

# **BEHAVIOUR OF MODEL PAVEMENTS WITH GEOSYNTHETICS UNDER REPETITIVE LOADING**

*by*

**SHEO GOPAL**

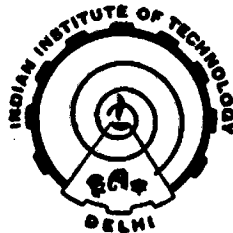
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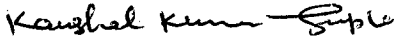
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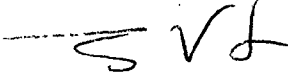
**DECEMBER, 1993**

**CERTIFICATE**

This is to certify that the thesis entitled "**BEHAVIOUR OF MODEL PAVEMENTS WITH GEOSYNTHETICS UNDER REPETITIVE LOADING**" submitted by Mr. Sheo Gopal to Indian Institute of Technology, Delhi, for the award of the degree of the Doctor of Philosophy is a record of the bonafide research work carried out by him. Mr. Sheo Gopal has worked under our supervision for the submission of this thesis, which to our knowledge has reached the requisite standard.

This thesis, or any part thereof has not been submitted to any University or Institution for the award of any degree or diploma.

  
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**ABSTRACT**

Temporary or unpaved roads with low volume of traffic are often constructed for construction and access roads, contractor's haul roads, forest roads etc. Unpaved roads are usually expected to carry heavy axle loads over subgrades along their alignment. In such circumstances the use of geosynthetics at the aggregate-subgrade interface is found to be a convenient and economical alternative to improve their performance. When a geosynthetic is introduced at the aggregate-subgrade interface, it offers restraint to the deflection of aggregate and possibly enhancing its load spreading capacity. In addition a geotextile separates subgrade and aggregate. Since a variety of geosynthetics are available in the market, their relative influence on the behaviour of unpaved roads needs a careful laboratory study under similar test conditions.

Water bound macadam (WBM) is being widely used in India as subbase/base course in roads and its use is likely to continue in future also because of the rising costs of bitumenous materials. Despite this, limited attempts have been made to understand the engineering behaviour of such materials. Eventhough it is well established that evaluation of resilient parameters of pavement materials through repeated load triaxial tests would be beneficial in developing a theoretical design procedure, still few attempts have been made on different materials separately. Keeping this in view to understand the behaviour of unpaved roads it has been thought that it would be more appropriate to study the simulated aggregate-subgrade interface under repetitive

loading triaxial condition, because it gives the response of the system as a whole under an ideal condition.

More specifically, towards a better understanding of the role of geosynthetics in improving the performance of unpaved roads, the proposed research work included:

- a. studies on the behaviour of silt, WBM and composite specimens (representing base/subgrade interface) with and without a geotextile under conventional undrained triaxial compression conditions.
- b. studies on the behaviour of composite specimens (representing a typical sample obtained from an aggregate subgrade interface) with and without a geotextile under repetitive triaxial condition, to investigate its influence on permanent axial strain, resilient axial strain and resilient modulus.
- c. studies on the behaviour of modelled two/three layered pavement systems with and without geosynthetic inclusion under static and repetitive loading conditions.

These have been achieved through an extensive laboratory programme broadly categorised into **Triaxial Test Series** and **Model Test Series**, detailed in **Chapter 3** and the results are presented and discussed in **Chapter 4**.

The **Triaxial Test Series** consisted of conventional consolidated undrained triaxial tests and repeated load triaxial tests. These were conducted on saturated specimens of Delhi silt, WBM and composite specimens of WBM over silt subgrade

(representing the condition at the interface) with and without a nonwoven geotextile (GTNW1) at confining pressures upto 200 kPa. The repeated load triaxial tests were conducted under different repeated axial loads upto 5000 repetitions. The following salient observations are drawn.

