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THE USE OF GEOGRIDS IN HIGHWAY CONSTRUCTION IN NSW

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ABSTRACT: Since 1990, the RTA has constructed several projects using geosynthetic grids. The spectrum of high strength geogrids has included slope remediation, reinforced soil retaining walls, and pavement rehabilitation. Geogrid reinforced soil structures have been used to directly support bridge surcharge loads, and offer a cost effective practical solution to road formations in widening of highways where road easements are restrictive.

INTRODUCTION

The past decade has seen a significant trend towards the use of high strength geosynthetic materials in road construction in New South Wales.

Geogrids, in particular, have shown an increased use as a reinforcement in pavements and slope remediation projects.

This paper focuses on a number of recent projects involving the use of geogrids in slope and pavement repair, and in earth retaining structures by the Roads and Traffic Authority of New South Wales (RTA). The paper addresses major issues in the design and construction of these structures together with the problems and benefits identified in the post construction period.

BACKGROUND

The RTA was the first State Road Authority to embrace the concept of soil reinforcement with the introduction of the Reinforced Earth System in the mid 1970's.

The Reinforced Earth System uses ribbed steel strips as the reinforcing elements together with cruciform shaped concrete panels to form the face of the reinforced soil structure. Careful consideration must be given to the properties of the soil used in the backfill, to avoid corrosion of the reinforcing strips.

The introduction of geogrids has widened the spectrum of applications for soil reinforcement. Geogrids have been used in slope stability, foundation improvement and pavement reinforcement projects world-wide.

As geogrids are typically manufactured from chemically inert polymers, the problem of chemical degradation is negligible. Additionally geogrids act to interlock with the soil mass. In a majority of cases, these factors enable insitu soils to be used in the reinforced zone, eliminating the need to import fill.

The RTA has been using geogrids since the early 1990's. Initial trials conducted in the Western Suburbs of Sydney were based on the potential of geogrids to extend the life of existing asphaltic pavements.

Primarily, however, geogrids have been used in slope remediation work and, more recently, incorporated into reinforced soil retaining structures such as gravity walls and bridge abutments.

The Authority has found geogrids a satisfactory, cost effective alternative to the more conventional earth retaining structures (ie: mass gravity retaining walls or sheet piling).

TYPES OF GRIDS USED

Based on structure, geogrids fall into the two general categories of strip reinforcement and sheet reinforcement.

Strip reinforcement consists of strips of a high strength polymer material. It is used as either a continuous reinforcing strip or in the form of a welded mesh ie: two sets of the strips at right angles to each other, heat welded at their intersection.

Sheet reinforcement consists of a polymer sheet, which is punched with a regular pattern of holes. The sheet is then extruded in the longitudinal direction, re-orientating the polymer chains into an ordered, aligned state. This creates a high strength uniaxial grid. Repetition of the process in the cross direction produces a biaxial grid (Netlon Ltd, 1990).

To date, three different geogrid products have been used in reinforced soil applications ie: Tensar Geogrids which are a High Density Polyethylene (HDPE) extruded sheet reinforcement; Paragrid biaxial welded mesh reinforcement and Websol strip reinforcement. The last two products consist of high strength polyester fibres encased in a polyethylene skin.

Geogrids have also been developed for specific use as asphalt reinforcement. This application is discussed later in the paper.

SLOPE REMEDIATION

The major application of geogrids has been to reinstate slopes after landslides. Traditionally, this involved flattening the batter angle or the construction of a gravity retaining wall. In all case the failed soil was replaced with a durable granular aggregate.

Geogrids help to maintain equilibrium in a soil mass by providing additional tensile strength. This effective increase in strength enables the failed soil (in most cases) to be re-used in the new slope. As such geogrids provide a cost-effective alternative in slope remediation.

