Christchurch City Council

Ex Memorial Room Avonhead Park Cemetery

Detailed Engineering Evaluation

Quantitative Assessment Report

Christchurch City Council

Ex Memorial Room

Avonhead Park Cemetery

Quantitative Assessment Report

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Date: April 2013
Reference: 6-QC111.00
Status: Final

Summary

Ex Memorial Room
Avonhead Park Cemetery
PRK 0217 BLDG 005 EQ2

Detailed Engineering Evaluation
Quantitative Report - Summary
Final

Background
This is a summary of the quantitative report for the Avonhead Park Cemetery Ex Memorial Room, and is based on the Detailed Engineering Evaluation Procedure document (draft) issued by the Structural Advisory Group on 19 July 2011.

Key Damage Observed
No damage to the above-ground, exterior structure was noted. Other parts of the structure were unable to be investigated.

Critical Structural Weaknesses
No critical structural weaknesses are present in the structure.

Indicative Building Strength
The analysis rated the building to be at 100%NBS and it is therefore not earthquake prone.

Contents

1 Introduction

Opus International Consultants Limited has been engaged by the Christchurch City Council to undertake a detailed seismic assessment of the Avonhead Park Cemetery Ex Memorial Room, located at 140 Hawthornden Rd, Avonhead, Christchurch following the Canterbury Earthquake Sequence that began September 2010.

The purpose of the assessment is to determine if the building is classed as being earthquake prone in accordance with the Building Act 2004.

The seismic assessment and reporting have been undertaken based on the qualitative and quantitative procedures detailed in the Detailed Engineering Evaluation Procedure (DEEP) document (draft) issued by the Structural Engineering Society (SESOC) [3] [4].

2 Compliance

This section contains a brief summary of the requirements of the various statutes and authorities that control activities in relation to buildings in Christchurch at present.

2.1 Canterbury Earthquake Recovery Authority (CERA)

CERA was established on 28 March 2011 to take control of the recovery of Christchurch using powers established by the Canterbury Earthquake Recovery Act enacted on 18 April 2011. This act gives the Chief Executive Officer of CERA wide powers in relation to building safety, demolition and repair. Two relevant sections are:

Section 38 – Works

This section outlines a process in which the chief executive can give notice that a building is to be demolished and if the owner does not carry out the demolition, the chief executive can commission the demolition and recover the costs from the owner or by placing a charge on the owners' land.

Section 51 – Requiring Structural Survey

This section enables the chief executive to require a building owner, insurer or mortgagee to carry out a full structural survey before the building is re-occupied.

We understand that CERA require a detailed engineering evaluation to be carried out for all buildings (other than those exempt from the Earthquake Prone Building definition in the Building Act). CERA have adopted the Detailed Engineering Evaluation Procedure (DEEP) document (draft) issued by the Structural Engineering Society (SESOC) on 19 July 2011. This document sets out a methodology for both initial qualitative and detailed quantitative assessments.

It is anticipated that a number of factors, including the following, will determine the extent of evaluation and strengthening level required:

1. The importance level and occupancy of the building.

2. The placard status and amount of damage.
3. The age and structural type of the building.
4. Consideration of any critical structural weaknesses.

Christchurch City Council requires any building with a capacity of less than 34% of New Building Standard (including consideration of critical structural weaknesses) to be strengthened to a target of 67% as required under the CCC Earthquake Prone Building Policy.

2.2 Building Act

Several sections of the Building Act are relevant when considering structural requirements:

Section 112 - Alterations

This section requires that an existing building complies with the relevant sections of the Building Code to at least the extent that it did prior to the alteration. This effectively means that a building cannot be weakened as a result of an alteration (including partial demolition).

The Earthquake Prone Building policy for the territorial authority shall apply as outlined in Section 2.3 of this report.

Section 115 – Change of Use

This section requires that the territorial authority is satisfied that the building with a new use complies with the relevant sections of the Building Code 'as near as is reasonably practicable'.

This is typically interpreted by territorial authorities as being 67% of the strength of an equivalent new building or as near as practicable. This is also the minimum level recommended by the New Zealand Society for Earthquake Engineering (NZSEE).

Section 121 – Dangerous Buildings

This section was extended by the Canterbury Earthquake (Building Act) Order 2010, and defines a building as dangerous if:

1. In the ordinary course of events (excluding the occurrence of an earthquake), the building is likely to cause injury or death or damage to other property; or
2. In the event of fire, injury or death to any persons in the building or on other property is likely because of fire hazard or the occupancy of the building; or
3. There is a risk that the building could collapse or otherwise cause injury or death as a result of earthquake shaking that is less than a 'moderate earthquake' (refer to Section 122 below); or
4. There is a risk that other property could collapse or otherwise cause injury or death; or

5. A territorial authority has not been able to undertake an inspection to determine whether the building is dangerous.

Section 122 – Earthquake Prone Buildings

This section defines a building as earthquake prone (EPB) if its ultimate capacity would be exceeded in a 'moderate earthquake' and it would be likely to collapse causing injury or death, or damage to other property.

A moderate earthquake is defined by the building regulations as one that would generate loads 33% of those used to design an equivalent new building.

Section 124 – Powers of Territorial Authorities

This section gives the territorial authority the power to require strengthening work within specified timeframes or to close and prevent occupancy to any building defined as dangerous or earthquake prone.

Section 131 – Earthquake Prone Building Policy

This section requires the territorial authority to adopt a specific policy for earthquake prone, dangerous and insanitary buildings.

2.3 Christchurch City Council Policy

Christchurch City Council adopted their Earthquake Prone, Dangerous and Insanitary Building Policy in 2006. This policy was amended immediately following the Darfield Earthquake on 4 September 2010.

The 2010 amendment includes the following:

1. A process for identifying, categorising and prioritising Earthquake Prone Buildings, commencing on 1 July 2012;

2. A strengthening target level of 67% of a new building for buildings that are Earthquake Prone;

3. A timeframe of 15-30 years for Earthquake Prone Buildings to be strengthened; and,

4. Repair works for buildings damaged by earthquakes will be required to comply with the above.

The council has stated their willingness to consider retrofit proposals on a case by case basis, considering the economic impact of such a retrofit.

If strengthening works are undertaken, a building consent will be required. A requirement of the consent will require upgrade of the building to comply 'as near as is reasonably practicable' with:

- The accessibility requirements of the Building Code.

- The fire requirements of the Building Code. This is likely to require a fire report to be submitted with the building consent application.

Where an application for a change of use of a building is made to Council, the building will be required to be strengthened to 67% of New Building Standard or as near as is reasonably practicable.

2.4 Building Code

The Building Code outlines performance standards for buildings and the Building Act requires that all new buildings comply with this code. Compliance Documents published by The Department of Building and Housing can be used to demonstrate compliance with the Building Code.

On 19 May 2011, Compliance Document B1: Structure was amended to include increased seismic design requirements for Canterbury as follows:

- increase in the basic seismic design load for the Canterbury earthquake region (Z factor increased to 0.3 equating to an increase of 36 – 47% depending on location within the region);
- Increased serviceability requirements.

2.5 Institution of Professional Engineers New Zealand (IPENZ) Code of Ethics

One of the core ethical values of professional engineers in New Zealand is the protection of life and safeguarding of people. The IPENZ Code of Ethics requires that:

Members shall recognise the need to protect life and to safeguard people, and in their engineering activities shall act to address this need.

1.1 Giving Priority to the safety and well-being of the community and having regard to this principle in assessing obligations to clients, employers and colleagues.

1.2 Ensuring that responsible steps are taken to minimise the risk of loss of life, injury or suffering which may result from your engineering activities, either directly or indirectly.

All recommendations on building occupancy and access must be made with these fundamental obligations in mind.

3 Earthquake Resistance Standards

For this assessment, the building's earthquake resistance is compared with the current New Zealand Building Code requirements for a new building constructed on the site. This is expressed as a percentage of new building standard (%NBS). The loadings are in accordance with the current earthquake loading standard NZS1170.5 [1].

