SCIRT Rebuilding Infrastructure LEARNING LEGACY

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.

Repairing Christchurch City Council Owned Retaining Walls Damaged by the Christchurch and Canterbury Earthquakes

Story: Retaining Wall Design Solutions

Theme: Design

A paper which outlines SCIRT's approach to asset assessment, design and repair of damaged retaining walls, and presents a case study of a retaining wall rebuild, on Cunningham Terrace, Lyttelton.

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Repairing Christchurch City Council Owned Retaining Walls Damaged by the Christchurch and Canterbury Earthquakes

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ABSTRACT

The earthquakes in 2010 and 2011 caused significant damage to retaining walls in Christchurch. This included many Council owned retaining walls which protect both the road network and other infrastructure. The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) was established to repair the Council owned horizontal infrastructure, including a significant number of retaining walls. Since the inception of SCIRT in 2011, 2875 retaining wall assets have been assessed with 440 of these remaining in SCIRT's scope for refurbishment or repair. The SCIRT process includes prioritising the wall assets, concept and detailed design of solutions and construction. The works required include both wall repairs as well as complete rebuild solutions. This paper will discuss the nature of the SCIRT retaining wall projects and how the SCIRT process has evolved to facilitate the repairs. In addition it will present a case study of Cunningham Terrace Retaining Wall. This project was a particularly complex retaining wall rebuild. The case study will illustrate some of the constraints and challenges encountered during the project, but it will also highlight many of the advantages of the SCIRT process and the benefits to this particular project.

Keywords: retaining wall, earthquake, alliance, rebuild, anchors

1 INTRODUCTION

The earthquakes in 2010 and 2011 caused significant damage to retaining walls in Christchurch. This included many Council owned retaining walls which protect both the road network and other infrastructure. The Stronger Christchurch Infrastructure Rebuild Team (SCIRT) was established to repair the Council owned horizontal infrastructure, including a significant number of retaining walls. The author of this paper is on secondment to SCIRT and has been involved since 2011 with the design and rebuild of Council owned retaining walls.

1.1 The Stronger Christchurch Infrastructure Rebuild Team

SCIRT is an alliance of three client organisations and five delivery teams. They are Christchurch City Council, Canterbury Earthquake Recovery Authority (CERA) and New Zealand Transport Agency along with City Care, Downer, Fulton Hogan, McConnell Dowell and Fletchers. SCIRT was established in September 2011. Along with the organisations which make up the alliance there is an integrated services team (IST). The functions of the IST include design, asset assessment, estimating and communications.

The greatest value of work carried out by SCIRT is related to three waters infrastructure. That is wastewater, stormwater and water supply assessment, design and construction. Aside from this, roading projects include both Council and NZTA assets. SCIRT also assesses and designs repairs for bridges including foot bridges, road bridges and the Bridge of Remembrance.

With regard to retaining walls 2875 assets have been assessed with 440 of these being within SCIRT's scope. The walls in scope have a total length of more than 15km and the range of damage is from walls requiring only minor patch repairs to those which suffered complete collapse. Wall types include crib walls, timber pole walls, gabion walls, stone facings and mass concrete walls. In addition some assets which are not technically walls are also within scope. This has included rock stabilisation projects and the protection of steep slopes. Rebuilding all the infrastructure with in SCIRT scope is likely to cost around $2 billion dollars.

2 DESIGN PHILOSOPHY

2.1 Asset Assessment

The first challenge to be realised, prior to the inception of SCIRT, was to identify the retaining walls requiring rebuild or repair. The Council had no complete record of its assets and therefore the first step was to catalogue the city's walls. This cataloging allowed the extent of the damage to be recorded. One of the most complex aspects of this was evaluating if walls were Council assets, or if they were privately owned. Walls could be inside a private property boundary, but still council owned, and vice versa. Where walls were built as part of a subdivision, this was even more complex. Ultimately wall ownership was determined based on the purpose of the wall. For example a wall constructed to protect or support a road was a council asset. Where the purpose of the wall was to create a building platform, the wall was private.

