Geosynthetics – Alternative Material for Low Cost Pavement

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Abstract--**Geotextiles have been used in recent years in construction of temporary and permanent roads, railway tracks, embankments, retaining walls etc., as well as in river bank protection. The main functions of geotextiles make them suitable for application in geotechnical problems involving soft clay. But the high cost of fabric often acts as a deterrent to its large scale use in India. It should be appreciated, however, that the cost of fabric alone does not determine the overall economy of the use of geotextiles. An economic evaluation should take into consideration all the direct and indirect costs of a specific application. For evaluating the direct cost effect of geotextile applications in the context of India, five different pavement sections have been examined in this paper. Cost of material, labour and land have been collected for the metropolitan cities. For identical soil data and design parameters the variation of cost with or without geotextiles for the selected functions has been determined. The paper presents an economic evaluation of the use of geotextiles in pavement from the Indian perspective, after a review of the present state of usage.**

Key Words: **Geosynthetics, Pavement, Cost, Subgrade improvement, etc**

I. INTRODUCTION

ROAD often have to be constructed across weak and compressible or expansive soil subgrades. It is therefore a common practice to distribute the traffic loads in order to decrease the stresses on the soil subgrade. This is generally done by placing a granular layer over the soil subgrade. The granular layer should present good mechanical properties and enough thickness/toughness. The long-term interaction between a fine soil subgrade and the granular layer, under dynamic loads, is likely to cause pumping erosion of the soil subgrade and penetration of the granular particles into the soil subgrade, giving rise to permanent deflections and eventually to failure. At present, geosynthetics are being used to solve many such problems. Based on the type of pavement surfacing provided, roads can be classified as (i) unpaved roads and (ii) paved roads. If roads are not provided with permanent hard surfacing (i.e. asphaltic/bituminous or cement concrete pavement), they are called unpaved roads. Such roads have stone aggregate layers, placed directly above soil subgrades, and they are at mostly surfaced with sandy gravels for reasonable ride ability; thus the granular layer serves as a base course and a wearing course at the same time. If permanent hard pavement layers are made available to unpaved roads, to be called paved roads, their behaviour under traffic loading changes significantly. It can be noted that unpaved roads can be utilized as temporary roads or permanent roads, whereas paved roads are, in most cases, utilized as permanent roads which usually remain in use for 10 years or more.

Engineers continuously face maintaining and developing pavement infrastructure with limited financial resources. Traditional pavement design and construction practices require high-quality materials for fulfilment of construction standards. In many areas of the world, quality materials are unavailable or in short supply. Due to these constraints, engineers are often forced to seek alternative designs using substandard materials, commercial construction aids, and innovative design practices. One category of commercial construction aids is geosynthetics. Geosynthetics include a large variety of products composed of polymers and are designed to enhance geotechnical and transportation projects. Geosynthetics perform at least one of four functions: separation, reinforcement, filtration, and drainage. One category of geosynthetics in particular, geogrids has gained increasing acceptance in road construction.

During the past two decades, the use of geosynthetics in pavements has increased dramatically (Barksdale et al., 1989[4]; Dass, 1991[9]; Austin and Coleman et al., 1993[3]; Koerner et al., 1994[15]; Al-Qadi et al., 1994[2], 1996[1]). Various studies have been performed in the past few years to validate the performance of geosynthetics in highway pavements (Li et al., 1992[17]; Al-Qadi et al., 1994[2]; Koerner and Koerner, 1994[15]). Attempts were made to develop design methods for pavements stabilized with geotextiles and geogrids (Hass, 1986[12]; Carroll et al., 1987[6]; Barksdale et al., 1989[4]; Koerner et al., 1994[15]), but with little success. Several field and laboratory studies using static and dynamic loading conditions were conducted to validate the various claims of improving pavement performance due to geosynthetic inclusion. In 1993, researchers at Virginia Tech undertook a laboratory study to validate the performance of geogrids and geotextiles under controlled laboratory conditions using dynamic loading (Al-Qadi et al., 1994[2]; Smith et al., 1995[19]). The conclusions from that study supported the idea that geotextiles do improve pavement performance due to the separation mechanism when they introduced in a layered system, and not by reinforcement, as previously believed (Jorenby et al., 1986[14]; Lair and Brau, 1986[16]).

II. Geosynthetics in Pavement

Geosynthetics, especially geotexiles and geogrids, have been used extensively in unpaved roads to make their construction economical by reducing the thickness of the granular layer as well as to improve their engineering performance and to extend their life. A geosynthetic layer is generally placed at the interface of the granular layer and the soil subgrade (Fig. 1).