A generally accepted classification of earthquake risk for existing buildings in terms of %NBS that has been proposed by the NZSEE 2006 [2] is presented in Figure 1 below.

Description	Grade	Risk	%NBS	Existing Building Structural Performance	Improvement of Structural Performance – Legal Requirement	Improvement of Structural Performance – NZSEE Recommendation
Low Risk Building	A or B	Low	Above 67	Acceptable (improvement may be desirable)	The Building Act sets no required level of structural improvement (unless change in use) This is for each TA to decide. Improvement is not limited to 34%NBS.	100%NBS desirable. Improvement should achieve at least 67%NBS
Moderate Risk Building	B or C	Moderate	34 to 66	Acceptable legally. Improvement recommended		Not recommended. Acceptable only in exceptional circumstances
High Risk Building	D or E	High	33 or lower	Unacceptable (Improvement required under Act)	Unacceptable	Unacceptable

Figure 1: NZSEE Risk Classifications Extracted from table 2.2 of the NZSEE 2006 AISPBE Guidelines

Table 1 below compares the percentage NBS to the relative risk of the building failing in a seismic event with a 10% risk of exceedance in 50 years (i.e. 0.2% in the next year).

Table 1: %NBS compared to relative risk of failure

Percentage of New Building Standard (%NBS)	Relative Risk (Approximate)
>100	<1 time
80-100	1-2 times
67-80	2-5 times
33-67	5-10 times
20-33	10-25 times
<20	>25 times

3.1 Minimum and Recommended Standards

Based on governing policy and recent observations, Opus makes the following general recommendations:

3.1.1 Occupancy

The Canterbury Earthquake Order[1] in Council 16 September 2010, modified the meaning of "dangerous building" to include buildings that were identified as being EPB's. As a result of this, we would expect such a building would be issued with a Section 124 notice, by the Territorial Authority, or CERA acting on their behalf, once they are made aware of our assessment. Based on information received from CERA to date and from the DBH guidance document dated 12 June 2012 [6], this notice is likely to prohibit occupancy of the building (or parts thereof), until its seismic capacity is improved to the point that it is no longer considered an EPB.

3.1.2 Cordoning

Where there is an overhead falling hazard, or potential collapse hazard of the building, the areas of concern should be cordoned off in accordance with current CERA/territorial authority guidelines.

3.1.3 Strengthening

Industry guidelines (NZSEE 2006 [2]) strongly recommend that every effort be made to achieve improvement to at least 67%NBS. A strengthening solution to anything less than 67%NBS would not provide an adequate reduction to the level of risk.

It should be noted that full compliance with the current building code requires building strength of 100%NBS.

3.1.4 Our Ethical Obligation

In accordance with the IPENZ code of ethics, we have a duty of care to the public. This obligation requires us to identify and inform CERA of potentially dangerous buildings; this would include earthquake prone buildings.

[1] This Order only applies to buildings within the Christchurch City, Selwyn District and Waimakariri District Councils authority

4 Building Description

4.1 General

The building is a concrete shell structure with a shape akin to that of a tent (see photos in Appendix 1). It was designed in 1979 by what was then Waimairi County Council. It is one of three similarly shaped structures in its locale, the other two being the cemetery male and female public toilets, which are not covered in this assessment. Figure 2, Figure 3 and Figure 4 show the north, south and side elevations of the buildings respectively, taken from the Waimairi County Council drawings. The building is approximately 6m high x 16m wide x 9m deep.

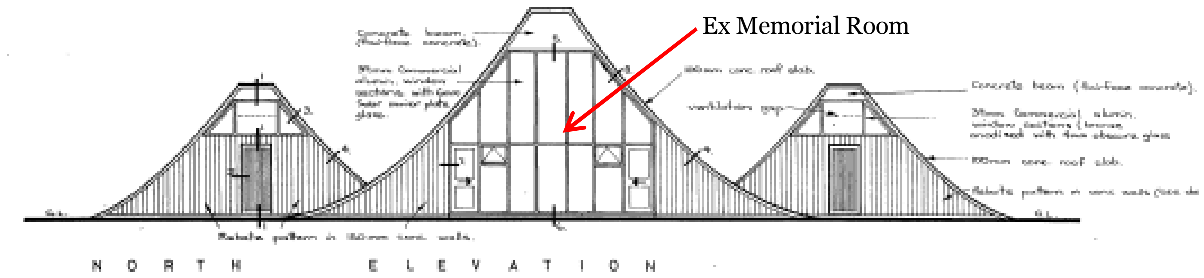

Figure 2: North elevation of the Ex Memorial Room and public toilets.

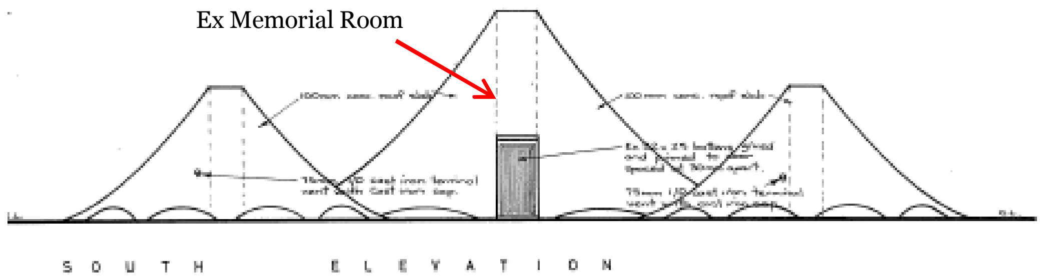

Figure 3: South elevation of the Ex Memorial Room and public toilets.

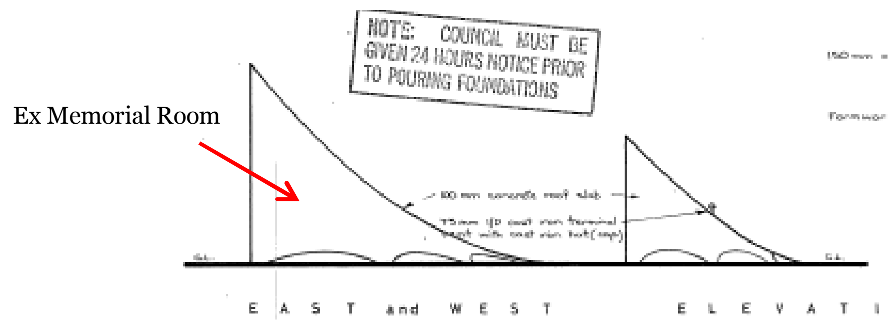

Figure 4: Side elevation of the Ex Memorial Room and public toilets.

The structure consists of a shaped, external, reinforced concrete roof slab on top of internal and external reinforced concrete walls. The roof slab is 100mm thick and reinforced in both directions, the walls are 150mm thick and reinforced in both directions. Figure 5 shows the ground floor plan of the Ex Memorial Room, showing the location of the internal concrete walls and the external concrete walls along the front face. The void bound by the roof slab, the walls and the ground was filled with 'water compacted sand', according to the Waimairi County Council drawings. As seen in

Figure 2, the front wall of the building is glazed from ground to roof height between the concrete walls.

