Use of Geotextiles in Low Volume Roads — A Case Study

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SYNOPSIS The application of geotextiles has been well 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 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. Based on the detailed data analysis, it is concluded that the geosynthetics 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 Large sections of our road network happen to be routed over areas containing soft clays, alluvial soils, organic soils, marine clays etc., under water logged conditions. Roads built on expansive clayey soil subgrades suffer from many problems and deteriorate early. Studies on behaviour of roads in expansive soils in India, have clearly established that the provision of a blanket course composed of coarse/medium sand or non plastic moorum or altenatively lime/cement stabilised black cotton soil as a subbase serve as an effctive intrusion barrier and greatly adds to the performance of such roads. However, such blanket courses prove to be very expensive when the sand or other good quality materials are not available within the economic leads.

There are enough evidences that geotextile act as an effective long term separator by resisting the migration of coarse aggregates into the soft subgrade and also prevent the pumping of fine soils up into the coarse base aggregate, while still allowing pore water pressure to dissipate. Hence geotextile offers itself as an effective substitute for such a blanket course and bids fair to become a very cost effective alternative with the added benefit that they ensure more effective subsurface drainage of the pavement compared to the conventional blanket courses.

To study the relative efficacy of the use of geotextiles as compared to the use of conventional techniques in the construction of road pavements on soft subgrades, a low volume road in a command area of a major irrigation project is chosen. The road is built on a soil of low bearing capacity and suffer from the effect of high water table due to constant irrigation. About 11 number of test specifications varying from 100 m to 300 m in length are laid. The total road length of the experimental sections is about 1.7 Kms. Water level indicators and settlement gauges are installed along the experimental stretches. The road is completed and opened for traffic in the year of 1988 after completion of the experimental stretches.

The long term performance of the test sections are recorded through periodic observations. The road surface condition is evaluated in terms of surface distress such as cracking, patching, potholing, ravelling, rutting and transverse/longitudinal slope variance. The structural adequacy of the different specifications are determined using Bankleman beam deflection. The reduced level at the top of the subgrade and pavement surface are also recorded periodically to study the change in pavement thickness with time. In order to assess the survivability of geotextiles in road pavements, a number of samples of geotextile are taken out from the test sections to study their condition. The degree of survivability of different fabrics is evaluated in terms of percentage strength retained. The migration of the fine soil into the road bases/sub-bases are also studied. Based on the analysis of the data, it is observed that the geotextiles are an effective substitute for the conventional blanket courses.

SELECTION OF SITE AND LAYOUT OF EXPERIMENTAL STRETCHES

The road identified for the experimental test tracks is a rural road, passing through the sugarcane fields and connecting a big village to the main highway. The road is water logged for more than 6 months in a year due to constant agricultural activity in that area. The water table in the area varies from 2 m to 3 m in mansoon and 5 m to 6 m during summer and winter seasons. The average rainfall in the area is in the range of about 1500 mm. The soil used for the embankment and subgrade is very soft clayey soil. Typical soil properties of the subgrade and the embankment soil are given at Table 1

TABLE - 1

TYPICAL SOIL PROPERTIES

SOIL TYPE	PLASTICITY INDEX	PROCTOR DENSITY (gm/cc)	UNSOAKED CBR (%)	SOAKED CBR (%)	SOAKED MOISTURE (%)
BLACK COTTON CLAYEY SOIL (CH GROUP)	35-40	1·49-1·57	5-12	1-2	36-48

The carriageway width of the road is about 3.6 metre with a formation width of 7.0 metre. The height of the embankment is about 0.5 metre with a side slope of 2:1.

The traffic on the road mostly comprises of solid wheeled animal drawn carts, commercial trucks and buses and other vehicles such as car, jeep, tempo and tractor trolley etc. For the purpose of pavement design, only heavy vehicles such as trucks and buses were considered. In the begining of the project, the number of such heavy vehicles were in the range of 25 to 30 vpd and was expected to increase by 60 to 70 vpd. On the basis of present and projected traffic data, the pavement thickness for test sections (as per CBR design method) worked out to be 45 cms.

The typical test specifications used for the experiments are shown at Fig.1.

