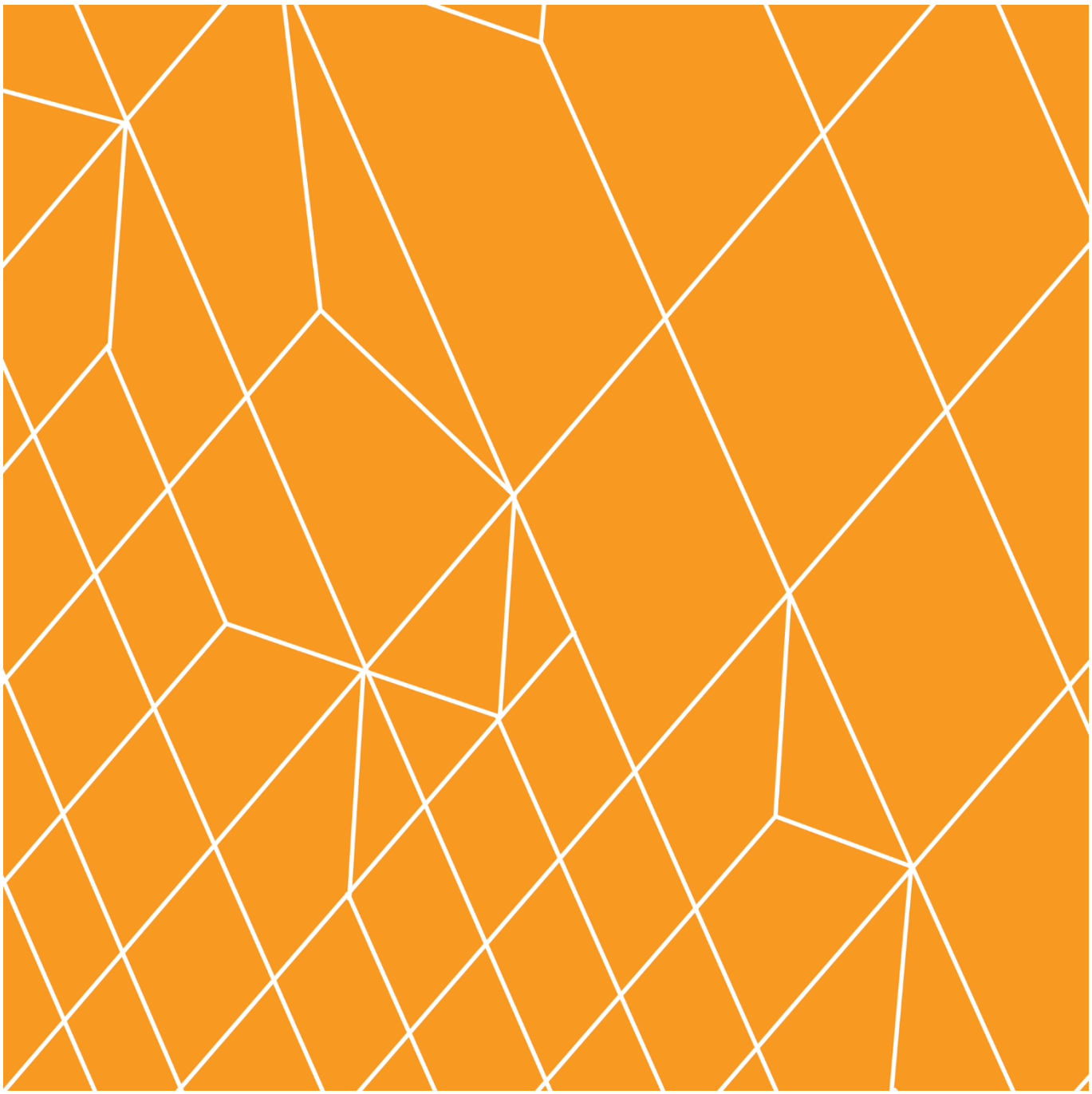


Seismic Strengthening Options Summary
Robert McDougall Gallery

Rolleston Avenue

Report

Holmes Consulting

Revision 1.0
28 November 2017
104653.05

Holmes Consulting

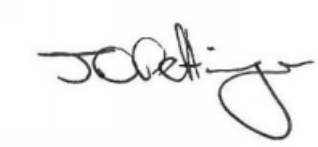
Level 2, 254 Montreal Street
Christchurch Central
PO Box 6718
Christchurch 8442
holmesgroup.com

