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USE OF GEOTEXTILES IN ROAD PAVEMENTS

A.V.S.R. Murty, S.K. Soni and Sudhir Mathur

Central Road Research Institute, P.O. CRRI, New Delhi-110 020, India

ABSTRACT : The application of geotextiles has been accepted as a construction material in Civil Engineering works. However, in India, the utility of geotextiles is very limited to particular areas of application in Civil Engineering such as highways, railways and irrigation projects etc. On an experimental basis, these fabrics have been used as an intermediate layer between subgrade and subbase to serve as a separation and drainage layer in a road constructed on soft subgrade soil. The main objective of field trials was to study the need, relevance and the relative efficacy of the use of geotextiles as compared to the use of conventional techniques in the construction and maintenance of road pavements on soft subgrades. The performance and surface characteristics of different test sections were evaluated in terms of riding quality, rut depth and transverse/ longitudinal slope variance. The structural adequacy of different specifications were determined using Benklemen Beam deflection tests. The cost analysis for sections with different specifications is also made. Based on the detailed data analysis, it is concluded that the geotextiles are an effective substitute for conventional blanket courses as a separator with the added benefit that they ensure more effective subsurface drainage of the pavement compared to conventional blanket courses.

INTRODUCTION

Over the last two decades, the use of geosynthetics has recorded a tremendous application in highway structures in many developed or developing nations of the world. One of the major application of the use of geosynthetics in highways is the construction of roads over soft subgrade using geosynthetics as a separator between the soil and pavement material. In such a situation the geosynthetics is supposed to act as a long term separator by resisting the migration of coarse aggregate into soft subgrades and also prevent the pumping of fine soils into coarse base aggregate while still allowing the pore water pressure to dissipate. Conventionally in such a situation a blanket course made up of coarse /medium sand or non plastic moorum or alternatively lime/cement stabilised soil is provided between subgrade and base course material. However, such blanket course prove to be very expensive when good quality blanket course materials are not available within the economic leads.

This paper presents a field study which was taken up on a low volume road in command area of major irrigation project to study the need relevance and the relative efficacy of the use of geosynthetics as compared to the use of conventional techniques in the construction and maintenance of road pavements on soft subgrades especially in Black Cotton (B.C) soil areas.

SELECTION OF SITE AND LAYOUT OF EXPERIMENTAL STRETCHES

For laying of experimental stretch, a road in command area of a major irrigation project was chosen. This road connects a big village to the main highway. The traffic on the road mostly comprised of solid wheeled animal drawn carts, buses and other vehicles such as car, jeep, tempo and tractor trolley, etc. On the basis of present and projected traffic data, the pavement thickness for test section worked out to be 45 cms. In order to access the performance of different road sections with and without geosynthetics, a number of specifications were formulated. These include test stretches constructed with three varieties of geosynthetics (woven, non-woven thermally bonded and non-woven needle fleeced) between subgrade and subbase and test sections with sand and lime stabilised black cotton soil as a subbase layer. These specifications are shown at Fig.1. The road embankment material of this road consist of clayey soil having low bearing strength. The depth of water table in this area was also shallow. The typical site condition and properties of the subgrade are given in Table 1 & 2. This area also remains water logged due to constant irrigation activities

