COOPERNOOK TO HERONS CREEK PACIFIC HIGHWAY UPGRADE – GEOSYNTHETICS OVER SOFT GROUND

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ABSTRACT

As part of the Pacific Highway Upgrade by the New South Wales Roads and Traffic Authority (RTA), the Coopernook to Herons Creek section presented some interesting challenges with deep soft soil profiles. High strength soil reinforcement geosynthetics were used over piled foundation to stabilise bridge abutments. In other areas a working platform and access road to support a 300T crane also represented an opportunity for a composite geosynthetic geogrid reinforced pavement design. The paper examines the pavement design adopted, the critical design parameters, the benefits and savings to a traditional pavement and the contractors' experiences with the unique composite used on site within this case study.

1 INTRODUCTION

The Coopernook to Herons Creek Pacific Highway upgrade project is a duplication of the highway essentially along its existing alignment with bypasses of the villages of Moorland, Johns River and Kew. The RTA formed an alliance team with Thiess Pty Ltd and Parsons Brinckerhoff Australia Pty Ltd to design and construct the 33 km dual carriageway upgrade. The project is jointly funded by the NSW and Australian governments. The alliance commenced construction commenced in November 2007 and plans to complete the project by the end of 2009.

Geosynthetics have been used for the stabilisation and reinforcement of pavements since the 1970s. Generally placed between the subgrade and base course of the pavement, the geosynthetic improves the performance of the pavement by increasing the traffic volume or reducing the base course thickness required relative to a non-reinforced pavement. The geosynthetic may also permit the combination of increased traffic and thickness reduction as well as the opportunity to use lower quality base course.

2 GEOSYNTHETICS

2.1 GEOSYNTHETIC TYPES

There are two main types of geosynthetics used in pavement stabilisation: geotextiles and geogrids. Geotextiles are either woven or nonwoven permeable fabrics made from synthetic fibres. Geogrids are relatively rigid polymeric mesh structures formed into regular grid like patterns. Though not limited to, the most common geosynthetics are made from polypropylene or polyester.

Figure 1: Type of geogrids.

The key feature of all geogrids is the apertures are large enough to allow for soil interaction through one side of the geogrid to the other. The ribs of some geogrids are often quite stiff compared to the fibers of geotextiles and hence provide reinforcement to the adjacent soil particles.

The shear interaction is also known as the *interlocking* effect. The interlocking restrains the aggregate laterally and transmits the tensile forces from the aggregate to the composite grid, reducing the magnitude and orientation of the shear stresses on the subgrade. Providing a tensioned membrane support, the surface deformation of the pavement is reduced.

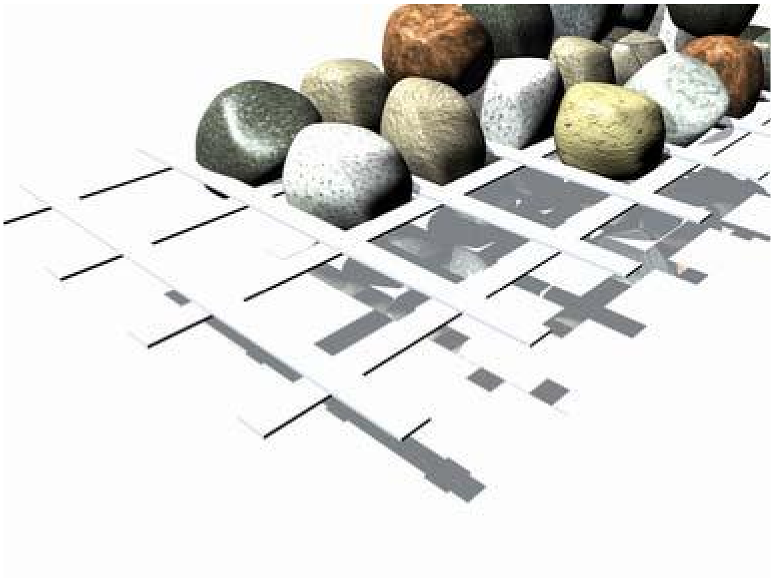

Figure 2: Shear Interaction or *interlock* between base aggregate and geogrid.

2.2 GEOSYNTHETIC FUNCTIONS

Geosynthetics can provide separation between subgrade and base course materials and reinforcement of the base course. Separation prevents the intermixing of soft subgrade soils with the base course aggregate. Reinforcement increases the bearing capacity of the subgrade, stiffens the pavement, provides lateral restraint to the base and subgrade and in the case of unpaved surfaces, reduces the rut depth.