Report
Robert McDougall Gallery Seismic Strengthening – 2017: Options Summary

Prepared For:
Christchurch City Council

Date: 28 November 2017
Project No: 104653.05
Revision No: 1.0

Prepared By:



Didier Pettinga
SENIOR PROJECT ENGINEER
Holmes Consulting LP

Reviewed By:

Richard Seville
BUSINESS MANAGER

Report Issue Register

DATE	REV. NO.	REASON FOR ISSUE
28/11/17	1.0	Issued to CCC

CONTENTS

Holmes

1 EXECUTIVE SUMMARY

The structural seismic capacity of the Robert McDougall Art Gallery was assessed in 2012/2013. The key structural issues identified at the time were;

1. Wall in-plane shear capacity i.e. the ability of the main walls to sustain shear stresses acting along the length of the walls. In-plane shear seismic performance was rated at 67%*NBS* (Importance Level 3) and this behaviour did not govern the seismic performance of the building and it is not considered necessary to strengthen for these actions.

2. Wall out-of-plane flexural capacity i.e. the ability of the main walls to resist forces that push the wall in/outwards from the building, perpendicular to the wall length. This behaviour is considered critical for the structural capacity with perimeter walls being < 33%*NBS* and some internal walls <67%*NBS* (IL3).

3. Loss of gravity support for the skylight lintel beams over the north and south wings due to failure of the masonry piers supporting the beams (< 33%*NBS* IL3).

4. Parapet toppling capacity. This also is a critical issue for life-safety of occupants and people in the vicinity of the building exterior walls (<33%*NBS* IL3).

This report summarises the out-of-plane wall strengthening options previously put forward at a concept level. On the back of this, options for parapet restraint are also discussed which include a new concept option that would be applicable where the parapet has a number of corners and returns. These structural strengthening options target 67% of current code for Importance Level 3 demands (commensurate with the classification of the structure per the NZ Loading Standard AS/NZS1170.0) and can be summarised as follows;

1. The recommended out-of-plane wall strengthening is to introduce centre-cored grouted reinforcing bars at regular spacing around the perimeter of the building. On the critical north and south elevation walls, these bars would project above the roof slab and be connected to the back of the parapet walls. These bars would then also provide restraint to the parapets. To make detailing of the new roof membrane along these elevations easier, the new bars could be encased in a thin concrete wall that is formed against the back of the parapet. This would serve as corrosion protection to the bars and their fixings to the parapet, while also providing a stable substrate onto which the roof membrane can be lapped.

2. The introduction of steel posts to the inside of the north and south wings, that will provide vertical gravity load support at the ends of the skylight lintels, is a reasonably straight-forward strengthening solution and one that would not be achievable via hidden or external means. Previous discussions have indicated that a light-weight bulkhead could be used to frame-out and hide these posts.

3. Where deep internal gutters and large parapet height make centre-core bars insufficient or difficult to install due to the final waterproofing conditions, we have provided a whaler-beam detail. This allows such portions of parapet with regular corners and returns to effectively be self-restraining. In these areas the centre-core bars being used for the main wall out-of-plane strengthening can be stopped below the roof slab level, and the new roof membrane to be extended over the holes without complicated detailing.

Holmes Consulting LP have been engaged by the Christchurch City Council (CCC) to provide updated structural engineering advice on the options available for seismic strengthening of the Robert McDougall Art Gallery (RMAG). The concept strengthening options developed in 2012/2013 were completed in isolation

to any potential non-structural works that might be required such as roof replacement and weather-proofing.

The new phase of review has been initiated as part of a more general need for information on what structural strengthening work could be carried out in conjunction with proposed roof replacement and weather-proofing. These non-structural aspects are being covered by others, however the CCC has identified that a coordinated approach could aim to mitigate the need to penetrate/damage a new roof membrane in future. At the same time this coordination can provide a structural strengthening solution that allows simpler architectural/water-proofing details, to be prepared by others, to be formed around the back of the parapets.

It is noted that other aspects of building fit-out, relating to non-structural items that might require seismic restraint, are not dealt with in these primary structural strengthening schemes.

2 INTRODUCTION

Holmes Consulting LP have been engaged by the Christchurch City Council (CCC) to provide structural engineering advice on the options available for seismic strengthening of the Robert McDougall Art Gallery. As outlined in the scope below, this initial phase of reporting draws on earlier assessment and reporting completed by Holmes Consulting in 2012 and 2013[i]. The concept strengthening options developed at that time were completed in isolation to any potential non-structural works that might be required such as roof replacement and weather-proofing.

