Flexible Solutions in Flexible Ground, Te Ngaere Bay Slip Repair

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ABSTRACT

On Thursday 5th June 2003 a large crack appeared in Wainui Road above Te Ngaere Bay, part of the million dollar view tourist route in the Far North of New Zealand. The crack was initially sealed but continued to open up and by the 10th of June the road had subsided to the extent there was difficulty in traffic traversing the area. GHD was asked to urgently respond and report on the risk to road users and to properties below the road. The immediate risk was assessed and urgent safety measures arranged to avoid the road being completely cut.

Site investigations were implemented and a report outlining the causes of the failure, the ongoing risk, recommended remedial measures and estimated costs of repairs was prepared within two days. The recommended repair was a reinforced earth wall and deep subsurface drainage. Design and contract documentation was prepared and issued to selected tenderers and awarded 10 days after the initial crack had appeared in the road. Due to the rapid response and limited investigations undertaken, a flexible solution was chosen to allow modification and fine tuning of the design during construction resulting in an innovative and efficient solution.

INTRODUCTION

On Thursday 5 June 2003 a large crack appeared in Wainui Road above Te Ngaere Bay (Photo 1). The crack was initially sealed but continued to open up. By the 10th of June the road had subsided to the extent, there was difficulty in traffic traversing the area. Concern was also expressed about the risk to dwellings below the road. GHD was asked to urgently respond and report on the risk to road users and to properties below the road.

Photo 1. Head Scarp of Slip on evening of 10 June 2003

SITE DESCRIPTION

The failure affected a 25m long section of the road (Figure 1). The failure was defined by several cracks extending across the road. The cracks had vertical displacements of up to 200mm. At the location of the failure the road appeared to have been formed on a fill embankment.

The toe of the landslide was 3/4 of the way down the bank where a prominent bulge has developed on the slope. There are two large blue gum trees on the slope, which had been back tilted. This indicated a deep-seated failure on which might be the margins of a pre-existing landslide.

Several houses were located below the slip but our assessment indicated no distress of the house's structure or the surrounding ground.

There was evidence of past instability affecting the site. A two-basket gabion wall had been constructed to provide support along the outside edge of the road and a rock spoil buttress constructed along the uphill side of the road immediately adjacent to the recent slip site.

GEOLOGICAL SETTING

The site is mapped as being underlain by Waipapa Group greywackes and argillites with cherts, marbles and interbedded basic marine volcanics (Kear, D. and Hay, R.F. 1961). These greywackes are relatively massive but can be locally contorted, jointed, indurated siltstones with rarer sandstones. The regional dip is west along the eastern coastline, bedding is rarely seen.

This material typically forms weathering profiles consisting of several meters of soft, low permeability soils overlying rock. The greywacke, exposed in road cuttings adjacent to the site was closely jointed (50 – 100mm) with a dominant sub vertical joint set. Batter cuts in the area typically stand up vertically to 6m. The surficial soil veneer appeared to be relatively shallow.

