Full-Scale Field Study on performance of geogrid stabilised pavement on soft and expansive subgrade

Amir Shahkolahi & Chaminda Gallage (Indicate the presenter in bold font) (Arial 10)
School of Civil and Environmental Engineering, Queensland University of Technology (QUT), Australia

David Lacy
Foundation Specialist Group (FSG), Australia

Jörg Klompmaker
NAUE GmbH & Co. KG, Germany

ABSTRACT: Geogrids are used to reinforced and stabilise the roads and improve the bearing capacity of pavements on soft subgrades. Additionally, geogrids installed within granular layer of a pavement formation are frequently used to control environmental distress and limit longitudinal cracking due to expansive subgrades by providing the stiffening, known as the new function of geosynthetic material to control deformations in the soil-geosynthetic composite. In order to quantify the effect of geogrid reinforcement / stabilisation, a full-scale pavement field trial was established upon a soft and expansive subgrade in 2018. Sections with variable geogrid arrangements were constructed in order to allow the quantitative assessment of geogrid reinforcement/stabilisation; both in terms of their initial contribution to composite insitu stiffness parameters and their benefit to the long-term performance of a pavement. On site testing was completed within all trial sections during the project's construction phase, such that the initial state (strength and stiffness) of the subgrade and each pavement layer was adequately characterised. Post construction, ongoing performance monitoring has included the use of embedded strain gauges and pressure cells. An analysis of the first 3 years of monitoring of this full-scale field trial was conducted in January-February 2021, with selected results presented herein. The data demonstrates that the inclusion of geogrids successfully improves the bearing capacity of the pavement profile by reducing the traffic imparted vertical pressures being exerted upon the underlying materials. The results also demonstrate that the presence of two geogrid layers (with one placed at the subgrade-subbase interface and one at the subbase-base interface) offer a greater improvement of the bearing capacity than the installation of a single geogrid at the interface of subgrade-subbase materials. Additional observations relate to longitudinal cracking of the pavement, where greater control of cracking has been initially achieved in the test sections where geo-reinforcement was installed.

KEYWORDS: Gogrid, expansive soil, pavement

1 INTRODUCTION

Geogrids are used to stabilize and reinforce the roads and improve the bearing capacity of pavements on soft subgrades. Additionally, geogrids installed within granular layers of a pavement formation are frequently used to control environmental distress and limit longitudinal cracking due to expansive subgrades by providing the stiffening, known as the new function of geosynthetic material to control deformations in the soil-geosynthetic composite. Early use of geosynthetics in road application was the use of geotextiles and goes back to early 1900 when the South Carolina highway department began studies on cotton fabric as a reinforcement for bituminous surface treatment. Geogrids and geogrid reinforcement were first studied in the late 1980s (Barker 1987, Haas et al. 1988, Barksdale et al. 1989, Perkins et al. 2010). Barker (1987) used an outdoor test track facility with a moving single wheel load to study the reinforcement effect of biaxial geogrids placed between subbase and base layer in a trial section with a firm subgrade, 150mm subbase, 150mm base, and 75mm asphalt layer (Berg et al. 2000). Haas et al. (1988) used a 300mm stationary circular plate and a laboratory tank to investigate the benefits of geogrid reinforcement placed between subgrades with low to moderate CBR values and the base layer. He also investigated the effect of the location of the geogrid in the base layer, with base material between 100mm and 300mm and asphalt thickness of 75mm and 100mm. Barkside et al. (1989) then used an indoor test track facility with moving single wheel load to study the effect of geogrids and woven geotextiles separately, when placed be-tween a soft subgrade and base layer. He used a thinner asphalt layer in his study though (Berg et al. 2000). Anderson and Killeavy (1989) were the first team who studied the use of a geogrid-geotextile composite placed between the soft silt/clay and base layer. They used an out-door field truck with loaded track traffic on sections with 200mm-350mm base layers and 105mm asphalt layer. The results of more than 75 laboratory and field tests on geogrid, geotex-tile, and geogrid-geotextile composite reinforced paved roads since early 1980s till late 1990s showed a Traffic Benefit Ratio (TBR) of 1.5 to 10 for geotextile reinforcement and 1.5 to 70 for geogrid reinforcement. Same studies showed a Base Course Reduction (BCR) of 20%-30% for geotextiles, 30% to more than 50% for geogrids, and about 56% for geogrid-geotextile composites (Berg et al. 2000).