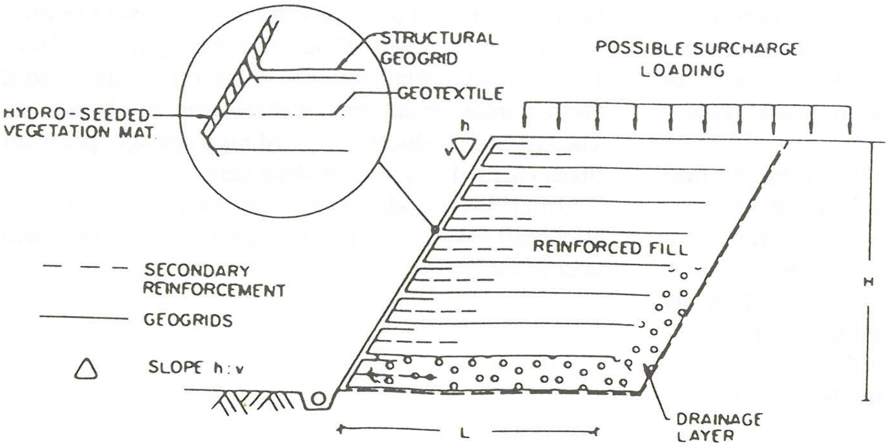
Geogrids were first used by the Authority in 1991, for the repair of a failed embankment along the New England Highway at Murrurundi. Since then, three failures in roadside batters have been reinstated with geogrid reinforced structures along the Princes Highway at Kiama Bends, Main Road 217 at Dora Creek and the Pacific Highway at Eungai.

Project details are presented in Table 1.

TABLE 1 - BRIEF SUMMARY OF SLOPE REMEDIATION PROJECTS

JOB	MURRURUNDI	KIAMA BENDS	DORA CREEK	EUNGAI
LOCATION	New England Hwy, 305km nth of Sydney	Princes Hwy, 123km sth of Sydney	MR 217, Dora Ck, 120km nth of Sydney	Pacific Hwy, 440km nth of Sydney
PROBLEM	slumping of clayey-silt fill in road embankment, over a 50m length	slumping of talus in roadside batter, over a length of several hundred metres	2 part wedge failure of weak claystone in roadside batter, over a length of 60m	block sliding failures of phyllite in roadside batter.
NEW SLOPE DIMENSIONS	9m reinforced slope at 34.5°	6.5m reinforced slope at 53.5°	5m reinforced slope at 31°	9.5m reinforced slope at 34.5°
GEOGRIDS	Tensar SR55	Tensar SR80 and SR55	Tensar SR55	Tensar SR80
GRID LENGTH	4.6m	5m	5.8m	7m (at base) to 4m
SPACING	1.0m	layers 1-3 at 0.5m layers 4-8 at 1.0m	1.0m	1.0m
BACKFILL	failed soil reused	crushed slag for 3.5m, then failed soil	failed soil reused	granite gravel

FIGURE 1 - TYPICAL LAYOUT OF REINFORCED SLOPES



Grids are installed horizontally on the slope. At the face each layer of grid is wrapped around the compacted fill above, and anchored immediately below the next layer of reinforcement (see Figure 1).

Initially the working strength of the geogrids must be determined. Each different geogrid has a reference strength representing the ultimate tensile strength of the grid at failure. This strength must be reduced to account for the effects of creep, temperature, construction damage, and an overall factor of safety for the structure.

The first three reductions are characteristic to the geogrid and are usually supplied by the manufacturer. The final factor is dependant on the risk associated with the structure. The choice is left to the discretion of the designer.

The length of the grids can vary from 0.6H to 2H (where H is the vertical height of the slope), and is dependant on backfill properties, the grade of the slope and the presence of any surcharge loads.

The layout of the geogrids is designed to maintain both the internal stability of the reinforced zone and the global equilibrium.

Global stability is assessed by the limit equilibrium slope stability approach. Programs used by the Authority to aid analysis include : PC SLOPE (Geo-Slope International, 1993) and STARES (Balaam N. P., 1993).

One of the uncertainties with this form of analysis, is the choice of partial factors of safety for the reinforcement. In particular, the magnitude of the partial factors against sliding will dictate the geometry of the critical failure surface.

These factors represent the ability of the geogrid to integrate into the soil mass. Research (Martin, Koerner and Whitty, 1984) has shown the factors to vary with both the properties of the backfill soil and the type of grid used. Results indicate an increase in resistance to sliding and pullout in more granular soils.

