MODEL STUDIES ON GEOTEXTILE REINFORCED PAVEMENTS

By

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1. INTRODUCTION

The geotextiles which have practically invaded the civil engineering industry the world over as viable and economic material, is now increasingly finding uses in India. Nearly 70 per cent of the total use of geotextiles is in the construction of pavements. The functions of geotextile in road pavements are:

- Separation between old and new layers.
- Separation and reinforcement between subgrade and sub-base in paved and unpaved roads.
- Reinforcement of jointed flexible pavement.
- Control of propagation of cracks into overlays.

The available literature shows that the parameters considered for the design of road pavement, are mainly related with geotextiles. A number of design methods are in vogue for use of geotextile in pavements. Some methods have a reasonable theoretical basis and some methods are based on small or large scale model studies. However, they cannot be generalised. It has been concluded by Rao et. al[7] that the method proposed for geotextile reinforced unpaved roads by Giroud and Noiray[3] can be extended for use in India. Another method which is quite useful and can be directly used, has been that proposed by Haliburton and Barron[4]. However, it should be kept in mind that all these methods need verification in our country. Thus the study of road pavement with varying location of geotextile in subgrade and with varying base and sub-base material is still required to augment the data and results available from few studies carried out so far.

In the present study, CBR test has been conducted with/without geotextile layers at various depths and in different numbers on 'CL' type of soil. Secondly, a laboratory model study for temporary roads has been carried out using geotextile as reinforcing material. The tests have been repeated by varying the location and number of geotextile layers in the soil subgrade.

A brief literature review, mainly with reference to geotextile reinforced pavement is presented in the following section.

2. LITERATURE REVIEW

A large number of structures have been built all over the world using earth

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reinforcement technology. Among them Road/Railway embankments, pavements and retaining walls are major structures. A brief literature review with reference to the road pavement is presented hereunder.

Steward, Williamson and Mohney[8] developed a design procedure based on Quinault test, in which the fabric is used for separation rather than reinforcement. They observed that little rutting [less than 5 cm] would occur under even a relatively large number of load applications if stress levels in the subgrade were held to 2.8 or less times the undrained shear strength without fabric and 5.0 or less times the undrained shear strength with fabric. They also noted that approximately 10 cm of surface rutting would be about equal at stress levels of 3.3 c without fabric and 6.0 c with fabric, where 'c' is the undrained shear strength of the soil.

Bender and Barenberg[1] developed a design procedure based on laboratory model studies for temporary roads on soft subsoil using light-weight non-woven geotextile as reinforcing material. The tests were conducted in a rectangular tank. A low plastic clay was compacted at different compaction efforts and water contents which gave CBR value ranging from 0.6 per cent to 2.5 per cent. Next, various thicknesses of stone base aggregate [depths of 7.5, 15 and 22.5 cm] were placed to form a soil aggregate system, or if a geotextile was placed at the interface, a soil-fabric-aggregate system was evaluated. Cyclic load of known stress level were applied to a 10 cm x 15 cm footing on the surface of the aggregate, and deflections were measured after a given number of load application. Graphs were plotted between rut depth and the ratio of applied stress to the undrained strength of the sub-soil. It was noted from the graph that, without fabric an increase in rutting occurs at ratio equal to 3.3 while for the case with fabric, the increase occurs at the ratio equal to 6.

Giroud and Noiray[3] developed a design criteria for temporary roads based on theoretical considerations and an investigation at the USAE Water-ways Experiment Station. Soil has been assumed to be saturated and to have a low permeability. Woven geotextile has been considered as reinforcing material placed between aggregate interface. The analysis of aggregate thickness is carried out including the influence of number of traffic, rut depth and axle load for unreinforced case. Then for reinforced case, thickness of aggregate over geotextile has been calculated taking into consideration "membrane effect". The thickness of aggregate in reinforced and unreinforced cases are compared and finally a design chart has been developed for axle load of 80 kN, rut depth of 0.3 m and tyre pressure of 480 kpa. for different geotextile modulus, elongation of geotextile and number of passes.

Haliburton and Barron[4] presented method for design of fabric reinforced unsurfaced roads. They showed that optimum depth of aggregate placed on the geotextile significantly increased the strength and deformation resistance of the aggregate cover. They have showed that their method requires significantly less aggregate on the geotextile than predicted by other design methods for geotextile reinforced roads.

Werner[9] developed a design criteria for the separation function of geotextiles on the basis of test procedures. He evaluated the relevant stress situations for geotextile by means of puncture, burst and tear analysis of the mechanical properties of Polyfelt TS non-woven geotextile. He designed the fabric taking the puncture stress, burst stress and tear into consideration. Also puncture elongation and burst elongation have been taken into account.

