Launched Soil Nails – Successful Development within the New Zealand Market

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Abstract

Soil nailing has now gained acceptance as a tool for enabling the construction and remediation of oversteep slopes and/or oversteep excavations in soils. The methodology could have wider applications if it were able to be mobilised faster, was quicker to install, had nails ready for service sooner, and didn't cost any more. A new tool that has these attributes has been developed - the soil nail launcher.

Originally a British military invention, it has successfully been adapted for civilian use within the construction industry. Six metre long hollow steel rods are able to be fired into the ground in a single shot, using high pressure compressed air.

This design and construction expertise has been successfully transferred to New Zealand via a technology agreement with a specialist geotechnical contractor from the USA. The track record of this technology to date, particularly in the USA, demonstrates that launched soil nails are suitable for both temporary and permanent works on the construction and/or remediation of steep slopes.

Successfully brought to the New Zealand market early in 2006, Launched Soil Nails are a serious tool that geotechnical engineers in New Zealand will find many and varied uses for, not just in the obvious area of steep slope problems. Four case studies from New Zealand are presented which illustrate the range of applications successfully completed to date.

1.0 INTRODUCTION

Traditional soil nail technology was developed in the 1970's, whereby small diameter steel bars are grouted into predrilled holes. The nails provide tensile strength to the treated soil block. Conventional design theory dictates that the contribution of the nails is limited by the bond strength at the grout/soil interface.

Launched soil nails (LSN), branded as 'Shotrods' in New Zealand, use high pressure air to fire the nails into the ground. During this process, a pressure wave forms at the head of the nail as it accelerates, forcing the ground to elastically expand around the nail. As the nail comes to rest, the ground relaxes around the nail forming a bond with the rod. While research into this interaction is still at an early stage indications, so far, are that the achieved soil/nail bond strength is typically greater than that of an equivalent driven pile.

As LSNs eliminate the need to drill and grout holes in the slope face, the nails provide support to the soil as soon as they are installed and can be installed at a much faster rate (typically between 60-80 per day).

This paper aims to provide an insight into four of the Shotrods sites in order to provide the reader with background on the versatility of this system.

2.0 CASE HISTORIES

2.1 Wharehine Road

Since it was first constructed in the 1960s, a large number of sections along Wharehine Road have been subject to ongoing movement. Much to this is due to the complex underlying geology. The section under review here experienced a dramatic slump, of around 600mm following a storm event in mid 2006. Figure 1 below shows the extent of damage caused.

Figure 1: View of Wharehine Road showing collapse in Pavement

Following a request from the client to investigate the site and comment on the feasibility of an LSN based design to provide a cost-effective solution, some basic geotechnical investigation work was carried out to determine the typical soil profile and to establish the most likely failure mechanism. The investigation showed that the road fill material was underlain by a layer of very weak, completely weathered siltstone of the Northern Allochton Group (locally referred to as Onerahi Chaos). Back analysis indicated that the likely soil parameters at the site for this type of material were c'=0kPa, ø'=19º.

A model was then generated of the site to predict the increase in overall FoS which an LSN type reinforced soil block might provide. Three rows of LSN's were modelled on a 1m x 1m grid as shown in Figure 2 below. This indicated a dramatic increase in the FOS against failure could be achieved by installing the nails. This initial design was then verified by an external geotechnical consultant using a Plaxis FE model.

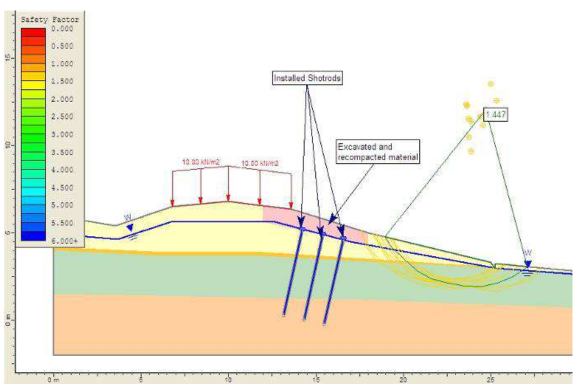

Figure 2: Analysis of final solution with 3 rows of LSN's installed

The project was completed within 3 days with the project costing less than 70% of the Engineer's estimate. No further movement has occurred at the site since.