However, as there is no consensus on the magnitude which should be adopted, conservative factors tend to be used.

Designs assume that the slope is drained and well compacted. Drainage is provided through the placement of a layer of granular aggregate at the base of the reinforced structure. This drainage layer is continued up behind the structure to a height of between 1/2H and 2/3H or to the level of a measured watertable (see Figure 1).

Additionally, at all sites it is good practice to construct external drains and to intercept and redirect flow away from the structure.

A final consideration is the revegetation of the slope. Vegetation serves to protect the surface soil from erosion, provide a pleasant finish to the structure as well as shading the geogrids from UV light.

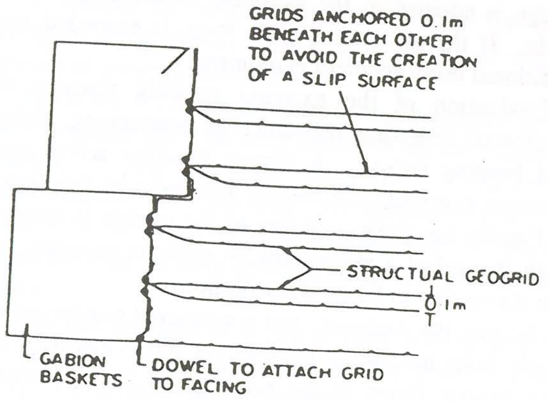
VERTICAL REINFORCED SOIL WALLS

Reinforced soil walls are an extension of the application of geogrids in slope remediation to vertical and near vertical slopes. In these applications the reinforced soil block acts as a self supporting composite structure, used to retain fill and support external loads.

Typically in these structures, the geogrids are used in combination with a facing unit which, during construction, helps form the front of the wall and aid compaction of the reinforced soil. The units also serve as anchor points for the reinforcement, protect the face from sloughing failures and provide an exterior finish for the structure.

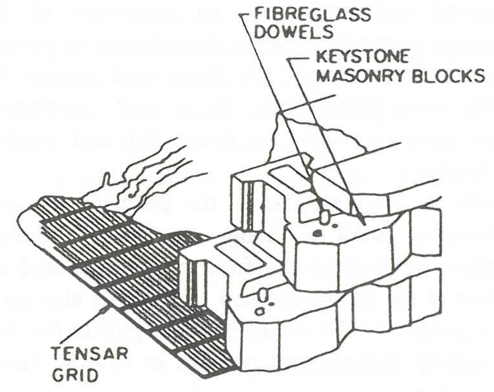
Common facings include incremental concrete panels, rock filled gabion baskets, and 'Keystone' segmental masonry blocks. Both the concrete panel and Gabion basket facings are attached to the reinforcement via dowels fastened to the back of the facing units (see Figure 2).

FIGURE 2 - TYPICAL CONNECTION DETAILS



The Keystone system attaches the grids between successive levels of blocks. Each block is stacked and interlocked to the level of blocks below by two high strength fibreglass dowels (see Figure 3). The grids are hooked over the dowels forming a high strength connection between the reinforcement and the facing. This connection method is applicable for use with the Tensar Geogrids.

FIGURE 3 - KEYSTONE CONNECTION DETAILS



As with reinforced slopes, the degree of backfill compaction and the provision of drainage are major considerations in the construction.

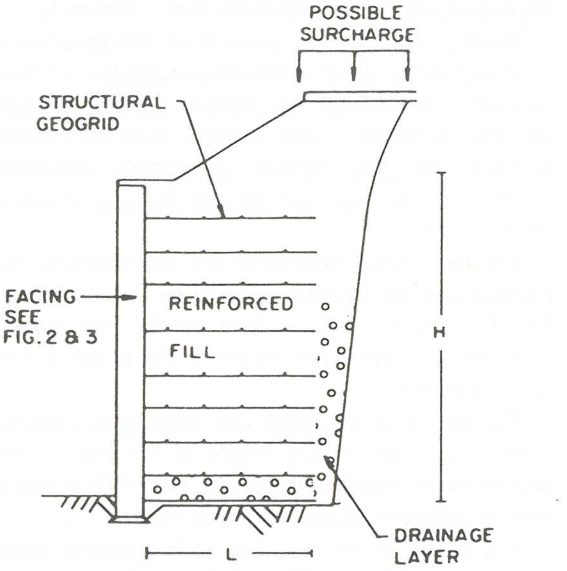
The structures are designed to be free-standing and to support retained fill and surcharge loads. Internal stability is checked by assuming that a wedge failure may develop at any point along the face of the structure. The horizontal thrust generated by the wedge is equated to the available tensile force in the grids. If the available tensile force is exceeded then additional reinforcement is required.