The seismic strengthening options presented here focus on the two critical structural weaknesses previously identified by our analyses. The first is the out-of-plane stability of the exterior walls (and a limited number of interior walls), while the second is the unrestrained parapets.

The new phase of review has been initiated as part of a more general need for information on what structural strengthening work could be carried out in conjunction with proposed roof replacement and weather-proofing. These non-structural aspects are being covered by others, however the CCC has identified that a coordinated approach could aim to mitigate the need to penetrate/damage a new roof membrane in future, and at the same time provide a structural strengthening solution that allows simpler architectural/water-proofing details, to be prepared by others, to be formed around the back of the parapets.

This report summarises the out-of-plane wall strengthening options previously put forward at a concept level. On the back of this, options for parapet restraint are also discussed which include a new concept option that would be applicable where the parapet has a number of corners and returns.

3 SCOPE OF WORK

The scope of work for this project included the following:

1. Provide a brief summary of the seismic repair and strengthening options for the Robert McDougall Art Gallery (RMAG) structure that have been conceptually developed through 2012 and 2013
2. With the CCC, Heritage Architect and Environmental Consultants meet on-site and consultant team meetings to review the scope of structural strengthening and how this would potentially interact with proposed water-proofing works that are being considered for the roof and parapet areas.

4 LIMITATIONS

Findings presented as a part of this project are for the sole use of the client in its evaluation of the subject properties. The findings are not intended for use by other parties, and may not contain sufficient information for the purposes of other parties or other uses.

Our observations have been visual only and are limited to representative samples, as described in our record of observations. Our observations have been restricted to structural aspects only. Waterproofing elements, electrical and mechanical equipment, fire protection and safety systems, service connections, water supplies and sanitary fittings have not been inspected or reviewed, and secondary elements such as windows and fittings have not generally been reviewed.

Our professional services are performed using a degree of care and skill normally exercised, under similar circumstances, by reputable consultants practicing in this field at this time. No other warranty, expressed or implied, is made as to the professional advice presented in this report.

5 SUMMARY OF CURRENT SEISMIC CAPACITY AND PERFORMANCE

5.1 Building Form

The Robert McDougall Art Gallery was designed in 1930 and building opened in 1932. The original building is predominantly one storey with basement through approximately two thirds of the footprint (the original basement only extended on the east side of the building but was subsequently extended). Above the entrance hall there is a second floor with office space. The Canaday Wing attached to the north end of the gallery is a two storey addition constructed in 1983 (Figure 5-1).

The gallery is constructed of unreinforced masonry with the walls varying from two to three wythes (layers) thick. Around the exterior walls there is a single brick veneer that is tied (with wire ties) to the two wythe main wall. The original building layout is essentially symmetrical about both principal axes with the regular layout of masonry walls providing the seismic lateral force resisting system.

The walls are generally tied together at their top by concrete (assumed to be lightly reinforced) roof slabs although these slabs are not complete plate elements due to the presence of the central skylights. The main floor is an in-situ reinforced concrete slab on in-situ concrete beams. The foundations are formed by strip footings beneath the basement wall lines (which correspond to the gallery walls above) and individual pad footings beneath the interior columns.

The Canaday Wing is constructed from a mixture of concrete block walls (assumed to be partially filled and reinforced), steel framing and timber flooring. Given the relatively new age of construction, it is expected that this will have had a level of seismic design carried out, commensurate with the building code requirements of that time.

Due to the buildings heritage classification and more-so due to the contents of the building, it is considered an Importance Level 3 (IL3) structure under the current New Zealand Loading Standard AS/NZS1170.0:2002.