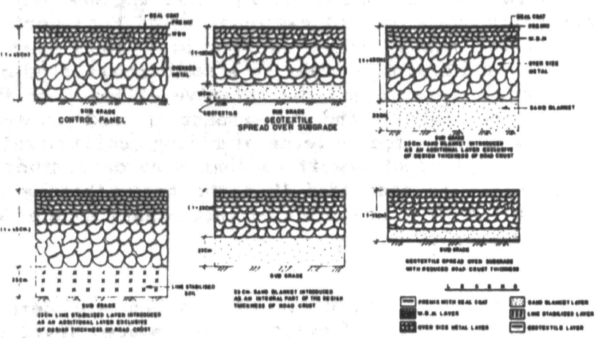

Fig.1 : Typical Test Specifications Incorporated for Field Trials.

These include test stretches constructed with three varieties of geotextiles (woven, non woven and non woven needle fleeced) between subgrade and subbase; test sections using conventional techniques such as sand, moorum and lime stabilised black cotton soil as a subbase layer; test sections with sand, moorum and lime stabilised black cotton soil as an additional thickness layer; and one stretch is provided with a reduced thickness to check, whether the pavement thickness can be reduced with the inclusion of geotextiles in the road pavement.

GEOTEXTILE INSTALLATION AND ROAD BASE CONSTRUCTION

The laying of the geotextile began only after the subgrade was properly cambered and side slopes are graded for proper slope and drainage. Any hard particle or roots of vegetation that may puncture the fabric are removed from the subgrade and loose pockets on the top of embankment were filled with natural soil and compacted. The formation width and the central line were clearly marked. The geotextile roll was placed across the road with one end of the roll at the edge of formation width and was slowly unrolled to make sure that the geotextile is uniformly spread above the embankment. An overlapping of 0.3 m to 0.6 m was allowed transversely and longitudinally for each length of the fabric roll. The laying of geotextile over the finished subgrade is shown in Fig.2. The major basic materials of all the three varieties of geotextiles used are either polypropylene or polypropylene-nylon mix. The geotextile rolls are about 4.5 m wide and about 100 metre long. Some of the typical properties of the geotextiles are given at Table 2. Initially it was proposed in the project report to lay oversize metal aggregate (80-100 mm size) directly over the geotextile and roll it with a 8-10 ton power roller. But later during the construction it was observed that hard stone metal aggregate when rolled punctured the fabric at many places. Subsequently, it was felt judicious to provide a cushioning layer of 10 cm of

TABLE - 2

TYPICAL GEOTEXTILE PROPERTIES

S.NO.	TYPE OF FABRIC	BASE MATERIAL	SPECIFIC GRAVITY	UNIT WT. (gm/m²)	THICKNESS (mm)	TENSILE STRENGTH warp/weft (kg/m)	POROSITY	ELONGATION warp/weft (%)	PERMEABILITY (lit/m²/sec)
1.	PLAIN WOVEN	POLYPROPYLENE	0·92	120	0·30	1632/1570	90% FINER THAN 300 µ	21/15	12
2.	NON WOVEN	POLYPROPYLENE	0·86	165	0·77	1340	—	27·7	17
3.	NEEDLE FLEECED	75% POLYPROPYLENE + 25% NYLON	0·98	147·5	0·40	1500/1500	90% FINER THAN 60 µ	11/16	6

