Lessons learned from one of New Zealand's most challenging civil engineering projects: rebuilding the earthquake damaged pipes, roads, bridges and retaining walls in the city of Christchurch 2011 - 2016.

New Zealand Geomechanics News Magazine June 2013 Article - Retaining Walls and Ground Improvements in Christchurch

Story: Retaining Wall Design Solutions

Theme: Design

A magazine article which outlines the observations of engineers working on SCIRT retaining wall and ground improvement projects.

Programme funded by

Programme funded by

PROJECT NEWS

Retaining Walls and Ground Improvement in Christchurch – General Observations and Findings

1.0 Introduction

This article briefly discusses some key observations made by engineers working on retaining wall and ground improvement projects in Christchurch. The first section discusses the behaviour of old stone block walls, crib walls and cantilever timber walls. The second section discusses more complicated anchored walls, focussing on anchor behaviour. The last section describes a ground improvement case study.

2.0 Stone block walls, concrete crib walls and cantilever timber pole walls – general behaviour and performance

2.1 Stone Block Walls

Most stone block walls in Christchurch were constructed in the early 1900's. The extent of mortaring is highly variable with some walls appearing to consist of "dry stacked stones" only. Seismic design or resilience considerations would not have been a consideration at that time. The majority of the walls have been built in front of largely free-standing loess or volcanic cut faces with weather protection and provision of an aesthetic facing being the prime considerations.

Photographs 1 and 2 show two examples of contrasting behaviour exhibited by these stone walls during the recent seismic events.

Photograph 1 shows a stone wall which has suffered collapse over the majority of its length, with a short section remaining virtually undamaged for some reason. This wall initially had very little mortar placed between the blocks. Significantly variable behaviour such as this is a common feature of these walls. It is difficult to provide conclusive explanations for this variance in behaviour, but factors such as vegetation, the direction and severity of accelerations,

Photograph 1: Collapsed Stone Block Wall

Photograph 2: Stone block wall with cracked "panels"

wall backslope, and the method of construction are all likely to have played a part in determining whether any given section of a stone wall has collapsed or not.

Photograph 2 shows another example of a stone wall but in contrast to that in Photograph 1, mortar has been placed between the blocks at some point. It can be seen that the recent earthquakes have caused the wall to crack into discrete "panels" but the wall has not suffered complete collapse.

It appears from the above two examples that a cost effective measure of reducing the risk of complete collapse of stone block facing walls would be to point them.

2.2 Concrete Crib Walls

Similar to stone walls, the general performance of concrete crib walls has been extremely variable. Although the factors listed above all probably play a part in determining the degree of damage suffered, it appears from recent inspections that a key factor governing the resilience of concrete cribs is the degree of face vegetation which, crucially, seems to have held the infill stones in place. It is conceded that formal research testing this observation, has not been carried out and this is an impression based on a few inspections only. Nevertheless, it does appear to the authors that highly vegetated concrete crib walls have faired better. Photographs 3 and 4 below show examples of these two types of behaviour.

Photograph 3: Unvegetated Crib – fill loss and collapse.

Photograph 4: Vegetated crib – fill intact & in good condition.

2.3 Timber Pole Walls

Generally, timber pole walls appear to have been among the most resilient in the recent earthquakes. Relatively few appear to have suffered completed collapse but two key observations coming from the recent inspections in Christchurch are:

Timber pole walls have not faired well on outside corners (see Photograph 5)

The flexibility of timber pole walls appears to have reduced damage to the wall itself but the footway and road behind have suffered subsidence and cracking due to the high degree of seismic movement.

Photograph 5: Timber pole wall – damaged corner section

3.0 Anchored King Post Retaining Walls – Performance of Anchors

The Cunningham Terrace Retaining Wall and Maffeys Road Retaining Wall were both concrete crib walls and both failed during the February 2011 Christchurch Earthquake. Maffeys Road Retaining Wall is in Mt Pleasant, a suburb on the edge of the Port Hills and reaches about 7.5m in height. Cunningham Terrace has an average height of about 4 m and is located within the steep residential

Photograph 6: Intact timber pole wall with cracked road behind

Photograph 7: Anchor Installation at Maffeys Road

streets of the port town of Lyttelton.

Cunningham Terrace Retaining Wall and Maffeys Road Retaining Wall are being rebuilt as anchored king post walls. The design working load for the anchors of both walls was 100kN. These are distal plate anchors, comprising of a plate secured at the end of a 32mm bar, grouted within a 110mm diameter novacoil sheath. The bar is debonded from the grout to transfer the load to the distal plate. These prefabricated units were installed in 165mm diameter drill holes and grouted.

All the anchors for Maffeys Road Retaining Wall were installed and bonded 5m in rock. The distance to rock varied across the site and anchors were installed through Loess or soft organic silt soils for a distance of between zero and 15m.

At Cunningham Terrace Retaining Wall rock was not encountered and all anchors were installed in Loess. The strength of Loess was variable across the site and the anchor lengths ranged from 6m to 15m.

All anchors were subject to acceptance testing to 150% of the design working load. At Maffeys Road, where the anchors were bonded about 5m into rock, the measured extension was typically between 2mm and 8mm, with all the anchors fixed directly into rock generally not extending more than about 3mm. All anchors at Maffeys Road passed acceptance testing.

At Cunningham Terrace initial testing cycles typically gave rise to extension of between 2mm and 15mm. The apparent free length was calculated for each load test and where the apparent free length was outside of acceptable

Photograph 8: Grouted Anchors at Cunningham Terrace

Photograph 9: Maffeys Road RW as at end of March 2013

Photograph 10: Installed anchors and Waling at Cunningham Terrace

limits, as described in BS8081, further load cycles were carried out in order to ensure the anchor response was elastic. Approximately 30% of the anchors installed required retesting to ensure they were acceptable with 6% of anchors being replaced.

