The performance of road aggregate reinforced with geogrid found from repeated load triaxial and dynamic plate bearing tests

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ABSTRACT: The RLT (Repeated Load Triaxial) apparatus applies repetitive loading on cylindrical road aggregates for a range of specified stress conditions, for predicting rutting deformation (shortening of the cylindrical sample) versus number of load cycles (usually 50,000) is recorded. Multi-stage RLT tests at many different combinations of confining stress and vertical cyclic stress were conducted on a range of pavement quality aggregates with and without layers of geogrid. For each multi-stage RLT test a relationship between stress (vertical and horizontal) and permanent strain along with a non-linear elastic model was determined. These models were used in a finite element model to predict pavement rutting. Results showed the beneficial performance effect of incorporating geogrids was most evident in the saturated undrained conditions of a premium quality basecourse aggregate. Repeat tests were conducted to confirm this result. In addition to the Repeat Load Triaxial tests repeated load plate bearing tests were conducted on unbound aggregates with and without geogrids. The aggregates were compacted in a steel rectangular mould (150x150x530mm) and repeated loading from 5 to 550kPa was applied to a 150mm diameter plate to simulate vehicle loading. This dynamic plate bearing test clearly showed that the aggregate reinforced with geogrid took 5.5 times the number of loadings (635k) to achieve the same rut depth (15mm) as the aggregate with no geogrid (115k). The larger area of the beam mould and the sideways shear forces developed during loading is considered a better test to represent the benefits of geogrid reinforcement within the aggregate.

1 INTRODUCTION

Granular pavement layers play an important role in the pavement. They are required to provide a rut resistant base layers and reduce compressive stresses on the sub-grade. For thin-surfaced pavements the unbound granular material (UGM) contributes to the full structural strength of the pavement. It is therefore important that the granular materials have adequate stiffness and do not deform. Material specifications usually ensure this is the case. The repeated load triaxial (RLT) (Arnold 2004), hollow cylinder (Chan 1990) and k-mould (Semmelink et al, 1997) apparatuses can in various degrees simulate pavement loading on soils and granular materials. Permanent strain tests in the Repeated Load Triaxial (RLT) apparatus commonly show a wide range of performances for UGMs even though all comply with the same specification (Thom and Brown, 1989). Accelerated pavement tests on thinly sealed pavements show the same results and also report that 30% to 70% of the surface rutting is attributed to the granular layers (Arnold et al., 2001; Little, 1993; Pidwerbesky, 1996; Korkiala-Tanttu et al, 2003).

There is evidence from research (Webster, 1992) that Geogrid's when placed in granular pavement layers provide some lateral restraint increasing shear strength to reduce the amount of traffic induced rutting. This beneficial effect of resisting rutting/permanent deformation in aggregates was investigated in the Repeated Load Triaxial apparatus and in dynamic plate bearing tests using the recently released TriAx multidirectional geogrid. Results and associated predictions of rutting of the multidirectional geogrid reinforced aggregates compared with unreinforced aggregates are reported in this paper.

2 REPEATED LOAD TRIAXIAL (RLT) TESTING

The RLT (Repeated Load Triaxial) apparatus applies repetitive loading on cylindrical materials for a range of specified stress conditions, the output is deformation (shortening of the cylindrical sample) versus number of load cycles (usually 50,000) for a particular set of stress conditions. Multi-stage RLT tests are used to obtain deformation curves for a range of stress conditions to develop models for predicting rutting. The method of interpreting the RLT results involves relating stress to permanent deformation found from the test. From stresses computed in a pavement model of a standard cross-section at New Zealand Transport Agency accelerated pavement testing facility CAPTIF the permanent deformation is calculated using the relationship found from RLT testing. This approach effectively predicts the amount of rutting that would have occurred in a test at CAPTIF if the aggregate tested in the RLT apparatus was used in the pavement. This method of assessment was validated with accelerated pavement tests at CAPTIF (Arnold, 2004 and Arnold et al, 2008).

Arnold et al, (2008) simplified the RLT test to a 6 stage test and the rut depth prediction method to enable an approximate prediction of the traffic loading limit (no. of passes to a 10mm rut) to be obtained from the average slope from the RLT test. Transit New Zealand has developed a draft specification TNZ T/15 (Transit 2007) to incorporate the simplified RLT test and analysis which is currently being revised based on the results of commercial RLT tests on many different aggregates and to consider the use of a RLT test at saturated undrained conditions that have been conducted commercially showing all unbound granular materials fail prematurely to various degrees depending on the moisture sensitivity of the aggregate.