Brorsson and Erikson[2] determined the long term properties of geotextiles and their function as a separator in road construction. Nine different geotextiles were installed on a very frost susceptible road subgrade. Samples of the geotextiles were dug out after 5 and 10 years and tested. Test result showed that the strength properties of the geotextile have changed in course of time. But in spite of these reductions, there was no migration of fines from the subgrade into the sub-base.

Hausmann[5] carried out a parametric study for fabric reinforced unpaved road design procedure. According to most design methods, the aggregate height required is a function of the subgrade strength, permissible rut depth, wheel load traffic, fabric modulus and load spreading capacity. The result presented by the Hausmann showed the relative importance of these input parameters and demonstrated that a significant increase in modulus is required in order to benefit from the membrane effect.

Yashuhara et.al.[10] have conducted small scale model test at the laboratory in order to find a design method of unpaved road paved roads on soft foundations reinforced with the geosynthetics and to provide a basis for the selection of compatible embankment geometry and reinforcement layout. According to the results of the model tests for adoption of the several kinds of geosynthetics, it was proved that application of a geogrid is most favourable for controlling differential settlement of the fill on soft grounds under cyclic loading. He concluded that cubical form of the geogrid is most preferable for reinforcement of soft ground judging from both view points of settlement (which depends not only upon the rigidity of the material but also upon the frictional resistance among material and granular fill) and softness of clay. Rao, Gupta and Yadav[7] have presented a critical appraisal for use of geosynthetics in road pavement in India.

A review of literature indicates that in road pavements, studies have been performed mostly with geotextiles. Method for designing the roads with geosynthetics in separation and reinforcement function have been developed but these are few in number and cannot be generalised. The design methods for reinforcing function are only for unsurfaced temporary roads in which formation of rutting is permitted. Subgrade soil is generally assumed to be fine grained and less permeable (silt and clay with CBR>1). Base materials are sufficiently strong to distribute the wheel load effectively. Study of road foundation with varying base and sub-base material is still needed alongwith the study of effect of the location and number of geosynthetic layers.

3. EXPERIMENTATION

In the present work, soil used is Alluvial soil of Allahabad, classified as CL. Woven geotextile manufactured by M/s. Bombay Dyeing has been used as reinforcing material. California Bearing Ratio test were conducted on unreinforced and reinforced sub-grade soil. From the result obtained, a pavement section was chosen and plate bearing tests were performed in unreinforced and reinforced pavement model.

There are three basic materials required for construction of pavement section. These are-Foundation soil, Aggregates and Geotextile. Various factors such as material availability, material properties, relative cost, delivery restriction and theoretical consideration affects the choice of materials to be used for the construction of road. In the present model study, foundation soil used for carrying out the experiment is a silty clay of little plasticity. This is a local soil, yellowish in colour and consists mainly silt with little clay and has been classified as CL. The engineering properties of the soil used are given in Table 1.

The aggregates chosen for the base course and sub-base course of the pavement, were based on the specification of materials for WBM pavement given by IRC.

TABLE 1. PROPERTIES OF SOIL

S.No.	Properties	Value
1.	Liquid Limit	32.5%
2.	Plastic Limit	20.0%
3.	Plasticity Index	12.5%
4.	Specific gravity	2.67%
5.	Optimum moisture content	15.0%
6.	Maximum Dry Density	1.75f g/cc
7.	Percentage of soil particles finer than 2 microns	35%
8.	Percentage of soil particles finer than 75 microns	95%
9.	Silt content	60%
10.	Clay content	35%
11.	Sand content	5%
12.	Cohesion	0.6 kg/cm^2
13.	Angle of internal friction	23^0

3.1. Description of experimental Set up

1. California Bearing Ratio Test

CBR test has been carried out at OMC and soaked conditions. Samples have been prepared by static compaction and the experiment has been carried out for five types of samples with reference to geotextile layer placement in the mould, Table 2.

A load *vs.* settlement curve has been plotted for each case mentioned above. Then a graph is drawn in order to study the variation of CBR value with number and location of geotextile layer. The aim of CBR test has been to study the effect of location and number of geotextile layer on CBR value of subgrade soil.