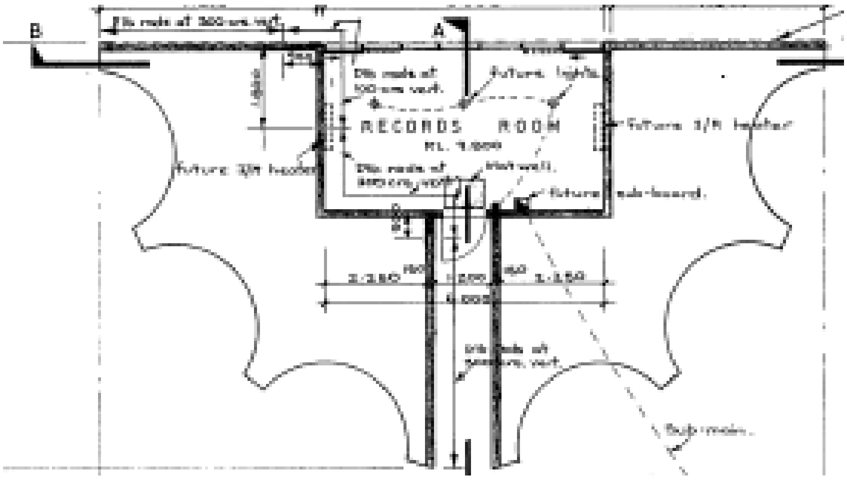

Figure 5: Ground floor plan of the Ex Memorial Room.

4.2 Gravity Load Resisting System

Gravity loads are resisted by the reinforced concrete roof slab and the reinforced concrete walls. These elements are supported on 300mm deep strip footings of varying widths. Figure 6 shows a cross-section through the front of the structure which shows the primary gravity load resisting elements.

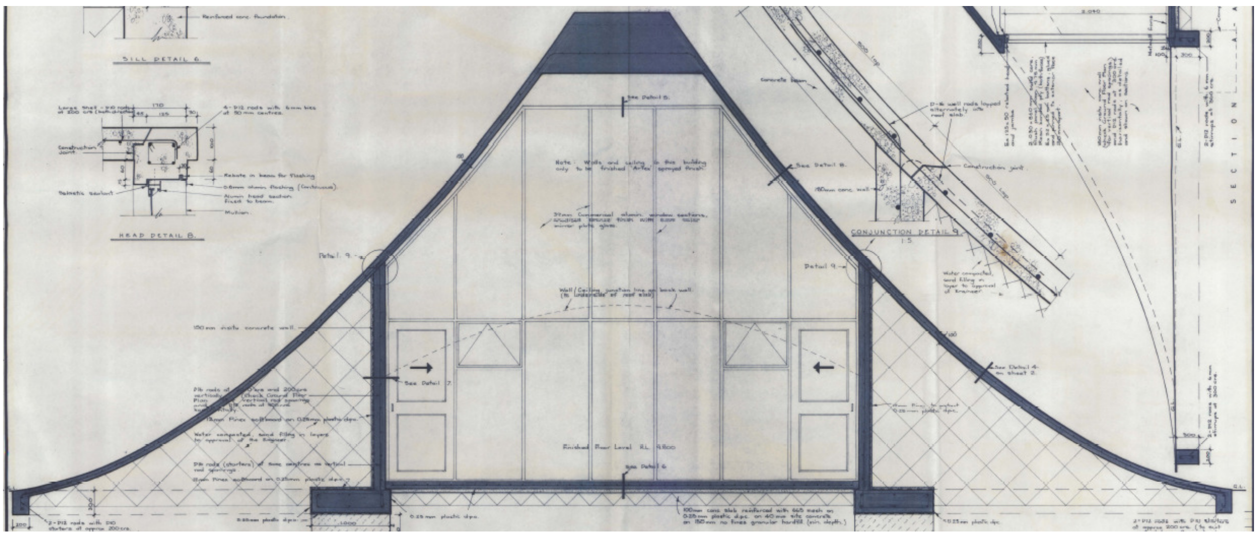

Figure 6: Cross-section through the front of the Ex Memorial Room.

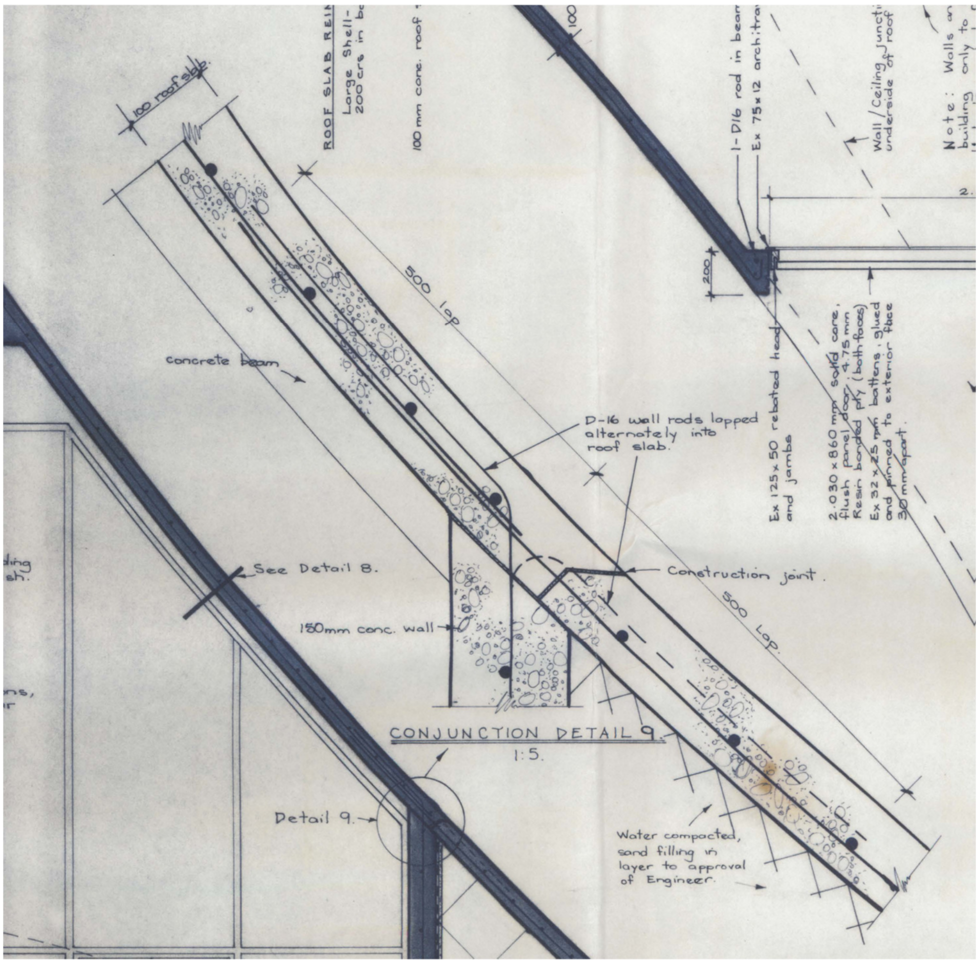

Figure 7 - Conjunction Detail (9)

4.3 Seismic Load Resisting System

Seismic loads are resisted by the same elements as the gravity loads.

5 Survey

An external inspection of the structure was conducted by Opus on 27 July 2012. The investigation was non-intrusive and internal access to the building was not available at the time.

6 Damage Assessment

No earthquake-induced damage to the structure was noticed during the inspection by Opus. This inspection only included the above-ground, external structure and so damage to the footings and internal structure, if present, would not have been observed.

7 General Observations

The building is a very rigid structure that is likely to move as a whole during an earthquake. It appears to have performed as expected during the Canterbury Earthquakes starting in September, 2011.

8 Detailed Seismic Assessment

The detailed seismic assessment has been based on the NZSEE 2006 [2] guidelines for the "Assessment and Improvement of the Structural Performance of Buildings in Earthquakes" together with the "Guidance on Detailed Engineering Evaluation of Earthquake Affected Non-residential Buildings in Canterbury, Part 2 Evaluation Procedure" [3] draft document prepared by the Engineering Advisory Group on 19 July 2011, and the SESOC guidelines "Practice Note – Design of Conventional Structural Systems Following Canterbury Earthquakes" [5] issued on 21 December 2011.

8.1 Critical Structural Weaknesses

The term Critical Structural Weakness (CSW) refers to a component of a building that could contribute to increased levels of damage or cause premature collapse of a building. No potential CSW's have been identified.