In addition, in recent years, "Stiffening" has been introduced by Prof. Jorge Zornberg (2017a,b) as a new function of geosynthetics to control pavement deformations (e.g. due to environmental loads) for applications such as pavements on expansive subgrades. "stiffening" refers to development of tensile forces in the geosynthetic material to control deformations in the soil-geosynthetic composite, while "reinforcement" refers to development of tensile forces in the geosynthetic material to maintain or improve the stability of the soil-geosynthetic composite. Although both functions provide mechanical improvement, the required geosynthetic properties to achieve these functions are slightly different. The key property for "reinforcement" is the geosynthetic tensile strength and stiffness, while the main design parameter for "stiffening" is the stiffness of soil-geosynthetic composite (Zornberg, 2017a,b). Supported by more than 20 years of research and field monitoring, the use of stiffening geosynthetics has now become a standard practice in many countries specially in united states to mitigate cracks and improve pavements life on expansive subgrades. The use of geosynthetics was found to effectively minimise the detrimental effects of expansive soil subgrades on flexible pavements. Geosynthetic-stiffened pavement sections on expansive clay subgrades have showed significantly better field performance than control (non-stiffened) sections or even lime stabilised sections. On the other hand, geogrid-stiffened section with less gravel thickness could perform equal/better to the sections without geogrid and thicker gravel (Roodi and Zornberg, 2020; Roodi et al., 2016; Roodi, 2016; Zornberg et al., 2012; Zornberg et al, 2008). This verifies the benefit of geogrid stiffen-ing in reducing the cover thickness for construction on expansive subgrades.

2 FULL SCALE FIELD TRIAL DETAILS

The trial included different sections with different geogrid and gravel combinations. Each test bed is to be 9.0m (length) x 4.85m (width). The main sections for this study are the control section (no reinforcement) with 350mm subbase and 200mm base layer, single reinforced section with 350mm subbase and 200mm base layer and geogrid composite at the subgrade level, and double reinforced section with 280mm subbase and 200 base layer with one geogrid composite at the subgrade level and one geogrid between subbase and base. Pressure cells were installed on top of the subgrade to measure the effect of geogrid stabilisation and stiffening (Figure 1).

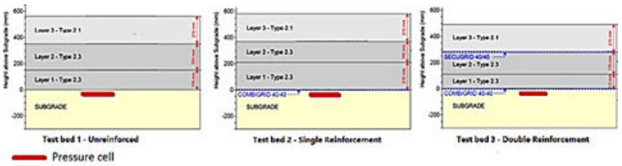

Figure 1. Test cross sections

The field was open to local traffic for at least 3 years to make sure the gravel-geogrid interaction and activation of geogrid is occurred. Measurements were conducted after 3 years and results of unreinforced, single reinforced and double reinforced sections were compared to each other.

Geotechnical investigations have shown a black silty clay subgrade with hi plasticity (PI = 86%) with soaked CBR of 2% and swell of 5%. After excavation of the subgrade to the required level, onsite testing was conducted on the subgrade to measure the in-situ subgrade properties. These included DCP, Panda test, LFWD and Static Plate Load Test according to DIN 18134:2012-04 (Figure 2). After installing gravel layers, Plate Load Testing was also conduct-ed on top of every granular layer for each section.

Figure 2. Subgrade preparation and testing

To monitor the long-term performance of benefit of geogrid reinforcement in single and double reinforced sections, pressure cells were installed during the project and monitored beyond project completion. A total of three test beds were instrumented with pressure cells.

To isolate the study to the effect of geogrid only and provide separation between subgrade and granular layer for all sections, a laid and welded biaxial geogrid-geotextile composite with textured surfacing and with the geotextile integrated between geogrid bars was installed at the subgrade level for reinforced sections and a separation nonwoven geotextile was installed on the subgrade for unreinforced (control) sections. Subbase layers were placed and compacted according to standard installation practice to achieve minimum 98% compaction. Gravel used was type 2.3 according to QLD TMR specification MRTS04 (2021). The thickness of the gravel layer was checked and measured for each subbase layer. Where a second reinforcement layer was planned, a laid and welded biaxial geogrid with structured surfacing was used. A 40mm thin asphalt surfacing was placed and compacted on top of the base course layer. The road was then opened to the public local traffic. Figure 3 shows the placement and compaction of the materials.

Figure 3. Installation of pressure cell, geocompsoite, geogrid, gravel and asphalt

After 3 years of local trafficking, a full load water truck was used to apply pressure on the road surface in sections with no reinforcement, single reinforcement and double reinforcement. The water truck stayed on top of the pressure cell point for few minutes, so the pressure cell could have enough time to measure the transferred pressure to the subgrade. The data collect-ing intervals of the pressure cell was also reduced to few seconds for the time period of the testing. To be able to measure the pressure accurately and apply the load directly on the pres-sure cell, the exact location of pressure cells was determined and marked on the road surface using a Ground Penetrating Radar (GPR) system.