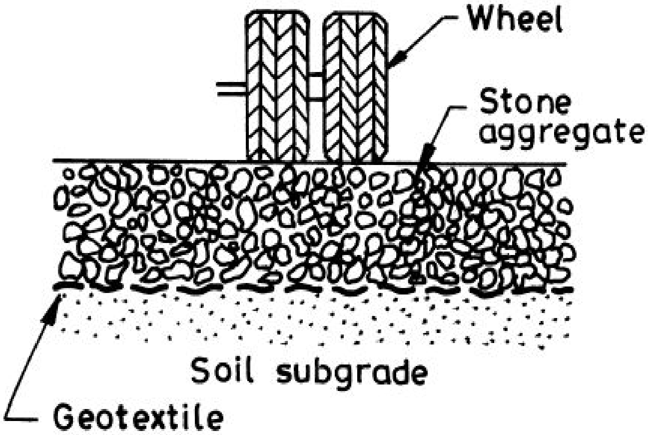

Fig. 1. Typical cross-section of geosynthetic-reinforced unpaved road

Reinforcement and separation are two major functions served by the geosynthetic layer (see Table: I). If the soil subgrade is soft, that is, the California Bearing Ratio (CBR) of the soil subgrade is low, say its unsoaked value is less than 3 (or soaked value is less than 1), then reinforcement will be the primary function because of adequate tensile strength mobilization in the geosynthetic through large deformation, that is, deep ruts (say, greater than 75 mm) in the soil subgrade. Geosynthetics, used with soil subgrades with an unsoaked CBR higher than 8 (or soaked CBR higher than 3), will have negligible amount of reinforcement occurring, and in such cases the primary function will uniquely be separation. For soils with intermediate unsoaked CBR values between 3 and 8 (or soaked CBR values between 1 and 3), there will be an interrelated group of separation, filtration, and reinforcement functions, may be called stabilization function of the geosynthetic. Geosynthetics, especially geotextiles and some geocomposites, may also provide performance benefits from their filtration and drainage functions by allowing excess pore water pressure, caused by traffic loads in the soil subgrade, to dissipate into the granular base course and in the case of poor-quality granular materials, through the geosynthetic plane itself.

By providing a geosynthetic layer, improvement in the performance of an unpaved road is generally observed in either of the following two:

- ✓ For a given thickness of granular layer, the traffic can be increased;
- ✓ For the same traffic, the thickness of the granular layer can be reduced, in comparison with the required thickness when no geosynthetic is used.

A few design methods are available for unpaved road constructions with geosynthetics. Research work is still continuing for the development of new design methods and for the improvement of these in the existing ones. Some of the manufacturers have developed their own unpaved road design charts for use with their particular geosynthetics. All these design charts recommend greater savings of granular material, required in construction, as the soil subgrade becomes softer, showing logical results. A design method based on the specific well-defined geosynthetic property, such as geosynthetic modulus, is generally acceptable by all.

The introduction of a geotextile layer can typically save one-third of the granular layer thickness of the roadway over moderate to weak soils. Giroud & Bonaparte (1984)[11] reported reduction of about 30–50% of thickness of the aggregate layer with the inclusion of geogrids. Improvement in the performance of unpaved roads can also be observed in the form of reduction in permanent (i.e. non-elastic) deformations to the order of 25–50% with the use of geosynthetics, as reported by several workers in the past (De Garidel and Javor, 1986[10]; Milligan et al., 1986[18]; Chaddock, 1988[7]; Chen et al., 1989[8]; Hirano et al., 1990[13]).

III. Life Cycle Cost Analysis

A detailed cost analysis should be performed to determine if the geosynthetic reinforced pavement design is justified. The cost of the geosynthetic reinforced pavement section should be compared to the cost of an unreinforced pavement section. A direct cost comparison based upon material savings alone, however, does not include the indirect benefits of using geosynthetic reinforcement. These indirect benefits include increased site mobility, improved ease of construction, reduced haul costs for additional aggregate, and an improved ability to meet compaction requirements over soft subgrades. These indirect benefits may compensate for slight increases in material costs Berg et al. (2000)[5].

Consider Fig. 2, showing different pavement sections. Firstly typical design of pavement is followed represented by A (IRC - Unpaved Road). IRC 37:2001 – has special recommendations for the pavement on expansive soil in Annexure - 4. It suggest 0.6 to 1.0 m thick non-expansive cohesive soil (CNS) cushion on the expansive soil for road construction, as shown and represented in B (IRC - Road on Expansive Soil - CNS Cushion). Alternatively in-situ Lime – Flyash stabilized soil layer has been prepared as subgrade, as represented by C (IRC - Alternative Lime FA Stabilization). Lastly geosynthetic pavement section is shown represented by D and E. It is seen that there is considerable decrease in layer thickness and hence saving time and cost of construction. The comparative evaluations of cost of different ground improvement for road section (per 1 Km length x 7 m width road) are shown in Table II.