8.2 Seismic Coefficient Parameters

The analysis of the structure was conducted using the SAP2000 software package. A response spectrum analysis was used and the following inputs were required:

- Soil Type D
- Z = 0.3 (Christchurch)
- R = 1.0 (Importance Level 2)
- D ≥ 20km (Christchurch)
- $S_p = 0.925$ ($\mu = 1.25$)
- $k_\mu = 1.143$ ($\mu = 1.25$, $T \leq 0.4$s)
- $g = 9.81$ m.s^{-1}

8.3 Expected Ductility Factors

It is anticipated that the structure would behave in a nominally ductile manner and so a ductility factor of 1.25 was assumed for all seismic loading.

8.4 Detailed Seismic Assessment Results

A summary of the structural performance of the building is shown in the following table. Note that the values given represent the worst performing elements in the building, as these effectively define the building's capacity. Other elements within the building may have significantly greater capacity when compared with the governing elements.

Table 2: Summary of Seismic Performance

Structural Element/System	Failure mode and description of limiting criteria	Critical Structural Weakness and Collapse Hazard	% NBS based on calculated capacity
Reinforced concrete roof slab.	In-plane shear.	No.	>100%
	Out-of-plane bending.	No.	>100%
	Out-of-plane shear.	No.	>100%
Reinforced concrete walls.	In-plane shear.	No.	>100%
	Out-of-plane bending.	No.	>100%
	Out-of-plane shear	No.	>100%

8.5 Discussion of Results

The results of the analysis show that the building is not earthquake prone and is greater than 100% NBS. This is expected given the reinforced concrete shell construction.

The building is classified as a low risk building in accordance with NZSEE guidelines.

8.6 Limitations and Assumptions in Results

The observed level of damage suffered by the building was deemed low enough to not affect the capacity. Therefore the analysis and assessment of the building was based on it being in an undamaged state. There may have been damage to the building that was unable to be observed that could cause the capacity of the building to be reduced; therefore the current capacity of the building may be lower than that stated.

The results have been reported as a %NBS and the stated value is that obtained from our analysis and assessment. Despite the use of best national and international practice in this analysis and assessment, this value contains uncertainty due to the many assumptions and simplifications which are made during the assessment. These include:

a. Simplifications made in the analysis, including boundary conditions such as foundation fixity.
b. Assessments of material strengths based on limited drawings, specifications and site inspections
c. The normal variation in material properties which change from batch to batch.
d. Approximations made in the assessment of the capacity of each element, especially when considering the post-yield behaviour.

9 Summary of Geotechnical Appraisal

9.1 General

A geotechnical desktop investigation has been conducted for the Avonhead Park Pavilion Building on the adjacent Avonhead Park. The desktop assessment for the Pavilion Building used information gained predominantly from three Environment Canterbury (ECan) boreholes. Figure 8 shows the location of the Pavilion Building and the Ex Memorial Room relative to the ECan boreholes. As the proximity of the Ex Memorial Room to the boreholes is similar to that of the Pavilion Building, the geotechnical report for the Pavilion Building will also be relevant for the Ex Memorial Room. The full report is shown in Appendix B.

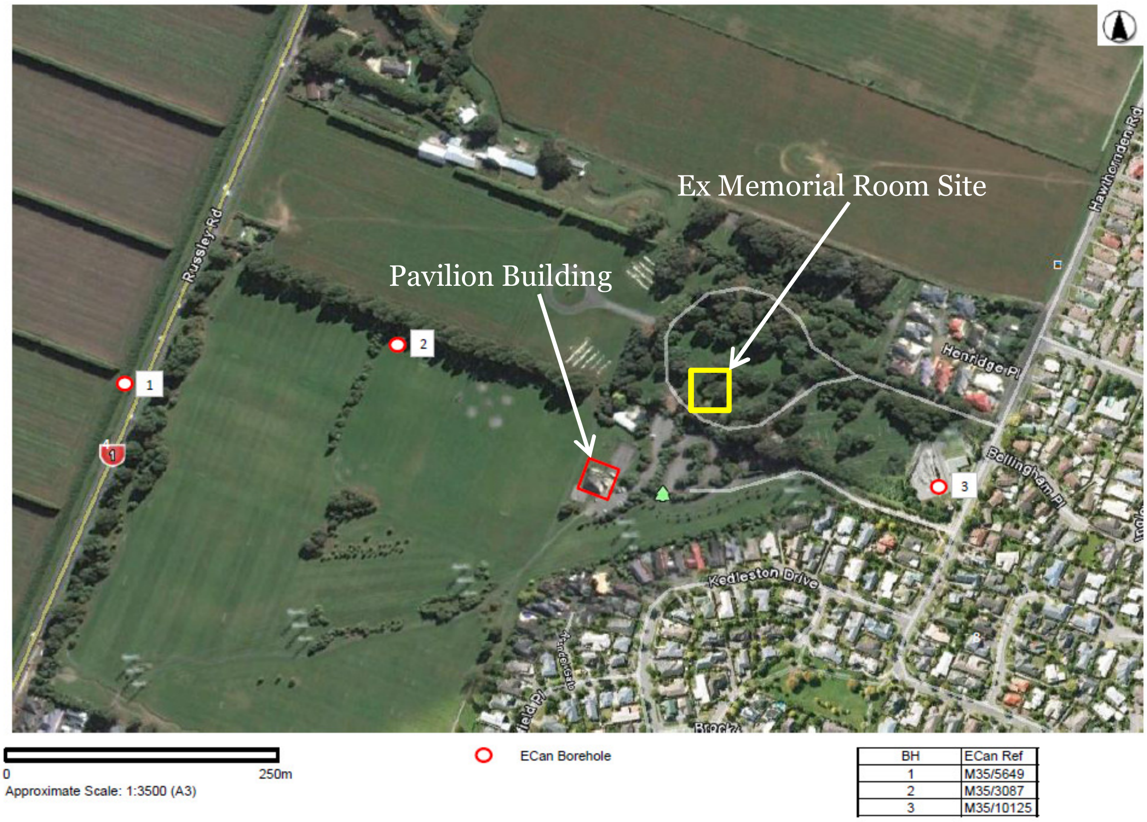

Figure 8: ECan borehole locations relative to the Pavilion Building and the Ex Memorial Room.

The published geological map of the area (Brown and Weeber, 1992) indicates the site is underlain on dominantly alluvial and silt overbank deposits belonging to the Yaldhurst Member of the Springstone Formation.

A groundwater depth of approximately 5.5m to 6.5m below ground level has been inferred from ECan groundwater depth contour maps (Elder et al., 2003).

The ECan boreholes have been used to infer the ground conditions at the site. These conditions are presented in Table 3.

Table 3: Inferred ground conditions for the Ex Memorial Room.

Geological Unit	Stratigraphy	Thickness (m)	Depth encountered below ground level (m)	Average groundwater level below ground (m)
Springston Formation (Yaldhurst Member)	SILT	2.0	0.0	5.5 - 6.5
	SAND	1.4	2.0	
	GRAVEL	-	3.0 – 3.4	

9.2 Liquefaction Hazard

A liquefaction hazard study was conducted by ECan in 2004. The study identified the Avonhead Park area has having 'low liquefaction ground damage potential'. Opus agrees with the assessment, citing the underlying dense gravels and the relatively deep groundwater levels as factors contributing to the low liquefaction hazard.

Following the Canterbury earthquake sequence beginning in September 2010, CERA has zoned land in the greater Christchurch area according to its expected ground performance in future large earthquakes. The Department of Building and Housing has sub-divided the CERA "Green" residential recovery zone land on the flat in Christchurch into three technical categories. As the Ex Memorial Room is on Council owned land, it was not subject to the zoning process. However, the surrounding residential area has been zoned as Green-TC1 "grey zone". This indicates negligible land deformation is expected in future small to medium sized earthquakes and up to minor land deformation in a future moderate to large earthquake.