3 RESULTS AND DISCUSSION

3.1 *Strain modulus*

Test result from insitu Plate Load Testing during construction showed that the improvement in the strain modulus Ev2 is higher in section with double reinforcement even with a thinner gravel layer compared to section with single reinforced, and both are higher than the unrein-forced control section. The improvement has been calculated as EV2 on the top of the base layer for each section divided by EV2 of subgrade only. Figure 4 shows the results of these test sections.

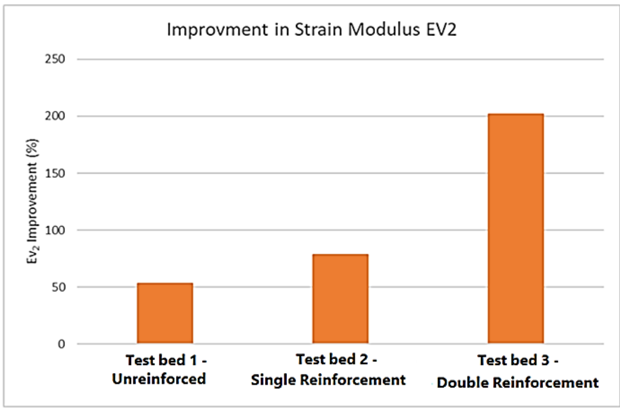

Figure 4. Percentage of increase in Ev2 for different sections

3.2 *Subgrade deformation*

The results from the pressure cell measurements after 3 years were also analysed for the above sections (Figure 5.). Results clearly showed that a single reinforcement performed better than unreinforced section, and double reinforcement performed bet-ter than single reinforcement in terms of reducing the vertical stresses transferred to the sub-grade even with a bit less gravel thickness. This can be due to the better load distribution be-cause of the presence of the geogrid, especially in the double reinforced section compared to the single reinforced section. This can lead to less vertical deformation of the subgrade and longer service life of the pavement in the double reinforced section compared to the single rein-forced section. On the other hand, the reduction in the vertical stress was higher for double reinforced section with thinner gravel compared to single reinforced and unreinforced sections, This means by using a double reinforcement, the thickness of the pavement can be reduced and still the same or better performance can be achieved.

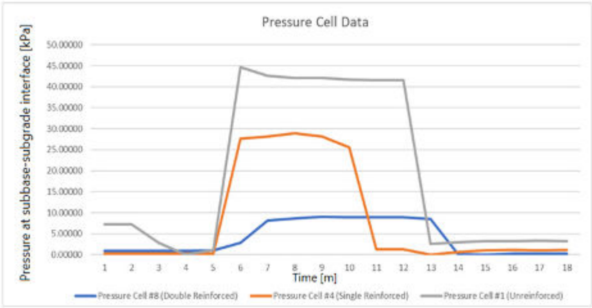

Figure 5. Pressure transferred to the subgrade for different sections

3.2 Subgrade deformation

To study the 'stiffening' effect of the geogrid in controlling the cracks caused by expansive subgrade shrinkage and swell, a single reinforced section was considered between two double reinforced sections in the full-scale field trial to be studied along with the control section with no reinforcement. All sections had the same thickness and subgrade conditions. The single re-inforced section had only one layer of geogrid-geotextile composite at the subgrade layer while the double reinforced sections had an extra geogrid within the granular layer. The same geogrid and geocomposite used in other sections were used here. After 3 years under local traffic, lon-gitudinal cracks had developed in the section with no reinforcement. The sections with single and double reinforcement had no cracks on the surface. There was a minor crack in the section with single reinforcement, which was more towards the edge of the cross section in the longi-tudinal joint with the other road lane. Even this minor crack in the single reinforced section was stopped when reached to the double reinforced sections. Figure 6 shows then results.

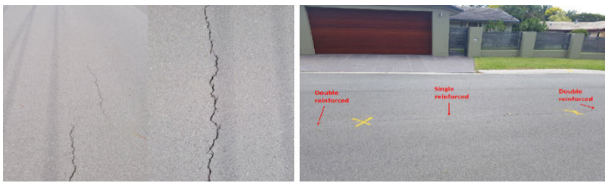

Figure 6. Performance of unreinforced (left photo) vs single reinforced and double reinforced sections (right photo) on expansive subgrade.

