

INTERNATIONAL SOCIETY FOR SOIL MECHANICS AND GEOTECHNICAL ENGINEERING



This paper was downloaded from the Online Library of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE). The library is available here:

<https://www.issmge.org/publications/online-library>

This is an open-access database that archives thousands of papers published under the Auspices of the ISSMGE and maintained by the Innovation and Development Committee of ISSMGE.

Emergency and final works for anchored residential retaining wall, Lyttelton, New Zealand

Cid Chenery
Golder Associates (NZ) Ltd, Christchurch, New Zealand

Keywords: anchor, emergency, loess, retention, stability, wall

ABSTRACT

In December 2004, a hillside residential lot had been partly excavated with the intent of providing an expanded level area for an architecturally designed house incorporating a retaining wall. We were involved in an initial investigation in December 2004 for the retaining wall. At this time the design thoughts were heading in the direction of either an anchored retaining or a soil nail with shotcrete facing when the client decided to opt out of this design intent and go with the 'more economical' solution of a crib wall.

In May 2005, the author was conducting a review of the proposed crib wall design, when an urgent call was received from the client. The excavation had proceeded prior to design approval and had collapsed and was encroaching upon the foundations of an upslope residence.

This paper describes initial design efforts; the emergency works put into place, wall design through construction to completion. It includes the design and construction issues for an anchored retaining wall using steel soldier piles and sleepers to achieve a rustic effect. Careful liaison with the Council and neighbouring property owners was required and the design and construction was integrated with the adjacent slopes to complete the works.

1 LOCATION AND GEOLOGY

Lyttelton is located on Banks Peninsula south east of Christchurch, South Island, NZ (Figure 1). It is located on the northern rim of the collapsed and extinct Lyttelton Volcano. Geological publications, Brown et al (1995), Sewell et al (1993) indicate that the site is underlain by Lyttelton Volcanic Group, Port Hills Loess and Loess Colluvium.

This area is part of the Banks Peninsula volcanic complex, formed between 7 and 11 million years ago. The Lyttelton Volcano erupted a sequence of lava flows interbedded with air fall deposits.

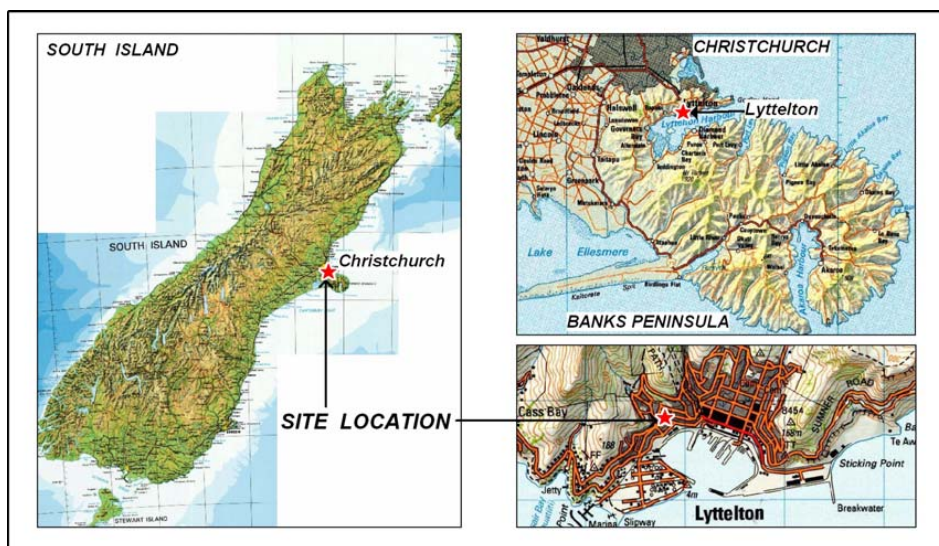


Figure 1: Site Location Plan

Banks Peninsula was an offshore volcanic island until approximately 1 million years ago when glacial outwash gravels from the Southern Alps filled the shallow sea floor to the island. After initial erosion of the extinct volcanic cone, Banks Peninsula was covered in a mantle of loess.

