Geogrid 'Tie-Back' System Used to Complete Pre-Cast Concrete Bridge Abutments

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ABSTRACT: Geogrid reinforcement of bridge abutments is used to complete pre-cast 'kit' bridge systems in Australia.

The system comprises piles, cast in-situ footings, pre-cast abutments and wingwalls. Pre-cast concrete beams and deck complete the system. The abutments and wingwalls are "tied-back" with geogrid to form a reinforced soil block which supports the structure against the various modes of failure.

This tie-back system effectively creates a reinforced soil block behind the abutments which does not rely on cantilever action and hence is not subject to such problems. The structural flexibility of this system enables it to accommodate differential settlements when building on soft soils.

Up to 20mm to 30mm of lateral movement of the abutment was allowed for in the design, however actual movement was around half of this. Construction time was reduced from 6 weeks to 8 working days. Erection and back-filling of each abutment took only two days. Costs were reduced by 20%.

1 INTRODUCTION

An innovative, prefabricated 'kit' bridge system, incorporating high strength polymer geogrids has been used in Australia recently in a number of projects. This paper highlights a bridge constructed at Wagga Wagga, N.S.W. in 1993, including design, construction and performance details.

2 BACKGROUND

A new bridge and 1.5km road deviation was required to replace an old timber bridge that was no longer serviceable. Greatly increased waterway area was needed, and consideration of design alternatives indicated that a spill-through type abutment would require a comparatively long bridge to provide the required waterway area. On the other hand, a sheeted or wall type abutment , although inherently more costly, would enable the bridge length to be reduced significantly, resulting in a lower overall cost.

Geotechnical site investigation showed soil conditions to be poor quality alluvial soils to depths of 5m to 6.5m, underlain by residual soils to depths of 9 to 9.5m, overlying weathered shale rock. Hence piled foundations were required and driven steel piles were adopted for the foundation system.

3 DESIGN

The poor foundation soils precluded conventional cantilever type retaining walls, due to concerns about differential settlements and low allowable bearing stresses. Possible alternatives included:

a) Use of additional vertical and raked piles to resist the over-turning moment of the abutments. This involves additional on-site work and makes backfilling operations behind the abutments more difficult. This limits the time-saving advantages of a precast bridge system.

b) Reinforced soil abutments were considered for the following reasons:

i) lateral forces could be resolved within the soil block

ii) tolerance to settlement that was likely to occur within the 2.5m depth of fill

iii) strengthening of the backfill would help spread applied loads and enhance its capacity to withstand wheel loads.

Proprietary reinforced soil systems using galvanised steel straps were considered but these involve special attachment points being cast into the precast panels. The overall high cost of these systems led to geogrid reinforcement being considered and used due to the cost savings.

One piece reinforced concrete tilt-up panels incorporating geogrid as soil reinforcement were used for abutments and separate wingwalls. The vertical joint between abutment and wingwalls was used as a continuous drainage line, to ensure adequate drainage behind the abutments. The main abutments were approximately 8m wide and 2.5m high, and with the incorporation of four girder support pedestals (another advantage) weighed approximately 12 tonnes.

HDPE high strength geogrids were cast-in to the rear face of the concrete panels and connected to the steel reinforcement for added security.

Two possibilities existed regarding the fixing of the geogrid to the concrete panels: either the geogrid could be directly embedded in the rear face of the concrete walls or short 'tail' lengths of geogrid could be cast-in enabling the subsequent attachment of further lengths of geogrid with a 'bodkin' joint.

The former was adopted for simplicity. Some difficulties occurred at first with the geogrid impeding the casting of the slabs, but techniques were quickly devised to overcome the problems. Rolling up and tying the geogrid strips into neat rolls obviated most of the problems during manufacture, transport and erection. (Refer Figure 1.)

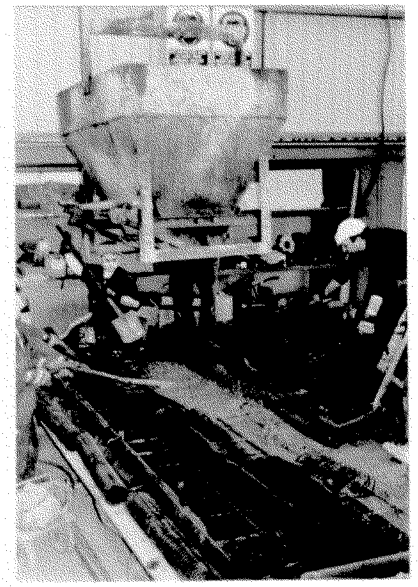

Fig 1.Casting Geogrid into Abutment

With the main abutments designed to transfer the bridge girder loads to piles via the support pedestals the geogrid reinforcement was designed to take loading from traffic and lateral earth pressures. The tie-back wedge method of design was used to define the required geogrid strengths, lengths and vertical spacing. The reinforced soil block was designed for a surcharge loading (traffic loading and dead load) of 20kPa. Backfill was designated as sandy gravel with $\phi = 30^{\circ}C$. The design called for five layers of Tensar SR55 geogrid, 3.0m long, spaced approximately 0.5m between layers. (Refer Fig. 2.)