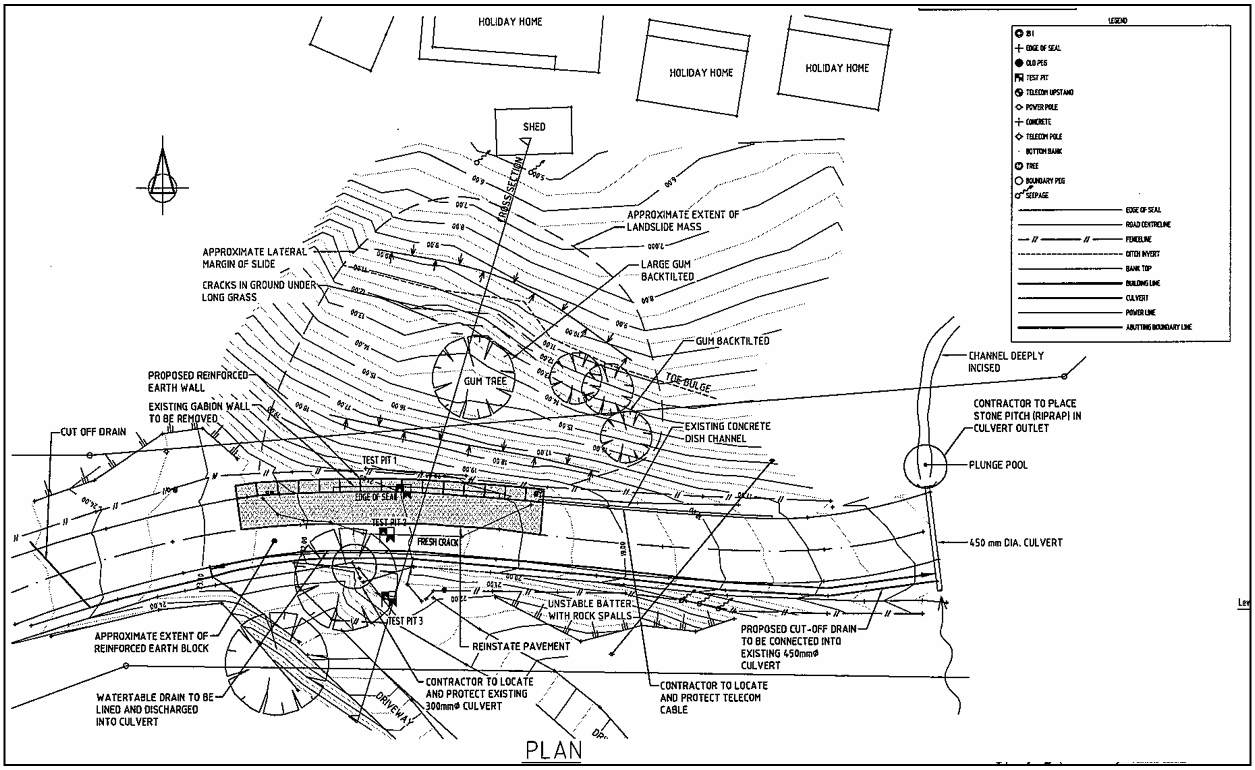

Figure 1. Site Plan

LANDSLIDE RISK ASSESSMENT

A landslide risk assessment was undertaken using the Australian Geomechanics Society Landslide Risk Management Guidelines. A Qualitative method of analysis was used.

Hazard Identification

The feature was identified as a landslide that had affected the road and adjacent properties. It was assessed as having the potential to develop into an earth flow and to impact on the dwellings. Although most of the dwellings are intermittently occupied, there were two permanent residents. The area affected was approximately 1200 square metres with an approximate depth of 3 metres. The volume of failed material was approximately 3500 cubic metres. The current rate of movement was slow but had the potential to be triggered into a fast earth flow with heavy rain.

Consequences of Failure

The consequences of failure were assessed as:

- Loss of road resulting in disruption to travelling public & residents.
- Danger to road users. Vehicles may drive into hole in scarp area.
- Damage to property. Landslide debris will fall onto private property.
- Damage to Dwellings – Landslide debris could impact dwellings or outbuilding.
- Public Outrage – Concern over danger and longer travel times.
- Political effects – FNDC could be criticised for not acting in timely fashion.
- Lives at risk – Motorist drives into hole. Catastrophic failure demolishes house with occupants inside (assessed as low).

The Qualitative Consequences to property were assessed as MAJOR.

Likelihood of Failure

Due to the continuing movement and widening of the tension cracks the landslide probability was assessed as almost certain. The Earth Flow probability was assessed as possible.

Risk Level Implications

The risk level matrix for the landslide case returns a result of Very High Risk

The Risk Level Matrix for the Earth Flow case returns a result as High Risk.

Due to the risk assessment returning a result of High to Very High Risk a rapid response was required with urgent remedial measures needed to avoid possible loss of the road resulting in damage to property and the public.

SUBSURFACE INVESTIGATIONS

Ground conditions were immediately assessed by 3 shallow machine-excavated testpits. Due to the remote location and urgency, the investigations were undertaken using a small 2-ton excavator with a 3m reach. Investigations locations are shown on the Site Plan, Figure 1. Subsurface conditions are summarised on the section (Figure 2).

RESULTS OF INVESTIGATIONS

The test pits encountered mixed, loose, wet, fill underlain by an apparent hard layer at least 2.8 meters down under most of the roadway width. After discussions with local contractors, it was revealed that the site used to be a gully where uncontrolled fill from local road widening projects had been dumped for many years.

CAUSE OF FAILURE

The failure below the road appears to have occurred as a result of saturation of the fill due to an extreme weather event resulting in elevated porewater pressures along the fill/natural ground boundary resulting in instability.

