Falling Weight Deflectometer (FWD) Tests on Granular Pavement Reinforced with Geogrids – Case Study

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ABSTRACT: The use of geogrids in granular pavement layers could increase the modulus and the stiffness of granular layer and hence the required layer thickness can be reduced. Though, geogrids are being used in granular pavements to provide lateral restraint, bearing capacity, and membrane tension support, very limited studies have been carried out to investigate the effects of geogrids on modulus and stiffness of granular layer. In this study, two sections of a granular pavement were constructed: one with a geogrid at the bottom of the base layer and the other without a geogrid. Two sections were then tested using Falling Weight Deflectometer (FWD) and FWD results were analysed to determine the effect of geogrid on the overall modulus and stiffness of the granular pavement. The results suggested that the pavement section with geogrid has higher overall modulus and deflection ratio compared to the pavement section without geogrid.

1 INTRODUCTION

A large amount natural granular (crushed rocks) is used in pavement construction. The expansion of road networks due to increase in population and rehabilitation of existing pavements demand more natural granular. It is important to adapt alternative methods to reduce the amount of natural granular used in pavements due to the depletion of natural resources (natural rocks). Use of recycled aggregates in pavements can be considered as one of alternatives to reduce the amount of natural aggregates used in pavements (Jayakody et al. 2014). geogrids can be another alternative material to reduce the required thickness of granular layers in pavements.

According to Sprague et al. (2004), geogrids provide reinforcement by three possible mechanisms: lateral restraint, increase in bearing capacity, and membrane tension support. The geogrid creates interlocking between the aggregates to provide lateral restraint of granular material and that helps to minimise the rutting of the pavement. The geogrid can provide tension support to unbound materials which has no tensile strength. These tensile reinforcements increase the bearing capacity of granular layers which reduces the bearing failures in the granular layers and associated rutting.

A number of studies carried out on the use of geogrid in granular pavements has demonstrated the positive effects (Al-Qadi et al. 2008). However, it has been identified that the proper installation of geogrids in pavements would be essential to achieve the expected benefits (Paquini et al. 2013).

In Australia, no guidelines are available on how geogrids can be used in granular pavement layers to increase their structural capacity and to reduce the granular layer thickness. The *Austroads Guide to Pavement Technology Part 4G: Geotextiles and Geogrids(2009)*provides some guidelines only for using geotextiles for filtration and drainage in pavements. The American Association of State Highway and Transportation Officials (AASHTO) has developed an empirical design method for geogrid-reinforced granular pavements and further researches are being carried out to develop more accurate mechanistic-empirical design approach (Sprague et al. 2004).

In developing a design methodology for geo-reinforced granular pavements to reduce the granular layer thickness, it is important to understand the effects of geogrids on the deformation and the modulus of granular pavements. Therefore, in this study, a granular pavement constructed with geogrids was tested using FWD (Falling Weight Deflectometer) tests and their results were analysed to understand the effects of geogrids on deformation and modulus of the granular pavement.

2 TRIAL PAVEMENTS AND MATERIALS

As shown in Fig. 1, two granular pavement sections were constructed on subgrade with CBR value less than 3%. The subgrade was improved by applying subgrade treatment type H. In this reatment, geofabric (Bidim) and geogrid (TriAx) were placed on the subgrade and then a 150 mm thick drainage layer was placed on geofabric – geogrid composite.

Each section was approximately 100 m long and consisted of 50 mm thick asphalt surfacing layer, 150 mm thick base layer of unbound granular subtype 2.1 and 175 mm thick sub-base of unbound granular subtype 2.3. According to Austroads (2012), typical moduli values for base and sub-base layers are 300 MPa and 250 MPa, respectively.

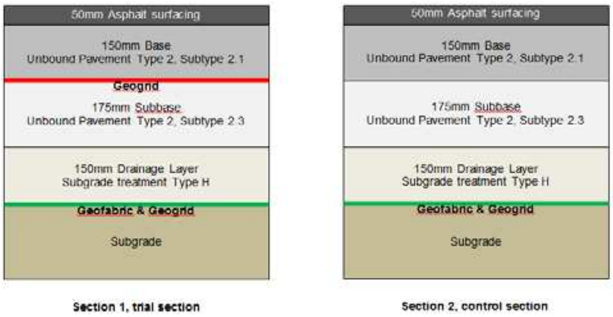

Fig. 1 Two pavement sections

In section 1(trial section, chainage 11070 – 11160), a geogrid layer was installed at the interface of base and sub-base layers. No geogrid layer was installed in section 2 (control section, chainage 11160 – 11265)and this section was considered as the control section.

