AGS VICTORIA 2016 SYMPOSIUM

Excavations and slope stability in Melbourne geology: experiences and recent developments

Wednesday, 16 November 2016, 12:00pm – 7:00pm
Engineers Australia, 600 Bourke Street, Melbourne

AUSTRALIAN GEOMECHANICS SOCIETY
VICTORIA CHAPTER

WELCOME

The Victorian chapter of the Australian Geomechanics Society (AGS) is pleased to welcome you to this half-day symposium titled “Excavations and slope stability in Melbourne geology: experiences and recent developments”.

Since the publication of the “Engineering Geology of Melbourne” in 1992, both the geotechnical profession and Melbourne has undergone significant change. Urban sprawl over the past few decades has seen increasing development in the hillside areas in the Dandenong and Mornington Peninsula regions. This coupled with changes to the regulatory environment and the introduction of the Landslide Risk Management Framework by the AGS in 2007 has changed the way in which local and state government as well as geotechnical practioners manage and assess slope stability.

In addition to development in hillside areas, significant development in the inner parts of Melbourne has posed many challenges for excavations not just in the soft soils of the Yarra Delta but also the weak rock of the Melbourne Formation.

This symposium seeks to bring together practioners from consulting, construction and academia to share and discuss their experiences on the separate, but related, topics of excavation and slope stability. Best practices, case histories and innovative solutions for dealing with these challenges will be presented and discussed, with a particular emphasis on local geotechnical issues.

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MT ELIZA – SLOPE STABILISATION

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ABSTRACT

Triggered by excessive water, a landslip occurred on the cliff face of this bayside suburb with the potential to repeatedly slip and undermine beachfront residences located at the top of the cliff. Stabilization was imperative.

The coastal cliff is almost 15 m high, at an angle of 40 degrees to 60 degrees to the horizontal. The landslip, which was of approximately 4 metres wide was located immediately above a foreshore area that is frequented by the public. The cliff geology comprises Tertiary age sedimentary sandy clays, clayey sands and gravels of the Baxter Sandstone formation. Unlike most of the landslip issues in the Frankston South / Mt Eliza area, which are associated with the Selwyn Fault or the unfavourable geological conditions of the Balcombe Clays, the landslip on this site was considered a direct result of human interaction with the slope.

For the remedial works ATC Williams considered several methods including staggered retaining walls, and retaining wall with soil nail combinations; but ultimately developed a soil-nail only solution. Design challenges included a high groundwater with preferential seepage zones within the cliff face. However, the prime challenges were during construction, with site access only available across the foreshore at low tide, and access up the slope for nail installation achievable by small plant only. The success of the project depended on developing an appropriate construction method which enabled design requirements to be achieved.

With no equipment access to the top of the cliff, various means of providing access from the foreshore were considered including earth bunds, platforms, scaffolding and long reach excavators.

It was concluded that the only viable option was to use a crane to support a drilling rig mast at each nail position.

This arrangement limited the drilling depth and soil nail installation length to a relatively shallow 6 m and required a design modification necessitating the re-design of the pattern of soil nails to match the depth capabilities of the rig, whilst still meeting the local and global slope stability requirements. In total 137 soil nails were installed and the cliff was adequately stabilised.

Keywords: slope stabilisation, Mt Eliza, landslip, soil nailing, difficult access.

1 INTRODUCTION

Landslips in the coastal foreshore cliff area of Mt Eliza are often triggered by wave erosion at the toe of the cliffs causing under cutting and toppling failure.

Figure 1 - Typical landslip in area

Landslips inland from the foreshore in the Oliver's Hill South area and further south to Mornington are often associated with the unfavourable geological conditions associated with the Selwyn Fault or a low strength silty clay deposit known as Balcombe Clay. However, the landslip discussed within this paper was not associated with any of these causes. It was triggered by excessive water from a broken garden irrigation system saturating the cliff.

2 COASTAL INSTABILITY

The steep coastal slope in an exclusive area of Mt Eliza comprises sandy clays, clayey sands and gravels of the Tertiary age sedimentary deposit, of the Baxter Sandstone formation. The slopes face north and west and are up to approximately 20 m high. The slope angle from the horizontal varies between approximately 40 degrees to more than 60 degrees; with the steeper areas being largely dependent upon the presence of iron oxide rich cemented zones for stability.

The section in question is approximately 15 m high, with a slope of approximately 40 degrees and did not include significant cemented zones.

The exposed sandy clay and clayey sand faces are metastable and are essentially reinforced by surface vegetation. The steep slope often experienced surface erosion and minor surficial slips after:

a) periods of wet weather with direct exposure of the faces to rainfall and runoff;
b) periods of dry weather drying and desiccation of the soil, vegetation die back, and denuding of areas.

