Geotextiles and Geomembranes xxx (2017) 1–13

Contents lists available at ScienceDirect

Geotextiles and Geomembranes

journal homepage: www.elsevier.com/locate/geotexmem

Effect of geogrid-reinforcement in granular bases under repeated loading

Lekshmi Suku, Research Scholar, Sudheer S. Prabhu, Project Associate,
G.L. Sivakumar Babu, Professor *

Department of Civil Engineering, Indian Institute of Science, Bangalore 560012, India

ARTICLE INFO

Article history:
Received 12 March 2016
Received in revised form
23 March 2017
Accepted 29 April 2017

ABSTRACT

The thickness of the base plays a crucial role in the stability of pavements and the lack of availability of good quality aggregates is a major concern in India and other countries. Loading on top of the base plays a crucial role in the design of pavements. Usually, the design of the pavement is done for standard axle load, however, in the field, in some of the cases, the vehicles are overloaded which results in a higher wheel load on the pavements. The current paper examines the performance of geogrid reinforced unpaved sections at higher stresses with the primary objective of reducing the thickness of base layer required in the field. Experimental studies were carried out using repeated plate load tests to obtain the optimum depth of placing the geogrid in granular base layer to achieve maximum reduction in rutting of pavement. Resilient deformation behavior of both reinforced and unreinforced sections are obtained and these values are utilized to predict the resilient modulus of the base sections. The paper also discusses the reduction in permanent deformation by the introduction of geogrid. Rut depth reduction studies were carried out in order to compare the performance of reinforced and unreinforced sections. The role played by the reinforcement in reducing the strains on top of the subgrade is studied in detail. A comparison is also carried out to understand the pressure distribution along the base layer and role played by the geogrids in reducing the pressure on the subgrade. Further, values of stress distribution angles were obtained for reinforced and unreinforced sections. It is evident from the studies that geogrids contributed to improved performance as well as reduction in thickness of the aggregate layer.

1. Introduction

The major factor that determines the service life of the pavement is the thickness of the pavement layers which in turn depends on the strength of each of these layers. In conventional flexible pavements, distress occurs due to repetition of traffic load which leads to structural or functional failure of pavements. The failure of flexible pavements can be attributed mainly to the phenomena of rutting and fatigue. These phenomena, along with the accumulative damage concept, have been used in developing the pavement thickness and material combinations needed to prevent structurally related distresses. In case of unbound pavements, rutting failure is the governing criteria that determines the thicknesses of pavement layers. Rutting is defined as the process of development of permanent deformations along the wheel paths. This criterion with respect to permanent deformations connects the number of load repetitions (producing damage to the pavement) to the compressive strains developed on top of subgrade and determines the design life of pavements. Flexible pavements are designed for specific axle loads by conducting the axle load survey. For a higher design life of unpaved roads, a high thickness of the base layer is required. But, due to the lack of availability of quality materials as well as the tremendous increase in traffic, there is a dire need to reduce the thickness of pavement without affecting its design life.

The geotextile reinforcement mechanism was initially studied in the design of low volume unpaved roads by Barenberg (1971). This study also showed the effectiveness of geotextile in stabilizing the aggregate layer along with providing a separation to base and subgrade layer. This lead to the reduction of the material used in the base layer and thereby reducing the base thickness. Based on these studies design methods were developed to introduce geotextile in unpaved roads (Kinney, 1979; Giroud and Noiray, 1981). Giroud et al. (1985) conducted extensive work on reinforced pavements

---

* Corresponding author.
E-mail address: gls@civil.iisc.ernet.in (G.L. Sivakumar Babu).

http://dx.doi.org/10.1016/j.geotexmem.2017.04.008

and presented methods to design geogrid-reinforced unpaved roads. It was noted from the studies that the reduction in permanent deformation due to the geogrid could be mainly attributed to the interlocking of aggregates and geogrids rather than the membrane effect of the geogrids. It was evident from the studies that for unpaved roads where large displacement was acceptable (say, 0.075 m or 0.15 m), only a 10% reduction in thickness of pavement (from its unreinforced thickness) was achieved due to the membrane effect of the geogrid. Brown et al. (1985) conducted a series of studies to examine at the effectiveness of a polypropylene geogrid in improving the performance of pavement, such as resistance to rutting, reflective cracking, and fatigue cracking. From the studies it was reported that the geosynthetic were highly effective and could reduce the rut depth by 20–58%. An important parameter that needed consideration was the depth of placing the geogrids. Haas et al. (1988) reported that for thick base layer, the performance of pavement improved when the reinforcement was placed at the midpoint of base rather than at the subgrade base interface. For optimum grid reinforcement they proposed placing the grid in a zone of moderate elastic tensile strain (i.e., 0.05%–0.2%) beneath the load center, and stated that maximum permanent strain in the geogrid during its design life should not exceed 1–2% depending on the rut depth failure criteria.