Loess is a wind blown deposit; predominantly silt derived by glacial and fluvial erosion of the Southern Alps, and is transported and deposited by wind. Loess is susceptible to surface and subsurface erosion in the form of tunnel gullies. Tunnel gullies form in the in-situ loess and can lead to collapse and instability. Loess is also very moisture sensitive and studies have shown the effective cohesion to drop significantly with just a few percent increase in moisture content.

Loess colluvium is created by the down slope erosion, transportation, and then re-deposition of the in-situ loess. Gravel forming from exposed volcanic bedrock is often incorporated into the colluvium during reworking.

2 INITIAL FINDINGS

The Banks Peninsular District Council had granted Consent for the redevelopment of the site to accommodate a split level residential dwelling.

Our initial inspection in December 2004 revealed that site preparation had largely been completed, resulting in a 4 - 5m high unsupported excavation at the rear of the site (Figure 2). The unsupported cut was formed partly of in-situ loess, a buried top soil horizon and about 1.5 - 2 m of non-engineered fill which formed the surface layer. The consented design included a timber pole retaining wall to about mid slope height, and to batter the slope back above this level to its full height.

The steeply sloping nature of the slope above the excavated bank combined with the presence of non-engineered fill and buried top soil indicated that there was a significant potential for instability to occur particularly in the event of adverse rainfall conditions during construction. Any failure could also impact on the two adjoining properties immediately above this area.

We undertook initial investigative works and indicated to the client that we considered that the original timber pole retention system was not appropriate. A more substantial support system such as an anchored retaining wall, or a soil nail wall with shotcrete facing was recommended. The client considered the cost implications for these wall types, gained an attractive cost for a crib wall design and subsequently ended of involvement in the project in January 2005.

In early May 2005, we were commissioned to review the design of a 5m high wooden crib wall design. We found that because of the height of the proposed structure (5m) and the proximity of the proposed residence, the crib wall had to be designed for an earthquake event. While this further design check was being undertaken and prior to our review approval, we received a call from the client indicating that a failure had occurred during excavation for the proposed crib wall.



Figure 2: Excavation as at the end of December 2004

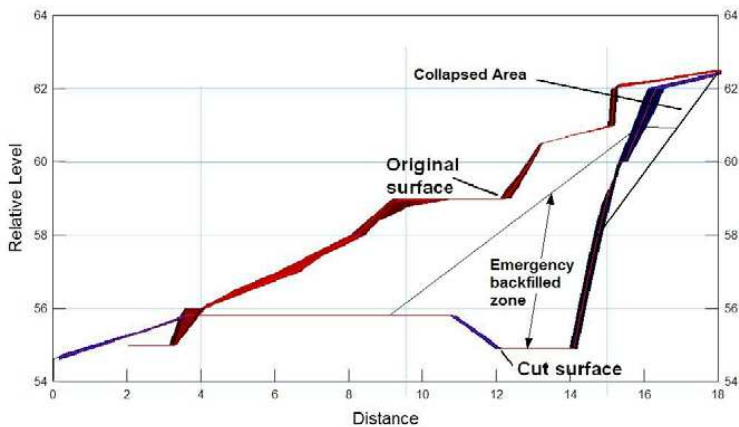


Figure 3: Comparison between original and unstable cut surface

3 EMERGENCY WORKS

The subsequent inspection revealed that the excavation for the 5m crib wall now had a sub-vertical face height of 7.5m (Figure 3). A collapse had occurred in the non-engineered material and this had extended to below the small deck of the residence immediately uphill. Council placed a stop notice on the works and we were directed to undertake remedial and final design works for the project.

The following points were considered:

- that the area had been open for some time,
- winter and probably inclement weather was approaching,
- that completion of works in a short time was unlikely, and
- the undermining of the uphill residence.

It was decided to immediately place backfill against the slope to stabilise the area.

An underdrain consisting of a perforated pipe, 110 mm diameter pipe surrounded by free draining (20 - 40 mm) gravel, all wrapped within a geotextile fabric was placed prior to backfilling. This drain had to be directed toward the road via an excavated channel through the building platform to prevent ponding of waters at the base of the fill. A weathered volcanic rock was sourced from a local quarry as suitable backfill material.

Plastic sheeting was placed over the exposed slope to reduce erosion, water infiltration and subsequent further instability. A downpipe from the affected residence was also temporarily directed away from the site.