Figure 2 - Typical denuded area

The local area had experienced two more substantial landslips in the immediate past. The two landslips were believed to have been possibly triggered by the processes described above as well as by local saturation of the soils associated with groundwater seepage which was observed to be daylighting at a relatively high level(s) in the slope at the time of the slippages.

Groundwater in the area can be problematic due to the relatively large catchment and low permeability soils causing a delayed effect on the steep coastal slopes. The sedimentary Baxter Formation soil is not uniform and exhibits strong anisotropy with sub horizontal bedding and well defined horizontal flow paths, as a result of its sedimentary deposition. The delay between a specific rainfall event and the daylighting of seepage in the steep slope is not known, but could be between hours and weeks.

Figure 3 - Steeper area of slope including cemented zones

Figure 4 - Slope instability indicated by leaning trees

Extended periods of wet weather are likely to result in near constant but variable flow of seepage.

The two landslips that had occurred were not particularly large, each being approximately 3 m to 4 m wide, half to two thirds of the slope height and of shallow depth (1 m to 1.5 m),

however they threatened the integrity of closely neighbouring private properties.
Since the landslips were on Crown land there was little the local property owners could do to repair and stabilise the slopes and protect their properties, apart from:

a) lobby Council and Government Departments to carry out works to stabilise the area; and
b) attempt to stabilise the steep faces themselves by the installation of minor engineering works (small retaining walls) and planting and maintaining vegetation.

3 EARLY CONCEPT ENGINEERING SOLUTIONS

The concept engineering solutions recommended to Local Council and Government departments for slope stabilization by the local property owners included:

a) Gravity retaining walls (crib wall types);
b) Gravity retaining walls with soil nailing;
c) Bored pier cantilever retaining walls; and
d) Anchored bored pier retaining walls.

No action was taken with the regard to the early concepts provided to authorities.

4 GROUNDWATER LOWERING

The property owner whose land was most at risk by the landslips installed a groundwater extraction well and two groundwater monitoring bores and set about locally lowering the groundwater level, to improve the global stability.

At the same time, the opportunity was taken to obtain vital information on the subsurface conditions and each borehole was drilled as a geotechnical investigation borehole with regular undisturbed and SPT sampling. The drilling was followed by laboratory soil classification, index and strength testing, including effective stress triaxial tests.

The exercise resulted in lowering the groundwater by several metres at the pumping well and by between 0.3 m and 0.5 m in the two monitoring bores located toward the boundaries of the private house site. While no analysis of the slope stability was carried out at the time, there would certainly have been an improvement in the stability of the slope.

5 SLOPE STABILISATION

5.1 Soil Nailing

As was mentioned in Section 1, a broken garden irrigation system associated with a neighboring property triggered the critical landslip. A major leak in the system, located in the lower half of the slope, saturated the lower half of the 15 m high slope and trigged the landslip. This slip was nominally 3 m to 4 m wide by 7 m high by 1.0 m to 1.5 m deep. This slip was initially stabilized using a proprietary (Ecocell cellular confinement system) for re-establishing topsoil and vegetation on the slope), however this only had moderate success, and signs existed (slippage of the Ecocell, loss of toe support for the upper soil and tension cracking) that the upper half of the slope remained at risk of failing.

As there was the potential for imminent failure of the slope which would most likely have resulted in significant property damage; an emergency order, arranged by the lawyers for the property owner most at risk, allowed the stabilization of the slope to proceed without the normally required regulatory planning and building permits.

The soil nail design, which was carried out in-house by ATC Williams, was to achieve a minimum factor of safety of 1.5 for the global stability case. The design was carried out using the geotechnical data previously obtained and assumed conservative groundwater levels (i.e. the long term groundwater levels and not the lowered levels). The soil nail layout was optimized to provide a solution which relied on the minimum number of variable length nails.

5.2 Slope Access

Access to the slope to install the soil nails was not straight forward. Typically soil nails are installed using a top down method whereby the nails are installed from benches as an excavation is deepened. In this case the 15 m high nominally 40-degree slope was already formed. Access was only available from the base of the slope. To complicate the situation further, the access to the base of the slope was only available across a narrow beach on the foreshore and only at low tide.