Evaluation of the external stability assesses the reinforced structures resistance to overturning, sliding and bearing failure. A simple Rankine active earth pressure distribution is usually adopted with this check.

Finally the global stability of the system is assessed with the aid of a slope stability analysis program (see the discussion in Slope Remediation).

To date the Authority has constructed reinforced soil walls along the Pacific Highway at West Gosford and San Martin Drive in the Ku-ring-gai Chase National Park. Both these structures were constructed as batter treatments using the Keystone-Tensar system (see Table 2 and Figure 4 for details). Three projects are currently under construction ie: a road embankment off the Putty Road at Windsor; bridge abutments over James Ruse Drive in Parramatta and the Tweed River at Barney's Point, Chinderah.

FIGURE 4 - TYPICAL LAYOUT OF A REINFORCED SOIL WALL



The first two projects have been designed with strip reinforcement. Paragrid reinforcing mesh with a gabion facing is being used at the Putty Road site and Websol reinforcing strips and Freyssinet concrete panels at James Ruse Drive.

The bridge abutments at Barneys Point consist of a terraced reinforced embankment, constructed with Tensar SR 110 geogrids and Keystone modular block facings. This structure will directly support the end spans for a major bridge over the Tweed River.

The abutments represent the first large scale masonry faced geogrid reinforced structure to be constructed by the RTA.

On completion it will be the largest geogrid structure in Australia .

GEOGRIDS AS REINFORCING IN ASPHALT

Application has been found for geogrid reinforcement technology in pavement, specifically as reinforcement in asphaltic (flexible) pavements.

Since 1990, the RTA has trialed four different geogrid products in heavily trafficked roads around Sydney's Western Suburbs. The products are HateLit (Germany), Tensar AR Grids (UK), Rehau Armapal (Germany) and Glasgrid (Canada).

The geogrids are composed of a high strength polymer or fibreglass based material. To facilitate their use in asphalt pavements, the surface of the grids is typically coated with a modified bitumen adhesive

TABLE 2 - BRIEF SUMMARY OF REINFORCED SOIL WALL PROJECTS.

JOB	ILLAWONG BAY	WEST GOSFORD	PUTTY ROAD
LOCATION	MR 525 Ku-ring-gai Chase National Park, 40km nth of Sydney	Pacific Hwy, 70km nth of Sydney	Putty Rd, 80km nth of Sydney
REASON	Foreshore Protection	Construction of a Roadside batter.	Construction of a road embankment
WALL DIMENSIONS	2m vertical reinforced wall	H1 : 1.4m, H2 : 1.7m H3 : 1.9m, H4 : 2.8m	5.5m reinforced embankment at 80°
GEOGRIDS	Tensar SR55	Tensar SR55	Paragrid 100/25s
FACING	Keystone masonry blocks	Keystone Masonry blocks	Rock filled gabion baskets
LENGTH	2.2m	1.2m for H1 1.7m for H2 1.9m for H3 2.8m for H4	6.0m
LOCATIONS OF GRIDS BELOW TOP OF WALLS (m)	0.6, 1.4, 1.8	H1 : 0.6, 1.2 H2 : 0.8, 1.6, 2.2 H3 : 0.8, 1.4, 2, 2.4 H4 : 0.8, 1.4, 2, 2.6, 2.8	0.3, 1.1, 1.7, 2.3, 2.9, 3.5, 3.9, 4.3, 4.7, 5.1, 5.5
BACKFILL	RTA rotomill waste	crushed sandstone	crushed sandstone

The geogrids were developed to reduce problems characteristic to asphaltic pavements eg: reflective cracking in overlays; cracking in pavement widening/repair work; rutting; and to potentially increase the fatigue life of the pavement.