2. Plate Bearing Test on Pavement

A model box of size 1.35 m x 1.1 m x 0.6 m has been constructed from teak

TABLE 2. ARRANGEMENT OF GEOTEXTILE IN SOIL IN CBR TEST (H/D=2.54, H-HEIGHT OF MOULD, D-DIAMETER OF PLUNGER)

(i)	without geotextile layer.
(ii)	with one layer of geotextile at H/2 from the top of the mould.
(iii)	with one layer of geotextile at H/3 from the top of the mould.
(iv)	with two layers of geotextile at H/3 and 2H/3 from top of the mould.
(v)	With three layers of geotextile at H/4, 2H/4 and 3H/4 from the top of the mould.

wood with heavy reinforcement both from outside and inside. A simple hydraulic jack loading system manually operated with a calibrated proving ring of capacity 2500 kg. has been used for loading arrangement.

The soil used was placed in the box in three layers, each being 12 cm thick and compacted at OMC. The base course (aggregate size 20 mm) and sub-base course (aggregate size 40 mm) was of 7.5 cm each. The plate used for applying load is of mild steel with 10 cm diameter. The criterion adopted for plate size is that the diameter of plate should be such that the distance of wall of the box from edge to plate on either side is not less than 4 times the diameter of plate. (Lee[6] has also used plates of diameter varying from 7.5 cm to 30 cm in plate bearing tests). Load is applied by jack and settlement was observed by dial gauge. The plate bearing test has been carried out on model pavement section under the following set of conditions given in Table 3.

TABLE 3. ARRANGEMENT OF GEOTEXTILE IN SUBGRADE IN PLATE BEARING TESTS (H/D=6.0, H-PAVEMENT THICKNESS, D-DIAMETER OF PLATE)

I.	Without geotextile layer in subgrade soil	
II.	With one layer of geotextile in the subgrade soil	
	(a)	At 2 cm (H/30) from the top of Subgrade
	(b)	At 4 cm (H/15) from the top of Subgrade
	(c)	At 6 cm (H/10) from the top of Subgrade
III.	With two layers of geotextile in the subgrade soil	
	(a)	At 2 cm and 4 cm (H/30 & H/15) from the top of subgrade.
	(b)	At 2 cm and 6 cm (H/30 & H/10) from the top of subgrade.
	(c)	At 4 cm and 6 cm (H/15 & H/10) from the top of subgrade.

Load *vs.* settlement curve has been plotted for each case studied. Log-Log plot has also been prepared (Fig.5) to determine the exact point at which failure occurs.

4. RESULTS AND DISCUSSION

The CBR test on subgrade soil and the plate bearing test on model pavement section has been carried out. The results of various tests are as follows:

4.1. CBR Test

The values of CBR obtained for subgrade soil at optimum moisture content and soaked condition for the different cases are shown in Table 4. A typical load *vs.* settlement curve for Geotextile Reinforcement is shown in Fig.1. Fig.2.

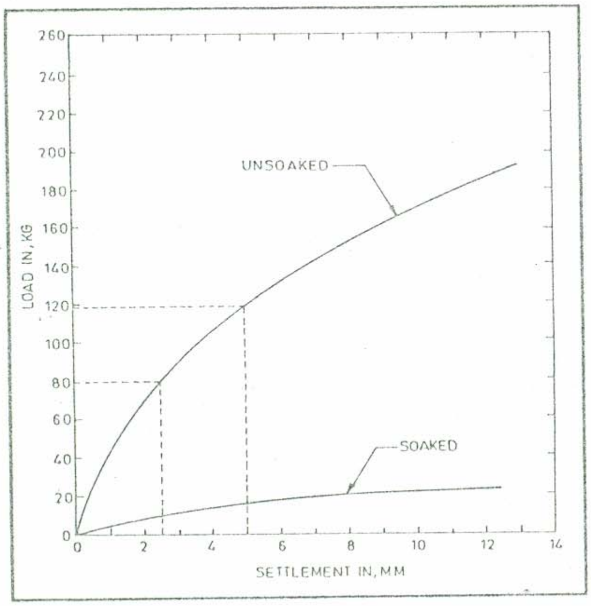

Fig. 1. CBR test (soaked and unsoaked) reinforced with three layer geotextile (at H/4, 2H/4, 3H/4 from top)