The initial list of walls was prioritised based on visual observations of damage and risk. The walls could then be assigned to one of the SCIRT design teams for solutions to be designed.

2.2 Repair or Rebuild Solutions

The range of damage experienced is significant. As mentioned, some walls required only minor patch repairs while others call for a complete rebuild. During the concept design for each project it is decided if the scope is to rebuild, repair or do nothing to the wall. It is an important decision considering the fixed budget and time frame for SCIRT. This decision making process has changed throughout the project.

In October 2011 the process was obvious. There were lots of very badly damaged walls and many of these were endangering other Council assets or private property. There was a lot of public pressure to have repairs completed. The walls were prioritised by the asset assessment team within SCIRT and it was necessary to design rebuild solutions with the aim of getting the delivery teams on site and constructing the new walls without delay.

However, once the most damaged walls were in the system, the walls assessed next were less damaged. The question of repair versus rebuild was raised with a view to achieving cost savings. By the middle of 2012 a guideline to assist in these decisions had been produced. Further details of this guideline are presented later.

By early 2013 projects did not consist of single walls, but packages of 10 or more walls. For example a whole road with multiple walls along its length would be classified as one project and within this project there would be moderately damaged walls, but also walls with little damage. The designers' initial task was to determine if any work was required. In some cases just minor repairs, with no specific design, were appropriate and these walls were often handed back to the Council for maintenance type repairs.

In 2014 the financial impact of our decisions came under increased scrutiny from the funding organisations. Our scope was modified and walls were more strictly prioritised. Ultimately this removed some assets from our scope.

As the end of the project comes into sight, many of the design engineers have left SCIRT and increasing amounts of time is required for construction monitoring, rather than design.

As mentioned, a guideline was produced to assist in the decision making around the repair or rebuild of retaining walls. At SCIRT the asset owners are part of the same organisation as the designers. This allows for good communication between the parties. The design engineers could offer advice as well as design solutions to problems. However, the volume of assets being designed meant that a decision making framework was required to decide if an asset required rebuilding, refurbishing or no work at all. To establish this the document presents the designer with a series of questions:

- It asks if a full replacement is necessary. This allows engineers to consider keeping sections of the wall if appropriate.
- Where the designer considers that the full wall does not need to be replaced, it asks if the damage is of a superficial or minor nature. For example in some cases the damage has not reduced the stability or integrity of the wall. If the damage is superficial or minor the tool indicates maintenance or minor repairs can be carried out.

- However, if the damage is not minor according to these conditions it asks if the wall is repairable. This evaluation considers if the damage is limited to only discrete sections, if the structural form is suitable for the location and if a repair can give rise to a structure where the failure mechanism is progressive rather than collapse.
- If, according to these criteria, the wall can be repaired the tool gives the requirements for the refurbishments. Alternatively it suggests a replacement wall is designed.

Where a wall is to be repaired, rather than rebuilt it was necessary for any replacement elements to meet 100% of NBS, but the global stability for the structure was to be 34%NBS. This provided an opportunity for cost savings and allowed for the repair of more structures, rather than rebuild.

2.3 Design Guidelines

The design of retaining walls at SCIRT is in accordance with several design guidelines. The Council's business as usual Infrastructure Design Standard (IDS) still applies. This is complimented by the Infrastructure Recovery Technical Standards and Guidelines (IRTSG) which is specifically in relation to earthquake repairs. There is also a specific Retaining Wall Design Guide. This document was produced on behalf of the Council just prior to the design teams coming into SCIRT. Some of the specific design requirements for the retaining walls designed at SCIRT are:

- The design life for materials is to be 100 years, except under certain circumstances.
- Design earthquakes are derived based on a prescribed annual probability of exceedance for an ultimate limit state event. These are according to the location of the wall and type of road it is adjacent to. For example, a wall on a local road will be designed to withstand a smaller peak ground acceleration then a wall on an arterial road. Typically design accelerations are in the range of 0.3g – 0.6g.
- Walls supporting roads are designed for traffic surcharge of 12kPa.
- New walls are designed and constructed with a backslope no steeper than 1H:20V.
- A refurbishment solution calls for the walls to withstand two thirds of the design peak ground acceleration required for a new wall.
- Crib walls are not acceptable.