3 TESTING AND ANALYSIS OF PAVEMENTS

3.1 *FWD test*

Falling Weight Deflectometer (FWD) test was adapted in this study to investigate the performances of these pavements. In FWD test, a weight of 40kN or 60 kN is dropped on the pavement and the surface deflections are measured by geophones at different offsets from the point of impact (at 0 mm, 200 mm, 300 mm, 450 mm, 600 mm, 900 mm, and 1500 mm). The measurements are denoted by D with subscript of the offset; for example, D_{900} denotes the deflection measurement at 900 mm offset from the point of impact. A typical deflection bowl produced by a FWD test is shown in Fig. 2. The deflection bowl of FDW can be analysed to determine the properties of pavement layers.

In this study, FWD was conducted on trial pavements at spacing of 10 m along the both outer (OWP)and inner (IWP) wheel paths. The loading on the IWP was offset by 5 m to that on OWP to produce the recordings effectively in 5 m staggered intervals. For each point of impact, both 40 kN and 60 kN were applied.

At each loading point, two drops of 40 kN were initially applied for calibration of the pavement and then the third drop of 40 kN was applied to produce the result (deflection bowl). An additional drop of 60 kN was also applied to produce a result. The amount of loading was controlled by the height at which the loading mass was dropped.

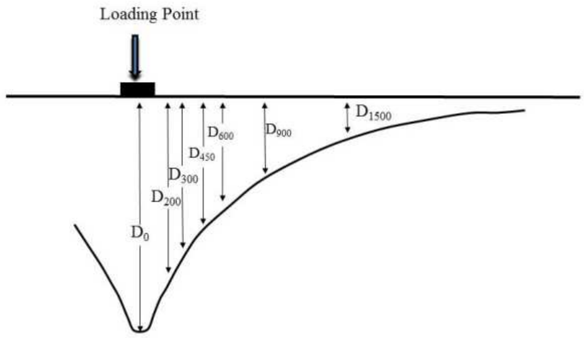

Fig. 2 Typical FWD deflection bowl

The maximum deflection (D_0), curvature function (D_0 –D_{200}), deflection ratio (D_{250}/D_0), and D_{900} are used to assess condition, performance, and properties of pavement and its layers (Transport and Main Roads, 2012).

3.2 *Numerical Analysis*

The deflection bowls produced by FWD tests are used to back-calculate the modulus of each pavement layer to evaluate the effectiveness of geogrid layer in the pavement in improving the layer modulus.

In this study, the back-calculation was performed using two analytical software (elastic): CIRCLY and EfromD3 (Department of Transport and Main Roads, 2012). Table 1 shows the parameters used for the back-calculation. Once seed modulus and thickness of each layer is given, CIRCLY can produce a FWD deflection bowl for a specified load (e.g: 40 kN, 60 kN). EfromD3 compares the CIRCLY produced deflection bowl with the corresponding field measured one and repeated analysis is performed changing the layer modulus within its minimum and maximum values to produce a deflection bowl to closely match with the field measured one. This iteration process continues until the specified numbers of iterations or accuracy is reached. The layer moduli used to obtain the best-fit are called back-calculated moduli.

Table 1. Pavement layer details

Layer	Thickness (mm)	Vertical Modulus E_v (MPa)			Poisson's ratio	E_v/E_h
		Minimum	Maximum	Seed		
Surface (Asphalt)	50	1000	20000	2800	0.40	1.0
Base (Granular)	150	50	500	300	0.35	2.0
Subbase(Granular)	175	50	500	300	0.35	2.0
Drainage (Granular)	150	20	500	300	0.35	2.0
Subgrade	0	20	3000	100	0.45	2.0

4 RESULTS AND DISCUSSIONS

4.1 *FWD Deflection Survey*

In this study, FWD tests were conducted on both trial and control sections along inner and outer wheelpaths at 10 m interval using both 40 kN and 60 kN loads. Since both inner and outer wheelpaths' FWD deflections are similar at a given changage, only IWP deflection data are analysed and discussed in this section.