2.2 North Shore Busway Project – Temporary Retention of Bridge Abutment

On a major infrastructure project in Auckland, a large, high tension service pit was located at the base of an embankment supporting a 4 lane motorway bridge abutment. The services within the pit required urgent diverting by the client to allow a major traffic diversion scheme at the intersection to take place the following weekend. As conventional retaining systems, including conventional soil nails, could not be procured within the short time-frame available, the client considered an LSN based solution.

Following a site inspection and review of all available geotechnical information, an LSN option was designed and installed within 2 days. The design was modelled using Plaxis FE software.

The section of bank to be reinforced was 10 m long and approximately 6m high, with the design based on 3 rows of LSNs, staggered at 1m centres. Surface erosion was to be prevented by designing a geotextile mat, which was to be placed along the slope following installation of the LSNs. Further reinforcing was supplied by providing a steel mesh which attached to the nails. Figure 3 below shows the LSN's being installed.

Figure 3: Photo showing installation of LSNs into bridge embankment

Had conventional nails been used, the installation would have taken approximately three weeks. The LSN based solution, only took one afternoon to install. The main difference in the time being that each bench could be cut immediately following installation of the previous row of LSNs.

2.3 Murray Road

Murray Road is a two lane, sealed rural road situated approximately 100kms north of Auckland city. It is constructed on a sidling cut-fill embankment.

During the early part of 2006 cracks appeared in the pavement and minor settlement was noted over a length of 50m. Subsequently, following a severe storm event, a section of the embankment collapsed undermining a portion of the road.

A basic geotechnical investigation carried out at the site allowed for a preliminary design and cost estimate to be completed which was submitted to the client. The design involved excavation and removal of all slumped material (3-4m layer), strengthening of the remaining embankment by installing LSNs and construction of a Geosynthetic Reinforced Soil (GRS) Wall to reconstruct the shoulder.

Figure 4: Photo showing failed portion of Murray Road

This removal would have resulted in a 4m near-vertical cut face being required at the edge of the carriageway. Without additional temporary support, this would have resulted in the collapse of a significant portion of the remaining embankment and hence would not have been contemplated. The purpose of the installation of the LSNs was therefore to (1) ensure adequate stability in the temporary cut case and to (2) form a key part of the final design solution.

Part of the design back analysis indicated a FoS of around 1.0 for a fully saturated case, with a FoS of around 1.3 for a partially/non-saturated case (normal groundwater regime).

A basic design model was generated to incorporate the temporary cut condition required during construction. As the works were carried out during a particularly dry period and as no groundwater was encountered in the top 3m the site investigation, an unsaturated (drained case) was analysed. This indicated that, without the installation of any LSNs, the slope would have completely failed (FoS <<1). However, with the installation of three rows of LSNs, the temporary FoS increased to around 1.2 which was deemed acceptable. The result of this model is shown in Figure 5.

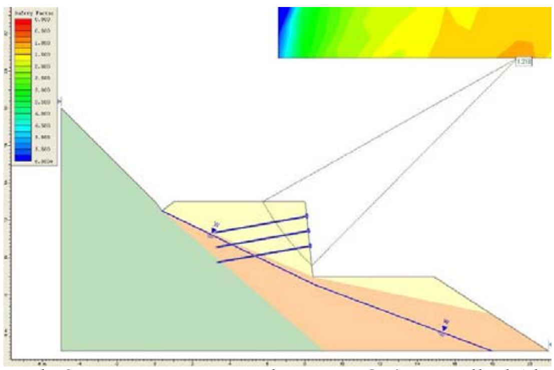

Figure 5: Result for temporary cut showing LSN's installed (drained case)

The observations made on site during construction matched the analysis carried out extremely well, with additional surcharge load from construction plant leading to the commencement of minor cracking at the surface (as predicted by the modelling). Thus the methodology used limited the extent of construction plant surcharge to >3m from the excavated face. The temporary excavation is shown in Figure 6.

Figure 6: Photo showing temporary excavation

Finally the GRS Wall was constructed outside of the temporary cut and the works completed. The final FoS was around 1.65 under a high groundwater regime. Using LSN technology allowed the contractor to complete the works in less than one week with the project costing an estimated 30% less than other conventional solutions.

2.4 Biscuit Bend

In early 2006 a slip occurred on a roading embankment on State Highway 2 just South of Gisborne on the East Coast of the New Zealand's North Island. The embankment had been constructed some 50 years ago using fill which would not meet today's standard for engineered embankment fill. The side slopes of the embankment were typically between 35 - 40^{o} with no additional support measures present.

Figure 7: Slip on the eastern side of the road. Western side of road similar.