The studies carried out by Chan et al. (1989) indicated that for same deformation of geogrid and geotextile, geogrids provided better resistance against rutting than geotextile. It was also concluded from the study that the resistance offered by the geotextile against rutting was developed only when the deformation of pavements were very high. Another study carried out by Miura et al. (1990) also supplemented these results and concluded that the interlocking effect of the geogrid was the governing mechanism by which geogrid reinforced pavements improved its performance while the performance was not significantly affected by the membrane tension effect of geogrid. An important observation made by Moghaddas-Nejad and Small (1996) concluded that the inclusion of geogrids led to lesser deformation of pavements and thus reduced the thicknesses of base materials needed. This in turn led to saving in quantity of base material.

From the earlier studies, it was evident that reinforcement in the base layer helps in reducing the permanent deformation of the pavement and thus improves the pavement performance. However, there is still a major ambiguity regarding the position of placing the geogrids in the base layer. In the studies by previous researchers, geogrids were placed on the interface of base course and subgrade soil. Montanelli et al. (1997) rightly pointed out that there was a lack of understanding about the behavior of the base-geogrid composite system and the need to check the effect of reinforcement with depth of placing. Perkins et al. (1998) used polypropylene geogrid and woven geotextile to reinforce the pavement. The results from the studies showed an improvement in pavement performance with the presence of geosynthetics. Several studies were carried out in the field in order to better understand the field performance of geogrids. Field monitoring carried out by Al-Qadi and Appea (2003) over a period of eight years showed the effectiveness of geosynthetics in the field. Rutting results, deformation data and service analysis showed that geosynthetic reinforced sections significantly improved the performance of base course materials thus reducing the rutting and increasing the service life of pavements. A major mode of failure of pavement was due to the tensile load induced on the pavement. Studies by Ling and Liu (2001) showed that application of geogrid increased the tensile strength of the pavements, and was effective in reducing the distress due to the tensile load on the pavements. These studies also indicated a decrease in the short term permanent deformations, reduction of fatigue cracking, and increase in durability of the pavement structure and lowering the life cost of the pavement structure.

A few researchers have used accelerated pavement tests (Yang et al., 2008) in order to replicate field conditions in the laboratory. However, these studies concentrated only on the permanent deformation of the pavement while importance was not given to the resilient deformation of the pavement. Static and cyclic triaxial tests by Nair and Latha (2015) studied the changes in stress in the granular base due to the introduction of geogrid. The interesting observations from experimental results were that at the same strain level, reinforced systems carried higher stresses compared to unreinforced systems. The improvement of pavement induced by the reinforcement was generally provided by the Rut depth reduction (RDR). RDR can be defined as the ratio of difference between cumulative permanent deformations of the unreinforced layer and geogrid reinforced layer to that of the unreinforced layer for a particular number of loading cycle (Saride et al., 2014). The performance of geogrid reinforcement in reducing the surface as well as subgrade deformations were studied by Sun et al. (2015a,b). The study showed that the geogrid reinforcement was effective in reducing the deformations and recovering from the lateral deformations when compared to the unreinforced sections. the geogrid reinforcement also improved the radial stress distribution with in the base as well as subgrade layer. Wu et al. (2015) also investigated the performance of different types of geogrid by conducting loaded wheel testing and cyclic plate load test. The results were studied by evaluating the traffic benefit ratio, rate of deflection and the rutting reduction ratio. The study concluded that the geogrid reinforced base sections showed significant improvement in terms of high rutting resistance. The study conducted by Mounes et al. (2016) showed that the asphalt concrete reinforced with fiber glass geogrid exhibited better performance when grids of higher tensile strength and smaller mesh size were used for reinforcement.

In the current study, the optimum position of placing the geogrids in order to achieve the maximum rut depth reduction or enhanced pavement performance was obtained by varying the position of geogrid. For all the subsequent tests in the paper, geogrids were placed at the optimum position found from above. The applied pressure on all the test sections was to simulate the higher loading conditions in the field. Permanent and resilient deformation studies were carried out for both reinforced and unreinforced sections of varying thicknesses and a comparison was carried out in order to better understand the effect of reinforcement. A study was also carried out on the resilient modulus of the reinforced and unreinforced sections in order to obtain a direct relation between resilient modulus and thickness of base layer. A major concern in the field was regarding the strains and pressure exerted on top of the subgrade due to the loading applied on top of the pavements. In the current study, the strain gauges and pressure cells were placed on the subgrade to capture the load transferred to the subgrade. The pressure distribution along the depth for different thicknesses of the base layer is obtained and these observations establish a direct relation between the thickness of the base layer and the pressure transferred to the subgrade. Data from the above study was used for determining the stress distribution angle and rut depth reduction which helps in understanding the effect of reinforcement.

2. Materials and methods

Repeated plate load tests were carried out in the present study to characterize the deformation of the pavement materials subjected to different patterns of loading and to observe the effectiveness of geogrid in reducing the permanent deformation of