4 DESIGN DELIBERATIONS

The excavation for the original proposed crib wall had now extended into all three adjoining properties at the rear and sides of the site. Two property owners had already been approached, however the loss of a Right of Way (ROW) at the rear of the property had affected others and this was not well received. The owner of the residence, whose deck had been undermined was also distressed and in a litigious mood. Prompt action was required.

The client wanted to persist with the wooden crib wall design. This wall was initially to be 5m high with small return wings. A two tier system to incorporate the ROW and support the 7.5m in height, with much larger return walls was now proposed. Three options were considered; two consisting of the crib wall design and one with an anchored wall design (Figure 4). The first option considered minimal further excavation (after clearing of emergency backfill), the second required further excavation (up to 100m³) and the anchored wall required less excavation than the first option. The first option gave about 0.5m clearance to the consented residence design, the second about 1.8m and the third up to 2m. We also considered that soldier pile installation would give some immediate mitigation affect against possible gross instability. The client opted for the anchored wall design.

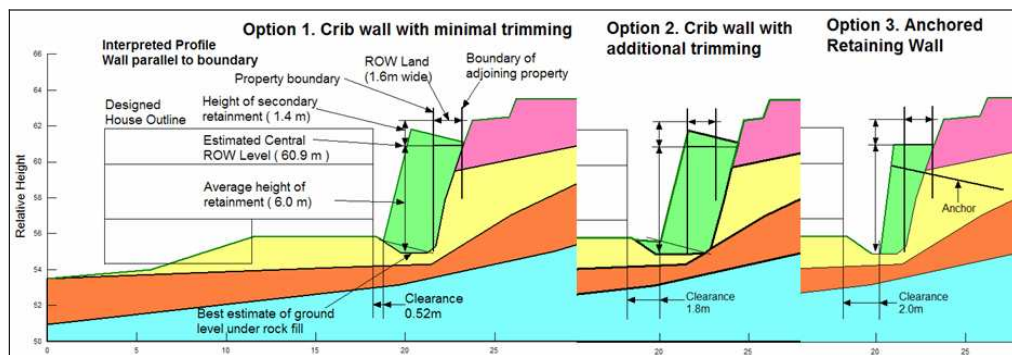


Figure 4: Three design options considered

At a late stage a retaining structure for the adjacent property (owned by the clients' relatives) was also designed and incorporated into our design. This area had previously had consent for construction of a series of retaining walls (all < 1.2m height) and the profile of this design was close to the slope in this area prior to any works being conducted on the adjacent site.

5 RETAINING WALL DESIGN

The client wanted a rustic appeal to the wall and wished to incorporate railway sleepers in the design and wanted minimal paintwork in the final product. The design had to also incorporate the ROW at the appropriate level, restore the deck of the upper residence and link into the gardens of the neighbouring properties (Figure 5).

Analyses for the design were undertaken using SlopeW. Profiles were assessed from survey and estimates of excavation depth, along with the results of our initial ground investigations.

Large UC steel columns were used as soldier piles as treated wooden poles at the required lengths were not readily available. A corrosion allowance for the 'sea spray' zone of Lyttelton was required for the 50 year design life of the wall. Second hand hardwood railway sleepers were to be placed as lagging between the soldier piles in the slot areas provided by the UC members. The quality of the second hand materials was managed by pre-purchase inspections and agreement with the client that poor quality sleepers would be discarded at the engineers' direction. The average length of the sleepers was also considered and the design distance between soldier piles adjusted so minimal trimming of the sleepers was required.

Designed anchors were galvanised 32mm diameter bar centralised and grouted within a 100mm diameter hole with a design working load of 192kN. Bar design included minimum 6m bond and 4m unbonded lengths with an assumed allowable adhesion of 10kPa; however the onus for the anchors' capacity was placed on the clients' subcontractor. The unbonded lengths averaged at 5m and were lined by PVC tubing with Denso tape to seal the ends prior to grouting the annulus (Figure 7). Each anchor was proof load tested to 133% working load and locked off at 50% working load (Figure 6).

Drainage for the wall was to be achieved by the use of the emergency drain already placed, coupled with the use of a free draining backfill. After design completion, to save on costs, the client wanted to use the materials used for emergency stabilisation works as backfill materials. As this was not the cleanest of product, it was only allowed with the inclusion of a series of vertical and horizontal proprietary product drainage systems pinned directly onto the exposed soils and intimately connected to the original drain.

