Laboratory Drop Weight Impact Tests on Geogrid Reinforced Pavements

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ABSTRACT: Typical pavement designs, consisting of surface, base, and sub-base courses and sub-grade. These typical pavement designs may not be sufficient to withstand impact loading. Thus there is a severe need to investigate new pavement materials to enhance the impact load resistance of pavements. The objective of this paper is to evaluate the effectiveness of including a geogrid layer inside the asphalt layer above a concrete base in resisting impact loading. A total of three configurations were tested in the laboratory to study the effects of geogrid. Each slab was 0.9m by 0.9m and 0.275m thick. Various instrumentations were installed and monitored during the tests. The pavement slabs were subjected to two cycles of one tonne drop weights at 1.5m height. It was found that geogrid reinforcement in the top asphalt layer helped to strengthen the asphalt layer. With the geogrid reinforcement, the depth and size of the crater formed was reduced significantly. The geogrid-reinforced asphalt layer can be used a sacrificial layer by taking the majority of the impact load. It can also be easily replaced or repaired upon damage.

1 INTRODUCTION

This paper focuses on the application of geogrids as reinforcement in a new pavement design which will be able to withstand impact loadings better than typical pavements.

Typical pavements consist of surface, base, and sub-base courses and sub-grade. The sub-grade is the natural in-situ soil material which has been cut to grade, or built up using suitable fill material. It provides a stable and uniform support for the overlying pavement structure. The sub-base course is constructed with lower quality granular aggregates which increases the pavement strength. The base course is made of high quality crush stone or gravel necessary to ensure stability under high tire pressures. The surface course is usually an asphalt (typical thickness of 5-10 cm) or Portland cement concrete material (typical thickness of 25-40 cm. Bound surfaces such as these provide stability and durability for proper operations. The surface course is also very important in the case of impact load as it is the part to be hit directly.

Typical pavement designs may not be sufficient to satisfy the needs of some pavements which require much higher resistance to impact loading. This is especially so in the last decade with the recent high spate in terrorists attacks. Thus there is a severe need to investigate new pavement materials and systems to satisfy these needs.

2 IMPROVEMENT OF RUTTING RESISTANCE USING GEOGRID ON ASPHALT PAVEMENT

Numerous rutting tests using an immersion wheel tracking system was conducted by NUS (Wong, 2005) to look into the Inclusion of geosynthetics in flexible pavement design in order to increase service life and enhance pavement performance. Two different types of geogrid (both with machine direction strength of 75kN/m) were tested. These were installed in between layers of asphalt. Figure 1 shows the test setup.

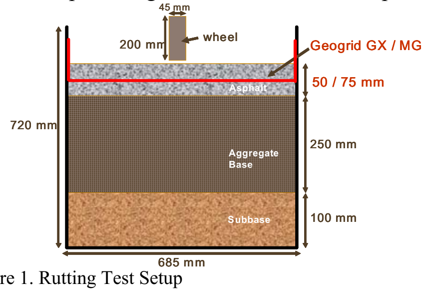

Figure 1. Rutting Test Setup

The sample was then subjected to a series of rutting tests and the settlement at the surface was measured after a certain number of passes. Figure 2 shows the results obtained. Geogrid had a significant effect in cutting down the rutting depth of the asphalt (Chew, 2005). This shows that geogrid has the potential to improve the ductility and durability of the asphalt.

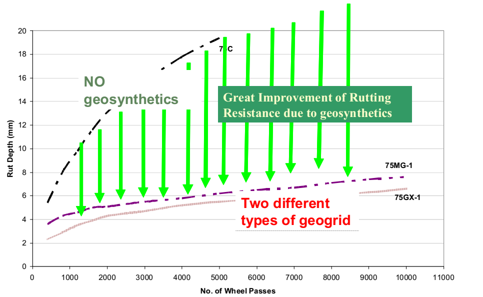

Figure 2. Effect of Geosynthetics Reinforcement on 75 mm thick pavement

3 TEST SCHEME FOR IMPACT TEST ON GEOGRID REINFORCED ASPHALT

For a better impact resistant pavement system, it was proposed that a geogrid reinforced asphalt layer was placed on top of a concrete base. For this paper, the focus will be on how geogrid affects the performance of this new pavement design.

Three different configurations for the proposed new pavement were designed to prove the concept. This new design will hopefully minimize the crater size and penetration depth caused by impact loading with a reduction in deformation and cracking. Figure 3 shows the detailed cross sectional view of the new pavement panels that have been tested. Sample A was a control sample with normal strength concrete. This simulates an actual concrete pavement. Samples B and C had the new pavement design. The only difference between them was the inclusion of geogrid in the asphalt layer for Sample C.