Combigrid is a unique product that combines the benefit of geotextile separation with the reinforcement benefit of the geogrid in a composite. Here the composite grid is formed from drawn bars that are ultrasonically welded with a geotextile integrally located within the bonded structure. The geotextile provides sufficient give to permit the interlocking of the stone particle.

A composite grid is able to prevent the contamination of the base course aggregate. The added benefit is that the aggregate is able to act more efficiently as a drainage layer allowing dissipation of pore water pressure and maintaining the integrity and the compressive strength of the base material.

The composite grid prevents the loss of base course aggregate stone thereby saving on additional *sacrificial* aggregate being placed. Within unpaved roads the composite grid may prevent tension cracking at the bottom of the base course which minimises contamination of the base course material.

A geosynthetic provides an economical solution to construction over soft ground. It minimises the need to excavate and dump subgrade material and reduces the volume of imported aggregate material.

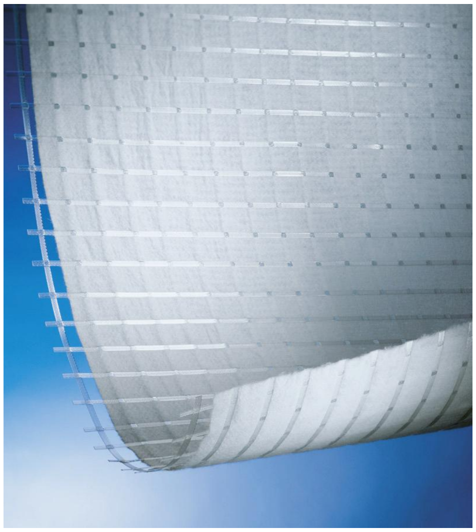

Figure 3: Composite grid – reinforcement geogrid with an integral geotextile providing separation.

2.3 LOAD DISTRIBUTION IN GEOGRID REINFORCED BASE COURSES

The interaction between the geogrid and base aggregate increases the elastic modulus and load distribution capacity of the pavement. This correlation enables the reduction of the reinforced base aggregate thickness relative to a pavement without a geosynthetic as illustrated in Figure 4.

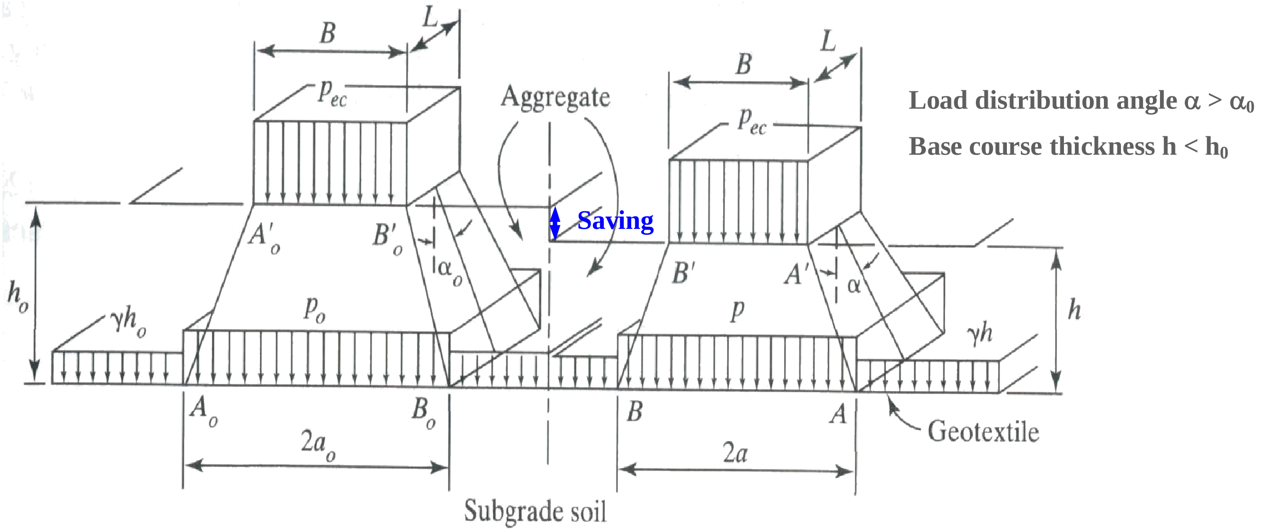

Figure 4: Increase of load distribution angle with geogrid (Giroud *et al.* 1984).