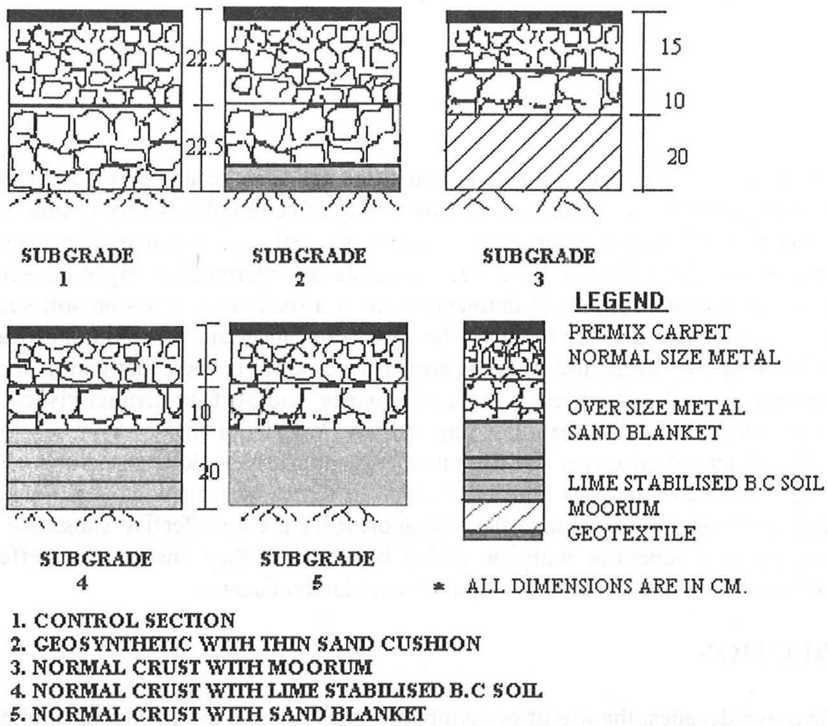

Fig. 1 : Shows details of Test Specifications

Carriageway Width (m)	Formation Width (m)	Height of Embankment (m)	Depth of Water Table (m)	Rainfall (mm)
3.6	6 - 7	0.5	6 - 8 in Summer 2 - 3 in Mansoon	1500

Table 1. Typical site conditions for different experimental stretches

Soil Type	Plasticity Index	Proctor Density (gm/cc)	Soaked / Unsoaked CBR (%)	Coefficient of Uniformity	Permeability
Black Cotton Clayey Soil (CH Group)	30 - 35	1.5 - 1.6	(2 - 3) / (6 - 10)	8	1.5 X 10 -6

Table 2. Typical soil conditions for experimental stretches

DESIGN, TESTING, SELECTION AND LAYING OF GEOSYNTHETICS

In order to select a fabric among the available one, it is necessary to work out the design requirement which a fabric should meet under the given load and environment condition. In this experimental study, the geosynthetics has been placed between two materials, i.e. between the subgrade and the base course materials. These two materials have a tendency to mix when they are squeezed together under the applied loads and the functions of the geosynthetics is to separate these two materials. As a separator, geosynthetics must retain the soil particles and must have sufficient strength to withstand stresses induced by the applied loads. Consequently designing a geosynthetics separator involves retention and strength analysis.

The key property of a geosynthetics involved in the retention analysis is its opening size. Depending upon the moisture and the loading conditions, the opening size of the geosynthetics can be worked out. Apart from the retention criterion, it is also expected that the geosynthetics must have sufficient permeability to transmit water in the plane of their structure. In addition to the opening size and the permeability, the other important strength parameters are grab tensile strength, puncture strength, burst strength resistance and percentage elongation at failure. These parameters must also be worked out for the proper selection of a geosynthetics. In order to determine the strength requirements of a fabric to be used in a highway for the given situation the acceptable values of burst strength, tensile strength and the puncture strength were worked out as per standard design methods suggested by Koerner R.M., (1992). The values of the same are given in Table 3.

After working out the design requirements of a geosynthetics for separation, the available fabrics were tested to determine their various characteristics such as apparent opening size, permeability, burst strength, puncture strength and tensile strength, etc. The results of the same are given in Table 3 and has been compared with the design values. From the table, it is evident that all the chosen fabrics are meeting the design requirements except the puncture strength requirement. In order to avoid the puncture strength of fabric, a thin cushioning layer of sand of non-plastic nature was provided over the geosynthetics. a thin layer of stone metal was laid over it and compacted with a 4 tonne roller. The compaction of other remaining metal layer (WBM) was carried out using a standard 8-10 tonne road roller.

S. No.	Type of Fabric	Speci -fic Gra-vity	Thick-ness	A. O. S mm	Water permea-bility at a pressure of 1 kg/cm2 (cm/sec) in plane	Tensile Stre-ngth (N) ASTM D-4595	Elon-gation (%)	Punc -ture Stre-ngth (N)	Mullen burst strength KN/mm 2
1.	**Woven**	**0.95**	**0.30**	**0.090**	**13X10-3**	**1700**	**8**	**250**	**12**
2.	**Non - Woven (T.B)**	**0.96**	**0.40**	**0.045**	**27X10-3**	**2000**	**18**	**375**	**22**
3.	**Non - Woven (N F)**	**0.98**	**0.45**	**0.030**	**36X10-3**	**1500**	**20**	**310**	**18**
4.	**Accept-able values for design require-ment**	-	-	**0.036**	**1X10-3**	**1382**	-	**320**	**14.3**

Table 3. Physical properties of the selected geosynthetics and comparison with designed values