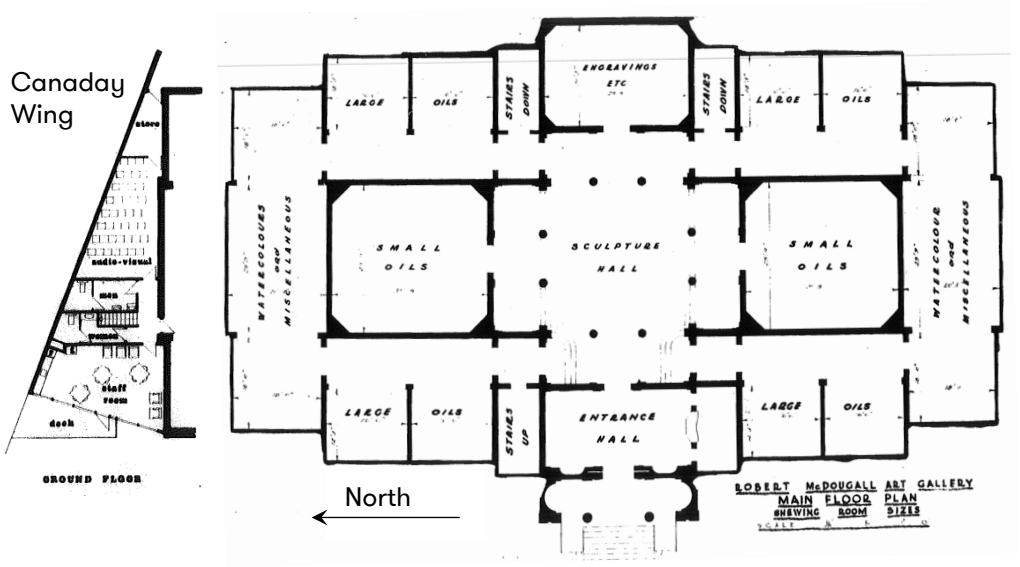


Figure 5-1: Robert McDougall Art Gallery plan, including Canaday Wing extension to the north

5.2 Seismic Capacity Pre-Canterbury Earthquakes

The Robert McDougall Art Gallery was designed and constructed prior to seismic design being considered in structural design practice. To this extent there is no reference design level to compare modern Code seismic requirements against.

The previous detailed assessment of the McDougall Art Gallery, carried out by Holmes Consulting, predicted that the primary building structure would perform relatively well in an earthquake. This assessment included time history analyses (undertaken to the current loadings standard, NZS1170.5:2004 [i]) which predicted the primary building structure to be capable of resisting an earthquake equivalent to 67% of current NZS1170.5:2004 demand by in-plane shear of the walls, but that the out-of-plane bending capacity of the walls was less than 33% current code.

The unreinforced masonry walls behave in a brittle manner under seismic loading, implying that they have little reserve capacity to sustain seismic demands greater than their nominal seismic capacity. Under moderate seismic demands (up to 67% of current code for an Importance Level 3 building) the main walls develop limited amounts of permanent damage when subject to in-plane demands, and are likely to maintain their ability to carry gravity loads from the self-weight of the roof.

The exterior walls have a seismic out-of-plane capacity to resist forces perpendicular to the wall face (Figure 5-2a) that is less than 33% of current code, and similarly the unrestrained parapets are considered a significant hazard with capacity at less than 33% of current code (Figure 5-2b).

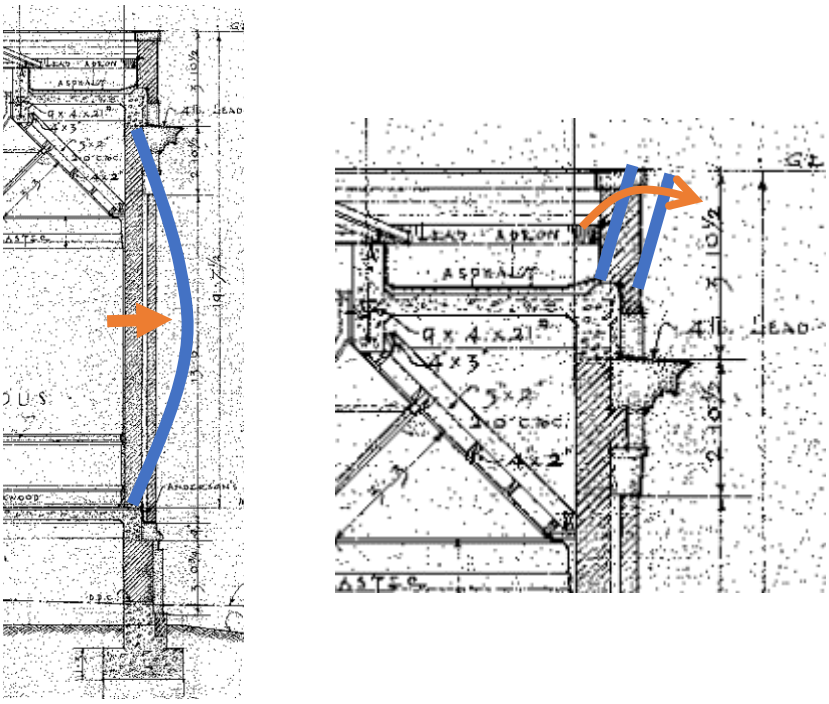


Figure 5-2: (a) Masonry wall out-of-plane seismic response and potential collapse (b) parapet out-of-plane topple mechanism.