Tonkin and Taylor Ltd, as the Earthquake Commission's geotechnical consultant, have prepared maps showing areas of liquefaction interpreted from high resolution aerial photographs for the September 2010, February 2011, June 2011 and December 2011 earthquakes. The photos indicated no evidence of liquefaction in the vicinity of the site.

9.3 Recommendations

The foundations system of the structure is considered appropriate for the site. No further geotechnical investigations are deemed necessary.

10 Conclusions

a) The structure is not considered Earthquake Prone in accordance with NZSEE guidelines and has a rating of 100%NBS.

b) No further geotechnical investigation is necessary for this building.

11 Limitations

- This report is based on information obtained from Waimairi County Council drawings and a non-intrusive site inspection. Some damage to the structure may not have been noticeable during the inspection and this report is not intended to be a complete reference for damage sustained by the structure.

- Our professional services are performing using a degree of care and skill normally exercised, under similar circumstances, by reputable consultants in this field at this time.

- This report is prepared for the Christchurch City Council to assist in the assessment of any remedial works required for the Avonhead Park Cemetery Ex Memorial Room. It is not intended for any other party or purpose.

12 References

[1] NZS 1170.5: 2004, Structural design actions, Part 5 Earthquake actions, Standards New Zealand.

[2] NZSEE (2006), Assessment and improvement of the structural performance of buildings in earthquakes, New Zealand Society for Earthquake Engineering.

[3] Engineering Advisory Group, Guidance on Detailed Engineering Evaluation of Earthquake Affected Non-residential Buildings in Canterbury, Part 2 Evaluation Procedure, Draft Prepared by the Engineering Advisory Group, Revision 5, 19 July 2011.

[4] Engineering Advisory Group, *Guidance on Detailed Engineering Evaluation of Non-residential buildings, Part 3 Technical Guidance*, Draft Prepared by the Engineering Advisory Group, 13 December 2011.

[5] SESOC (2011), Practice Note – Design of Conventional Structural Systems Following Canterbury Earthquakes, Structural Engineering Society of New Zealand, 21 December 2011.

[6] DBH (2012), Guidance for engineers assessing the seismic performance of non-residential and multi-unit residential buildings in greater Christchurch, Department of Building and Housing, June 2012.

Appendix 1 - Photographs

Ex Memorial Room, Avonhead Park Cemetery		
No.	Item description	Photo
1.	Front Elevation	
2.	Side Elevation	
3.	Rear Elevation	

Appendix 2 - Geotechnical Appraisal

20 November 2012

Michael Sheffield
Christchurch City Council
PO Box 2522
Addington
CHRISTCHURCH 8140

6-QUCC1.19

Dear Michael

Geotechnical Desk Study – Avonhead Park Pavilion

1. Introduction

Christchurch City Council (CCC) has commissioned Opus International Consultants (Opus) to undertake a brief Geotechnical Desk Study of the Avonhead Park Pavilion, Avonhead, Christchurch. The purpose of this study is to collate existing subsoil information, undertake an appraisal of the potential geotechnical hazards at this site and determine whether further investigations are required.

This Geotechnical Desk Study has been prepared in accordance with the Engineering Advisory Group's Guidance on Detailed Engineering Evaluation of Earthquake Affected Non-residential Buildings in Canterbury, Revision 5, 19 July 2011.

This geotechnical desk study has been undertaken without the benefit of any site specific investigations and is therefore preliminary in nature.

2. Desktop Study

2.1 Site Description

The Avonhead Park Pavilion is located at 146 Hawthornden Road on the eastern boundary of Avonhead Park. The Pavilion occupies an approximate footprint of 400m^2.

The Avonhead Park Pavilion building is bounded by a carpark to the south, tennis court to the east, and grassed areas of Avonhead Park to the north and west.

The ground profile is relatively flat, low lying and is typically level with the surrounding car park and grassed areas. The grounds surrounding the site are generally grassed with planted areas and with a small portion surfaced with concrete pavers.

2.2 Structural Drawings

Structural Drawings of the Pavilion have not been available for review. Based upon the photographs, the superstructure appears predominantly constructed from concrete masonry blocks. It is assumed that the building is founded on perimeter strip footings and concrete floor slab on grade.

No geotechnical investigations or geotechnical reports associated with the building were available on the CCC property file.

2.3 Regional Geology

The published geological map of the area, (Geology of the Christchurch Urban Area 1:25,000, Brown and Weeber, 1992) indicates the site is underlain on dominantly alluvial and silt overbank deposits belonging to the Yaldhurst Member of the Springston Formation.

2.4 Expected Ground Conditions

A review of the Environmental Canterbury (ECan) wells database showed three wells located within approximately 430 m of the property (refer to Site Location Plan in Appendix B).

Material logs available from ECan have been used to infer the ground conditions at the site, as shown in Table 1 below.

Table 1: Inferred Ground Conditions

Stratigraphy	Thickness (m)	Depth Encountered (m)
SILT	2.0	Surface
SAND	1.4	2
GRAVEL	-	3.0-3.4

A groundwater depth of approximately 5.5m to 6.5m below ground level has been interpreted from groundwater depth contour maps (Environment Canterbury (2003) and Elder et al. (1991)).

2.5 Liquefaction Hazard

A liquefaction hazard study was conducted by the Canterbury Regional Council (ECan) in 2004 to identify areas of Christchurch susceptible to liquefaction during an earthquake. The Avonhead Park Pavilion is located in an area identified as having 'low liquefaction ground damage potential'. According to this study, based on a low groundwater table, ground damage from liquefaction is expected to be minor and is likely to be affected by less than 100mm of ground subsidence.

Tonkin and Taylor Ltd (T&T Ltd) the Earthquake Commission's (EQC) geotechnical consultants have prepared maps showing areas of liquefaction interpreted from high resolution aerial photos for the September 2010 earthquake and the aftershocks of February 2011, June 2011 and December 2011. There has been no evidence of liquefaction in the vicinity.

Following the recent strong earthquakes in Canterbury, the Canterbury Earthquake Recovery Authority (CERA, 2012) has zoned land in the Greater Christchurch area according to its ground performance in future large earthquakes.

The Department of Building and Housing has sub-divided the CERA "Green" residential recovery zone land on the flat in Christchurch into technical categories. The three technical categories are summarised in Table 2 which has been adapted from the Department of Building and Housing guidance document (DBH, 2011).

Table 2: Technical Categories based on Expected Land Performance

Foundation Technical Category	Future land performance expected from liquefaction	Expected SLS land settlement	Expected ULS land settlement
TC 1	Negligible land deformations expected in a future small to medium sized earthquake and up to minor land deformations in a future moderate to large earthquake.	0-15 mm	0-25 mm
TC 2	Minor land deformations possible in a future small to medium sized earthquake and up to moderate land deformations in a future moderate to large earthquake.	0-50 mm	0-100 mm
TC 3	Moderate land deformations possible in a future small to medium sized earthquake and significant land deformations in a future moderate to large earthquake.	>50 mm	>100 mm

The land at Avonhead Park has been zoned as N/A-Urban Non-residential. However, the neighbouring properties 70m south have been zoned as Green-TC1 "grey zone", which indicates negligible land deformation is expected in future small to medium sized earthquakes and up to minor land deformation in a future moderate to large earthquake.

3. Observations

A walkover inspection of the exterior and interior was carried out by an Opus Structural Engineer on 24 May 2012. No evidence of liquefaction, surface rupture or lateral spreading due to the recent earthquakes was observed at the Avonhead Park Pavilion Site.

4. Discussion

ECan well logs indicate the building is founded on a layer of silt and sand overlying a thick densely packed gravel layer. Liquefaction typically occurs in recent (i.e. less than 10,000 years old), normally consolidated silts and sands beneath groundwater and is dependent on material density, grain size and soil composition. We would expect that liquefaction is unlikely at the Avonhead Park due to the underlying dense gravels and relatively deep groundwater level. The lack of ground damage reported at the site during the recent earthquakes of 2010 and 2011 confirms that the site is at low risk of liquefaction.