PERFORMANCE EVALUATION OF EXPERIMENTAL TEST TRACK

In order to assess the pavement performance of different test sections, i.e. with and without geosynthetics, a number of post construction pavement performance observations were recorded periodically. The surface characteristics of different test sections were recorded in terms of transverse rut measrement, transverse slope variance and percentage cracks, patchwork, ravelling, potholes and settlements etc. The surface deflections in each specifications on both the wheel paths were taken with Bankelman beam at an interval of 10 m. The characteristics rebound deflections were computed as per IRC guidelines. Keeping in view the fluctuating water table and rainfall intensity, appropriate moisture correction factors were also applied to obtain corrected rebound deflection. The results of deflection, rut depth and total distress over a period of time are shown at Table 4.

S. No.	Test Specifications	Rut Depth (mm)	Deflection (mm)	Distress (%)
1.	**Control Section** Compacted subgrade in embankment + 45 cm WBM + Bituminous top (BT)	6.0 - 18.0	1.6 - 2.5	1.0 - 15
2.	**Sections with Geotextiles** Compacted subgrade in embankment + woven fabric + 45 cm WBM + Bituminous top (BT)	6.0 - 9.0	1.5 - 2.0	1.0 - 6.0
3.	Compacted subgrade in embankment + Non woven fabric (thermally bonded) + 45 cm WBM + Bituminous top (BT)	4.7 - 8.5	1.5 - 1.8	0.6 - 6.0
4.	Compacted subgrade in embankment + Non woven fabric (needle fleeced) + 45 cm WBM + Bituminous top (BT)	4.5 - 10.0	1.5 - 1.9	1.3 - 6.0
5.	Compacted subgrade in embankment + Non woven fabric + 20 cm sand layer + 25 cm WBM + Bituminous top (BT)	4.0 - 7.0	1.4 - 1.7	0.0 - 5.0
6.	**Conventional Section** Compacted subgrade in embankment + 20 cm sand layer + 25 cm WBM + Bituminous top (BT)	4.0 - 14.0	1.7 - 2.2	0.0 - 5.0
7.	Compacted subgrade in embankment + 20 cm lime stabilised local soil + 25 cm WBM + Bituminous top (BT)	7.0 - 20.0	2.5 - 2.8	0.5 - 16.6

Table 4. Variation in rut depth, deflection and total distress in five years time for different test sections

SUBGRADE SOIL INTRUSION

In order to study the subgrade intrusion into different blanket courses, pits were dug out, 3 years after the test tracks was constructed and opened for full traffic. The soil/material samples just above the subgrade were carefully collected and tested in the laboratory. It was observed that the subgrade soil intrusion into the conventional oversize metal was maximum. There was also some intrusion into the sand blanket course. The angularity of the oversize metal was considered as dominating factor contributing to the intrusion while in case of sand blanket course, it is merely the void space in the granular structure. The samples collected just above the geosynthetics layer showed no sign of any migration of fines from the subgrade.

EXHUMING GEOSYNTHETICS SAMPLES

To study the strength loss due to the construction loading and vehicular traffic and other environmental conditions, several geosynthetics samples were exhumed from the pavement crust after 3 years period. The extent of degradation was evaluated in terms of loss of strength of the fabric i.e., tensile strength and puncture strength. Typical test results for all the three fabrics are shown at Fig.2 and 3. The results indicate that percentage elongation at failure reduced for all the three fabrics are shown at Fig.2 and 3. The results indicate that percentage elongation at break reduced for all the three fabrics. In addition to the above, recurring expenditure on the maintenance for different sections were also collected during the periodic performance observations.

