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Performance of road reinforced with polypropylene geotextile – a case study

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ABSTRACT: The paper deals with the design, subgrade treatment and construction methodology of a demonstration project involving the use of a Polypropylene woven geotextile as a separator cum reinforcement for a 2 km road stretch along one of the major district roads MDR82 in the Daund region of Pune District of Maharashtra, India. An indigenously custom designed and manufactured woven slit film polypropylene geotextile was used. The design of the Polypropylene woven geotextile reinforced pavement was carried out in accordance with the method proposed by Giroud and Noiray (1981). To control problems associated with expansive nature of subgrade soils, lime stabilization was carried-out. Construction of the geotextile reinforced road was completed and opened to traffic in April 2004. Monitoring of this stretch is currently under progress. Observations show that, in the geotextile reinforced section of the road, there are no signs of visible distress even after about eighteen months; where as earlier experience showed that road constructed as per standard conventional practice deteriorated within six months. The significant influence of geotextile layer in improving the performance of the road is demonstrated adequately.

1 INTRODUCTION

Civil Engineers, especially geotechnical engineer face several challenges while building structures for infrastructure development of the society. In such situations, one of the alternatives is to improve the ground using geosynthetics for building structures for infrastructure development. Geosynthetics is a generic term used to envelop family of materials manufactured from polymer materials, namely: (i) Geotextiles, (ii) Geogrids, (iii) Geomembranes, (iv) Geocomposites, and (v) Other products. Over the last three decades, the use of geosynthetics has recorded a tremendous growth, and is being increasingly employed in many civil engineering projects; especially the most common use of geosynthetics is in road construction. In addition to the application of geosynthetics in road construction, they can be used for number of applications like, slope stabilization, drainage control in embankment and dams, land reclamation, landfills, canal lining, railway embankments, erosion control, etc. Realizing the use and potential of geosynthetics in civil engineering structures, various engineering organizations the world over have been engaged in extensive research and development.

Geosynthetic materials perform five major functions, namely: separation, filtration, reinforcement, drainage, and as a moisture barrier. The concept of reinforcing soils is not new. As early as 1000 B.C. reeds and vines were used extensively to reinforce clay bricks and granular soils in the construction of many large earth structures. In the modern context however, reinforced soil began to be used during the early 1970's where, firstly steel strips, and later geotextiles. Geotextiles were first developed in the Netherlands in the 1950s as a result of an ambitious civil engineering construction program. It was initiated after the catastrophic flood of 1953, which inundated 150,000 hectares of land and killed 2,000 people. Since that time, many countries have shown growing interest in geotextiles.

Geosynthetic materials are primarily of three types (a) geotextile, (b) geogrid and (c) geomembrane. Geotextile can be sub-divided into two types: (i) Woven geotextile, and (ii) Non-woven geotextile. Woven geotextile is a geotextile comprising a planar structure produced by the interlacing of two or more sets of elements such as yarns, or filaments where the elements pass each other, usually at right angles and with one set of elements parallel to the geotextile axis. Secondly, non-woven geotextile is made by subjecting a web of fibres to either needle-punching, thermal bonding, resin-bonding, or a combination of the above. Almost all geotextiles are manufactured from either polypropylene or polyester. Both polymers are synthetic materials derived from the processing of crude oil and natural gas.

In this paper, a field trial involving the development and use of a Polypropylene woven geotextile in a 2 km stretch of road along MDR82 in the Daund region of Pune district is presented. The objective of the field trial is to evaluate and compare the performance of a geotextile reinforced stretch of the road with adjoining stretches of road constructed with conventional design under identical conditions.

2 DEVELOPMENT AND ASSESSMENT OF GEOTEXTILE PROPERTIES

A woven geotextile made of ultra-violet treated polypropylene tapes with a tenacity ranging from 6.5–7.0 g/denier was manufactured. The polypropylene tapes are weaved by adopting a twill weaving method. Tapes are arranged in such a way that the manufactured geotextiles will have identical tensile strength-strain behavior in the both warp and weft directions. In addition, the geotextile is observed to have a mass per unit area of 267 gsm and an Apparent Opening Size (AOS) equivalent to 1.18 mm.

Table 1. Summarizes properties of the woven fabric RPW3.