Fig. 3 depicts the variation of the maximum deflection (D_0) along the both trial and control sections (chainage: 11070 – 11265) for the dropping weigh of 40 kN and 60 kN. It can be seen that the trial section (chainage: 11070 – 11160) has greater deflections than those of control section. The opposite was expected assuming positive effects of geogrid on its performance. Since the maximum deflection (D_0) is related to the overall structural adequacy of the pavement, FWD deflection data were further analysedto investigate the subgrade conditions of both trial and control sections. It is important to note that the control section is on a cut, while the trial section is on a fill. Further, subgrade of trial section was exposed to overnight rain before the trial pavement section was constructed.

Using D_{900} obtained from 40 kN FWD tests and the chart given in Fig. 4 (Transport and Main Roads, 2012), the subgrade CBR was estimated and plotted with the chainage as shown in Fig. 5. As expected, the trial section's CBR values are between 17% and 22%which are slightly less than the CBR of subgrade of control section (25%). It can be suggested that slightly weaker subgrade in trial section has contributed for greater maximum deflection (D_0) than that of control section.

Deflection ratio (D_{250}/D_0) can be used to assess the strength of pavement. Fig. 6 shows the variation of the deflection ratio along the chainage. The trial section with geogrid has a value between 0.6 and 0.7 indicating it as a good quality pavement, while control section has a value less than 0.6. It can be suggested that geogrid has contributed to a higher deflection ratio for trial section than control section even though the trial section is on slightly weaker subgrade.

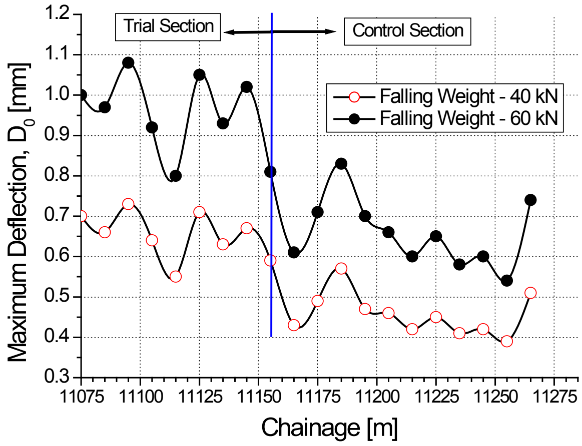

Fig.3 Variation of maximum deflection (D_0) with along IWP of trial and control sections

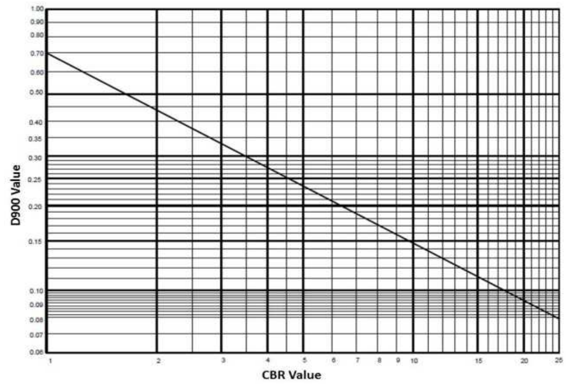

Fig. 4 D_{900} versus subgrade CBR for 40kN FWD results for a granular pavement with a thin asphalt surfacing or seal (Transport and Main Roads, 2012)

