Hiway Stabilizers Environmental
PO Box 225 Silverdale
New Zealand
79 Foundry Rd Silverdale
Phone 09 426 3419
Fax 09 427 4709
info@hiwaystab.co.nz

Ten Walls in Ten Weeks

Case studies in the use of Launched Soil Nail Supported GCS walls in the Far North District

Keywords: Slope Failure, Slope remediation, Launched Soil Nails (LSN), Geosynthetically Confined Soils (GCS)

Authors:
Andy O' Sullivan
Hiway Stabilizers Environmental, Silverdale, New Zealand

Tony Davies
GHD, Manukau City, New Zealand

Wataru Okada
SKM, Newmarket, New Zealand

Abstract:

During both March and July, 2007 the Far North district of the North Island in New Zealand was hit by a series of severe storm events, which caused over 60 large slope failures along the roading network. Faced with the challenge of remediating such a large number of slips in the minimum amount of time, FNDC and GHD looked to some innovative technologies, recently introduced to New Zealand, to ensure the shortest possible remediation time. In addition, all solutions proposed needed to be sufficiently robust and cost-effective when compared to conventional retaining wall options.

This paper will present several case studies and will discuss the extent of site investigation carried out at these sites, as well as outlining the general design assumptions used which allowed for Geosynthetically Confined Soil (GCS) walls, typically 2m wide and up to 6m high to be designed using the additional contribution of launched soil nails (LSNs) to extend the overall width of the reinforced soil block. This combination allowed for 10 walls, up to 200m² face area, to be constructed in 1ess than 10 weeks.

Introduction:

GHD Ltd provide the professional services input for the Far North District Council (FNDC) Network Maintenance Contract which covers Northland in the North Island of New Zealand.

Due to the geology of the Northland region, intense or prolonged rainfall generally results in landslips, often impacting upon the roading network. Traditionally these road slips are remediated by drainage, traditional mass or embedded retaining walls (typically tied back) or retreats/earthworks.

During both March and July, 2007 the Far North District of the North Island in New Zealand was hit by a series of severe storm events. The storms were both greater than a one in a one hundred year event (ironically occurring within 6 months of each other), with many hundreds of millimetres of rain falling in less than 24 hours (some ranges recorded over 400 mm). The intense rainfall resulted in severe overloading of the soils and the development of hundreds of landslips.

A rapid response with urgent remedial measures was needed to re-open the roading network. Following the storm event geological and geotechnical inspections were carried out along all roadways within the Far North District and over 60 significant slope failures along the roading network identified.

Figure1: Typical Slope failure after storm event

Faced with the challenge of remediating such a large number of slips in the minimum amount of time, FNDC and GHD looked to some innovative technologies, recently introduced to New Zealand, to ensure the shortest possible remediation time. In addition, all solutions proposed needed to be sufficiently robust and cost-effective when compared to conventional retaining wall options.

Site Investigation & Design

Given the large number of sites, a decision was made early on to group the sites by general failure mechanisms and geological profile and to carry out detailed designs on only the most critical site in each sub-group. The resultant design would then be modified to cover the remaining sites. This approach was justified by the fact that the remediation solutions all involved a combined LSN and GCS wall. The underlying design philosophy was therefore to design the LSN's to control external stability related forces and to check the design of the GCS Walls to ensure adequate internal stability.

The site investigations generally consisted of CPT's being carried out along the slip sites. Together with the exposed head scarp (up to 6m high), this allowed for a typical geological profile to be developed.

Typical fill, residual soil and highly weathered rock parameters were obtained either directly through triaxial cell and oedometer testing or inferred from previously obtained CPT correlations in similar soils.

Designs were carried out using the latest generation FE soil models. In most cases, the soil model chosen for design was the Hardening-Soil model, developed by Schanz, Vermeer and Bonnier[1]. This model allows for historic stress/strain storage with has advanced parameter entry for good correlation with obtained triaxial cell test results. This flexibility is ideal for back analysis of slopes prior to and during failure and allows the designer to superimpose the final proposed design on the failed slope.

An example of this is shown in Figures 2 below, where the final proposed solution is superimposed on a pre-failed cross-section.

