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Laboratory testing of reinforced unpaved roads

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ABSTRACT
Improving the rutting resistance and design life of unpaved roads is a major application for geosynthetics. A test facility has been developed at the University of Newcastle upon Tyne which allows pavement sections to be constructed in the laboratory at a practical scale. The finished pavement can then be trafficked using an electrically powered truck and subjected to full scale wheel loading to simulate in service loading.

The paper describes the development of the test facility together with the results of testing carried out to compare the performance of different geosynthetic reinforcing materials to enhance the performance of pavements over soft foundations.

1 INTRODUCTION

Improving performance of roads constructed over soft formations is one of the primary applications for geosynthetic reinforcement. Many researchers have studied this application both in the laboratory and at full scale (Giroud et al 1981 and Webster 1992). Recent work at the University of Newcastle upon Tyne, UK, has lead to the development of a test facility which allows pavement sections to be constructed in the laboratory at a full scale and subjected to full scale wheel loading to replicate in-service loading.

The test facility comprises a 9m long test bed in which a range of pavement conditions can be created. By placing different thicknesses of clay in the test bed and carefully controlling moisture content, a variety of foundation test conditions can be achieved. The pavement is then trafficked using an electrically powered truck, with the capability to vary the dual wheel rear axle load up to 140 kN. Within a single test a number of different test sections can be constructed and trafficked under controlled conditions allowing direct comparison of pavement performance. Driving the truck through its original rear axle, acceleration and deceleration forces are accurately controlled and transferred to the pavement thus simulating the true in-service condition. Trafficking conditions can easily be altered by programming the motor controller to different rates of acceleration and deceleration and constant speed durations.

Surface rutting caused by trafficking is recorded using displacement transducers linked to a computer, which enables contour plotting of the surface profile to be rapidly carried out. Using this automatic trafficking and data collection system pavements can rapidly be trafficked to their design life and beyond, enabling comparison of the performance of different systems to be made.

Following the development of the test facility, tests have been carried out to investigate the benefits of using geogrids to reinforce unpaved roads over soft formations. The results of this development and testing are presented below.

2 DETAILS OF TEST FACILITY

The Newcastle University Rolling Load Facility, NUROLF, comprises a 9m long by 2m wide test pit, Figure 1 and a trafficking vehicle which is a former gully emptying truck that has been adapted as follows :

1. Engine replaced with 60 HP 3-phase electric motor.
2. Guide wheels constructed on each axle to achieve constant tracking.
3. Rear axle weight increased to apply axle load of up to 140 kN.