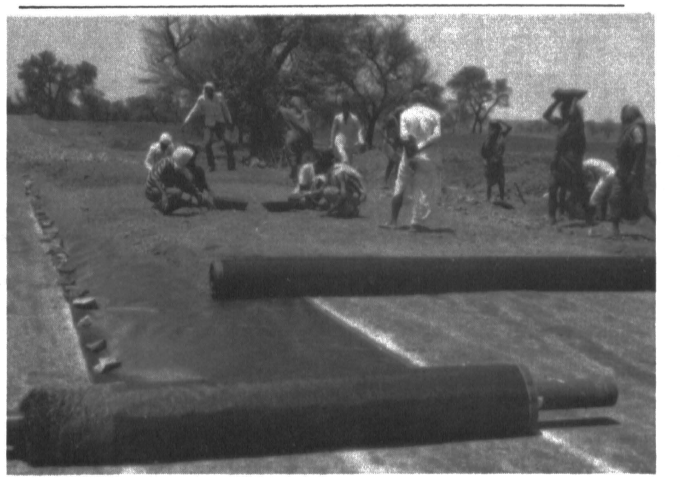

Fig.2 : Laying of Geotextile over Finished Subgrade

materials like sand /moorum over the fabric below the stone metal layer and same was compacted with a 4 ton roller, to avoid any puncture due to the penetration of sharp metal pieces into the geotextile layer. The compaction of the other remaining metal layer (WBM) is carried out using a standard 8-10 ton roller. The sand/moorum material used as a cushioning is carefully selected to have a plasticity index of less than 6 and free from nodules. The construction of other specifications such as control panel, lime stabilised section and sand/moorum cushion sections were carried out as per the procedures laid down by Indian Roads Congress.

As mentioned, water level indicators and settlement gauges were also installed along the experimental stretches. The settlement gauges are placed in the road crust by cutting a trench at 0.9 m from the outer edge of the cariageway i.e. on wheel path. The details of settlement gauges are shown at Fig 3. There are generally 4 settlement gauges in each test section. The water level indicators are also installed along the test track on the edge of the road embankment.

POST CONSTRUCTION PAVEMENT PERFORMANCE

Surface Characteristics

Transverse rut measurement : As per IRC guidelines, a 3.0 m straight edge is used for the measurement of rut depth. Rut depths are measured accurately by using a wedge scale to an accuracy of 1.0 mm. During the study, the rut depths on wheel path at an interval of 10 m in each section are recorded.

Crack and other distress measurement : In all the test sections, the legnth and width of cracks developed are

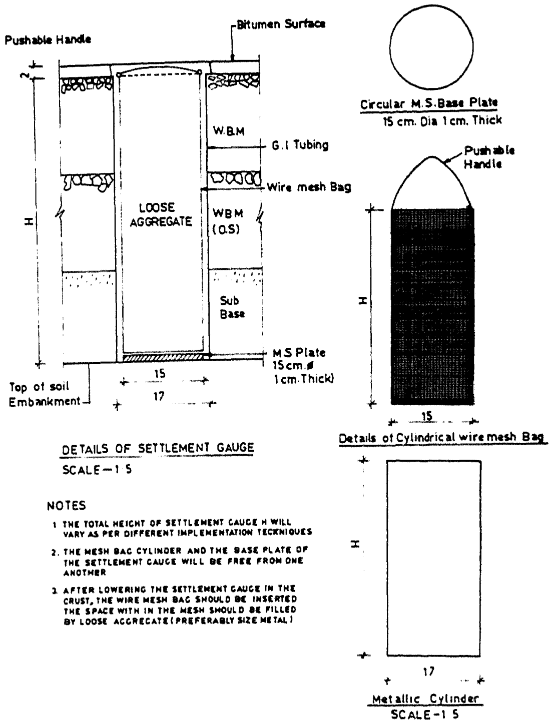

Fig.3 : Details of Settlement Gauge

measured with the help of a thread. The average width of the crack is measured to an accuracy of 1 mm. Apart from ruts and cracks, the surface condition in terms of patchwork, ravelling, depression, potholes and settlement etc. are also recorded periodically to determine the total distress.

Transverse slope variance : To study the variation of pavement surface in the transverse direction, reduce levels at 30 cm interval and at longitudinal distance of 10 m are also taken in each specification and have been computed in terms of transverse slope variance.

Bankleman Beam Deflection: The surface deflections in each specification on both the wheel paths are taken with the Bankleman beam at an interval of 10 m. The permanent deflection observation points in each section are established and marked with paint. For this study, characteristics rebound deflections have been computed as per IRC: 81-1981. Keeping in view of the fluctuating water table and rainfall intensity, appropriate moisture correction factors are applied to obtain corrected rebound deflection.

Settlement Gauge Observations : The reduce levels at the top and bottom of the settlement gauges are recorded periodically at an interval of six months. These observations could be taken up only upto a period of 2½ years, as settlement gauges provided in the road crust became non functional due to wheel loads and other environmental factors.

