adherence stress with 0.9kg/m² tack coat content

The SSR index is based on control sample value and variation in SSR value indicate the influence of type of geotextiles on shear stress value.

6.PERCENTAGE REDUCTION IN DISPLACEMENT

The percentage reduction in displacement (PRD) was determined using equation 2;

$$PRD = (S0 - Sr)/S0 \qquad (2)$$

Where S0= the displacement of unreinforced sample corresponding to its failure stress and Sr= the displacement of reinforced sample corresponding to failure stress.

The reduction in displacement for 0.9kg/m2 was shown in the fig20. The reduction in displacement was maximum for CCM 400 coir geotextiles with 41.4% and the minimum value was 14.3% for CSB 400-450 coir geotextiles. The reduction in displacement for CCM 700, CCM 800, and CCM 900 were 24.4%, 27.6%, 32.8% respectively.

Among the different type of coir geotextiles used, the percentage improvement in ultimate load carrying capacity was minimal for non-woven geotextiles CSB 400-450 for different tack coat contents. The maximum ultimate load was taken by CCM 700 coir geotextiles. Even though the maximum ultimate stress was taken by CCM 700, CCM 400 showed better improvement at smaller displacement ratio. In the case of CCM 400, the bituminous mix and geotextiles act together as a single unit which helps to activate mobilization of membrane action and lateral confinement of mix material than any other geotextiles.

When geotextiles of higher thickness placed as inter layer the discontinuity or layer separation zone is created in between, resulted in lower values of shear resistance. But all the geotextiles modified specimens showed improvement compared to control specimen. When mesh size is large the structure of coir geotextiles act similar to geogrid. The interaction mechanism between bituminous concrete and geogrid develops shear resistance at interface which takes place along longitudinal rib and the aggregate particles interlocked within the apertures mobilize passive thrust against transverse element.

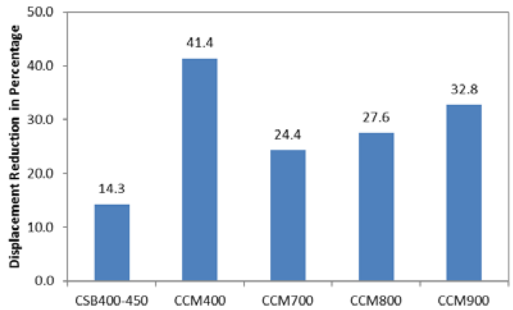

Fig.20 Reduction in displacement for 0.9kg/m2 tack coat content

Shear resistance of reinforcement material is a function of its structural composition, material characteristics, density of material and aperture size.

7. CONCLUSIONS

Conclusions were drawn based on the influence of the tack coat content and the type of Coir geotextiles used.

Laboratory tests conducted on overlay sample specimen with five types of coir geotextiles(CSB400450,CCM400,CCM700,CCM800,CCM900) obtained from different sources. Geotextiles introduced at the interface of middle layer with top and bottom layers, of the overlay. Test conducted was shear resistance test using UTM Static loading. From the result of shear resistance test, CCM 400 woven coir geotextile specimen showed maximum increase in shear stress. CCM 700 gives maximum failure load. 0.9litre/m² is the optimum tack coat content in all cases. Inclusion of coir geotextile irrespective of its type found to increase the shear resistance but non wovengeotextile (CSB400-450) show least improvement 200 % and CCM 400 showed max improvement (800%) followed by CCM 900 for optimum tack coat for given value of displacement ratio(0.02).

Thus it was conclude that, out of the different type of coir geotextiles used CCM 400 woven geotextile showed maximum shear resistance ie, eight times over control specimen.

Findings drawn from experiments and analysis concluded that, the shear resistance is sensitive to property of geotextiles and quantity of tack coat (binder). CCM 400 geotextile show higher value, because its thickness is less so layer separation effect was less and also large mesh size hold the bituminous mix giving a confining effect and better interlocking. In lower mesh size this effect is less also layer separation is predominant. In CSB400-450 non woven geotextiles confining effect is very less and layer separation is predominant but it act as a strong stress absorbing medium.

8. LIMITATIONS OF THE STUDY

The results presented in this study were interpreted based on small scale laboratory study under controlled test conditions only. It helps better understanding of the coir geotextiles tack coat interaction behaviour to some extent .The actual behaviour may vary in the actual field conditions while considering traffic and environmental factors. Large scale field study is required to predict exact performance of the material.

9. ACKNOWLEDGMENT

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