Figure 5-3 provides a plan summary of the wall out-of-plane capacities, as evaluated in 2012/2013.

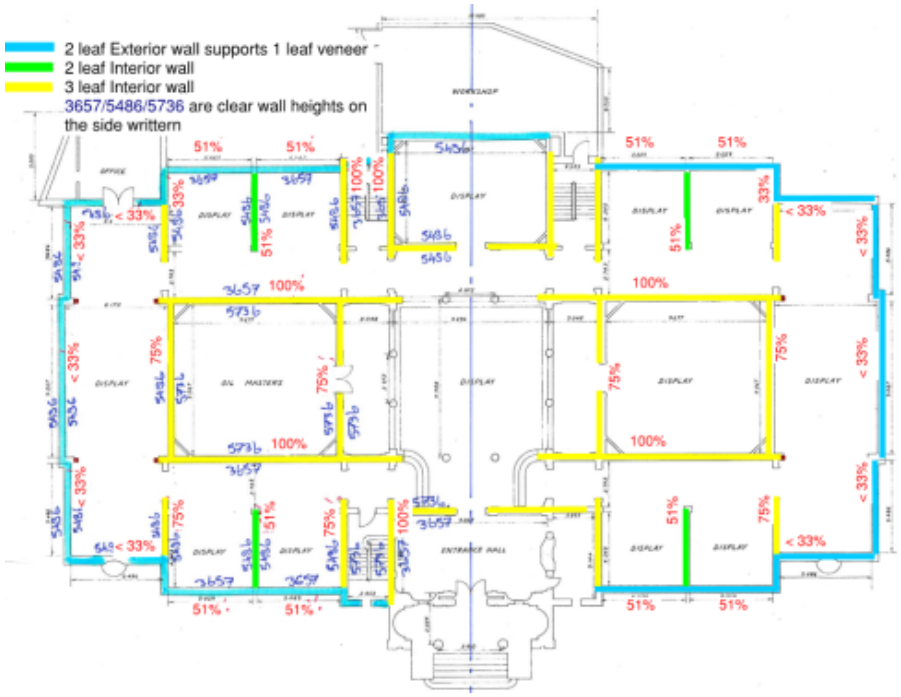


Figure 5-3: Summary plan of wall out-of-plane seismic capacity %NBS (of IL3). Values below 67% are being considered for out-of-plane seismic strengthening.

6 REVIEW OF EARTHQUAKE REPAIRS

As discussed in the Holmes Consulting Detailed Seismic Assessment (DSA) report (9/2013) the repairs to the structure following the Canterbury earthquake sequence are relatively insignificant. Generally they relate to minor step cracking in the mortar beds in the skylights and parapets, as well as cracking to the concrete that encases beams in the skylights and foundation walls and slabs.

The observed damage is not considered to have significantly affected the seismic capacity of the structure.

7 REVIEW OF STRENGTHENING OPTIONS

As part of the DSA report and subsequent discussion with the CCC through 2013, a range of possible strengthening measures were investigated by Holmes Consulting at the time. Primarily the focus of this work was to increase the wall out-of-plane seismic capacity and the parapet restraint capacity. While simple calculations were carried out to assist with size and set-out estimates, none of these options were considered in detail beyond concept design.

A number of issues were considered in developing the alternatives for out-of-plane wall strengthening and parapet restraint. In summary the primary drivers in previous discussion have been:

- Possible target seismic capacity (i.e. %NBS for an Importance Level 3 building)
- Future use and strengthening works that might be completed in addition
- Visibility and the ability to clearly delineate original materials from the newer strengthening materials

- Future reversibility
- Cost
- Disruption

At the time, discussions with the CCC did not reach a point of investigating the coordination of exterior and interior architectural and functionality remedial works. However, it was understood that there were important considerations that would be necessary to ensure that completed work was not disrupted by subsequent phases.