The installation process follows the same basic procedure for all the geogrid products. Initially the original pavement is milled to the desired depth of the work. A tack coat of bitumen is then applied and the grids installed. To ensure the grids are laid smoothly tensioning is required during the installation of all the grids except Glasgrid.

Finally, an asphalt overlay is applied. For the Tensar and HateLit grids, this can only be completed after a surface dressing, to facilitate a bond between the grids and the asphalt.

A control section of unreinforced pavement was constructed at all sites.

All the grids (except the Glasgrid) underwent some degree of lifting and ballooning during the paving process. Of the products used the Glasgrid was the simplest and quickest grid to install.

The results have been encouraging with the reinforced sections of pavement showing a reduction in the development of cracks and rutting. The locations and details of the trials are presented in Table 3.

DISCUSSION

Geogrid reinforcement provides a practical and cost-effective solution to a large proportion of geotechnical problems in highway construction.

A number of issues have developed as the use of geogrids has widened. The first is concerned with the choice of geogrid reinforcement.

Since the RTA commenced using geogrids, several new products have become available on the Australian market. The products represent a variety of combinations of polymer composition and grid structures (ie: sheet or strip reinforcement). Each is supplied with its own strength data and partial safety factors.

This has resulted in a competitive pricing structure for products. However, choice should not be on price alone. Given that characteristics such as serviceability, strength, quality, and structure will vary, and that supporting data provided by manufacturers is not always complete; there is a need for a standard and independent means of product evaluation. This should be presented in the form of a technical specification.

The final selection should reflect life cycle costs ie: the impact that the geogrid will have on the life and maintenance of the structure, and not on purchase price alone.

TABLE 3 - BRIEF SUMMARY OF ASPHALT REINFORCING GEOGRIDS

GEOGRID TYPE	HATELIT	GLASGRID	ARMAPAL G	TENSAR AR
COMPOSITION	Polyester	Glass Fibre	Glass Fibre	Polypropylene
LOCATION USED	Parramatta Rd, Granville	Woodville Rd, Guilford	Parramatta Rd, Five Dock	Great Western Hwy, Wentworthville
INSTALLATION				
Tack Coat	Required	Not required	Required	Required
Tensioning	Required	Not required	Required	Required
Surface Dressing	In hilly areas only	Not required	Not Required	Required
Overlay Thickness	Minimum 50mm	Minimum 40mm	Minimum 50mm	Minimum 50mm
INSTALLATION COMMENTS	Treatment OK, some ballooning of grids when laying asphalt	Easiest product to install	Treatment OK, some ballooning of grids when laying asphalt	Treatment OK, some ballooning of grids when laying asphalt 50mm overlay too thin

Other issues concern the reinforced structure itself, in particular, reinforced soil slopes. Common to the construction of all slopes, are limitations achieving adequate compaction close to the edge of the face. This results in a zone of loose material which is susceptible to localised slumping and erosion.

Slumping is reduced by the inclusion of a secondary reinforcement (such as a geotextile) at the face (see Figure 1). Surface erosion has proved more difficult to prevent.

Typically erosion is contained by revegetating a slope. This also serves to give the grids some degree of protection from UV degradation and provide an aesthetic finish to the slope. Experience has shown revegetation of a reinforced slope to be slow and sporadic. This is probably the result of a combination of factors including inadequate water supply, extreme weather conditions, and the aspect and grade of the slopes.

One example of this problem is at the Dora Creek site where surface erosion of soil from behind the reinforcement has left the geogrids loose at the face. This was not foreseen in the design phase ; and could cause a reduction in the anchorage strength of the geogrids. As such, maintenance work may be required at the site at sometime in the future.

CONCLUSION

The RTA has used geogrid reinforcement in slope and pavement repair, and in reinforced soil wall structures since 1990. The system has proven to be a satisfactory, cost-effective alternative to conventional solutions to geotechnical problems.

Additionally, trials using geogrids as an asphaltic reinforcement have demonstrated their potential to extend the life of flexible pavements.

Until a standard code of practice is developed for geogrid reinforced structures, designers should continue to apply caution in the choice and use of all geogrid products.

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