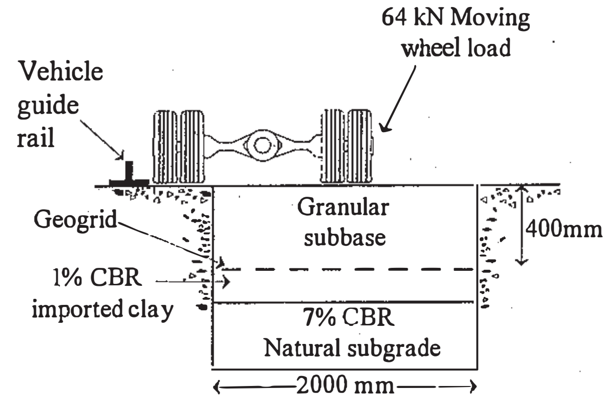

Figure 1 . Section Through NUROLF Facility

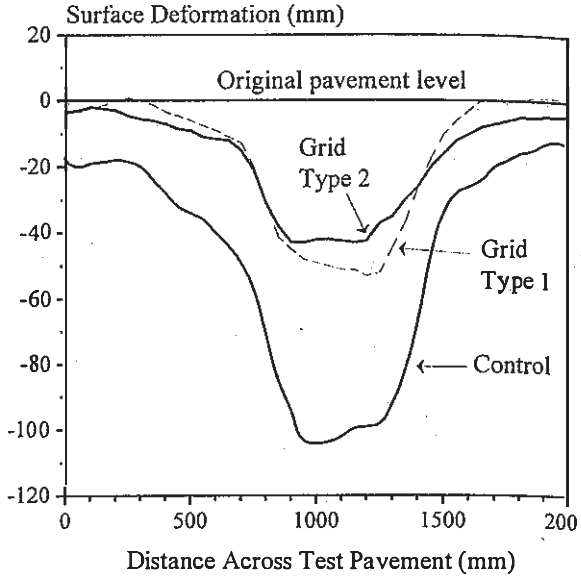

Figure 2 Typical surface profiles after 52000 passes

4. Power fed to motor by computer controlled inverter.
5. Guidance beam fitted with limit switch to achieve acceleration/deceleration
6. Inverter set to generate 0.1g acceleration / deceleration.
7. Electric motor drives rear axle.

During its load cycle, NUROLF applies a vertical wheel load of up to 70 kN through its offside wheel to the centre of the test site over the test length of 9m. It commences a cycle at one end of the site, initially off the test pavement and accelerates linearly over half of the test site so that the load wheel has attained a speed of 2.3 m/s at the centre of the test. It then decelerates over the remaining half of the facility until it comes to rest. It then accelerated in reverse to attain maximum reverse speed half way along the test facility prior to completing its cycle by decelerating. All accelerations and decelerations are programmable to permit a range of loading conditions to be modelled. The test vehicle normally undertakes a complete cycle in 53 seconds and in so doing applies a horizontal force of 10% of the applied vertical load to the pavement.

This combination of a wheel vertical load of 70 kN and a horizontal load of 7 kN relates closely to the heaviest loading to which a pavement is likely to be subjected in-service. By comparison, the maximum non-steering axle load normally applied by a fully laden commercial vehicle in the UK is 95kN, resulting in a wheel load of 42.5 kN.

Both before trafficking and throughout a test, a survey of the pavement surface is carried out using a set of 20 linear voltage displacement transducers (LVDT's) connected to a local computer controlled data acquisition system. The LVDT's are mounted at 100mm centres on a stiff beam which is positioned across the 2m width of the test site. The beam is positioned initially to survey a surface profile at a distance of 100mm from end zero of the test site. The 20 relative pavement heights are stored and the beam is moved a distance of 200mm along the test site, where a further set of heights is recorded. In this way, the whole of the test pavement is surveyed and 900 sets of X, Y and Z co-ordinates are stored locally on magnetic disk. The data is transferred to the processing computer and further load tests are carried out in parallel with downstream data processing.

The pavement survey data is fed to the 'Surfer' program which uses a Kriging routine to generate a representative surface from the survey data. This initial surface is stored on the computer for subsequent subtraction from later results so that a series of cumulative surface profiles can be viewed. The representative three dimensional surface generated by 'Surfer' can then be used to obtain cross sections of the surface, using 'Grapher' software.

3 TEST CONFIGURATION AND MATERIALS

Following an initial proving trial, a test pavement was constructed using a 1% CBR subgrade strength onto which crushed rock subbase was placed and compacted. To achieve the required formation strength, 300mm of imported soft clay was placed onto the natural boulder clay which forms the bottom of the pit and has a strength of 7% CBR . In order to ensure that a consistent subgrade strength was achieved, strict control was placed in the selection of the clay. The clay was obtained from a brick manufacturer and taken from the point in the brick making process when the clay had been dried and ground to a uniform and constant condition. By adding water in weights calculated following preliminary laboratory tests, clay of correct target strength was obtained. Prior to placing the granular fill, clay samples were taken for testing which confirmed the formation strength.

The test pit was divided into a number of equal length sections and the geosynthetic reinforcement installed prior to placing of a 400mm thickness of well graded granular fill of 37.5mm maximum particle size. For comparison an unreinforced control section was included in the trial. The fill was then compacted in layers in accordance with the Department of Transport Specification for Highway Works (1992).