The design included both construction and inspection procedures, liaison with Council and numerous inspections of the affected upslope residence. Construction had to be staged such that the stability of the exposed slopes was not compromised as excavation of the emergency backfill was undertaken and the construction progressed. Temporary measures were undertaken to ensure that the area directly below the residence atop the excavation was not further affected by construction activities (Figure 8).

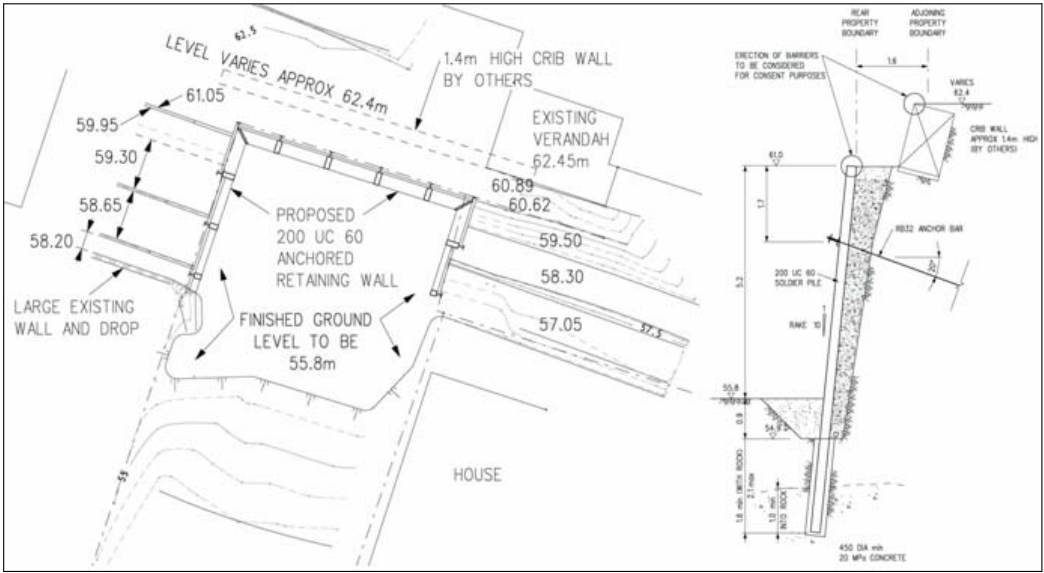


Figure 5: Proposed Design Plan and Section



Figure 6: Testing Anchors



Figure 7: PVC & Denso in unbonded area



Figure 8: Temporary stability works



Figure 9: Completed wall from side



Figure 10: Completed works

Inspections were required in order to satisfy ourselves that the wall was being constructed as designed. A small wooden crib wall was used to support the area above the ROW and a fence was installed on the perimeter of the ROW as a Council requirement.

Completion of the works incorporated the design, Council approval and construction of the neighbouring retaining walls into this wall (Figures 9 & 10). All Certification as required by Council were subsequently issued.

6 CONCLUSIONS

At first what looked like a routine retaining wall problem soon escalated into a high risk situation as a result of action by others. We were able to mitigate the immediate risks and working under close scrutiny from Council and affected parties, worked successfully with the client to produce a suitable solution for all parties.

Some key issues in this project were the staged construction, temporary supporting works, minimal sleeper trimming and incorporation of the emergency drainage system in final design to reduce disturbance, ease construction effort and increase stability and safety on the project. The integration of the neighbouring properties retaining systems and restoration of the up slope residences founding system combined to make this a successful project within this established hill side residential area.

REFERENCES

Brown et al (1995). *Geology of Christchurch, New Zealand*, Environmental & Engineering Geoscience, Volume 1, No. 4, pp 427-488

Kane, H. (1968), *A mechanistic explanation of the physical properties of undisturbed loess*, Research Project HR-126, Iowa State Highway Commission, Department of Civil Engineering, University of Iowa.

Mc Dowell, B.J. (1989), *Site investigations for residential development on the Port Hills, Christchurch*. Unpublished Masters Thesis, University of Canterbury.

Sewell et al. (1993), *Geology of Banks Peninsula, 100 000 map (1 sheet)*, Geological and Nuclear Sciences Ltd, Lower Hutt, New Zealand.