The structural strengthening options can be broadly summarised by the following (with Works Identification 1 to 6 with reference to Appendix sketches where provided as part of the proposed solution):

Wall Strengthening

1. Internal out-of-plane wall strengthening – vertical structural steel posts and horizontal transom beams bolted to the inside face of the brick walls. Finished structure is visible unless a false timber-framed wall is then provided to line the galleries (and this will impact floor space). No sketches provided here.

2. External out-of-plane wall strengthening – steel reinforcing bars grouted into the brick walls via centre-cored holes introduced/accessed through the concrete roof slab. Finished strengthening is invisible and permanent. This approach was trialled in 2013 by two different sub-contractors. Both were successful in completing one centre-core hole on the south elevation wall, with grouted reinforcing bar. Potential issues with this method include remaining on-centre of the wall while coring, and also mitigating excessive moisture penetration through the bricks and into the internal wall linings. Our understanding is that 'mist' coring is the current driest approach, which limits the water introduced to the coring operation. Refer SSK003 in Appendix sketches.

Parapet Strengthening

3. Parapet restraint frames – provided by structural steel frames bolted into the back of the parapet and down onto the concrete roof slab. Finished fixings through the roof membrane are visible and have multiple penetrations into (but not through) the roof slab. No sketches provided here.

4. Parapet restraint bars – provided by extending the reinforcing bars in (2), above the roof level and connecting these to the back face of the parapet with steel plates. Finished strengthening is visible (but minimal), and has limited penetrations through the roof slab that are in-line with the walls below. Where the bars emerge from the wall and concrete roof slab, the water-proofing detail around the bar may be difficult to detail. This could be made easier by encasing the bars in a concrete upstand skin-wall, or individual piers, formed against the back-face of the parapet. Refer Details 7 and 8 on SSK002.

5. Parapet restraint whaler-beams installed to the back face of the parapets. The proposal is that at the corners of the parapet, the whaler-beams tie to the perpendicular parapet walls, such that they are self-supporting and would not require connection to the roof slab. Given the lengths of parapet involved without returns/corners, it is uncertain whether this solution could work in all locations. Where there are numerous returns/corners in the parapet this approach will provide a viable solution. Refer Details 1 and 2 on SSK002.

Veneer Restraint

6. A review of the veneer ties on the back face of the parapet by the Heritage Architect has identified that in many areas the original ties have rusted and potentially have little remaining integrity. The remediation of the veneer ties can be achieved by various means, however a simple solution may be to introduce Helifix ties with a regular grid spacing through the veneer and into the main wall behind. Refer SSK003 in Appendix sketches.

In the context of the current discussions around replacing the roof system, the coordination of structural strengthening with such plans presents a key factor in deciding how to proceed with remedial works.

We understand that the primary concern at present is what impact the various strengthening options will have on the roof membrane and associated weatherproofing works also being reviewed at this time. Assuming that the entire roof membrane/finish is going to be lifted and replaced (which we understand to be the current proposal under review), we can confirm that various options (1) to (6) above will either need to have a coordinated install with the new roof weatherproofing system to avoid penetrating the finished membrane, or a strengthening option that does not require doweling into/through the roof slab (such as Option 5) might be considered.

The options that penetrate the roof membrane would need to be reviewed with the proposed membrane system. Consultation with the suppliers and architects will be necessary to identify what details could be developed to seal around the penetrations and structural elements.

From recent discussion and meetings with the rest of the project team, the current proposal for seismic strengthening is to use Works ID 2 for wall strengthening, and ID 4 & 5 for parapet strengthening. The combination of these would vary based on parapet and internal gutter geometry.

Where the parapet walls have a long unrestrained length, and are not suitable for whaler-beams combination, Works ID 2 + 4 would be applied. A key issue to develop in parallel with the roof replacement and membrane details (and heritage architecture) is the provision of a concrete upstand skin that encases the centre-core bars that project up behind the parapet. This will hide the bars, provide weather protection to them and also provide a sound substrate to which the roof membrane can be lapped, without the need to detail around the bars as they emerge from the concrete roof slab. Concept sketches of these details are provided in the Appendix attached to this report.