In an unpaved road, stresses from traffic loads are transferred to the base course aggregate mainly in the direction of traffic flow and perpendicular to it as the aggregate moves. Predominately a biaxial load distribution takes place within a road.

It is generally considered that the base course material used in a working platform or haul road should be of sufficient quality, i.e. a minimum friction angle of 35° in order to provide an efficient and practical design.

2.4 KEY REINFORCEMENT CHARACTERISTICS

The important parameters of the geogrid or composite grid are its tensile modulus or secant stiffness. Traffic loads are transient short term instantaneously applied loads. Large scale field tests and laboratory (GMA) tests show that typical strains within the geosynthetic are in the range of 0.5% to 2% when they are installed at the subgrade and base interface. This demonstrates that the ability of the geosynthetic to take load up to 2% deformation is more critical than its ultimate tensile strength. Test standards such as ISO 10319, ASTM D4595 and AS 3706.2 may be used to determine the wide strip tensile strength.

Using the data of the wide width tensile test, the secant stiffness J is then calculated as follows:

$$J_{a\text{-}b} = (F_a - F_b) / (\epsilon_a - \epsilon_b) \quad \mathbf{(1)}$$

Where:

$J_{a\text{-}b}$ = characteristic short term secant stiffness at strain between ϵ_a and ϵ_b (kN/m)
F = tensile strength at a given strain ϵ (kN/m)
ϵ = given strain (%)

The ultimate tensile strength of the geosynthetic should not be used in the design. Strain compatibility of the geosynthetic and adjacent soil limits the allowable working strength of the geosynthetic to 2% in critical pavements and 5% in working platforms and haul roads.

A feature of the geosynthetic products is their durability and resistance to naturally occurring chemicals. Polypropylene is highly resistant to acid sulphate soils, lime and concrete.

Installation damage is perhaps more likely to be hazardous. To limit the damage, the maximum particle size of the base course, adjacent to the geosynthetic should be limited to 75 mm. Subsequent base course layers above the initial lift may utilise a broader grading with little to no additional damage to the geosynthetic. The initial lift thickness is 200 mm to 300 mm depending on different manufacturers' recommendations.

3 DESIGN OF CRANE PLATFORM AND UNPAVED ROAD

At the Stewart River section of works the Alliance required an unpaved road and working platform able to support a Bauer BG28 crawler crane and drill rig over a subgrade CBR of 1% assumed.

The loads of the piling rig are applied to the subgrade via two chain tracks. Depending on the individual working modes, the imposed surface pressures by the piling rig tracks are variable due to the tilting movement of the vehicle. The critical load cases and track geometries with the derived uniformly distributed load pressures are shown in Table 1.

Table 1: Pressure summary for platform and haul road.

Mode	BRE Load Case	Length (m)	Width (m)	UDL Pressure (kPa)
Travelling	1	4.153	0.8	167
Handling	1	3.623	0.8	238
Extracting	2	2.924	0.8	317

The existing subgrade was unable to support these loads and a composite grid (geogrid and geotextile) was required to distribute the loads. The BRE guide requires the UDL loads to be increased by a factor of 1.6 for Load Case 1 and 1.2 for Load Case 2.

For fine grained, water saturated, soft soils with low shear strength a CBR of 1% was assumed, equivalent to 30 kN/m^2 (Ruegger *et al.*, 2003). The ultimate bearing pressure beneath the rectangular track may be calculated as:

$$q_{ult} = s_c * N_c * c_u \quad \mathbf{(2)}$$

where:

q_{ult} = Ultimate bearing capacity
s_c = Shape factor, 1.2 for rectangular plate
N_c = Bearing capacity factor; here 5.14 for $\varphi > 0°$
φ = Internal angle of friction
c_u = Undrained shear strength here 30kN/m^2

$$\text{Hence } q_{ult} = 185.04 \text{ kN/m}^2 \quad \mathbf{(3)}$$

The load distribution angle, α is increased when a geogrid is introduced into the base course (see Figure 4). According to Ruegger *et al.* (2003) the effective load distribution angle of a geogrid reinforced aggregate base layer will be between the internal angle of friction φ of the base course and 45° + φ/3. For the case of this project 45° was conservatively adopted.