REMEDIAL OPTIONS

Movement was expected to continue if stabilisation measures were not implemented and further regression of the head scarp was likely. The road was unsafe in its current state with several cracks extending across the entire road. The cracks had vertical displacements of up to 200mm causing cars and trucks to bottom out across the depression. There was a high risk of further large-scale slope failure and regression of the head scarp occurring.

There was a real risk of losing the entire road, the toe could break out, and the failure material could reach as far as the back of the houses. With the run out at the base of the slope, it was anticipated that structural damage to the houses would result.

The client required a low cost flexible solution that could be easily modified during construction without huge cost increases, which also provide a long-term permanent solution.

Several options were considered for remedial works including soil cement columns and pole walls. Soil cement columns were discounted due to the unproven NZ track record in this type of situation and the dire consequences of failure. A cantilevered pole or steel H pile wall was also dis counted, as the ability to drive the piles sufficiently into the underlying greywacke rock was unknown. It was likely to result in either damage to the H pile or a shattered rock socket with minimal strength possibly resulting in a toe kick out failure. There was no time or budget for additional field-testing to determine if sufficient embedment of the piles was achievable.

The remedial solution adopted was a geogrid reinforced fill in conjunction with deep drainage. Although reinforced walls were rarely used on the Far North Network, from experience, it was known to be a very practical and flexible solution that could be easily modified during construction without huge cost increases.

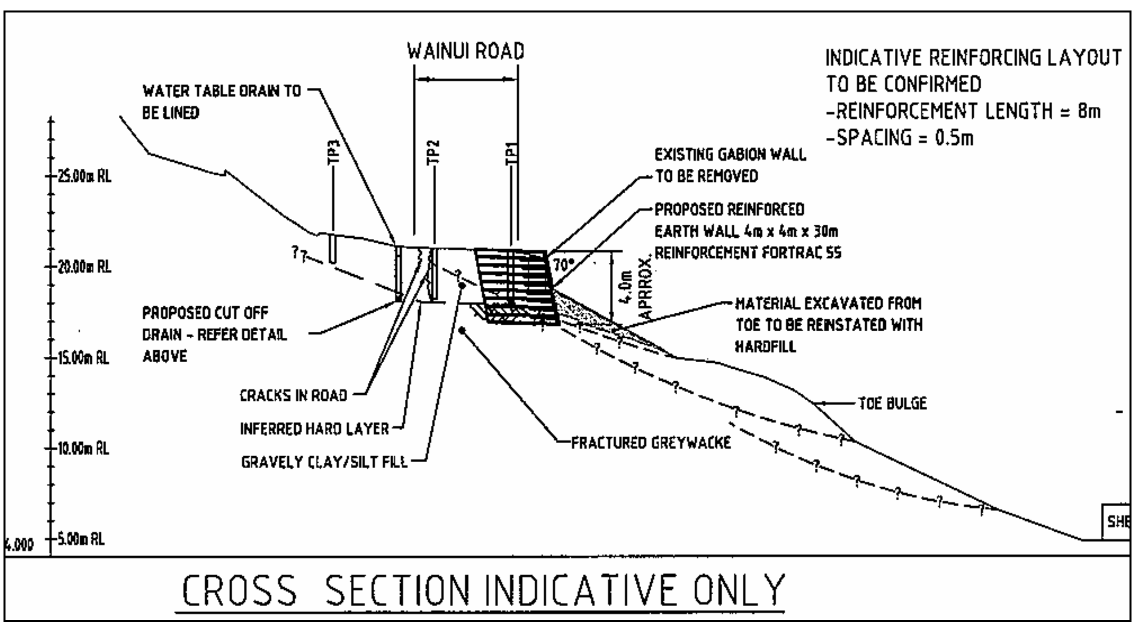

Figure 2. Section

Maccaferri software Macstars 2000 was used to design the wall (Figure 3). Due to the limited subsurface investigations undertaken and the possibility ground conditions would differ from those assumed several different wall heights were analysed.