Where the parapets have a number of closely located corners (such as the east and west elevations) the proposed solution is a combination of Works ID 2 + 5. We have reviewed the possibility of using a continuous whaler beam (Works ID 5) to allow the parapet walls to be restrained by spanning from parapet each corner/return. This would allow the restraint to be introduced without needing to penetrate the roof membrane, which in these areas would be difficult to achieve due to the deep gutters. A concept review suggests this whaler beam will be feasible, and that detailing would be reasonably simple provided the whaler beam can be made continuous around the corners. The plan attached in the Appendix to the report provides an indication of the extent of the whaler beam solution, and concept sketches of the fixing details are provided.

Where the brick veneer ties are found to have corroded significantly around the parapet extent, the installation of Helifix ties (Works ID 6) may be considered as a means to re-introducing the connection between veneer and wall. The full extent of this will need to be confirmed as part of the site investigation associated to the heritage report and subsequent remediation of mortar bed scope.

A further option that has not been investigated to-date is the introduction of fibre-reinforced polymer (FRP) strengthening to the internal walls (shown in green on the Appendix plan). This is a permanent and visible interior strengthening approach, that can provide a limited level of out-of-plane strengthening which may be sufficient for these walls that currently sit at 51% NBS. Before proceeding with any design calculations

we would recommend a review with the heritage team to confirm that a permanent visible solution would be acceptable. This option (or one similar to Works ID 1) may need to be employed to these internal walls is access for centre-coring around the skylights is not possible.

Finally, the introduction of individual posts to provide supplemental gravity support to the north and west wing skylight lintels is necessary to mitigate the potential for partial collapse of the roof in these areas. The posts would be stand-alone and bolted from the floor slab and concrete lintel beam. These have been indicated on the plan in the Appendix.

---

[i] *Robert McDougall Art Gallery – Detailed Seismic Assessment Report*, Holmes Consulting Group LP, September, 2013

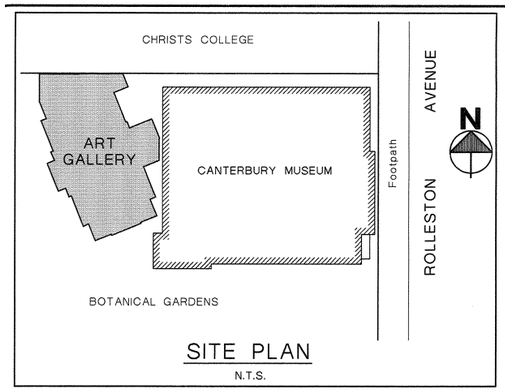
[ii] *Structural Design Actions Part 5: Earthquake Actions – New Zealand, NZS 1170.5:2004*, Standards New Zealand, 2004

Holmes Consulting

Level 2, 254 Montreal Street
Christchurch Central
PO Box 6718
Christchurch 8442
holmesgroup.com

Appendix A

Seismic Strengthening Concept Sketches



SITE PLAN

N.T.S.

Seismic Strengthening Key-Plan for 67% IL3

- Centre-coring @ 650 crs c/w RB20 reinforcing bar + parapet connection detail and concrete skin-wall
- Centre-coring @ 650 crs c/w RB20 reinforcing bar
  200UC46 Whaler-beam fixed to back face of parapet
- 200UC46 Whaler-beam fixed to back face of parapet only
- Centre-coring @ 750 crs c/w RB20 reinforcing bar

CANTERBURY MUSEUM

CARPENTERS WORKSHOP

Chimney to be strengthened -refer to details on Sht.2

workshop side walls tied to main building -refer to details on Sht.2.

Detail B S2

Detail C S2

CHRISTS COLLEGE

200UC posts installed inside gallery wing to support lintel beam. Span from floor slab to soffit of lintel

200UC posts installed inside gallery wing to support lintel beam. Span from floor slab to soffit of lintel

Detail A S2

water tank to be secured -refer to details on Sheet 2

ADMINISTRATION BUILDING

200UC posts installed inside gallery wing to support lintel beam. Span from floor slab to soffit of lintel

No parapet strengthening required

200UC posts installed inside gallery wing to support lintel beam. Span from floor slab to soffit of lintel