From the **Conventional Consolidated Undrained Triaxial Tests**, it is clear that the stress-strain behaviour of unreinforced composite specimens is similar to that of silt specimens indicating that the interface behaviour is basically influenced by the latter. However, the strength of composite specimens with GTNW1 is significantly higher (1.5 times) than that without GTNW1, demonstrating that structural contribution of WBM portion is enhanced due to GTNW1. From the **Repeated Loading Triaxial Tests**, it has been observed that permanent axial strain of the specimens is reduced upto 56 percent due to GTNW1 inclusion. For specimens with or without GTNW1 the resilient axial strain ( $\epsilon_r$ ) decreases steadily with number of load repetitions (N). The influence of GTNW1 inclusion is to reduce the  $\epsilon_r$  (upto 38 percent) at higher N values. For a given repeated axial load, this effect is further accentuated at low confining pressures. The resilient modulus ( $M_R$ ) of the unreinforced composite specimens decreases with N whereas  $M_R$  of the composite specimens with GTNW1 increases with N, consequently it was observed that the percent increase in  $M_R$  is substantial (upto 107 percent) at higher N values.

The relationship between applied repetitive deviatoric stress levels ( $q_r/\sigma_3$ ) and resulting permanent axial strain ( $\epsilon_p$ ) for composite specimens with or without GTNW1 is found as :

$$\epsilon_p = m (q_r/\sigma_3)$$

where,

$$\begin{aligned} m &= 0.05 \text{ to } 0.14 - \text{ for composite specimens without} \\ &\quad \text{GTNW1, and} \\ &= 0.03 \text{ to } 0.06 - \text{ for composite specimens with} \\ &\quad \text{GTNW1} \end{aligned}$$

The relationship is valid for stress range and number of load repetitions studied.

The **Model Test Series** consisted of static compression tests and repeated load tests using plates of 10 cm and 7.5 cm diameter. The models were prepared in a perspex tank of internal dimensions measuring 35 cm x 35 cm x 42 cm deep. The depth of silt subgrade was kept at 27 cm while its initial dry density was varied. The WBM was compacted over the finished subgrade and where desired a geosynthetic was laid over the subgrade before placing the WBM layer. In these tests a geogrid (GG) and a nonwoven geotextile (GTNW1) were used extensively whereas another nonwoven geotextile (GTNW2) and a woven geotextile (GTW) were used in limited test models. The repeated load tests were conducted upto 10,000 repetitions at different axial loads.

From the **model tests** under **static loading** it is clear that the geosynthetic inclusions change the failure mode of the models from punching shear failure to general shear failure,

thereby improving significantly the bearing pressure at any given vertical deformation. Behaviour of the models with geosynthetic, having 40 percent smaller thickness of WBM, is found to be better than that of an unreinforced model. This implies that for similar behaviour of the pavement geosynthetic inclusion can save more than 40 percent of the WBM base course thickness. This effect is more pronounced in respect of GG than GTNW1.

The **Repeated Load Model Testing** brought out that the permanent deformation of the models reduced substantially (upto 88 percent) due to geosynthetic inclusions and in general, this effect increases with number of load repetitions. Under similar test conditions the apparent resilient modulus  $AM_R$  of geosynthetic reinforced models is higher compared to unreinforced models at any specified number of repetitions and increase in  $AM_R$  is more pronounced at higher number of repetitions. From the limited model test results studied at higher loads, it appears that GTW is most effective in improving the performance of the models followed by GG, GTNW2 and GTNW1. At the end of 10,000 load repetitions no damage occurred to any of the geosynthetics used. The fatigue relationships show a systematic trend validating the test results of repeated as well as static loading.

**Chapter 5** presents the summary and the brief conclusions drawn from the experimental investigation.

The **practical significance** of the findings is that the use of geosynthetics in unpaved roads subject to repeated loading reduces the permanent deformation and increases the modulus of resilience significantly. The reduction in permanent deformation would increase maintenance cycle times, thereby reducing the maintenance costs. It may also enable a reduction in pavement thickness.

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