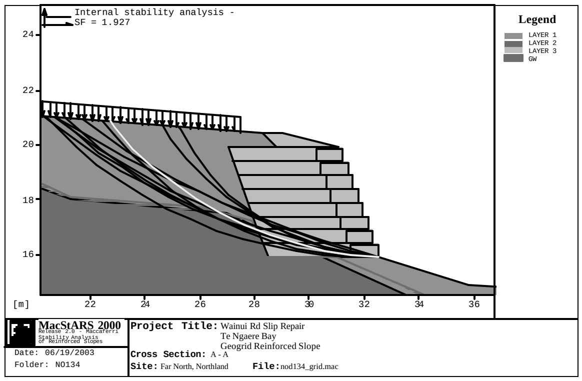

Figure 3. Macstars Reinforced Wall Analysis.

The reinforced earth wall would involve removal of the weak fill material underlying the road and replaced with compacted hardfill with a Fotrac 55 geogrid wraparound. The existing fill material was not reused due to high organic and clay content. The use of a locally available hardfill resulted in a higher strength fill, easy construction, lesser fill testing and monitoring requirements.

A major design consideration was to maintain at least one lane of traffic during construction, as there were no alternative detour routes close to the site.

Photo 3. One lane remained open during construction.

Drainage works would comprise deep subsurface drainage and surface runoff control. The aim of the drains was to intercept groundwater flow along the soil/rock boundary and divert surface runoff away from the slip area.

MODIFICATIONS DURING CONSTRUCTION

Due to the rapid response requested by the client the remedial solution was based on very limited subsurface investigations. Critical to the success of the remedial works and our cost estimate was adequate foundation conditions for the wall. It was therefore recommended that prior to works commencing, foundation conditions be confirmed along the entire length of the wall with additional investigations.

Due to budget constraints it was decided additional investigations would be undertaken during construction to confirm the assumed ground conditions.

The design was initially modified due to a shortage of Fortrac 55 and Terramesh was substituted with 0.5m high gabion baskets used as the facing.

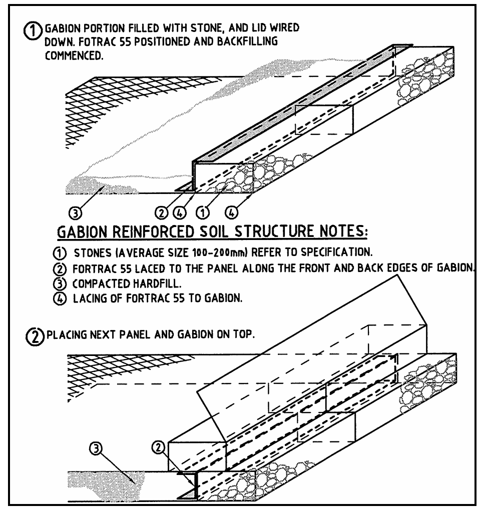

Figure 4. Gabion Facing

The design was modified a second time during construction when the assumed hard layer identified during the initial investigations at 2.8m below road level was discovered to be a layer of hardfill possibly associated with an old road.

Competent founding material was found to be a further 3m below this old road level. This was not unexpected and additional wall designs had been undertaken for just such an eventuality. The wall height was raised to 4.5m high with a 2m hardfill foundation pad excavated under the base. Groundwater was encountered in the base of the excavation and subsoil drains installed.

Photo 4. Completed wall

CONCLUSIONS

Due to the risk assessment returning a result of High to Very High Risk a rapid response was required with urgent remedial measures needed to avoid possible loss of the road resulting in damage to property and the public.

Due to the rapid response and limited investigations undertaken, a flexible solution was chosen to allow modification and fine tuning of the design during construction resulting in an innovative and efficient solution.

During construction, GHD staff were on site at critical times to inspect excavations and to vary the design of the remedial work to suit the final excavated profile.

Key features of this project included:

- The rapid response to the event – the total elapsed time from advice of the emergency to the letting of a competitively tendered contract for remedial measures was 10 days.
- An innovative but very practical solution – reinforced earth walls had been rarely used on the Far North Network.
- Minimum disruption to the road users.
- Value for money – the competitive tendering procedure resulted in a contract price below original estimates.

ACKNOWLEDGEMENTS

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REFERENCES

1. Kear, D. and Hay, R.F. 1961, Geological Map of NZ, Sheet 1 –North Cape, NZ Geological Survey, 1:250,000

2. Landslide Risk Management Concepts and Guidelines – Australian Geomechanics Society Sub-Committee on Landslide Risk Management *Australian Geomechanic – March 2000.*