Unexpected poor ground conditions meant that a number of anchors had to be drilled further than initially planned at Maffeys Road in order to create the desired bond in basalt. At Cunningham Terrace, installation was significantly easier in the loess but a longer bond length was required than for the Maffeys wall.

4.0 Pump Station 15 Ground Improvement Works – Geotechnical Aspects

In this section, geotechnical aspects of the repair works at Pump Station 15 (PS15) in the suburb of Woolston are discussed. The ground investigation, the general site geology and key considerations for the ground improvement are all covered.

4.1 The Pump Station

PS15 is a terminal wastewater pumping station located in the eastern Christchurch suburb of Woolston. The station sits on a 12m diameter, 9m deep concrete caisson. The caisson houses pumps and receives flow from a main trunk sewer line. It was knocked out of service by both February and June 2011 earthquakes (see photos below of the damage). Surveys after the February earthquake showed the caisson to have floated up to 400mm in relation to the surrounding ground. Emergency repairs quickly brought the station back into operation, but because of its key role, there was a need for more permanent repairs or a rebuild at another site. The pump station services a broad area including hill suburbs from Hillsborough to Taylors Mistake and residential and industrial areas in Bromley and Woolston. In total it pumps wastewater for the equivalent of 40,000 people and when out of service for extended periods, raw sewage can overflow into the Heathcote River.

4.2 Ground Investigation

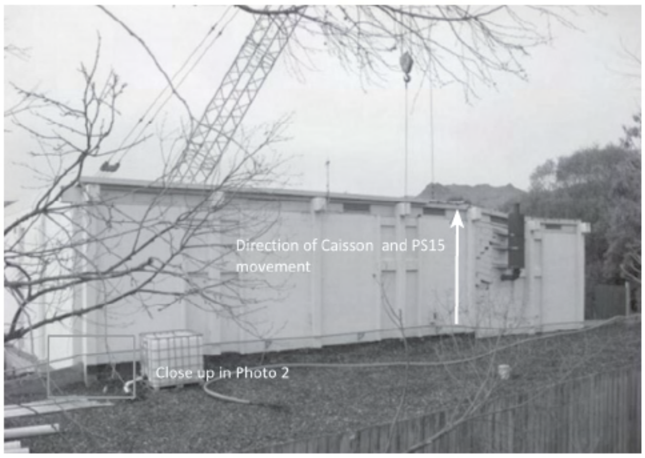
Piezocone Penetration Testing (CPTu) was carried out on the pump station site and an adjoining block of land was investigated using boreholes and additional CPTu tests. Once a repair option had been chosen, further testing on the existing site was carried out which included Seismic Dilatometers (SDMT), boreholes and testpits. Parameters derived included shear wave velocity, grading (with particle size distribution curves), undrained shear strength, and friction angles.

4.3 Geology

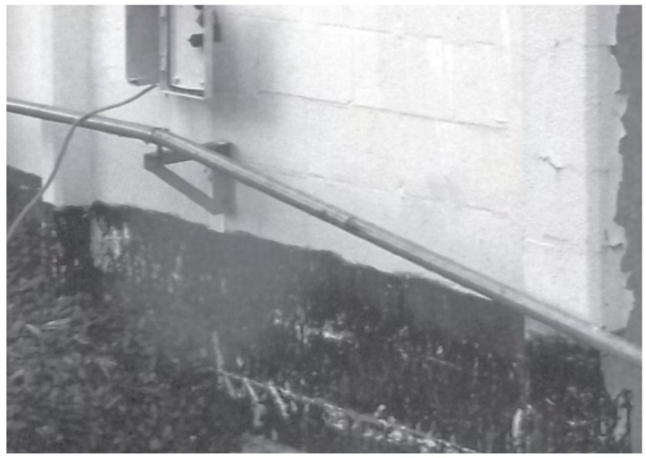
The ground investigation showed the geology of the site to be fill in the top 2 metres overlying potentially liquefiable sands with silt lenses to 14-15m below ground level (mbgl). Dense marine sands were encountered at 15 to18mbgl and these overlaid 3m of softer materials before the dense Riccarton gravels were encountered below 21m. The Riccarton Gravels at the site are an artesian aquifer with the softer layer at 18-21m acting as an aquiclude. The artesian head measured was 1m.

4.4 Ground improvement

The behaviour of the ground during the sequence of earthquakes since September 2010 and an analysis of the ground investigation data necessitated ground improvement to mitigate against future land damage. To prevent liquefaction on the site poses specific challenges in and around the caisson which is founded at 9mbgl. The need to prevent further floatation of the caisson and differential movement relative to pipes entering and exiting the pump station was a main consideration. The sequencing of the ground improvement to allow continued operation of the pump station and allow other repair work to continue, such as replacing pipes, will require



Photograph 11a: Pump station 15, note damage at right hand side of structure



Photograph 11b: Damage due to floatation of Caisson

Photograph 11c: Damage to pipe connected to PS15 caisson

Photograph 11d: Floatation of manhole on street outside PS15

co-operation between all the contractors. The ground improvement work is currently being completed under a design-build contract and at the time of writing was in the detailed design phase. The proposed design will see a grid of deep soil mixing (DSM) piles across the site with a ring around the caisson and particular focus being put on the prevention of flotation.

4.5 Quality assurance

As part of the Quality Assurance process, verification of the ground improvement works will consist of CPTu's and SDMT testing after the completion of site work.

Repoted by: P.Aynsley, I.Froggatt, L.Kendal Riches, and M.Lazzaro
Aurecon