There are no streams or open water courses within close proximity of the site. Accordingly, the site is evaluated to not be at risk of lateral spreading.

GNS Science indicates an elevated risk of seismic activity is expected in the Canterbury region as a result of the earthquake sequence following the 4 September 2010 earthquake. Recent advice (Geonet) indicates there is currently a 12% probability of another Magnitude 6 or greater earthquake occurring in the next 12 months in the Canterbury region. It is expected that the probability of occurrence is likely to decrease with time, following periods of reduced seismic activity.

Based on current evidence, the existing foundations are considered appropriate for the building with the client's acceptance that the potential for minor differential settlement may occur in future seismic events.

5. Recommendations

It is recommended that;

- Based on the past performance in recent earthquakes and the presence of shallow dense gravels, the existing foundations should be acceptable in terms of future ultimate limit state (ULS) and serviceability limit state (SLS) loadings, although CCC may have to accept the risk for potential differential settlement in the order of 0 to 50mm in a future seismic event.

6. Limitation

This report has been prepared solely for the benefit of Christchurch City Council as our client with respect to the particular brief given to us. Data or opinions in this desk study may not be used in other contexts, by any other party or for any other purpose.

It is recognised that the passage of time affects the information and assessment provided in this Document. Opus's opinions are based upon information that existed at the time of the production of this Desk Study. It is understood that the Services provided allowed Opus to form no more than an opinion on the actual conditions of the site at the time the site was visited and cannot be used to assess the effect of any subsequent changes in the quality of the site, or its surroundings or any laws or regulations.

7. References:

Brown, LJ; Webber, JH 1992: Geology of the Christchurch Urban Area. Scale 1:25,000. Institute of Geological and Nuclear Sciences geological map, 1 sheet + 104p.

Environment Canterbury, Canterbury Regional Council (ECan) website:

ECan Well Card
http://ecan.govt.nz/services/online-services/tools-calculators/Pages/well-card.aspx

ECan 2004: The Soild Facts on Christchurch Liquefaction. Canterbury Regional Council, Christchurch, 1 sheet.

Project Orbit, 2011: Interagency/organisation collaboration portal for Christchurch recovery effort. https://canterburyrecovery.projectorbit.com/SitePages/Home.aspx

GNS Science reporting on Geonet Website: http://www.geonet.org.nz/canterbury-quakes/aftershocks/ updated on 28 May 2012.

Appendices:
Appendix A: Site Photographs
Appendix B: Site Location Plans
Appendix C: Surrounding Site Investigation Data

Appendix A:
Site Photographs

Figure 1: West elevation of the Avonhead Park Pavilion.

Figure 2: East elevation of the Avonhead Park Pavilion.

Appendix B:
Site Location Plan

0 — 250m
Approximate Scale: 1:3500 (A3)

ECan Borehole

BH	ECan Ref
1	M35/5649
2	M35/3087
3	M35/10125

OPUS

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Project: Avonhead Park Pavilion Geotechnical Desktop Study

Project No: 6-QUCC1.19

Client: Christchurch City Council

Site Location Plan

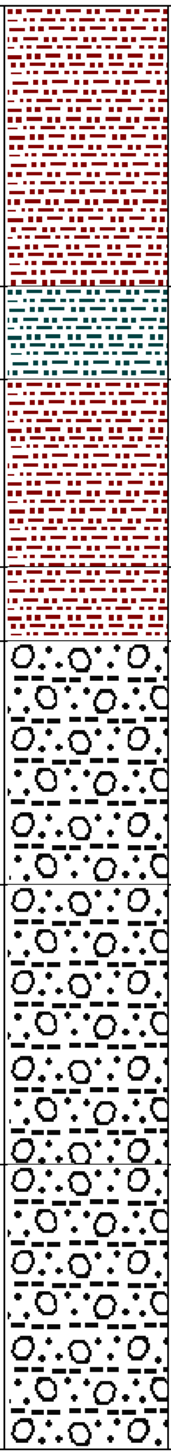
Drawn: Opus Geotechnical Engineer

Date: 22/06/2012

Appendix C:
Surrounding Site Investigation Data

Borelog for well M35/10125 page 1 of 2

Gridref: M35:7361-4406 Accuracy : 4 (1=high, 5=low)
Ground Level Altitude : 23.18 +MSD
Driller : CW Drilling and Investigation
Drill Method : Rotary Rig
Drill Depth : -15.45m Drill Date : 9/03/2004



Scale(m)	Water Level	Depth(m)	Full Drillers Description	Formation Code
-1		-1.50m	Loose light brown silt. Minor fine sand. Dry	sp
-2		-2.00m	Light orange, faintly bedded, thinly laminated sub-horizontal bedding silt. Minor fine sand	sp
-3		-3.00m	Loose dark brown to brown, fine to medium sand, trace silt	sp
		-3.40m	Medium dense dark brown to brown, fine to medium sand, trace silt.	sp
-4		-4.70m	Medium dense light,brown,grey fine to very coarse gravel. Some sand trace silt dry. Gravel well graded,sub-rounded elongate greywacke gravel	sp
-5, -6	-5	-6.20m	Dense light brown,grey fine to very coarse gravel. Some sand trace silt dry. Gravel well graded,sub-rounded elongate greywacke gravel	sp
-7		-7.72m	Medium dense light brown,grey fine to very coarse gravel. Some sand trace silt dry. Gravel well graded,sub-rounded elongate greywacke gravel	sp

Borelog for well M35/10125 page 2 of 2

Gridref: M35:7361-4406 Accuracy : 4 (1=high, 5=low)
Ground Level Altitude : 23.18 +MSD
Driller : CW Drilling and Investigation
Drill Method : Rotary Rig
Drill Depth : -15.45m Drill Date : 9/03/2004