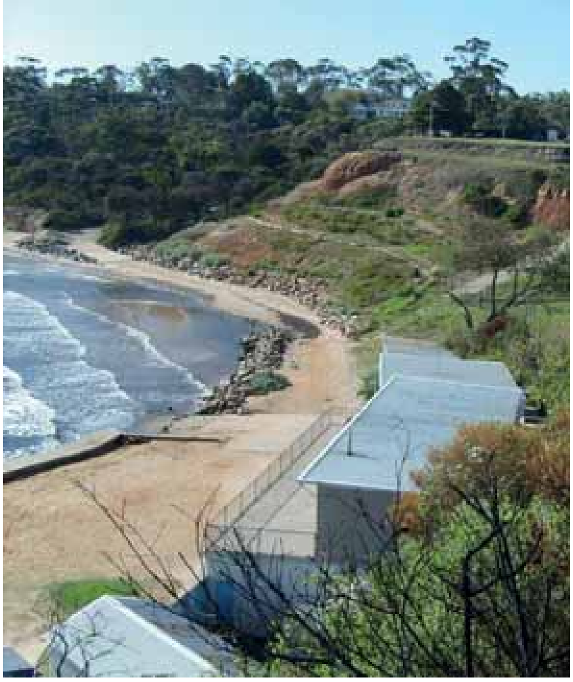

Figure 5 - General view of the site showing the access over the foreshore at low tide

The limited access to the site was a major consideration for the potential construction methodologies which were assessed.

Figure 6 - The problematic access over the foreshore at low tide

The methods considered to position a drilling rig up the slope to install the soil nails included:

a) Soil bund platforms - The volume of soil required to construct the soil platforms and the potential number of truck movements in local streets and across the foreshore, and the limited access to the site (low tide only) to import and then export the soil, ruled this option out,
b) Scaffold platform - This option was deemed to be too slow to rebuild for each and every soil nail and a crane would be required to lift the rig to position.
   Secondly, the crane required to safety lift the drilling rig and reach across to each location was large and not practical given the access available. While there were mobile cranes suitable for the task, none could access the site.
c) Sliding platforms – This option was considered better than the scaffold option because sliding platforms could be winched up and down the slope to reduce the potential number of platform rebuilds to access soil nail locations as well as reduce the number of crane lifts, but the fundamental problem of lifting the rig into position using a large crane still existed and hence eliminated the option.

It was a drilling contractor, thinking out of the box, that suggested removing the mast from a remote control drilling rig and lifting the mast alone with a smaller, but still substantial all-terrain crane. The concept was to attach a frame to the mast to lift it and hang it at the required soil nail installation angle, support it laterally and hold it against the face to provide a reaction to the drilling loads.

Figure 7 - The drilling rig mast separated from the drilling rig

Figure 8 - The drilling rig mast with umbilical cord of hydraulic hoses attached

A long umbilical cord of hydraulic hoses connected the mast to the rest of the remote control rig, which was left at the toe of the slope.

The weight of the mast alone and the maximum required reach was within the safe operating range of a nominal 70 tonne all terrain crane.

Figure 9 - The 70 tonne all terrain crane entering the site

One of the issues with the method was that only a six-metre solid auger drill string, which was equal to the length of the mast, could be used. This required a redesign of the soil nail pattern with maximum 6 metre long nails, with additional nails and additional rows of nails, to maintain the required global stability.

A 70 tonne all terrain crane was used to access the site and to safety reach all soil nail locations.

All equipment and supplies were required to be delivered by suitable rigid trucks (no articulated vehicles) across the foreshore at low tide. This made for some interesting delivery arrangement conversations.

Figure 10 - Soil nail preparation on site

All nails were assembled on site to maintain quality control and limit transportation and handing issues.

Nail design provided for three levels of corrosion protection, including pressure grouting inside corrugated HDPE sheathing using centralizers and pressure grouting the annular space around the outside of the sheathing. Nail heads consisted of grout filled HDPE sheathing to the surface and grease filled caps at the surface. A comprehensive program of test nail testing ensured that the design expectations would be met.

Figure 11 - Soil nail installation on the lower section of the slope

The soil nail installation on the lower section of the slope was carried out with a conventional drilling rig with the aid of an excavator for support.

Figure 12 - Soil nail installation on the upper section of the slope. Note; driller operating the remote controlled rig on the left.

Figure 13 - Soil nail installation on the upper section of the slope

Figure 14 - Soil nail installation on the upper section of the slope

The soil nail installation was carried out without major issues for the entire project on the steep and uneven slope. In total 137 soil nails were installed and the cliff was adequately stabilized.

6 CONCLUSION

Despite the challenges of the limited access to the site and the steep face, the adversities of the site access were overcome and an innovative construction methodology was found to successfully carry out the stabilisation works.

7 ACKNOWLEDGEMENTS

ATC Williams P/L thanks the property owners involved for their permission to publish this paper.

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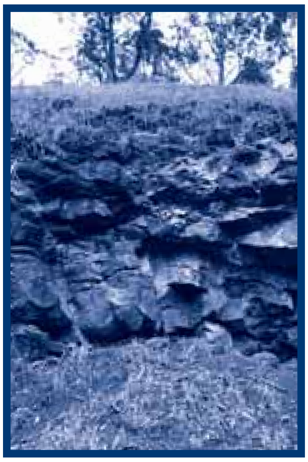

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