With regard to the requirement that the design life for material durability is 100 years, this is reduced to 50 years for walls which are not adjacent to a road. The result of this requirement was that most solutions were steel and concrete because timber and even gabions in some settings did not meet the design life requirement. Timber solutions often presented a significant cost saving and it was felt that this was an opportunity being missed. In 2013 a new guideline was produced that allowed a design life of 50 years to be adopted if:

- The road adjacent to the wall was not an arterial road
- Adjacent infrastructure or private property would not be significantly impacted by a future rebuild of the wall
- A design with a reduced design life would present a whole life cost saving

3 CUNNINGHAM TERRACE RETAINING WALL CASE STUDY

3.1 Introduction

Cunningham Terrace Retaining Wall in Lyttelton was one of the first projects undertaken in SCIRT and was designed as an anchored steel king post wall with concrete infill panels. The project encountered many of the challenges faced by projects at SCIRT as well as giving good examples of some of the advantages of the SCIRT alliance.

3.2 Design

The wall is 75m long and up to 4.8m high. The existing wall consisted of two sections of crib wall and three sections of mass concrete wall. The crib lost more fill with each aftershock and was badly deformed. The mass concrete sections were propped with railway irons prior to the earthquake. The road above the wall was closed due to the degree of deformation and loss of stability (Figure 1).

Figure 1 The damaged Cunningham Terrace retaining wall

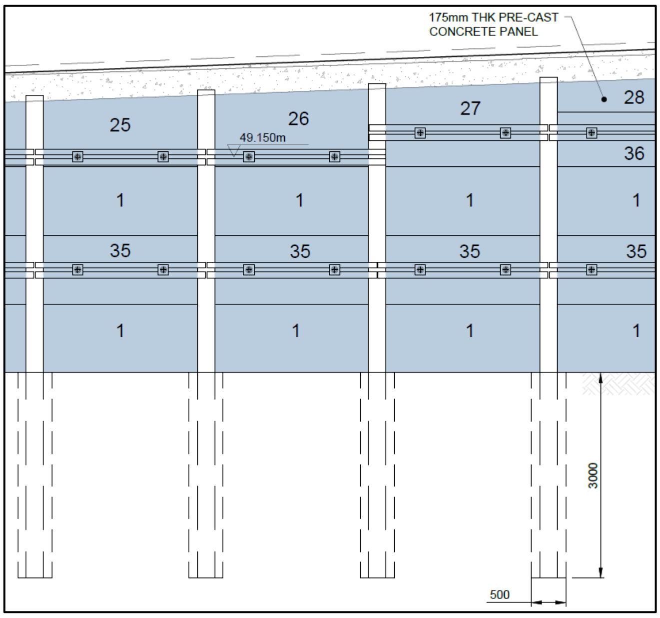

Figure 2 Design elevation for Cunningham Terrace retaining wall

The solution was an anchored steel kingpost wall with concrete panels (Figure 2). This gave the wall a 100 year design life. The king posts are I-sections, embedded in concrete sockets below ground level. Walings run across the I-sections and are anchored. The anchor heads can also be seen in Figure 2. The anchors are distal plate anchors with double corrosion protection. They are typically 10 metres long and have a working load of 100kN. The wall under construction can be seen in Figure 3.

The site was underlain entirely by loess, as is typical for this area of the Port Hills. The loess soils were typically dry and would stand vertically in excavated faces. However in places the loess had been reworked and was moist to wet. These areas displayed much weaker soil properties and the loess was significantly less stable. These different properties had to be accommodated for both permanent wall design, by locally increasing the length of the anchors, and temporary works design when maintaining stable excavations. Rock was not encountered at the site. This allowed the kingposts and the anchors to be embedded is relatively consistent material. Had rock have been encountered the anchors and posts could have been reduced in length, but construction would have been considerably more complex to allow for rock coring.