3 RLT RESULTS

Repeated Load Triaxial testing and rut depth prediction was undertaken on a low quality sub-base GAP40 (<37.5mm) and a premium TNZ M4 (Transit 2006) (<37.5mm) compliant basecourse aggregate with and without geogrid at both saturated and dry conditions. It was found that the geogrid did not improve performance of the low quality sub-base GAP40 aggregate in dry conditions but did show a significant improvement in performance of the premium basecourse aggregate at saturated/undrained test conditions. Tests were repeated to confirm this positive result for the geogrid. Full results of rut depth predictions are shown in Figures 1, 2 and 3 and Table 1.

Table 1. RLT results.

Aggregate	RLT Test	Number of Heavy Vehicle Axles (ESAs) to Result in 10mm of Rutting within Aggregate.
Sub-base GAP 40	Dry/ Drained	4.5 x 10^6
	Dry/ Drained	3.5 x 10^6
	Saturated	200
Subbase GAP 40 + Two Geogrids at 1/3rd and 2/3rd height	Dry/ Drained	4.04 x 10^6
	Dry/ Drained	3.25 x 10^6
Premium Basecourse TNZ M4 AP40 (note: Test repeated 5 times)	Saturated	0.02 x10^6 to 0.5 x10^6
Premium Basecourse TNZ M4 AP40 + Two Geogrids at 1/3rd and 2/3rd height	Saturated	1.8 x 10^6
	Saturated	4.3 x 10^6

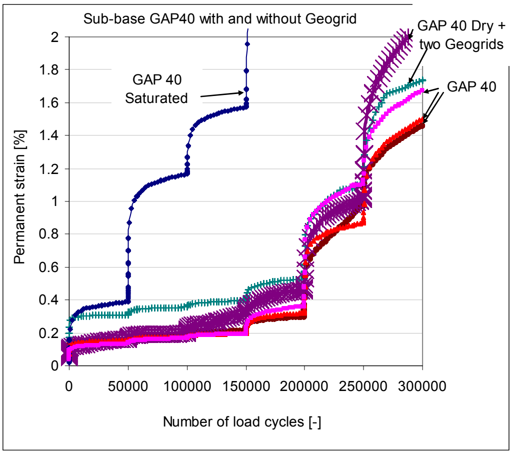

Figure 1. RLT Results for GAP40 at dry/drained conditions.

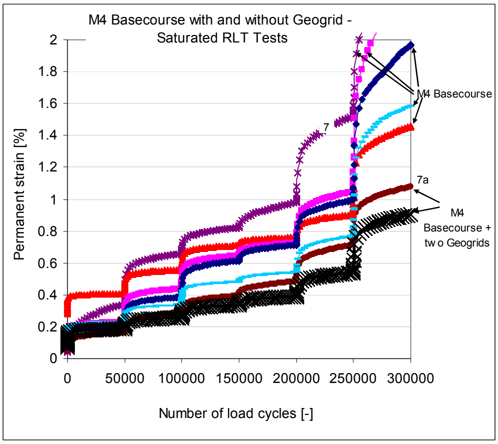

Figure 2. RLT Results for M/4 at saturated/undrained conditions.

4 DYNAMIC PLATE BEARING TESTS

A comparative experiment was undertaken on one aggregate that is classified in the Repeated Load Triaxial test as poor resulting in high deformations up to three times more than good quality aggregate. Utilising detachable concrete beam moulds 150x150x530mm long the poor performing aggregate was compacted at optimum moisture content in the moulds in three 50mm layers using a rectangular foot on a vibrating hammer (Figure 3). One of the moulds was with compacted aggregate only while the other mould had two layers of geogrid at 50 and 100mm heights.

Figure 3. Compacting aggregate in beam moulds

These moulds were placed under the universal testing machine used for Repeated Load Triaxial testing and 100 thousand repetitive loads at 1.3Hz of 550kPa on a 150mm diameter plate were applied. During the test the vertical displacement of the plate is recorded electronically with the LVDTs. This enables the rut depth versus number of load cycles to be recorded. Figure 3 details the test setup.

Figure 4. Dynamic plate bearing test setup.

After 100 thousand load cycles were applied a significant amount of rutting and shear or shoving movement occurred relative to the 150mm thickness of aggregate. Figure 5 shows how the geogrid layers deformed as a result of shear movements within the aggregate.

Figure 5. Resulting deformations within aggregate and geogrid after dynamic plate bearing test.

Rut depth (or the amount the plate as sunk into the aggregate) versus number of load cycles were plotted in Figure 6 for comparison between the aggregate with and without geogrid reinforcement. Extrapolating the geogrid reinforced rutting profile to a 15 mm rut found it took 635k load cycles compared with only 115k load cycles for the unreinforced aggregate. This is a 5.5 times increase in life for the aggregate reinforced with geogrid.