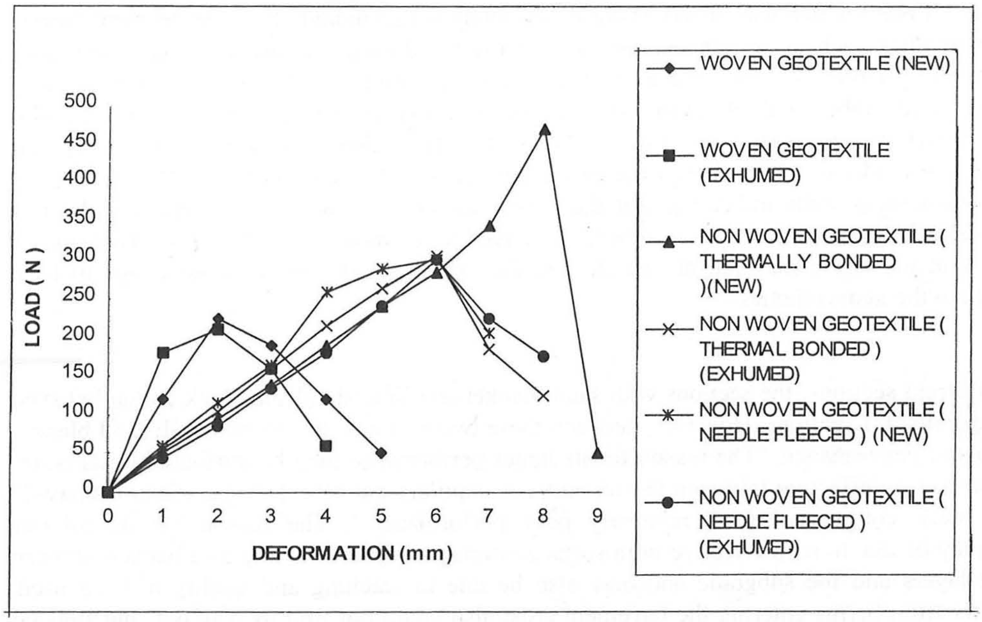

Fig. 2 : Showing Puncture Strength test results on new and exhumed samples

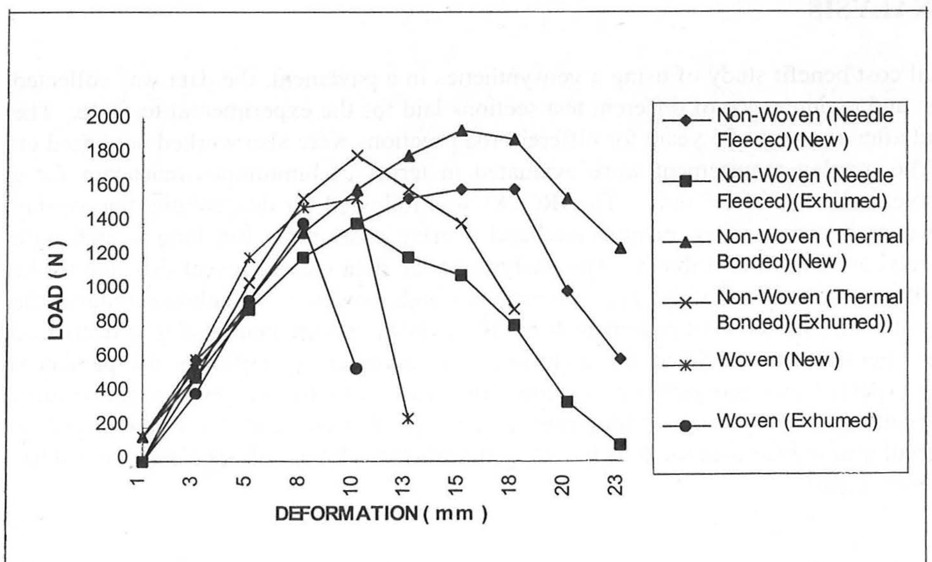

Fig. 3 : Showing Wide-Width Strip Tensile test results

DATA ANALYSIS AND INTERPRETATION OF PERFORMANCE RESULTS

Based on field data obtained so far during the study, it has been observed that the rut depth, deflection and the total distress developed over a period of time are minimal in geosynthetics test sections as compared to other conventional sections. Since all the above parameters are a measure of performance and structural capacity of the pavement, the test results clearly indicate that the inclusion of a geosynthetics improves the structural capacity of the pavement possibly due to its ability to confine and restrain movement of granular layers into the soft subgrades as well as better filtration and drainage capacity in the presence of wet/saturated subgrade.

Another important point which was observed during the study is that though the three different fabrics vary in characteristics such as weight per unit area, tensile and puncture strength and modulus of elasticity etc. there performance are comparable and it appears from the study that any proper quality woven or non-woven fabric will perform well if it is judicially chosen to withstand construction stresses and engineering properties ensuring its longevity. It is also evident from the study that irrespective of the modulus of the fabric, the deflection and rut depth in all the three sections are almost of the same magnitude indicating that the tensile modulus of the fabric should be adequate enough to sustain the pavement stresses and need not have higher value, since in a properly designed soil fabric system the fabric may not be stretched to the extent possible to have advantage of high tensile strength in the geosynthetics.