Figure 3 The partially constructed Cunningham Terrace retaining wall

3.3 Construction

One of the advantages of the system at SCIRT is the early contractor involvement (ECI). During design an ECI contractor is assigned to each project. For Cunningham Terrace this was Fulton Hogan. The design benefited from this involvement. For example the retaining wall panels were sized based on the maximum weight a particular piece of kit could lift. It was known that this was available for the works and could get access to the narrow site. In addition the anchor drill rig needed a certain width to operate in front of the excavated face. Benches at the base of the wall were designed to accommodate this and this ultimately determined the maximum height of the wall. The delivery team also had extensive anchoring experience and this knowledge was shared across the project.

Figure 4 Cunningham Terrace retaining wall before demolition showing the confined site

As can be seen in Figure 4 the site was particularly narrow. This is not uncommon in these hillside residential areas. The wall on the right of the photograph was demolished and replaced without removing any of the buildings which can be seen on the left of the photograph. In addition the road behind the wall contains water infrastructure and other buried utilities. Overhead cables also travel along this road.

During the construction phase a number of sacrificial test anchors were carried out in order to confirm the length of anchors required. But one area of the site had weaker soils and therefore a lower bond strength. The anchor design had to be revised to ensure the capacity was as required. This resulted in longer anchors being required.

All permanent anchors were tested and approx. 94% of the anchors were accepted with the remaining 6% being replaced.

One particular challenge for the delivery team was that the anchors had to pass through the wall panels to the waling. This was particularly complex because the anchors were installed before the panels were placed, the anchors were drilled in a surface up to 5m from the wall face, the anchors were inclined and the anchor with the corrosion protection was 75mm and the hole in the panel was 80mm. The required accuracy to complete this was achieved on site.

3.4 Adjacent Infrastructure

Projects at SCIRT have an emphasis on a one pass approach. That is, ideally there should be one phase of construction for the three waters, roading and any structures rebuild on a given street. So, this retaining wall project also included water supply, wastewater, stormwater and roading rebuild. All three waters were replaced behind the wall.

Coordination between all the aspects of the project was important because there were a number of conflicts between assets. These can be seen in Figure 5. A number of anchors were installed at an angle to avoid manholes and sumps behind the wall and a few anchors are above the wastewater pipes at the west end of the site so as the required grade could be achieved. There had been a wastewater drop structure behind the wall to convey wastewater from Cunningham Terrace to the wastewater line below. This was replaced with a drop structure in front of the wall so it could be accessed if required and a manhole was added. To accommodate this a retaining wall panel was designed with a hole in it for the wastewater pipeline to pass through.