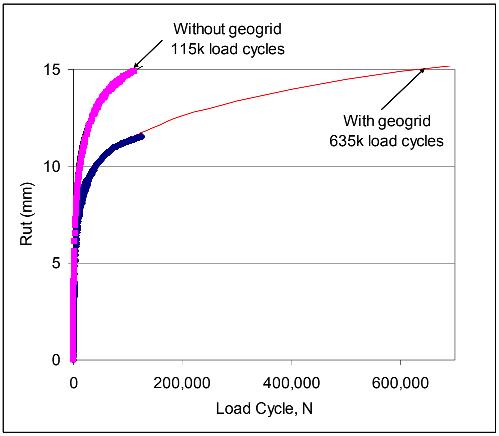

Figure 6. Rut depths from dynamic plate bearing tests.

5 CONCLUSIONS

The multi-stage permanent strain Repeated Load Triaxial test and associated rut depth prediction clearly showed an improvement in the performance of the premium basecourse TNZ M4 AP40 aggregate (Transit 2006) in saturated undrained conditions with two geogrids placed in the sample which was confirmed with a repeat test. The full benefits of the addition of geogrid into dry GAP40 sub-base aggregate are not realised in the RLT tests due to the small cross-sectional area of the sample.

Repeated load plate bearing tests were conducted on unbound aggregates with and without geogrids. The aggregates were compacted in a larger steel rectangular mould (150x150x530mm) and repeated loading from 5 to 550kPa was applied to a 150mm diameter plate to simulate vehicle loading. This dynamic plate bearing test clearly showed that the aggregate reinforced with geogrid took 5.5 times the number of loadings (635k) to achieve the same rut depth (15mm) as the aggregate with no geogrid (115k). Due to the larger area of the beam mould and the sideways shear forces developed during loading is considered a better test to represent the benefits of geogrid reinforcement within the aggregate.

6 REFERENCES

Arnold G., 2004. Rutting of Granular Pavements. PhD Thesis, University of Nottingham, Nottingham, UK.

Arnold, G., Werkemeister, S., Alabaster, D. 2008. Performance tests for road aggregates and alternative materials. Land Transport New Zealand Research Report 335. yy pp.

Arnold, G. Alabaster, D. Steven, B. 2001. Prediction of pavement performance from repeat load triaxial tests on granular materials. Transfund New Zealand Research Report, Wellington, New Zealand.

Arnold, G. Alabaster, D. Ellis, J. Lowe, J. 2008. Recycling & Stabilisation Conference The performance of New Zealand basecourse aggregates and glass aggregate mixtures found from Repeated Load Triaxial testing. NZIHT Recycling & Stabilisation Conference, Takapuna, Auckland, 22nd June 2008.

Chan, FWK. 1990. Permanent deformation resistance of granular layers in pavements, Ph.D. Thesis, University of Nottingham, Nottingham, UK.

Korkiala-Tanttu, L. Laaksonen, R. Törnqvist, J. 2003. Effect of the spring and overload to the rutting of a low-volume road. HVS-Nordic-research. Helsinki 2003. Finnish Road Administration. Finnra Reports 22/2003. 39 p. + app. ISSN 1457-9871, ISBN 951-803-052-9, TIEH 3200810E.

Little, P. H. 1993. The design of unsurfaced roads using geosynthetics, PhD thesis, Dept. of Civil Engineering, University of Nottingham.

Pidwerbesky, B. 1996. Fundamental Behaviour of Unbound Granular Pavements Subjected to Various Loading Conditions and Accelerated Trafficking. PhD Thesis, University of Canterbury, Christchurch, New Zealand, 1996.

Semmelink, CJ, Jooste, FJ & de Beer, M. 1997. Use of the K-mould in determination of the elastic and shear properties of road materials for flexible pavements, 8th Int. Conf. on As-phalt Pavements, August, Seattle, Washington, USA.

Thom, N and Brown, S. 1989. The mechanical properties of unbound aggregates from various sources. Proceedings of the Third International Symposium on Unbound Aggregates in Roads, UNBAR 3, Nottingham, United Kingdom, 11-13 April 1989.

Transit. 2006. TNZ M4 (2006) Specification for Basecourse Aggregate. Transit New Zealand, Wellington, New Zealand.

Transit. 2007. Draft TNZ T15 (2007) Specification For Repeated Load Triaxial (RLT) Testing Of Unbound And Modified Road Base Aggregates.

Webster, S. 1992. Geogrid Reinforced Base Courses for Flexible Pavements for Light Aircraft: Literature Review and Test Section Design. Waterways Experiment Station Vicksburg Ms Geotechnical Lab.