Subgrade Intrusion : In order to study the problem of subgrade intrusion into the different blanket courses, pits were dug out, 3 years after the test tracks were constructed and opened for full traffic. The soil/material samples just above the subgrade were carefully collected and tested in the laboratory. It is observed that the subgrade soil intrusion into the conventional oversize meterial layer as well as into sand blanket course was maximum. There was no subgrade intrusion into the lime stabilised and moorum blanket course probably due to non granular nature (less voids) of these bases. The angularity of the oversize metal is considered as dominating factor contributing to the intrusion while in the case of sand blanket course it is mearly the void space in the granular structure. The soil samples collected just above the geotextile layer showed no sign of any migration of fines from the subgrade.

Exhuming Geotextile Samples : To study the strength loss due to the construction loading and vehicular traffic and other environmental conditions, several geotextile samples were exhumed from the pavement crust after 3 years period. The extent of degradation is evaluated in terms of loss of strength of the fabrics i.e., tensile strength and puncture strength. During the laboratory tests of the samples, it is observed that the results are scattered but when averaged for two samples for each location, the results are consistent. Typical test results for all the three fabrics are shown at Fig.4 and Fig.5. The results indicate that percentage elongation at break reduced for all the three fabrics.

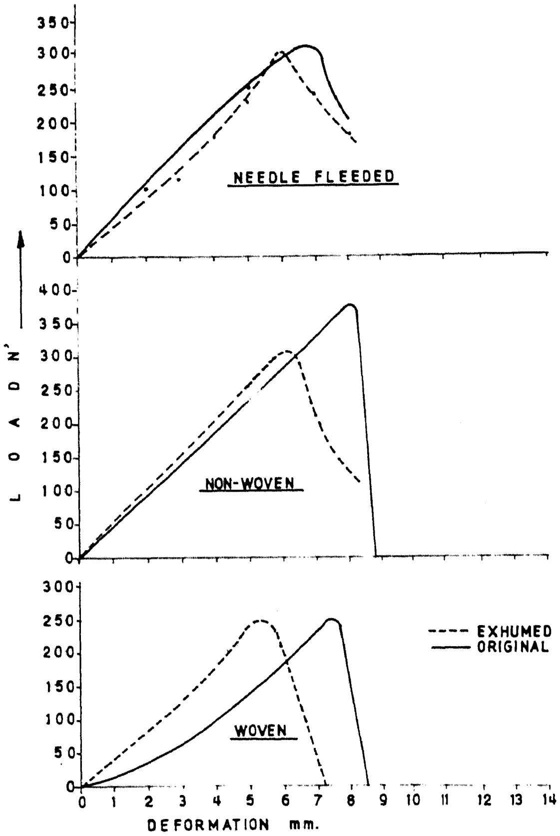

Fig.4 : Puncture Test Results

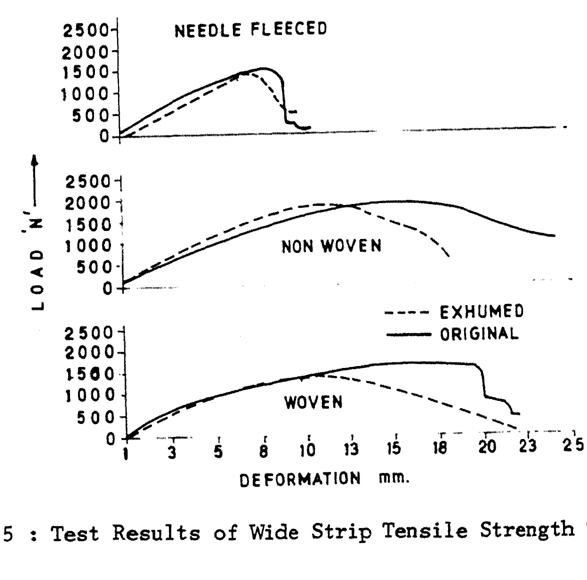

Fig.5 : Test Results of Wide Strip Tensile Strength Test

DATA ANALYSIS AND INTERPRETATION OF PERFORMANCE RESULTS :

For the purpose of analysing the performance of the test sections with the different specifications, the pavement condition is evaluated in terms of deflection, rut depth and the total distress. The details of the field data has been presented in Fig.6.