Adopting an overall base course thickness of 500 mm the following area of influence was calculated:

Load Case 1:

$A_{travelling} = \{[(2 * 0.5) + 4.64] * 2\} * \{[(2 * 0.5) + 0.8] * 2\} = 40.60 m^2$

$A_{handling} = \{[(2 * 0.5) + 3.623] * 2\} * \{[(2 * 0.5) + 0.8] * 2\} = 33.28 m^2$

Load Case 2:

$A_{extracting} = \{[(2 * 0.5) + 2.924] * 2\} * \{[(2 * 0.5) + 0.8] * 2\} = 24.65 m^2$

Where:

A = the area of influence

The net bearing pressure applied to the subgrade, with a 500 mm base course may be determined as:

Load Case 1:

$q_{travelling} = 167 kN/m^2 * 1.6 * [(4.64*0.8) * 2] / A_{travelling} = 48.86 kN/m^2$

$q_{handling} = 238 kN/m^2 * 1.6 * [(3.623*0.8) * 2] / A_{handling} = 66.32 kN/m^2$

Load Case 2:

$q_{extracting} = 317 kN/m^2 * 1.2 * [(2.924*0.8) * 2] / A_{handling} = 72.20 kN/m^2$

$$\text{The factor of safety } Fs = q_{ult} / q \text{ applied.} \qquad (4)$$

In all cases the factor of safety is above 2.5 with the extraction scenario being the critical one.

The product selected for the Stewart River bridge working platform was the Combigrid 40/40Q1. This product is a composite polypropylene geogrid with integral geotextile. Physical and mechanical properties are provided in Table 2.

Table 2: Mechanical and physical properties of the Combigrid.

Property	**Test Method**	**Unit**	**Combigrid® 40/40 Q1**
Raw Material	-	-	Polypropylene White
Max Tensile Strength md/cd	ISO 10319	kN/m	40 x 40
Elongation at Max load	ISO 10319	%	< 8%
Tensile Strength @ 2% elongation	ISO 10319	kN/m	> 16 kN/m
Secant Stiffness @ 2% strain, $J_{2\%}$	ISO 10319	kN/m	> 1100
Aperture Size	Nominal	mm	31x 31
Composite mass	ISO 9864	gsm	390
Roll Size	-	m	4.75 x 100

4 FINAL PAVEMENT AND SUMMARY

A 300 mm thick initial lift layer of clean rockfill base course was placed over the Combigrid. and over the rockfill a 230 gsm non woven geotextile and a further 200 mm of roadbase gravel – as per the attached typical section shown in Figure 5. The roadbase gravel has a CBR of 130.

The base course fill was a well graded 19 mm to 37.5 mm gravel, placed to a minimum 500 mm thickness. A maximum 2% fall was adopted to allow water run off and stability. Some plant may not be stable if the slope is greater than 5-10%.

A minimum 200mm overlap of the Combigrid was suggested on lateral and transverse joins. Being a cohesive subgrade, the Combigrid prevented the upward migration of soil fines into the working platform. Traffic was estimated at less than 500 passes with the occasional regrading of the surface to provide a smooth driving surface.

In summary the working platform and unpaved road design fulfilled the operational requirements of the contractor on site. Though the design of the geosynthetically reinforced pavement is derived from empirical formulae there is enough history for designers and contractors to be confident in its use.

The worse the subgrade conditions the more noticeable the geosynthetic contribution and efficiency in terms of speed of construction, savings in base course material and pavement performance.

Photo 1: Installation of geosynthetic composite on site.

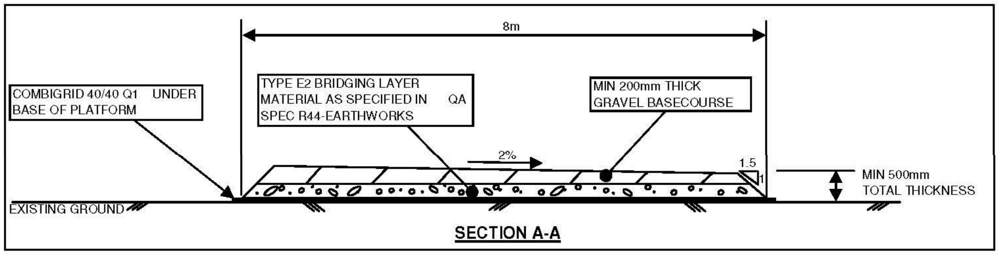

Figure 5: Typical cross section of reinforced crane unpaved road.

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