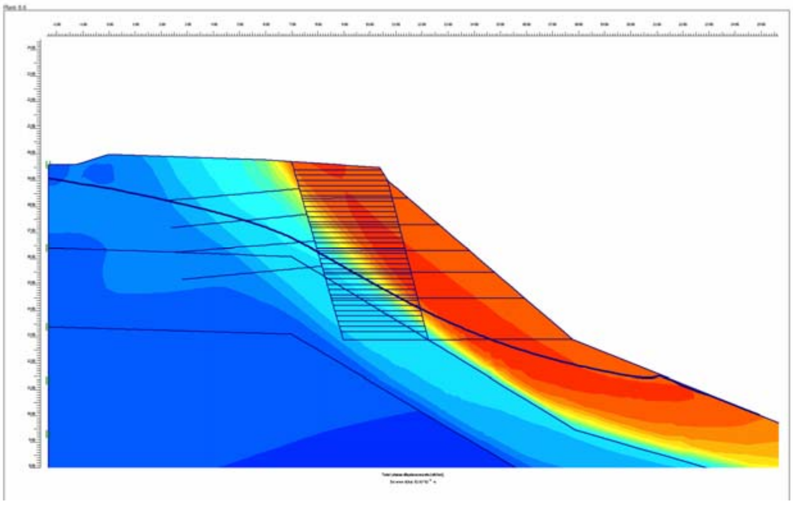

Figure 2: Typical Design Cross-Section showing proposed solution superimposed on failed surface

A key part of the design philosophy was to use launched soil nails (LSN's) to control the lateral earth forces upon the back of the proposed GCS walls. This allowed the width to height ratio of the walls to be greatly reduced to as low as 0.3. Typically in MSE and GRS walls this figure is between 0.6 and 0.7.

This reduction provided a considerable cost saving to the client and allowed for faster construction as the proposed scheme would benefit from a significantly reduced quantity of granular backfill to construct the walls. By providing a structural connection between the LSNs and the GCS wall, the effective overall width of the "reinforced soil block" was effectively increased and both elements would act compositely. A photo of this typical arrangement is shown in Figure 3 below.

Figure 3: Construction stage showing connection between LSNs and GCS backfill

Verification of LSN design assumptions

Extensive field testing has been carried out to verify the performance of LSN's. This testing has included the use of high speed digital cameras (up to 6,500fps) to measure accurately the deceleration of the nail and hence force distribution upon entry into a soil block. The data accumulated was then entered into an advanced dynamic FE (axi-symmetric) model. This model is shown in Figure 4 below.

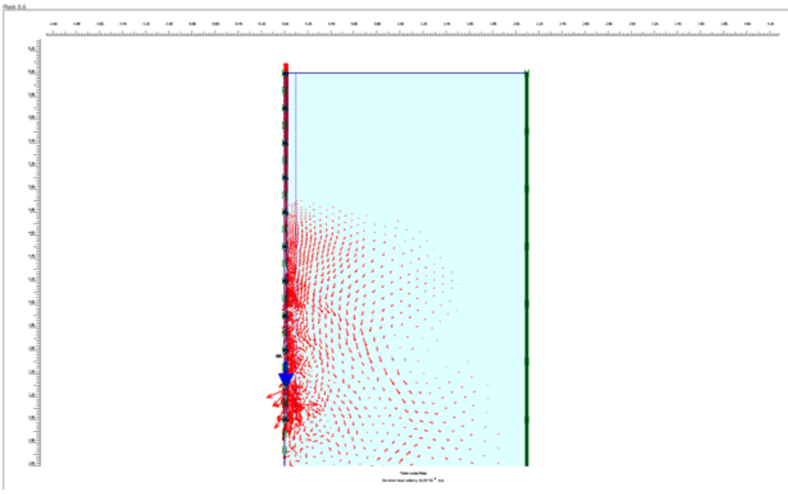

Figure 4: Output showing predicted phase velocity*
during installation of nail.

* Phase velocity is the recorded dynamic velocity pattern for the relevant calculation stage

By inserting an interface along the length of the nail, the shear strain pattern and magnitude was calculated. This is shown in Figure 5 below.