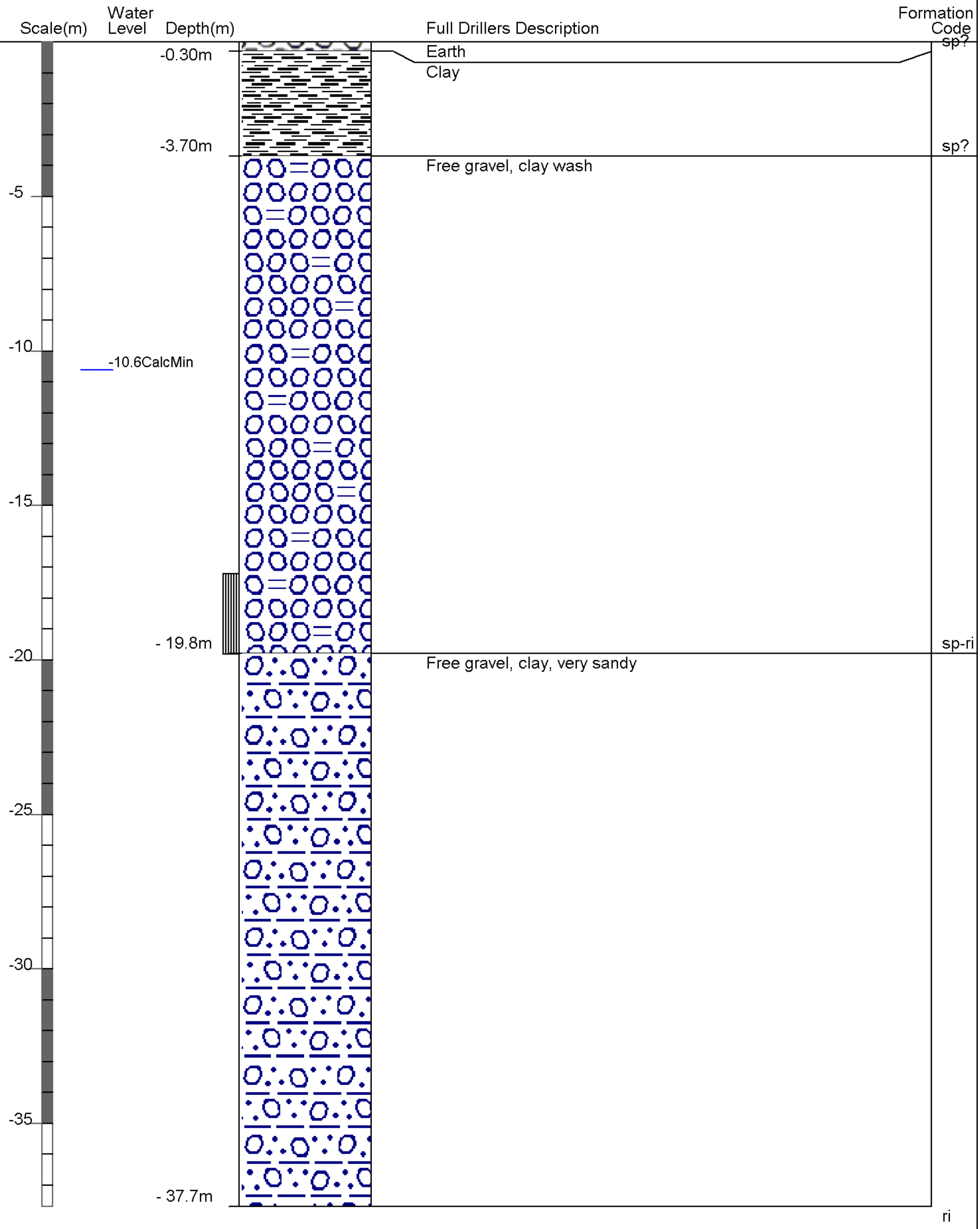
Environment Canterbury Regional Council

Water Level: -8.7CalcMin

Depth(m)	Full Drillers Description	Formation Code
-9.00m	Medium dense light brown,grey fine to very coarse gravel. Some sand trace silt dry. Gravel well graded,sub-rounded elongate greywacke gravel	sp
-9.20m	Light brown,grey fine to very coarse gravel. Some sand trace silt moist. Gravel well graded,sub-rounded elongate greywacke gravel	sp
- 10.0m	Dense light brown,grey fine to very coarse gravel. Some sand trace silt dry. Gravel well graded,sub-rounded elongate	sp
- 10.5m	Medium dense light brown,grey fine to very coarse gravel. Some sand trace silt moist. Gravel well graded,sub-rounded elongate greywacke gravel	sp
- 11.5m	Loose light brown,grey fine to very coarse gravel. Some sand trace silt wet. Gravel well graded,sub-rounded elongate greywacke gravel	sp
- 12.0m	Trace medium sand light brown,grey fine to very coarse gravel.Trace silt dry. Gravel well graded,sub-rounded elongate greywacke gravel	sp
- 13.5m	Dense light greyish brown, gravelly fine to medium sand. Wet non plastic. Gravel fine to very coarse well graded sub-rounded elongate greywacke gravel	sp
- 14.3m	Medium dense brownish grey fine to medium sandy fine to very coarse gravel. Trace silt wet non plastic. Gravel well graded sub-rounded elongate greywacke gravel	sp
- 14.9m	Medium dense brownish grey fine to medium sandy fine to very coarse gravel. Trace silt wet non plastic. Gravel well graded sub-rounded elongate greywacke gravel. Dark orange colouration iron oxide staining	sp
- 15.4m	Light brown matrix grey gravel some sand	sp

Borelog for well M35/3087

Gridref: M35:731-442 Accuracy : 4 (1=best, 4=worst)
Ground Level Altitude : 27.3 +MSD
Driller : McMillan Water Wells Ltd
Drill Method : Unknown
Drill Depth : -37.7m Drill Date : 12/01/1983

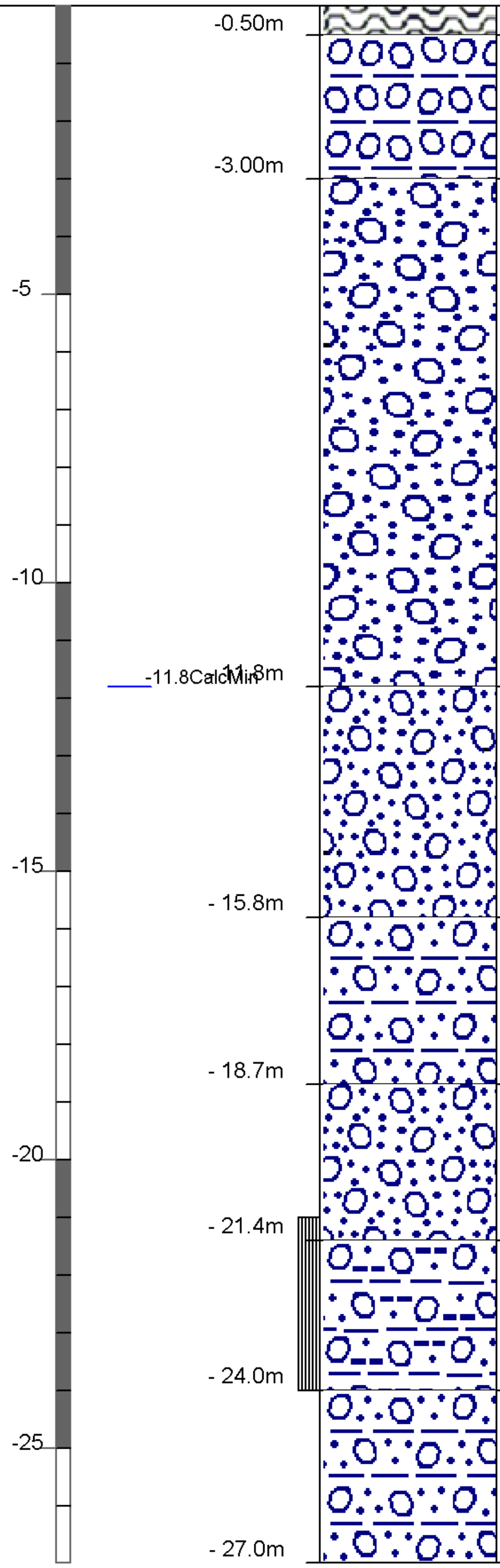


Borelog for well M35/5649

Gridref: M35:728-442 Accuracy : 4 (1=best, 4=worst)
Ground Level Altitude : 28.5 +MSD
Driller : Washingtons Exploration Ltd
Drill Method : Cable Tool
Drill Depth : -27m Drill Date : 10/05/1988

Depth(m)	Full Drillers Description	Formation Code
-0.50m	Topsoil	sp?
-3.00m	Clay and gravels	sp?
-11.8m	Medium to large gravels and sand	sp?
- 15.8m	Brown and Grey small to medium gravels and sand	ri
- 18.7m	Grey gravels and sand with clay layers	ri
- 21.4m	Grey gravels and sand	ri
- 24.0m	Grey gravels and sand, some silty clay	ri
- 27.0m	Grey gravels and sand, bands of claybound gravels	ri

Water Level: -11.8CalcMin



Appendix 3 – Analysis Methodology and Assumptions

Overview

In order to capture the complex geometry of the reinforced concrete roof slab and the reinforced concrete walls, the structure was modelled using the AutoCAD software package and then imported into the SAP2000 software package to undergo the structural analysis. A response spectrum analysis was required due to the complex distribution of mass and stiffness in the structure. Cracked section modifiers of 0.35 were used for bending in all reinforced concrete members.

Gravity Loads

The total gravity loads on the structure resulted from the self-weight of the reinforced concrete roof slab and walls and the static pressure on the walls from the compacted sand between the roof slab and the walls. This pressure was found by assuming a 35° failure slope in the sand and by assuming the lateral load was distributed uniformly across the wall.