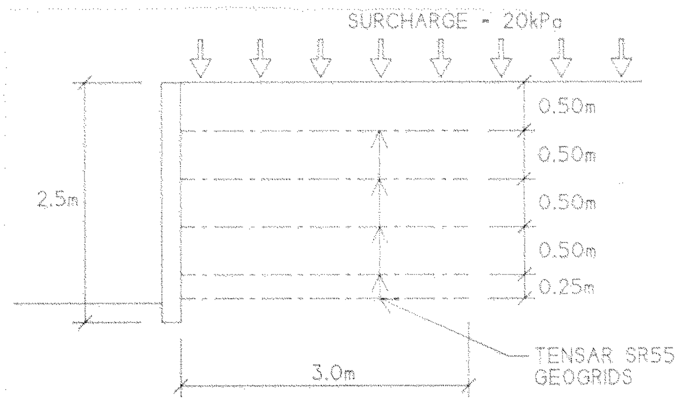

Figure 2. Geogrid Layout

The characteristic strength of the geogrid adopted for 120 year design life was 20.5 kN/m. A partial factor of safety of 1.25 was applied to allow for construction activities, and overall factor of safety of 1.35 was applied to give a safe design strength of 12kN/m.

3 CONSTRUCTION

The large abutments and wingwalls were erected and propped in position without difficulty, in less than one day. (See Fig 3.)

Figure 3. Abutment Erection

Backfilling commenced immediately, with granular material spread evenly and compacted with vibration. As each lift was completed, the next layer of geogrid was unrolled and pulled taut by hand as the fill material was placed and spread roughly by loader, then finished by hand. (See Fig 4.)

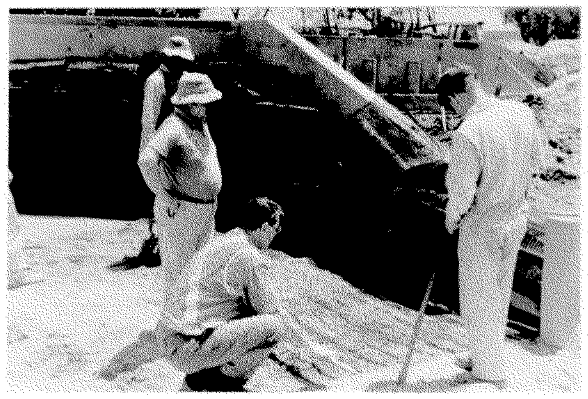

Figure 4. Backfilling Operations

A self-propelled vibrating roller did the bulk of the compaction work, with hand plate vibrators used to ensure complete compaction adjacent to the walls.

Blocks chocking the bottom edge of the walls were released when the fill was halfway up, and the props were removed at the two-thirds mark. Some outward movement of the walls was anticipated on release of the props, but rather than the 20-30mm allowed for, actual movement was in fact only 5-15mm.

The most severe test was on the day following completion of the abutments when they were subjected to a surcharge loading from a 50 tonne crane used to erect the prefabricated bridge components without any sign of distress.

Construction of the entire three-span bridge from the footings up took only 8 working days. The complete construction sequence is as follows:

ACTIVITY	TIME (days)
Preliminary earthworks	1-2
Commence piling for support of abutment piers	5
Pour pilecaps	4
Deliver & place precast abutments	1
Backfill abutments	4
Deliver & place pre-fabricated piers	1
Place beams (usually steel)	1
Place pre-cast deck units	2
Bolt guardrail & posts to attachment points cast into the deck units	3
Complete earthworks	7

4 PERFORMANCE

4.1 Cost Savings

Prefabricated bridges incorporating geogrid soil reinforced abutments and wingwalls typically save 20% when compared to a conventional method of construction.

4.2 Time Savings

This is the great advantage of this system. On-site work for a typical 3 x 12m span bridge is reduced from about 6 months to 4-6 weeks. This reduces inconvenience to road users and minimises construction delays due to inclement weather.

4.3 Ground Conditions

Because of the time savings, the construction team can be finished the sections which are vunerable to wet ground conditions in a much shorter period of time. This reduces the uncertain elements of the project.

4.4 Geogrid

Geogrid is lightweight, flexible and can be rolled up, thus allowing it to be cast into the precast sections, avoiding special attachment points.

4.5 Construction Movement

Observations made during construction indicated that where particular care was taken to pull the geogrid strips taut, outward movement of the walls was less than expected. With prefabricated construction, accuracy is very important, so reducing the amount of movement of the walls during construction is an important advantage.

5 CONCLUSION

The project was successful in every way, completed within budget and on time. The City of Wagga Wagga has now completed a total of three bridges using geogrid soil re-inforcement and Vic Roads, the Victorian State Government Road Authority has adopted similar designs for two bridges in Victoria.

6 ACKNOWLEDGMENTS

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7 REFERENCES

Tensar - Guidelines for the design and construction of reinforced soil retaining walls using 'Tensar' geogrids, Netlon Limited UK. Revised October 1991.