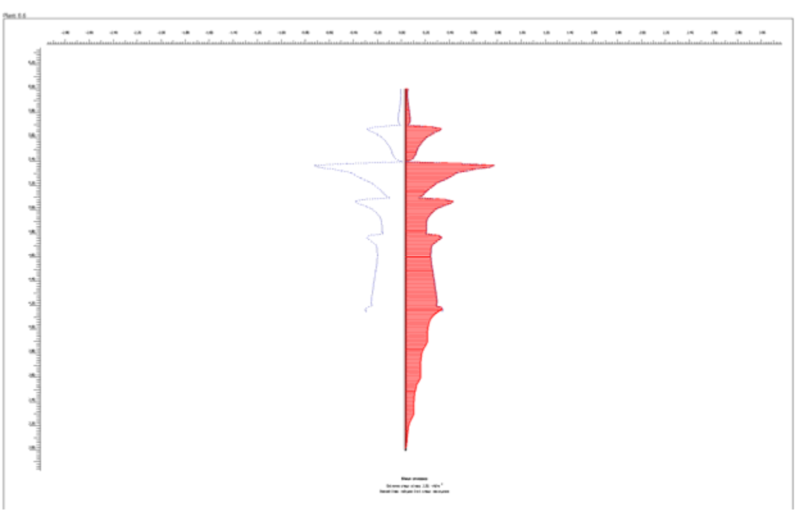

Figure 5: Example of Predicted Shear Strain regime in LSN

For the final verification step a pull-out test on the nail was simulated in the model. The result of this was then correlated against an in-situ shear strain verification test on the nail. The correlation allowed for verification of design assumptions, in particular the interface factor.

Figure 6: In-situ shear strain verification test

Having verified the design model assumptions sufficiently, a check was carried out to examine the temporary excavated conditions on each site – the phase between the installation of the LSNs and the construction of the walls. Figure 7 shows the results of such a temporary stage.

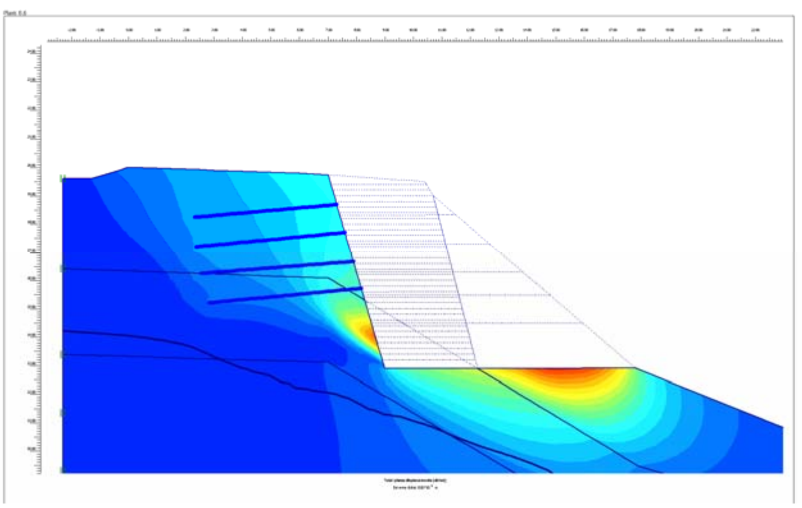

Figure 7: Temporary excavation deformation check (est. 8mm)

As a last check, a c′/ø′ reduction check was carried out on the proposed solution to verify the increase in factor of safety. The criteria agreed was 1.5 for normal groundwater and 1.3 for extreme high groundwater (with no predicted movements).

Conclusions

By utilising the additional benefits of LSN's with GCS walls, the failures were able to be remediated in record time and have proven to be excellent value. The client is satisfied that, compared to the cost of a conventional tie-back walls, the LSN/GCS combination cost significantly less and were able to be constructed in one-quarter of the time. Other key benefits of the LSN/GCS walls are:

- Less disruption to traffic than other conventional methods of repair
- Less excavation and cut to waste required
- Minimises temporary works risk

Figure 8: Photo of completed Wall

Acknowledgments

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