4 RESULTS AND DISCUSSION

In order to quantify the effect of geogrid stabilisation/reinforcement, a full-scale pavement field trial was established upon a soft and expansive subgrade. Sections with variable geogrid arrangements were constructed including control section with no geogrid, single reinforced sec-tion with on layer of geogrid-geotextile composite at the subgrade-subbase interface, and dou-ble reinforced sections with additional geogrid within the pavement between subbase and base layers. An analysis of the first 3 years of monitoring of this full-scale field trial was conducted. The data demonstrated that the inclusion of geogrids successfully improves the bearing capacity of the pavement profile by reducing the traffic imparted vertical pressures being exerted up-on the underlying materials. The results also demonstrated that inclusion of one geogrid in-creases the strain modulus (Ev2) v.s. the unreinforced section, and the double reinforcement can increase the strain modulus even more compared to single reinforcement. In addition, long term monitoring of longitudinal cracks due to the expansive nature of subgrade shows that the additional geogrid layer within the granular pavement between subbase and base (stiffening geogrid) can successfully control the longitudinal cracks due to swell-shrinkage of the expansive soil.

5 REFERENCES

Anderson, P. & Killeavy, M. (1989). Geotextiles and geogrids: cost effective alternate materials for pavement design and construction. Proceedings of the conference geosynthetics '89 (pp. 353-360). San Diego, CA, USA.

Barker, W.R. (1987). Open-Graded Bases for Airfield Pavements, Technical Report GL-87-16, USAE Waterways Experiment Station, Vicksburg, MS, USA, 76 p.

Barksdale, R. D., Brown, S. F., & Chan, F. (1989). Potential benefits of geosynthetics in flexible pavement systems (National Cooperative Highway Research Program Report No. 315). Washington, DC, USA: Transportation Research Board, National Research Council

Berg, R. R., Christopher, B. R., & Perkins, S. W. (2000). Geosynthetic reinforcement of the aggregate base/subbase courses of flexible pavement structures (GMA white paper II). Roseville, MN, USA: Geosynthetic Materials Association.

DIN 18134, German Institute for Standardisation (2012). Soil-testing procedures and testing equipment - Plate load test (DIN 18134). Retrieved from https://infostore.saiglobal.com/en-au/standards/din-18134-2012-413157_saig_din_din_935116

Haas R., Walls, J., & Carroll, R.G. (1988). Geogrid reinforcement of granular bases in flexible pavements (Transportation Research Record 1188), 19-27. Retrieved from http://onlinepubs.trb.org/Onlinepubs/trr/1988/1188/1188-002.pdf

MRTS04, 2021. Technical Specification MRTS04 General Earthworks, QLD Transport and Main Roads Specifications (TMR), December 2021.

Perkins, S.W., Christopher, B.R., Thom, N., Montestruque, G., Korkiala-Tanttu, L. and Watn, A. Geosynthetics in Pavement Reinforcement Applications, Proceedings of the 9th International Geosynthetics Conference, Vol. 1, pp. 165-192, Guaruja, Brazil, May, 2010.

Roodi, G. H., and J. G. Zornberg. 2020. Long-Term Field Evaluation of a Geosynthetic-Stabilized Roadway Founded on Expansive Clays. Journal of Geotechnical and Geoenvironmental Engineering, © ASCE, ISSN 1090-0241, 05020001-1 - 05020001-17.

Roodi, G. H., J. R. Phillips, and J. G. Zornberg. 2016. Evaluation of vertical deflections in geosynthetic reinforced pavements constructed on expansive subgrades. In Proc., 3rd Pan-American Conf. on Geosynthetics, 1970–1987. St. Paul, MN: Industrial Fabrics Association International.

Zornberg, J. G. 2017a. "Functions and applications of geosynthetics in roadways: Part 1." Procedia Eng. 189 (Jan): 298–306. https://doi.org/10.1016/j.proeng.2017.05.048.

Zornberg, J. G. 2017b. Functions and applications of geosynthetics in roadways: Part 2. In Geosynthetics, 34–40. Roseville, MN: Industrial Fabrics Association International.

Zornberg, J. G., J. A. Prozzi, R. Gupta, R. Luo, J. S. McCartney, J. A. Z. Ferreira, and C. Nogueira. 2008. Validating mechanisms in geosynthetic reinforced pavements. FHWA/TX-08/0-4829-1. Austin, TX: Texas DOT.

Zornberg, J. G., J. A. Z. Ferreira, R. Gupta, R. V. Joshi, and G. H. Roodi. 2012. Geosynthetic-reinforced unbound base courses: Quantification of the reinforcement benefits. FHWA/TX-10/5-4829-1. Austin, TX: Texas DOT.