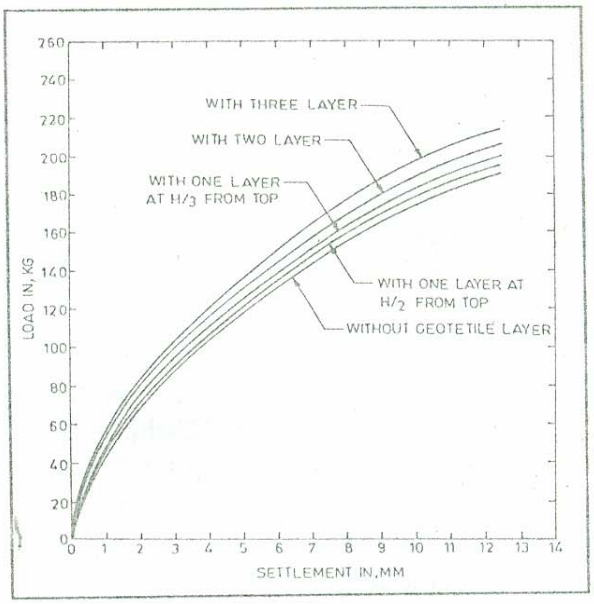

Fig. 2. Variation in CBR value with number and location of geotextile layer (Soil at OMC)

TABLE 4. CBR TEST RESULT

S.No.	Reinforcement details	Experimental condition	
		CBR% (soil at OMC)	CBR% (Soil Soaked)
1.	Unreinforced	5.93	0.494
2.	Reinforced with one layer of geotextile at H/2 from the top	6.0	0.579
3.	Reinforced with one layer of geotextile at H/3 from the top	6.18	0.612
4.	Reinforced with two layers of geotextile at H/3 & 2H/3 from the top	6.30	0.658
5.	Reinforced with three layer of geotextile at H/4, 2H/4 and 3H/4 from the top	6.79	0.862

shows variation of CBR value with number and location of geotextile layer.

4.2. Discussion - CBR Test Observations

The CBR test results indicate that the presence of geotextile influences the CBR value. The improvement of soil strength due to presence of geotextile is a function of interaction of geotextile with soil, in both the condition of soil, i.e. at OMC and soaked condition. It has been observed that there is no significant improvement in the CBR value when the geotextile layer is placed quite below. This is due to the reason that the depth through which the effective pressure bulb passes in a function of the diameter of the plunger and if the geotextile inserted in the middle does not come under the way of effective pressure bulb, no significant improvement is witnessed. To have an improvement in the CBR value, it is necessary that the geotextile inserted must intercept the effective pressure bulb generated due to the imposed load, otherwise it losses its meaning. So it is felt that it would be better to place the geotextile layer towards the top of the subgrade soil.

4.3. Plate Bearing Test

The values of maximum load at failure and corresponding failure stress obtained for different cases are presented in Table 5.

The comparison of load versus settlement curve with different geotextile reinforcement (single layer) arrangement is shown in Fig.3. Similarly the comparison of load versus settlement curve with different geotextile reinforcement (two layer) arrangement is shown in Fig.4. Finally, a comparison of load versus settlement curve on log-log plot for different geotextile reinforcement is shown in Fig. 5.

4.4. Discussion - Plate Bearing Test

The strength and life of a pavement is largely dependent on the quality and stability of the subsoil. The load carrying capacity of the subsoil rapidly decreases as it becomes saturated with water. Gradually, the granular material from the base course penetrates into the subsoil and pavement finally fails. The use of geotextile as a separation medium between the base course and the subsoil prevents the mixing up of the two, permits the water to drain off quickly through and along the plane of the fabric. As a result, the surface remains clean, dry and intact.

The plate bearing test reveals that the load carrying capacity of pavement enhances with the placement of geotextile reinforcement i.e. the failure stress increases.

TABLE 5. PLATE BEARING TEST

Experimental condition		Max. Failure load at failure (Kg)	Stress (Kg/cm^2)
Without Geotextile layer		521.85	6.64
Reinforced	2 cm from top	558.36	7.26
With one layer	4 cm from top	558.60	7.11
Of geotextile	6 cm from top	542.43	6.91
Reinforced	2,4 cm from top	626.51	7.98
With two layers	2,6 cm from top	608.58	7.75
Of geotextile	4,6 cm from top	579.18	7.37