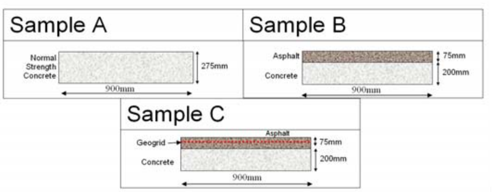

Figure 3: Sample Configuration for Impact Test

The new pavement panels were subjected to impact from a 1 tonne drop weight. The drop weight used is a cylindrical projectile with a hemispheric head (100mm diameter) dropped from different heights within a steel frame. Each Sample was subjected to 2 cycles of impacts from the same height of 1.5m. Figure 4 shows the drop weight machine that was used.

The pavement sample slab was placed on top of compacted soil/sand in a steel strong box. Directly below the slab will be the Geocell which are filled with compacted soil/sand. The geocell used in the test was of 100mm thickness. The flexible geogrid used had a tensile strength of 100kN/m in both directions. The asphalt used was the standard W3B used in Singapore pavements. Figure 5 shows the test setup and layout. A total of one tonne of sand was used and the sand was compacted to a density of approximately 1600 kg/m^3, with the aid of a 10 kg dead weight. Various instruments were installed and monitored during the drop weight. This is shown in Figure 6.


Figure 4. One Ton Drop Weight Machine in NUS

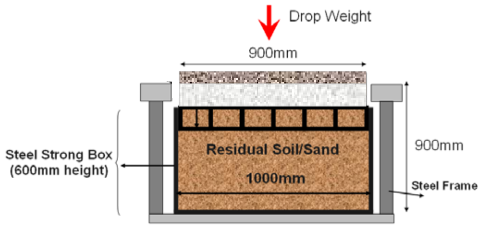

Figure 5. Setup of Test Configuration

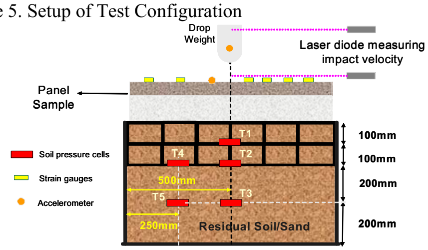

Figure 6. Instrumentation Set Up

The functions for the geosynthetics and asphalt used are as follows:

a) Geocell – Geocells are 3D polyethylene interlinked cellular structures filled with soil to increase the strength of the soil. Thus the soil base will deform less due to increase in confining stress In additional, overall shear strength of soil base is also increased (Wong, 2005).

Hence, residual soil can be used instead of more expensive granular sub-grade material. Thus this provides a 'strong base' to absorb the impact loading.

b) Asphalt – Asphalt surface is preferred as the skidding and friction properties of asphalt are well established. The ductility of asphalt will help to absorb some impact energy and can act as a sacrificial layer, resulting in less damage to the layers below.
c) Geogrid – Geogrid has high tensile strength and can be used to increase the lateral tensile strength of the asphalt layer significantly. It 'bonds' the asphalt layer together thereby reducing cracking and damage during impact loading.

4 RESULTS & DISCUSSION

Each of the sample slabs were subjected to two drops of 1.5m. The drop weight hits the slabs at a speed of around 5m/s based on the measurement from the laser diodes.

4.1 *Sample A – Control Sample of Concrete Slab*

After the 1st impact, a shallow crater of 140 mm in diameter was formed. The size of the crater was the largest of all the test samples. A higher propagation of cracks was observed at the sides of the sample. There was also significant debris of the surface upon impact. Upon 2nd impact, Sample A was fragmented into three segments with the projectile punching right through and stopped by the stopper of the frame (Figure 7). All the three major shear cracks propagated right through the whole thickness of the sample. Thus Sample A experienced a complete and sudden failure. Repair would be the replacement of the whole pavement section which requires more time and effort.

Figure 7. Sample A after 2nd Impact

4.2 *Sample B – Unreinforced Asphalt Layer on Top of Concrete Slab*

Upon the 1st impact, the asphalt layer of Sample B was completely destroyed and fragmented into three segments as shown in Figure 8. The projectile then landed on the concrete layer and there was minimal damage on this surface. There were no visible cracks propagating on the surface or by the sides of Sample B. This shows that most of the impact force was dissipated by the asphalt layer. Thus although the asphalt layer is completely destroyed, asphalt can serve as a 1st line of defense against the impact force. The asphalt layer is effective as a shielding material to minimize damage. However no proper bonding was also found between the asphalt layer and the concrete layer. Even after the 2nd impact, only a crater of diameter 60 mm is formed. This is in contrast to Sample A which was completely destroyed on 2nd impact.

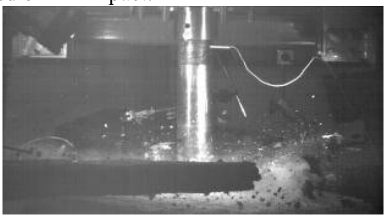

Figure 8. Sample B Asphalt Layer Destroyed on 1st Impact

4.3 *Sample C – Geogrid Reinforced Asphalt Layer on Top of Concrete Slab*

After the 1st impact, a crater of the same diameter as the projectile head at 100 mm is formed. This is shown in Figure 9. However, the reinforced asphalt layer remained intact even after impact. This showed that the geogrid held the asphalt layer together while the soft asphalt absorbed the impact force. At the crater, it was observed that the projectile had hit the concrete layer and the geogrid was punched through. Both the reinforced asphalt and next layer absorbed the impact force and a few minor cracks were observed at the asphalt surface of the sample which again proved that the geogrid prevented the fragmentation of the asphalt. Micro-cracks formed in the bottom of the concrete layer also showed that most of the impact force was already absorbed by the asphalt layer upon impact so bending was reduced. This is very different from Sample B where the asphalt layer was completely destroyed. This shows that geogrid improves the performance of asphalt significantly.