As a result of the substandard construction method, substantial water ingress allowed the embankment to become fully saturated during high rainfall events. This led to slip planes forming along the fill/underlying rock horizon on both sides of the embankment reducing usable pavement width significantly. A conforming gabion wall design was issued by the client for tender. A typical profile for this design is shown in Figure 8 below.

Using the available geotechnical investigation information provided, an LSN based alternative solution was proposed. Some additional investigations were undertaken in order to confirm the soil conditions on site and ensure that the soils properties were suitable for the proposed design. The site investigations consisted of hand auger boreholes with shear strength measurements.

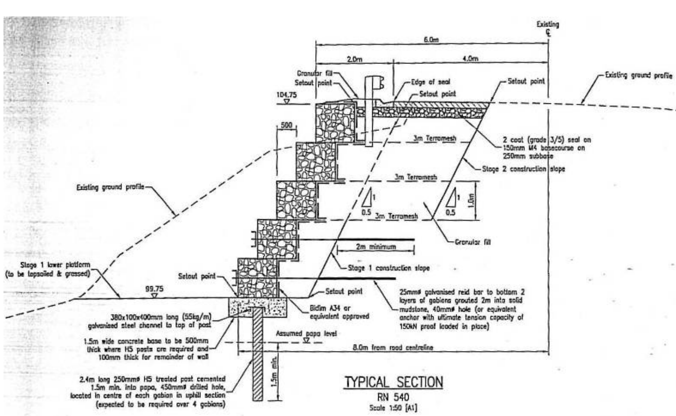

Figure 8: A typical cross-section of the conforming design.

The alternative design called for the use of LSNs to stabilise the lower portion of the embankment, thus forming a soil block for a Geosynthetic Reinforced Soil (GRS) wall to be founded on. The GRS wall would be used to recover the width of pavement lost due to the slip and/or stabilise the shoulder. A typical cross-section is shown in Figure 9 below for the alternative scheme.

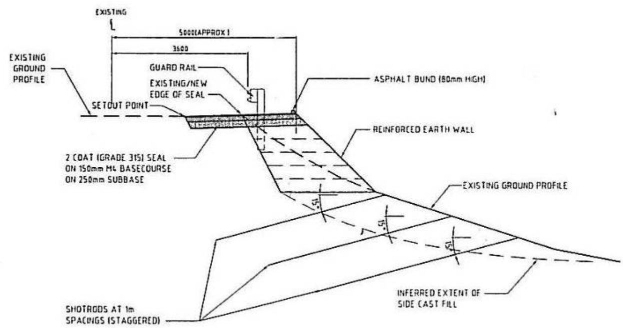

Figure 9: A typical cross-section of the alternative design.

The greatest operational advantages of the alternative related to substantial time and cost savings, although environmental benefits were also achieved, such as a reduction in both the materials to be cut-to-waste and valuable aggregates that were to be imported. Cost savings over the conforming design were in the order of $100,000 while the alternative design required only 15 working days to construct.

One final point of interest on the project was that a major storm event occurred during the construction period. This allowed for the performance of the LSN's to be monitored for their secondary function, that of reducing pore pressures in the soil. A series of 6mm ø holes drilled at 600mm c/c into the steel rods proved that the LSNs were effective at reducing pore pressures in the soil.

3.0 CONCLUSIONS & DISCUSSION

Over the past year, LSN technology has proven to be a cost-effective and efficient alternative on a range of projects in New Zealand. On all of the projects carried out to date the alternative, LSN-based, solution has proven to be to be faster, more economical and more environmentally friendly than other conventional design solutions proposed.

The LSN rig can be transported to site on one transporter, which helps contribute to its ability to be versatile and respond quickly to slips where further movement is threatening. Up to 80 nails can be installed per day, leading to the potential stabilisation of close to 100m2 of slope/day. Furthermore as LSNs achieve full capacity once installed, there is no need to wait for tensile capacities to develop as is the case with conventional nails.

Research is being carried out on LSNs in New Zealand in a number of areas to try and gain a better understanding of how exactly the LSNs interact with the soil. While more conservative design approaches, two-part wedge theory, are currently being adopted in most design cases, the goal is to prove that the nails perform differently to conventional soil nails and are more ductile and better at distributing shear strains than conventional soil nails.

4.0 REFERENCES

1. **Rocscience** SLIDE V5.0 2D Limit Equilibrium Slope Stability Analysis

2. **Plaxis** Version 8.5 Finite Element Software