On careful study of the different field data obtained so far during the periodic observations, indicated that the deflection, rut depth and the total distress developed over a period of time are minimal in the geotextile test sections. Since all the above parameters are a measure of the performance and structural capacity of the pavement, the test results clearly indicate that the inclusion of a geotextile improves the structural capacity of the pavement possibly due to its ability to confine and restrain movement of granular layers into the soft subgrade as well as better filteration and drainage capacity in the presence of wet / saturated subgrade.

Though the three different fabrics vary in characteristics such as weight per unit area, tensile and puncture strength and modulus of elasticity etc. their performance are comparable and hence it appears from this study that any high quality woven or non woven fabric will perform well, if it is properly chosen to withstand construction stresses and has properties ensuring its longivity. It is also evident from the study that irrespective of the modulus of the fabric, the deflection and rut depth in

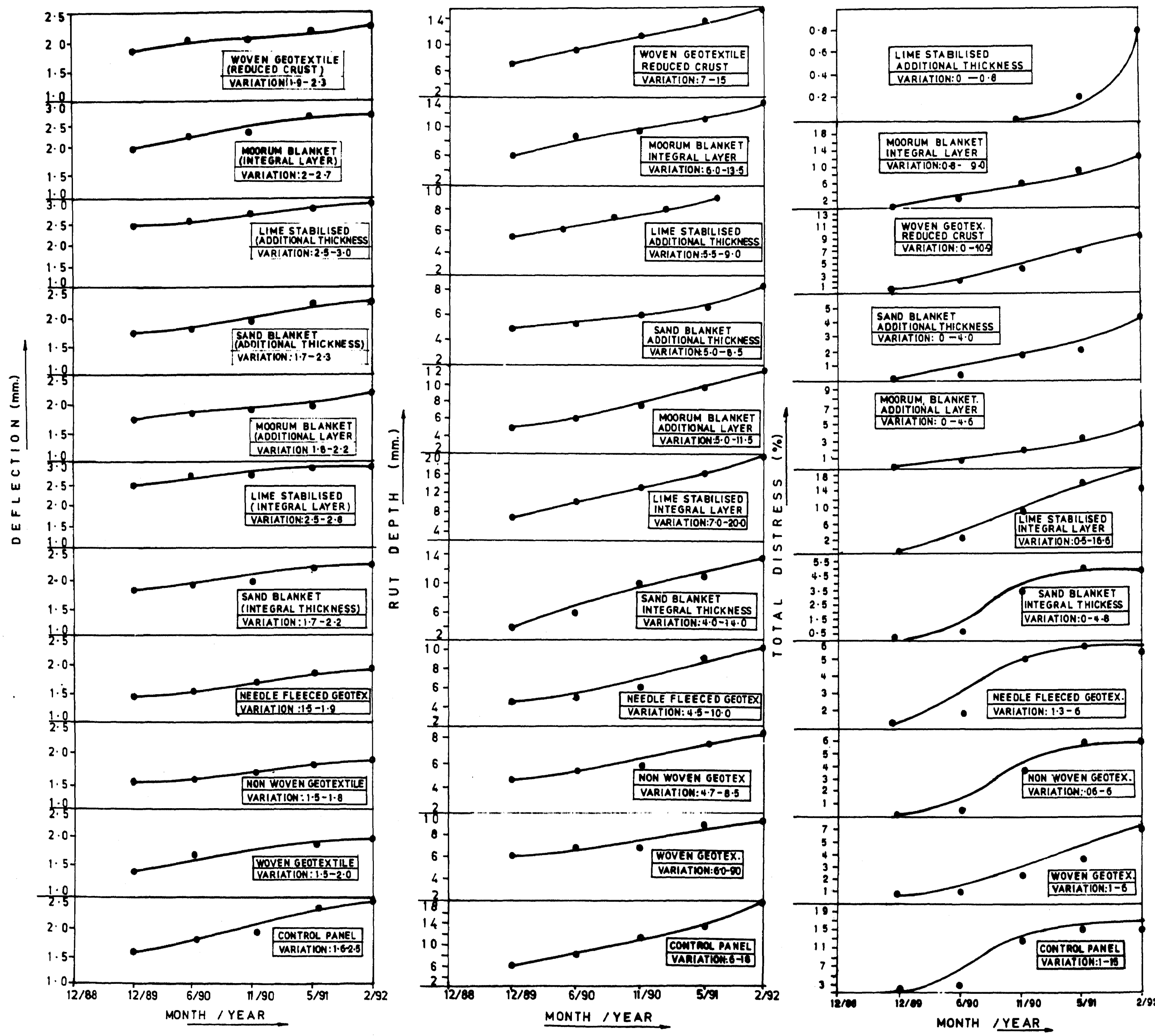

Fig.6 : Variation of Deflection, Rut Depth and Total Distress with time in Test Sections with & without Geotextile

all the three pavements are almost of the same magnitude indicating that the tensile modulus of the fabric should be adequate to sustain the pavement stress 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 the high tensile strength in the geotextile. However, the above observations are based on a short term performance and hence can be validated only when the experiments are designed only for reinforcement criteria and studies are conducted for a longer duration.

The stretches having the sand blanket, mooorum and lime-stabilised black cotton soil as integral layer of pavement performed inferior as compared to geotextile sections. However, among these three specifications, sand blanket course gave better performance. Recurring expenditure on maintenance measure was minimum with regard to the sand blanket course. The road surface provided a good riding quality without any significant distress. The reasons of its better performance may be attributed to its better capacity to serve as an effective intrusion barrier and as capillary cut off. The moorum blanket course specification behaved satisfactorily. It also served the purpose of barrier and capillary cut off. The specification having lime treated black cotton soil blanket 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 due to lack of strict quality control measures. Ingress of water from the berms entering the pavement crust also could not find its way out but flooded the pavement, thus accelerating the process of deterioration. This is further confirmed by the high deflection values obtained in the lime treated stretches.