Seismic Loads

Like the gravity loads, seismic loads were split between the self-weight of the reinforced concrete elements and the additional load from the sand.

The loads from the self-weight of the reinforced concrete elements were obtained using a response spectrum analysis with the parameters outlined in Section 8.2. As the structure is very stiff, the plateau of the elastic spectrum was extended to the T=0 ordinate. This was to conservatively ensure that any variability between the modal periods of the modelled structure and the actual structure did not reduce the loading on the structure. The scale factor applied to the elastic spectrum was as follows:

$$SF = g\frac{S_p}{k_\mu}$$

$$SF = 9.81 \times \frac{0.925}{1.143}$$

$$SF = 7.94$$

As the structure was considered to be nominally ductile, actions in both orthogonal directions had to be combined as per NZS 1170.5 requirements. The directional combination was conducted using as an absolute sum as per NZS 1170.5. The modal combination of actions was implemented using the CQC method.

The additional sand loading due to dynamic affects was applied to the reinforced concrete walls by assuming they are 'stiff' walls. This means a uniform pressure distribution across the wall is applied[2] with magnitude equal to:

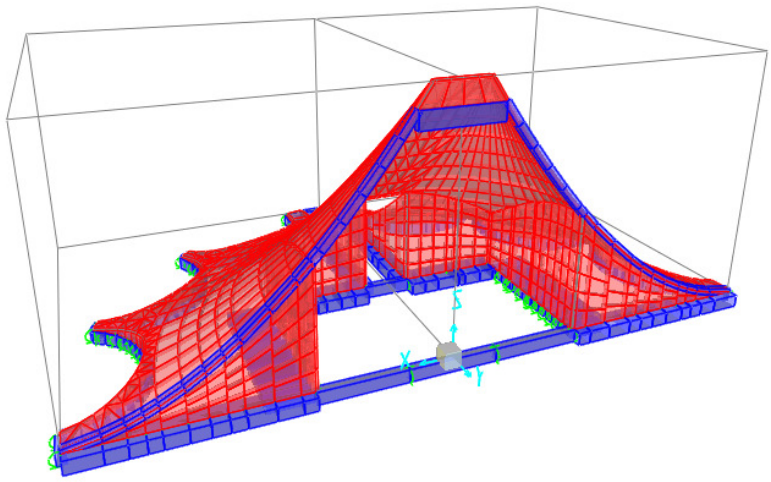
$$P(x,z) = 0.75 \times C(0) \times \gamma_{sand} \times H_{wall}$$

The unit weight of the wet sand was assumed to be 20 kN.m^{-3}. As the wall heights have some variability, the pressure for the highest part of the wall was used over all walls.

[2] Opus Technical Document CEP 702: Retaining Wall Design Notes (1997).

Model

A screenshot of the SAP2000 model is shown below.



%NBS Calculation

SAP2000 outputs contour plots across the structure. These plots were used to display in-plane shear, out-of-plane bending moments in both directions and out-of-plane shear for the reinforced concrete roof slab and walls. These were then compared against the section capacities of the elements to give a %NBS rating for the structure.

Appendix 4 – CERA DEE Spreadsheet

Detailed Engineering Evaluation Summary Data V1.11

Location

Building Name:	Avonhead Park Cemetery Ex Memorial Room	Reviewer:	John Newall
	Unit / No: 140 / Street: Hawthornden St	CPEng No:	1018146
Building Address:	140 Hawthornden St	Company:	Opus
Legal Description:		Company project number:	6-QUCC1.60
		Company phone number:	33635400
	Degrees / Min / Sec		
GPS south:		Date of submission:	12/04/2013
GPS east:		Inspection Date:	27/07/2012
		Revision:	Final
Building Unique Identifier (CCC):	PRK_0217_BLDG_005 EQ2	Is there a full report with this summary?	yes

Site

Site slope:	flat	Max retaining height (m):	
Soil type:	gravel	Soil Profile (if available):	
Site Class (to NZS1170.5):	D		
Proximity to waterway (m, if <100m):		If Ground improvement on site, describe:	
Proximity to clifftop (m, if < 100m):			
Proximity to cliff base (m,if <100m):		Approx site elevation (m):	

Building

No. of storeys above ground:	1 (single storey = 1)	Ground floor elevation (Absolute) (m):	
Ground floor split?	no	Ground floor elevation above ground (m):	
Storeys below ground			
Foundation type:	strip footings	if Foundation type is other, describe:	
Building height (m):		height from ground to level of uppermost seismic mass (for IEP only) (m):	
Floor footprint area (approx):			
Age of Building (years):		Date of design:	1976-1992
Strengthening present?	no	If so, when (year)?	
		And what load level (%g)?	
Use (ground floor):	public	Brief strengthening description:	
Use (upper floors):			
Use notes (if required):			
Importance level (to NZS1170.5):	IL2		

Gravity Structure

Gravity System:	load bearing walls		
Roof:	concrete	slab thickness (mm)	100
Floors:	concrete flat slab	slab thickness (mm)	100
Beams:	none	overall depth x width (mm x mm)	
Columns:			
Walls:	load bearing concrete	#N/A	

Lateral load resisting structure

Note: Define along and across in detailed report!

Lateral system along:	concrete shear wall		enter wall data in "IEP period calcs" worksheet for period calculation	
Ductility assumed, μ:	1.25			
Period along:	0.05	##### enter height above at H31	estimate or calculation?	calculated
Total deflection (ULS) (mm):			estimate or calculation?	
maximum interstorey deflection (ULS) (mm):			estimate or calculation?	
Lateral system across:	concrete shear wall		enter wall data in "IEP period calcs" worksheet for period calculation	
Ductility assumed, μ:	1.25			
Period across:	0.05	##### enter height above at H31	estimate or calculation?	calculated
Total deflection (ULS) (mm):			estimate or calculation?	
maximum interstorey deflection (ULS) (mm):			estimate or calculation?	

Separations:

north (mm):		leave blank if not relevant
east (mm):		
south (mm):		
west (mm):		

Non-structural elements

Stairs:	
Wall cladding:	
Roof Cladding:	
Glazing:	
Ceilings:	
Services(list):	

Available documentation

Architectural	partial	original designer name/date	
Structural	partial	original designer name/date	
Mechanical		original designer name/date	
Electrical		original designer name/date	
Geotech report	partial	original designer name/date	

Damage

Site: (refer DEE Table 4-2)

Site performance:		Describe damage:	
Settlement:	none observed	notes (if applicable):	
Differential settlement:	none observed	notes (if applicable):	
Liquefaction:	none apparent	notes (if applicable):	
Lateral Spread:	none apparent	notes (if applicable):	
Differential lateral spread:	none apparent	notes (if applicable):	
Ground cracks:	none apparent	notes (if applicable):	
Damage to area:	none apparent	notes (if applicable):	

Building:

	Current Placard Status:	green		
Along	Damage ratio:	0%	Describe how damage ratio arrived at:	
	Describe (summary):			
Across	Damage ratio:	0%		
	Describe (summary):			
Diaphragms	Damage?:	no	Describe:	
CSWs:	Damage?:	no	Describe:	
Pounding:	Damage?:	no	Describe:	
Non-structural:	Damage?:	no	Describe:	

$$Damage\_Ratio = \frac{(\%NBS\,(before) - \%NBS\,(after))}{\%NBS\,(before)}$$

Recommendations

	Level of repair/strengthening required:	none		Describe:
	Building Consent required:	no		Describe:
	Interim occupancy recommendations:	full occupancy		Describe:
Along	Assessed %NBS before e'quakes:	100%	##### %NBS from IEP below	If IEP not used, please detail assessment methodology: Quantitative
	Assessed %NBS after e'quakes:	100%		
Across	Assessed %NBS before e'quakes:	100%	##### %NBS from IEP below	
	Assessed %NBS after e'quakes:	100%		

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