TABLE I. PRIMARY FUNCTION OF GEOSYNTHETIC LAYER IN UNPAVED ROAD CONSTRUCTION BASED ON FIELD CBR VALUE

Soil Subgrade Description	CBR		Primary Function of the Geosynthetic	Cost Justification for Use of the Geosynthetic
	Un soaked	Soaked		
Soft	Less than 3	Less than 1	Reinforcement	Significantly less granular material utilization
Medium	3–8	1–3	Stabilization (an interrelated group of separation, filtration, and reinforcement functions)	Less granular material utilization and longer lifetime
Firm	Greater than 8	Greater than 3	Separation	Much longer lifetime

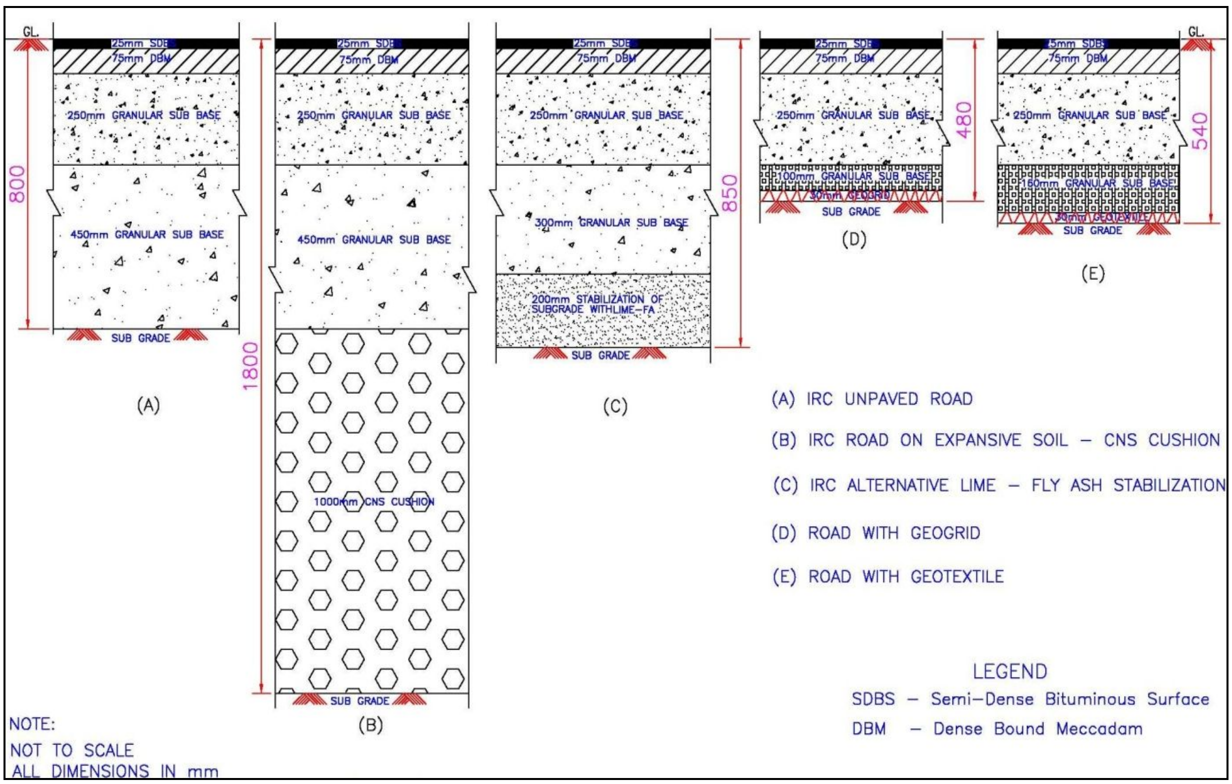

Fig.1. Comparisons of different pavement section.

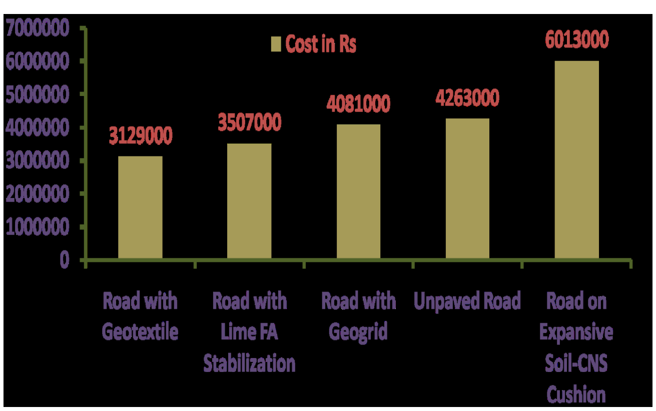

Fig. 3. Increasing order of comparative cost evaluation of road (Subgrade CBR = 2)

IV. CONCLUSIONS

Good road metal is not available at all places, thus the combination with geotextile and poor aggregates can also be adopted.