In order to see the settlement behaviour of test sections with and without geotextile, the reduce levels at the top and bottom of settlement gauges are also recorded periodically at six months interval. However these observations could be taken up only upto a period of 2½ years, as settlement gauges became non-functional.

Though, nothing significant could be concluded from the settlement observations data, however, it is observed that there is vertical movement of the subgrade soil in all the specifications probably due to the swelling and shrinkage characteristics of soil and in no way the presence of geotextile could reduce it. But the change in pavement thickness with time in geotextile sections is minimum, which again proved that geotextile worked as a separator between the layers and prevented intermixing. The transverse slope variance with time is also plotted for different test sections and it is found that the sections with geotextiles are much better than control panel and slightly better than the othr test sections.

The test specifications with additional sub-base thicknesses behaved better than the sections with integral sub-base layers due to the obvious reasons of higher crust thickness. However, their performance in terms of rut depth and diestress is again comparable to the geotextile sections. The deflections, in these sections are observed to be very high inspite of having additional thickness. The reason attributed for these high deflection values is due to the constant water logging along the road side embankment.

The test section with reduced crust of geotextile has shown high deflection and rut depth but the distress is low. The reason for low distress may be attributed to the capacity to retain the granular layers intact. However, the authors feel with this limited data, it is difficult to arrive at any significant conclusion in this section.

CONCLUSIONS

In the background of all available experience backed up by the results of field trials and laboratory studies, it is concluded that the geotextiles can significantly function as a separator between subgrade and sub-base layers of a road pavement. Invariably, the use of geotextiles are proved to be cost effective, when sand or good quality sub-base materials are not avalaible within economic leads; when the CBR Of the subgrade is low, (i.e. less than 2) when the roads are water logged or when the roads have to be constructed speedily and maintained in a good state under adverse subgrade/ drainage conditions.

With the limited period of field observations, it is also observed that the type /variety of geotextile is not having any significance, if geotextile is properly selected and soil fabric system is adequately designed. However, definite conclusion regarding which type of geotextile is better for use under prevailing conditions can only be drawn after observing the performane of the road for some more time.

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