S. No	Property	Sample	
1.	Mass per unit area	268 gsm	
2.	Thickness at 2kPa	0.788 mm	
3.	Grab Tensile strength	WARP	WEFT
	– Strength @ Ultimate	1.1 kN	1.05 kN
	– Elongation @ Ultimate	19.6%	13.6%
4.	Wide width tensile strength	WARP	WEFT
	– Strength @ Ultimate	50.12 kN/m	51.18 kN/m
	– Strain @ Ultimate	14.6 %	16.8 %
5.	CBR Burst	3693 kPa	
6.	Apparent Opening Size (AOS)	1.18 mm	

3 DESIGN DETAILS OF GEOTEXTILE REINFORCED ROAD

3.1 *Background of the road status along MDR82*

Figure 1 presents a typical road stretch along MDR82. As shown in Fig. 1, on an average, rut depths were observed to range from 200-300 mm. It was informed that along this particular stretch, every year new road is constructed. The possible reasons for the distress could be: (i) Presence of a swelling subgrade, like black cotton soil, (ii) Inadequate drainage, (iii) Seasonal heavy traffic with higher axle loads, etc.

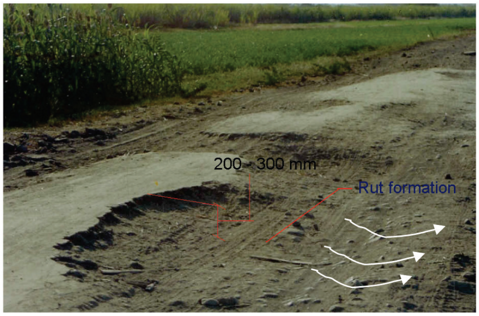

Figure 1. Status of road along MDR 82 in 2003.

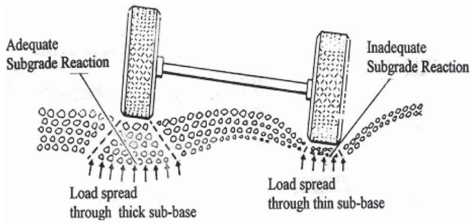

Figure 2. Load spreading phenomena of sub base on sub-grade.

During the process of severe rut formations, a non-uniformity in load spreading phenomena occurs (Fig. 2). This will result in inadequate subgrade reaction at one side (where thinning of the aggregate layer occurs) and more than adequate subgrade reaction at other side (i.e. where thickening of aggregate layer occurs). This type of situations reduce the design life of the road affect the riding quality and increase maintenance cost. In such situations, one of the viable alternatives is to strengthen the road by introducing a reinforcement layer in the form of geotextile at the interface of a granular sub-base layer and prepared subgrade.

For the roads constructed on weak sub-grade, the inclusion of geosynthetics, like geotextiles or geogrids can lead to less deformation of the road and can reduce the thickness of base materials needed. In many cases, this can be cost-effective, as the savings in importing the base material and in repairs to the road can offset the cost of reinforcement. A geosynthetic placed at the interface between the aggregate base course and the subgrade functions as a separator to prevent two dissimilar materials (subgrade soils and aggregates) from intermixing. Geotextiles and geogrids perform this function by preventing penetration of the aggregate into the subgrade. In addition, goetextiles prevent intrusion of subgrade soils into the base course aggregate. Localized bearing failures and subgrade intrusion only occur in very soft, wet, weak sub-grades. Therefore, separation is important to maintain the designed thickness and the stability and load carrying capacity of the base course. The stabilization of roads on weak

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subgrade with a geosynthetic material is primarily attributed to the basic functions of separation of the base course layer from the subgrade soil, and a reinforcement of the composite system. Geosynthetics are thus a great boon for ease in construction over soft soil as well as long-term performance of roads.

3.2 *Soil properties*

Table 2 presents the summary of soil properties. An average free swell of the soil sample collected is obtained as 93%, which indicates a high degree of expansion. The subgrade soil is of a black cotton soil and expanding in nature. Potentially expansive soils, such as, black cotton soils are montmorillonite clays and are characterized by their extreme hardness and deep cracks when dry and with tendency for heaving during the process of wetting. Roadbeds made up of such soils when subjected to changes in moisture content due to seasonal wetting and drying or due to any other reason undergo volumetric changes leading to pavement distortion, cracking and general unevenness. A proper design incorporating the following measures may considerably minimize the problems associated with expansive soils. As per IRC:37-2001, one of the alternatives is to stabilize the soil using quick lime extending over the road formation width along with measures for efficient drainage of the pavement section.

Table 2. Properties of soil.