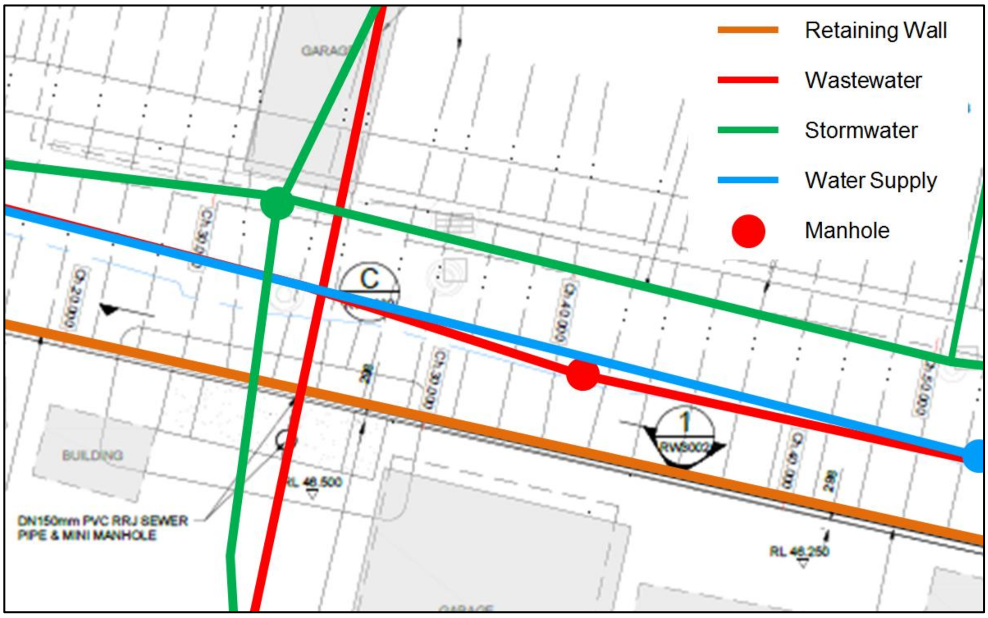

Figure 5 Buried Services adjacent to Cunningham Terrace Retaining Wall

Stormwater was improved including two double sumps at the low point on Cunningham Terrace and a secondary flow path over the wall was constructed. Due to the degree of excavation, a full carriageway reconstruction was required.

The alignment of the top of the wall is slightly different to what was there before due to the reduced rake of the wall. There is a garage on stilts on the low side of the wall and the new wall alignment would result in a 0.5m gap between the garage and the road. This can be seen in Figure 6. To remedy this access had to be provided without relying on the private structure for support. Therefore a cantilever access was built from the top of the wall as part of the capping beam.

Figure 6 The gap created by the new wall alignment

3.5 Project Constraints

At Cunningham Terrace some artefacts were found and this required an archaeologist to be called. Bottles and a few bones were found. It is thought that this is likely to have been an old dump site for a local pub. This dump site corresponded to the area of weaker soils found during anchor testing. There are a number of global consents at SCIRT which cover work for example in areas of archaeological interest, or near significant trees. These allow SCIRT designs to pass into construction relatively quickly and allow the rebuild to progress.

Where anchors pass under private property easements had to be sought before construction could begin. This was a particularly challenging process because many owners on this street lived elsewhere. In addition there was an unwillingness to sign due to some initial lack of understanding about the implications of the anchors. There was some education to be done in order to get the agreements. Then during construction, when longer anchors were required in one area, additional easements had to be negotiated. Difficulty in obtaining easements has been a recurring theme for anchored walls in the rebuild. Since this project was constructed new system for obtaining these permissions has been introduced.

4 CONCLUSION

The degree of damage suffered by Council owned retaining walls was wide ranging. Within SCIRT a number of refurbishment and rebuild solutions were developed. But the technical solutions are only a small part of the projects undertaken. There are many non-technical influences in the design decision making. As well as the challenges and advantages discussed as part of the project on Cunningham Terrace, there are other factors in the designs:

- There is a huge time constraint at SCIRT. The project will finish in 2016 and so it is essential that efficient designs are output quickly.
- SCIRT projects are funded by the Christchurch City Council, NZTA and CERA and therefore the spending comes under scrutiny. There must be value for money in the projects.
- There has been a lot of pressure on SCIRT to be making progress. Early on the public were often frustrated by an apparent lack of work in their area, or just a lack of information. This added pressure to getting designs completed in a timely manner, but also raised the

importance of giving realistic information about timeframes. There was a lot to be done in managing expectations and a strong communications team to do this in the public arena was key.

- SCIRT's mission statement is "Creating a resilient infrastructure that gives people security and confidence in the future of Christchurch." Therefore there is an expectation that what is built is resilient, but this must also be balanced with cost, time and appearance. The concept of resilience has evolved during the project so far. Where initially the emphasis was to quickly design a rebuild solution for every wall with a very conservative design, there is now an emphasis on getting the appropriate solution that also offers value for money.
- Perhaps one of the biggest influences is change. The decision to rebuild or refurbish any given wall may have been different at different stages of the project as it progressed. As previously discussed, this could be attributed to the change in focus as the project progressed, but in addition to this, the teams gained knowledge on different repair methods and could find more efficient solutions. The project changed from a desire to get a very strong structure built quickly, to one where cost savings and refining designs for efficiency was sought. The design systems have evolved and matured, but still SCIRT is less than 4 years old.

In just a couple of years SCIRT will come to an end and the legacy of a resilient Christchurch, including its retaining walls, will be there for the future of the city.