Geotextile takes stresses of swelling and shrinkage of sub-grade and controls overall durability, rut formation and hence reduces annual maintenance cost of roads. These materials can be quickly and inexpensively laid over soft soil and covered with aggregate, potentially reducing the volume of aggregate needed—which saves money as well as preserving a diminishing natural resource.

Use of Geosynthetics is very cost effective when good quality sub-base materials are not available within economic lead and CBR of subgrade is low i.e. less than 3.

TABLE II. COMPARATIVE EVALUATION OF COST OF DIFFERENT GROUND IMPROVEMENT

(PER 1 KM LENGTH X 7 M WIDTH ROAD)

No.	Layers	Thickness (m)	Length (m)	Width (m)	Rate / m^3	Total Rs/-
1	*A = IRC (Unpaved Road)**					
	Granular Sub Base	0.45	1000	7	800	2520000
	Granular Base	0.25	1000	7	900	1575000
	DBM	0.07	1000	7	200	98000
	SDBS	0.025	1000	7	400	70000
			Total Cost of IRC (Unpaved Road) =			42,63,000.00
2	*B = IRC (Road on Expansive Soil- CNS Cushion)**					
	CNS Cushion	1	1000	7	250	1750000
	Granular Sub Base	0.45	1000	7	800	2520000
	Granular Base	0.25	1000	7	900	1575000
	DBM	0.07	1000	7	200	98000
	SDBS	0.025	1000	7	400	70000
		Total Cost of IRC (Road on Expansive Soil- CNS Cushion) =				60,13,000.00
3	*C = IRC (Alternative Lime FA Stabilization)**					
	Stabilization	0.3	1000	7	40	84000
	Granular Sub Base	0.3	1000	7	800	1680000
	Granular Base	0.25	1000	7	900	1575000
	DBM	0.07	1000	7	200	98000
	SDBS	0.025	1000	7	400	70000
		Total Cost of IRC (Alternative Lime FA Stabilization) =				35,07,000.00
4	*D = Road With Geogrid*					
	Granular Sub Base	0.13	1000	7	800	728000
	Geogrid	-	1000	7	230	1610000
	Granular Base	0.25	1000	7	900	1575000
	DBM	0.07	1000	7	200	98000
	SDBS	0.025	1000	7	400	70000
			Total Cost of Road With Geogrid =			40,81,000.00
5	*E = Road With Geotextile*					
	Granular Sub Base	0.16	1000	7	800	896000
	Geotextile	-	1000	7	70	490000
	Granular Base	0.25	1000	7	900	1575000
	DBM	0.07	1000	7	200	98000
	SDBS	0.025	1000	7	400	70000
			Total Cost of Road With Geotextile =			31,29,000.00

Note: * Cost of Cutting / Excavation is ignored in all cases say by 60 Rs/m^3

- ✓ Design evaluation and for cost comparisons prices and materials approximately assumed for different site condition.
- ✓ Rating of cost evaluation design is shown in Fig: 3.

Increasing order of comparative cost evaluation of road (Subgrade CBR = 2) is shown below:

1. Road with Geotextile, (Rs/- 31, 29,000.00).
2. Road with Lime FA Stabilization, (Rs/- 35, 07,000.00).
3. Road with Geogrid, (Rs/- 40, 81,000.00).
4. Unpaved Road, (Rs/- 42, 63,000.00).
5. Road on Expansive Soil–CNS Cushion, (Rs/- 60, 13,000.00).

If the savings provided by the reduction in aggregate is greater than the cost of the geosynthetics reinforcement, then reinforcement of the section may represent a cost-effective design option.

These studies demonstrate that in subgrade working platforms, industrial byproducts can replace aggregate in stabilizing soft subgrades, and geosynthetics can help reduce the aggregate thickness required in pavement subbases. Research must still establish specific design values for most of these materials as they impact pavement structures, and with each material, values must be determined for full use in future mechanistic-empirical pavement design methods.

More research is required to use of high tensile geotextile with respect to swelling and shrinkage stresses and geotextile strength over years (creep). Woven geotextile with high strain modulus (E > 200 kPa) have potential to provide economic solution to pavements on CH soil with expansive behaviour.

Future research may address geosynthetics' potential to reduce the amount of aggregate used in subgrade enhancements and help define the performance characteristics of various geosynthetic materials.

Mere usage of Geosynthetics will not ensure good performance. Proper selection of Geosynthetics, correct design and quality assurance are essential. Hence, geotextile testing and control lab with integrity is need of time.

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