Among the different sections, the sections with sand blanket and lime stabilised black cotton behaved inferior to geosynthetics sections. However, between these two sections, the section with sand blanket course gave better performance. The reason for its better performance may be attributed to its better capacity to serve as an effective intrusion barrier and as a capillary cut off. The specifications having lime treated black cotton soil gave relatively poor performance. The reason for its inferior performance may be due to its ineffective intra surface drainage inspite of acting as a barrier between the pavement layers and the subgrade and may also be due to leaching and quality of lime used. Ingress of water from berms entering the pavement crust also could not find its way out but flooded the pavements thus accelerating the process of deterioration. This was further confirmed by high deflection values obtained in the lime treated stretches.

ECONOMIC ANALYSIS

To study the overall cost/benefit study of using a geosynthetics in a pavement, the data was collected for the construction and maintenance of different test sections laid for the experimental test site. The overlay requirement after a period of 5 years for different road sections were also worked out based on deflection data. The overlay requirement were evaluated in terms of bituminous macadam for a minimum permissible deflection of 1.5 mm. The IRC :81 was followed for determining the overlay requirement. The overall construction, maintenance and overlay costs for 1 km long stretch with different specifications are shown at Table 5. The analysis of the data clearly reveal that due to the high cost of geosynthetics, initial cost of the structure becomes high, however, its inclusion reduces the maintenance cost and result in increased pavement life. The overlay requirement also gets decreased by he inclusion of geosynthetics. Since the inclusion of geosynthetics reinforces the pavement structure, it is also expected that geosynthetics section will require less overlay even in subsequent cycles and hence resulting in cost savings in long run. Due to less distress and better riding quality, the road user cost shall also reduce with sections having geosynthetics. This analysis clearly reveal life and reduced maintenance cost.

S. No.	Crust Details	Cost of Constr-uction (Rs.)	Cost of Mainte-nance (Rs.)	Cost of Bitumin-ous over lay (it include profile correctio n also) (Rs.)	Total Cost (Rs.)
1.	Compacted subgrade in embankment + 45 cm WBM + Bituminous top (BT)	7,00,000	20,000	2,80,000	10,00,000
2.	Compacted subgrade in embankment + woven fabric + 45 cm WBM + Bituminous top (BT)	8,90,000	6,000	1,45,000	10,41,000
3.	Compacted subgrade in embankment + Non woven fabric (thermally bonded) + 45 cm WBM + Bituminous top (BT)	8,90,000	6,000	96,000	9,92,000
4.	Compacted subgrade in embankment + Non woven fabric (needle fleeced) + 45 cm WBM + Bituminous top (BT)	8,90,000	6,000	1,20,000	10,16,000
5.	Compacted subgrade in embankment + Non woven fabric + 20 cm sand layer + 25 cm WBM + Bituminous top (BT)	7,90,000	4,000	1,00,000	8,94,000
6.	Compacted subgrade in embankment + 20 cm sand layer + 25 cm WBM + Bituminous top (BT)	6,00,000	8,000	2,20,000	8,28,000
7.	Compacted subgrade in embankment + 20 cm lime stabilised local soil + 25 cm WBM + Bituminous top (BT)	6,00,000	20,000	3,50,000	9,70,000

Table 5. The construction, maintenance and overlay cost with different specifications for 1 km long single lane road

RECOMMENDATIONS

The long term field and laboratory studies have clearly revealed that properly designed and installed geosynthetics can increase stability of subgrade soils thereby increasing the load bearing capacity of the structural section. Additional benefits are derived when the geosynthetics provides secondary functions of filtration and drainage, allowing excess pore water pressure to dissipate into based granular material. The road performance observations have also been adequate to establish that the geosynthetics are an effective substitute for conventional blanket courses. Its uses is very cost effective when good quality subbase materials are not available within economic leads, the CBR if subgrade is low (i.e.2), roads are water logged and the roads are to be constructed speedily.

The techno-economic analysis of the data clearly reveals that the inclusion of a geosynthetics in road pavement reduces the maintenance and overlay costs and results in long service life of the pavement. However, due to its high initial cost it may not get a favour from the practising field engineers due to the general problem of budget limitations. Therefore, it is necessary that efforts must be made for the recognition of geosynthetics as an engineering material and make a good case for the consideration of Indian Government to reduce import duty on the finished product to bring down the prices of the same to reasonable level.

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