Two of the test sections were reinforced with geogrid reinforcement with the properties shown in Table 1.

Table 1. Properties of geogrids used in pavement test

Grid Property		Grid Type 1	Grid Type 2
Quality Control Strength*	LD	17.5 kN/m	30 kN/m
	TD	31.5 kN/m	30 kN/m
Approximate Peak Strain	LD	12.0%	11%
	TD	10.0%	10%
Load at 2% Strain*	LD	7.0 kN/m	10.5 kN/m
	TD	12.0 kN/m	10.5 kN/m
Load at 5% Strain*	LD	14 kN/m	21.0 kN/m
	TD	23.0 kN/m	21.0 kN/m
Typical Rib Thickness	LD	1.20mm	1.35mm
	TD	0.90mm	2.20mm

* Determined as a lower 95% confidence limit in accordance with ISO 2602 1980 (BS 2846 Part 2 1981).

The performance of grid type 1, Tensar SS2, in subbase reinforcement applications has been proven by independent research (Webster 1992) and through its use on sites world-wide since 1981. To provide a more balanced product for sub-base reinforcement, grid type 2, Tensar SS30 was developed to have a square aperture with equal short-term strength in both the longitudinal and transverse roll directions. In addition the new grid has relatively thick ribs in the vertical plane, compared with Tensar SS2 and other reinforcing products. This feature was intentionally engineered into the new product to achieve a high degree of mechanical interlock between fill and the grid, thus providing maximum bearing and reinforcing effect to granular fill materials. Work by Webster (1992) and Kinney (1995) has shown that the performance of a grid reinforced pavement is dictated by properties other than ultimate tensile strength. Rib shape and high aperture stability, a feature of grid types 1 and 2, have been shown to play a significant part in determining the performance of reinforced pavements under moving loads. Having developed the new grid, with improved geometry and a similar in-plane torsional rigidity (Netlon 1995), the laboratory pavement trial was undertaken to prove its performance under traffic loading.

For the trafficking test a 64 kN vertical wheel load was used. BS 7533:1992 recommends that fully channelled loading should be equivalenced to normal wandering highway loading on a 3:1 ratio. By taking account of this factor and by applying the 3.75 power law relating axle load to pavement damage sustained, one pass of NUROLF equates to 17 standard 80 kN axles, i.e. each full cycle of NUROLF inflicts damage onto the pavement surface that would be inflicted by 34 standard axles. When working continuously, NUROLF thus achieves 2300 equivalent standard axles per hour. In the test carried out the equivalent of 70,000 standard axles were applied to the pavement.

4 RESULTS OF TRAFFICKING.

Table 2 shows the average maximum depth of rut in the three test sections, Figure 2 shows typical rut profiles for the three pavement sections. From Table 2 and Figure 2 it can be seen that both types of grid provided a similar reinforcing effect to the pavement with measured surface ruts being approximately 50% of that for the control section after 52000 passes.

Table 2. Average maximum rut depths after trafficking.

Pavement Section	Average maximum rut depth at	
	14500 passes	52000 passes
Control	98mm	104mm
Grid Type 1	50mm	53mm
Grid Type 2	39mm	49mm

Further tests are underway using different subgrade strengths and reinforcing materials, the results of. which will be published at a later date.

5 CONCLUSIONS

1. NUROLF provides a rapid and economic means to testing pavements at full scale under laboratory conditions.
2. The method of subgrade preparation used allow a consistent formation strengths to be prepared.

3. The data acquisition and processing system developed is an effective means of collecting and processing the required pavement performance data.
4. The inclusion of the geogrid reinforcements tested effectively reduced the overall pavement settlement by approximately 70%.
5. Both of the geogrids used in the trial resulted in pavements with similar performance with respect to resistance to surface rutting with rut depths 50% of that for the unreinforced control section. The new Tensar SS30 geogrid giving marginally better performance.

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