Property	Black cotton soil
Hygroscopic water content, w_g [%]	9.9
Specific gravity, $G_{s\ [-]}$	2.80
Liquid Limit, LL [%]	69
Plastic Limit, PL [%]	33
Plasticity Index, PI [%]	36
Size fractions	
Gravel [> 4.75 mm] (%)	5.9
Sand [0.075 – 4.75 mm] (%)	11.88
Silt [0.002 – 0.075 mm] (%)	20.22
Clay [<0.002 mm] (%)	62
Soil classification	CH
Max. dry unit weight γ_d [kN/m^3]	14.42
Optimum moisture content [%]	31.5
*Undrained Cohesion [kN/m^2]	52.5
California Bearing Ratio CBR [%]	
– unsoaked	7.8
– soaked	1.8
Free Swell [%]	93

3.3 *Design details of geotextile reinforced road*

The design of the geotextile reinforced road was carried out as per the procedure outlined by Giroud and Noiray (1981). In the design, a standard axle load of 80 kN was considered with 10,000 passes. By taking the properties mentioned in Tables 1 and 2, the pavement block sections with and without geotextile layer were arrived. Keeping in view of the expansive nature of the subgrade, the subgrade is pre-treated with lime and saturated with water trickling. Figure 3 presents a schematic cross-section of geotextile reinforced road. The design particulars include the following: un-reinforced aggregate thickness with traffic h_0 is equivalent to 0.72 m and whereas reinforced aggregate thickness with traffic h_R works out to be 0.51 m. The reduction of aggregate thickness, Δh, resulting from the use of a geotextile, is 0.21 m. This results in 29% percentage savings in the aggregate requirement. These values were calculated for CBR = 1. However, in this study, in order to evaluate the performance of geotextile reinforced road along with adjacent stretches constructed without any geotextile, it was decided to provide an aggregate layer of 520 mm thickness above the geotextile layer. This includes 100 mm soft murrum cushion layer above and below the geotextile layer.

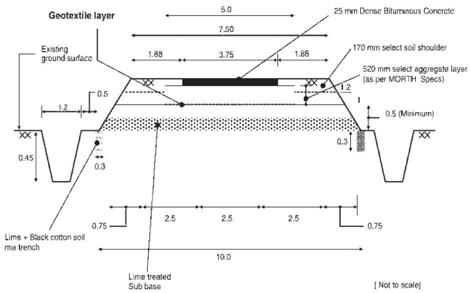

Figure 3. Schematic cross section of geotextile reinforced road.

The construction methodology involves trimming of the existing road surface and widening to obtain the road formation width for the entire 2 km stretch along MDR82. This is followed by treating the subgrade in two stages: (i) by forming lime + black cotton soil mix trenches on both sides and (ii) spreading of lime on top of the prepared subgrade and tricking with water (Fig. 3). Figure 4 shows a typical view of the road during geotextile fabric laying. As can be seen from the Fig. 4, the geotextile is overlaid on a compacted soft murrum base and pegged along the edges to keep it in position. After laying the geotextile fabric, a thin layer of soft murrum was laid to cushion the geotextile fabric. This is adopted to protect the geotextile from any damages during laying, installation and post-construction stages. The laying of the fabric was completed in April 2004 and is currently in the monitoring stage. Figure 5 shows a typical view of an un-reinforced road along MDR82 as on September 3, 2004. The surface of the road shown in Fig. 5 was built on the subgrade of almost identical conditions but without any ground improvement. The initiation of a rutting can be noted in Fig. 5. Contrary to this, the reinforced stretch was observed to behave well

Figure 4. View of the road during laying of geotextile.

Figure 5. Status of un-reinforced road along MDR82 as on September 3, 2004.

Figure 6. Status of the reinforced road as on September 3, 2004.

with reduced deformations and rutting (Fig. 6). This shows the significant influence of a geotextile layer along with a lime treatment in enhancing the performance of the road stretch along MDR82.

Figure 7 presents the status of the road in this year in September 2005. This shows the significant influence of geotextile layer on the performance of the road. However, in the present study a traffic upto 10,000 passes could only be selected. To some extent, this will be adequate to design low-volume roads (like major district road in this study) with geotextile layer, especially for rural areas. Further work in this direction is required to consider inclusion of traffic and arriving at a thickness of aggregate layer with a

Figure 7. Status of the reinforced road as on September 10, 2005.

geotextile at the interface of aggregate layer and subgrade. The aim of this particular trial was to bring-out significance of the usage of geotextiles in rural road construction. Further it is also required to quantify the accrued benefits due to: (i) enhancement of life and (ii) performance of the road.

4 CONCLUSIONS

In this paper, performance of a geotextile reinforced stretch along Major District Road (MDR) 82 was presented. Preliminary observations show that, in the geotextile reinforced section of the road, there are no signs of visible distress even after about eighteen months; where as earlier experience showed that road constructed as per standard conventional practice deteriorated within 6 months. This shows the significant influence of a geotextile layer along with a lime treatment in enhancing the performance of the road stretch along MDR82.

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