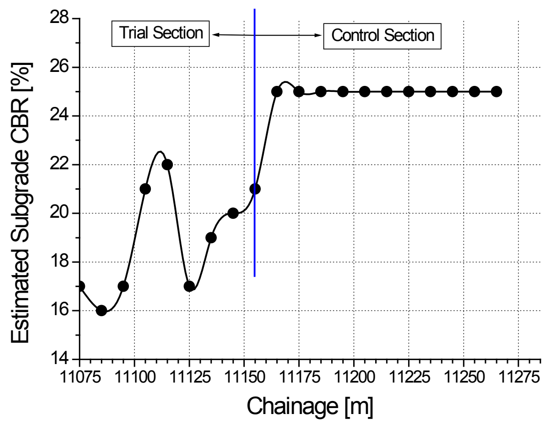

Fig. 5 Estimated subgrade CBR along the road

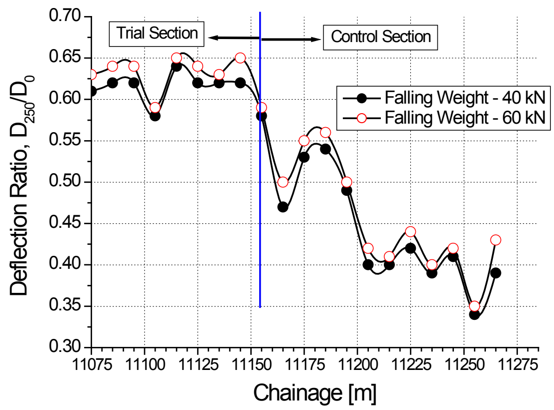

Fig.6 Variation of deflection ratio (D_{250}/D_0) with along IWP of trial and control sections

4.2 *Estimation of Moduli of Pavement Layers*

For each pavement section (e.g: trial and control), four deflection bowls were developed averaging the series of deflection bowls obtained for IWP with 40 kN, OWP with 40 kN, IWP with 60 kN, and OWP with 60 kN. Each of these deflection bowls was used with the properties given in Table 1 to back-calculate modulus of each pavement layer using CIRCLY and EfromD3 software.

Fig. 7 shows the back-calculated moduli for asphalt, base, and subbase layers, respectively.

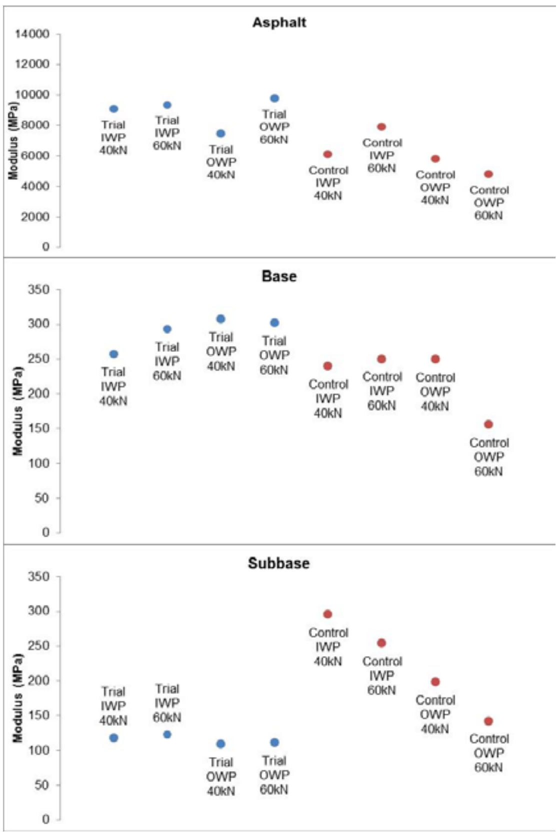

Fig. 7 Estimated moduli for asphalt, base, and subbase layers.

As shown in Fig.7, the moduli of asphalt and base layers in trial sections are greater than those of control section. It could be suggested that the geogrid layer in trial section has contributed to the overall moduli of layers above the geogrid. The modulus of the subbase is greater in control section than that of trial section. This suggests that the geogrid may not contribute to an increase in the overall modulus of layer below the geogrid.

5 CONCLUSIONS

This study was aimed to investigate the effectiveness of geogrid in granular pavements in reducing the granular layer thickness by increasing the modulus of geo-reinforced layer. To achieve the aim of this study, two pavements sections; one with geogrid and the other without geogrid; were tested with FWD tests and deflection data were analysed to draw the following conclusions:

- The deflection ratio, which is related to the strength of base layer, was higher for the trial section compared to that of control section. This implies that geogrid has strengthened the base layer.
- The estimated modulus of base layer in trial section was greater than that of base later in control section. This finding suggests that geogrid has contributed to increase the overall modulus of granular base layer.

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