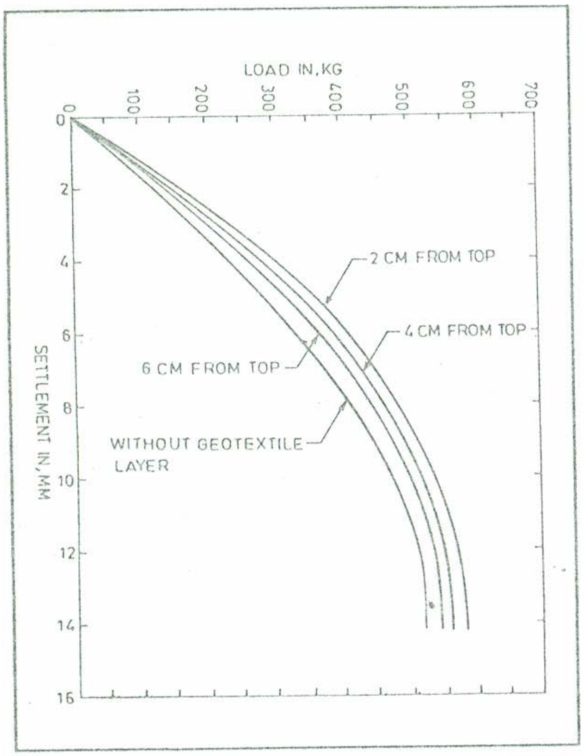

Fig. 3. Comparison of load bearing behaviour of pavement with different geotextile reinforcement (Single layer) arrangement

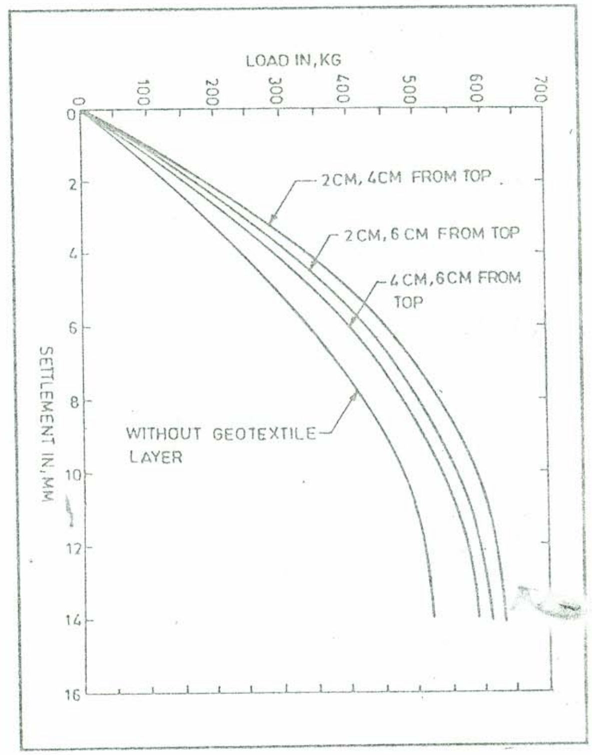

Fig. 4. Comparison of load bearing behaviour of pavement with different geotextile reinforcement (Two layer) arrangement

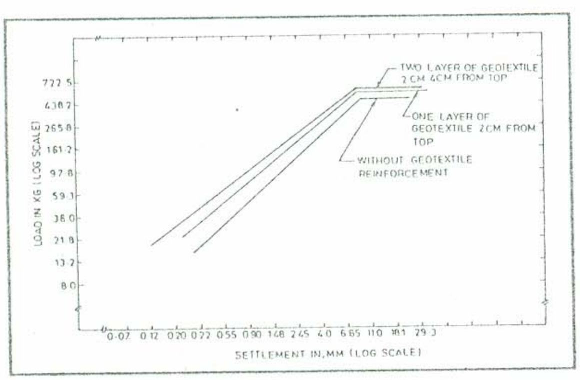

Fig. 5. Comparison of load bearing behaviour of pavement with different geotextile reinforcement arrangement (log-log plot)

In the present case the maximum increase in stress being 20 per cent. Actually there are number of factors on which the increase in stress depends, such as type of subgrade soil, type of aggregate and its thickness, quality of geotextile material used and various other factors.

The increase in the failure stress can be significantly used in reducing the thickness of aggregate layer, thereby achieving economy by incorporating geotextile in an unpaved road surface.

5. CONCLUSIONS

From the study carried out for CBR test, following conclusions have been drawn

(1) The presence of geotextile layer influences the CBR values of the soil.

(2) There is no significant improvement in the CBR value of the soil when the geotextile layer is placed in the lower half of the soil specimen.

(3) In order to improve the CBR value of the soil it is necessary to place geotextile in such a manner that it intercepts the effective pressure bulb generated due to imposed load.

From the result of the plate bearing test on model pavement performed under various set of conditions following are the conclusions:

1. The placement of geotextile reinforcement enhances the failure stress.
2. The failure stress increases with the increase in the number of geotextile layers.
3. For the same number of geotextile layers, the increase in failure stress is more when they are placed towards the top of the subgrade soil.
4. Due to increase in failure stress the thickness of aggregate layer can be reduced thus achieving economy and stability.

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