Upon 2nd impact, the crater's depth increased slightly by about 10 mm but the reinforced asphalt layer remained intact. Despite being hit at the same spot twice, Sample C could still absorb the force and maintain its structural integrity. The asphalt and concrete layers were still able to impede the projectile. More micro-cracks were observed to be propagating from the bottom concrete layer at the sides compared to the first impact and this showed that the force was absorbed and damage was mitigated.

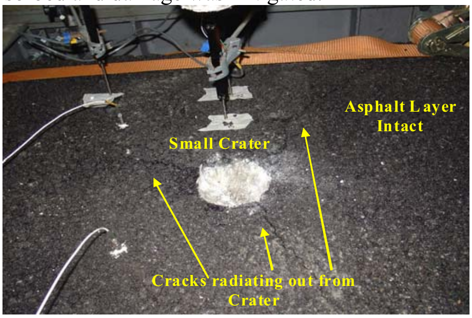

Figure 9. Sample C Crater after 1st Impact

For all 3 tests, the Geocell was also highly effective in providing a solid soil base for the slab to be placed on and absorbs residue impact force.

For the instrumentation installed, Figure 10 shows the vertical displacement of Sample C upon the second impact measured using LVDTs. There are two peaks. The initial vertical displacement downwards of less than 5mm (Peak 1) when the projectile hit the sample shows how well the geogrid reinforced asphalt layer and the geocell layers absorbed the drop weight impact load. Upon impact, there was a rebound and Peak 2 was the vertical displacement upwards. After Peak 2, the LVDT were dislodged The rebound was an average of 42.05 mm. This was obtained from the difference between Peak 1 and 2.

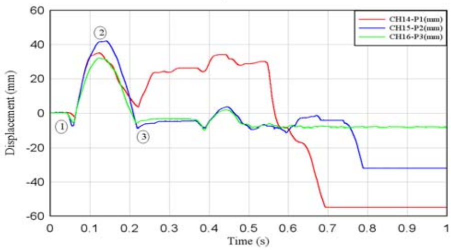

Figure 10. Vertical Displacement Readings for Sample C upon 2nd impact

Figure 11 shows the two peaks recorded by the soil pressure cells during the impact. The 1st peak occurred upon impact. This 1st peak value corresponds to the 1st peak value for the vertical displacement. T1, being nearest to the impact, recorded the highest reading of around 2500kPa. The lowest reading was recorded by T5 which was the furthest away from the impact among all the TPCs. The rebounding of the sample caused the 2nd peak and the subsequent peaks.

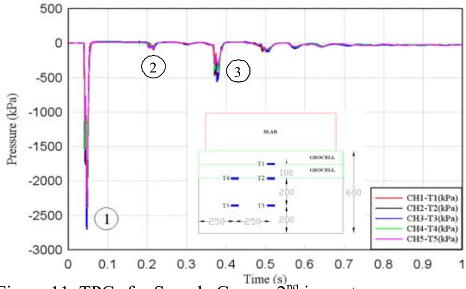

Figure 11. TPCs for Sample C upon 2nd impact

5 CONCLUSION & FUTURE RESEARCH

The results of these tests confirmed that geogrid can improve the impact resistance of pavements significantly. The Geocell layer below the sample acts a buffer to confine the sand/soil and absorbing the residual impact force. The impact test for Sample C showed that the geogrid was highly effective in preventing the asphalt layer from being destroyed. The asphalt layer was intact even after the 2nd impact. The geogrid was able to improve the tensile strength of the asphalt layer. The geogrid-reinforced asphalt layer can be used as a sacrificial layer by taking the majority of the impact load. The results also show that Sample C works the best in reducing the crater size

REFERENCES

Banthia, N., Mindess, S., Bentur, A. & Pigeon, M. 1989. Impact Testing of Concrete using a Drop Weight Impact Machine. *Experimental Mechanics*, Vol.29 (2), pp. 63-69.

Chew, S. H. & Lim., A. 2005. The Use of Paving Fabrics to Prevent Reflective Cracking in Asphalt Concrete Pavement. *4th Asia Pacific Conference on Transportation and the Environment*, Xian, China.

Wong, W. K. S. 2005. Laboratory Pullout Test on Geosynthetics Reinforcement-Geocell Soil Mass System. *B. Eng (Civil) Dissertation*, National University of Singapore.

Yong, C. K. 2005. Road Pavement Reinforced with Geosynthetics. *B. Eng (Civil) Dissertation*, National University of Singapore.