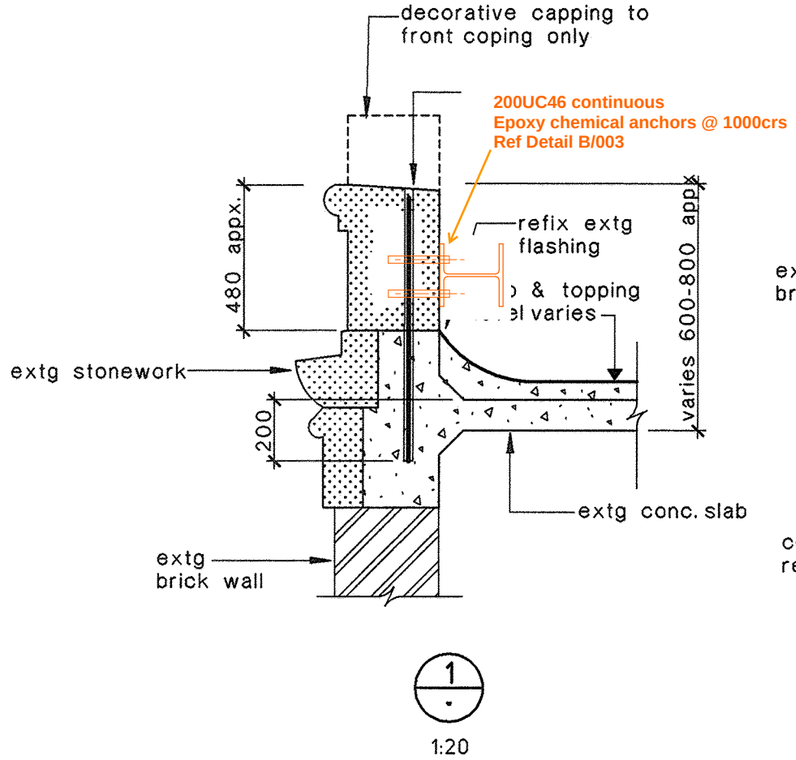
refix existing flashing

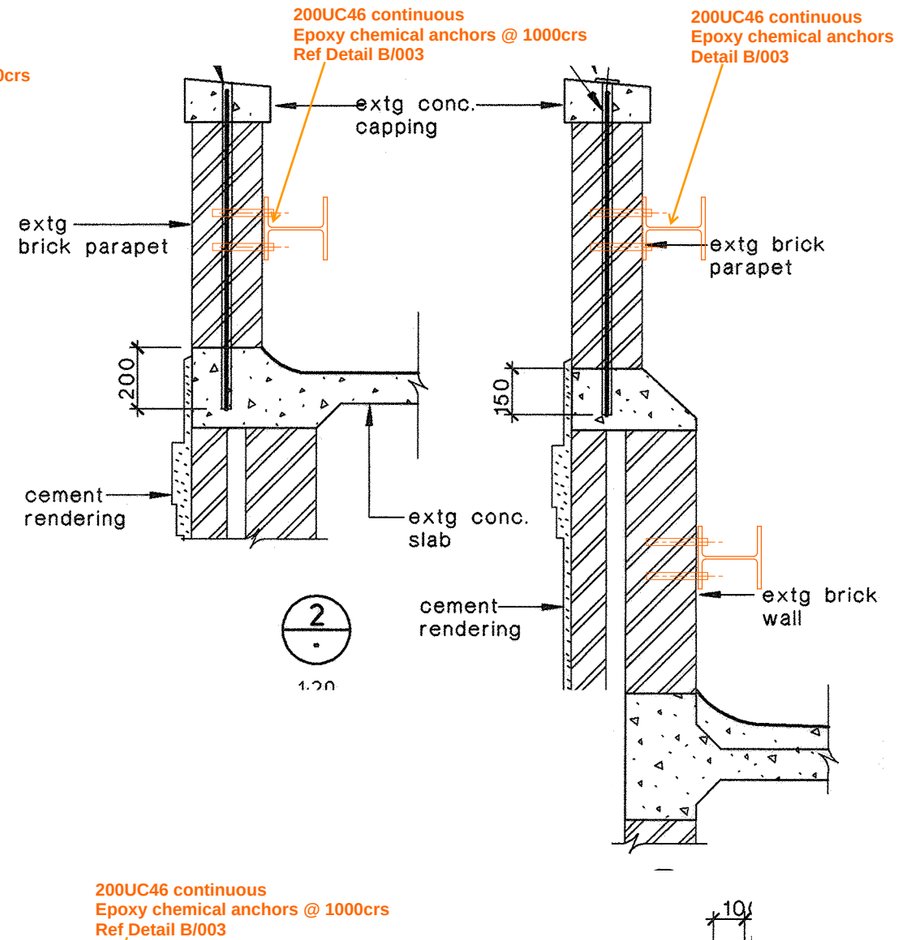
PLAN

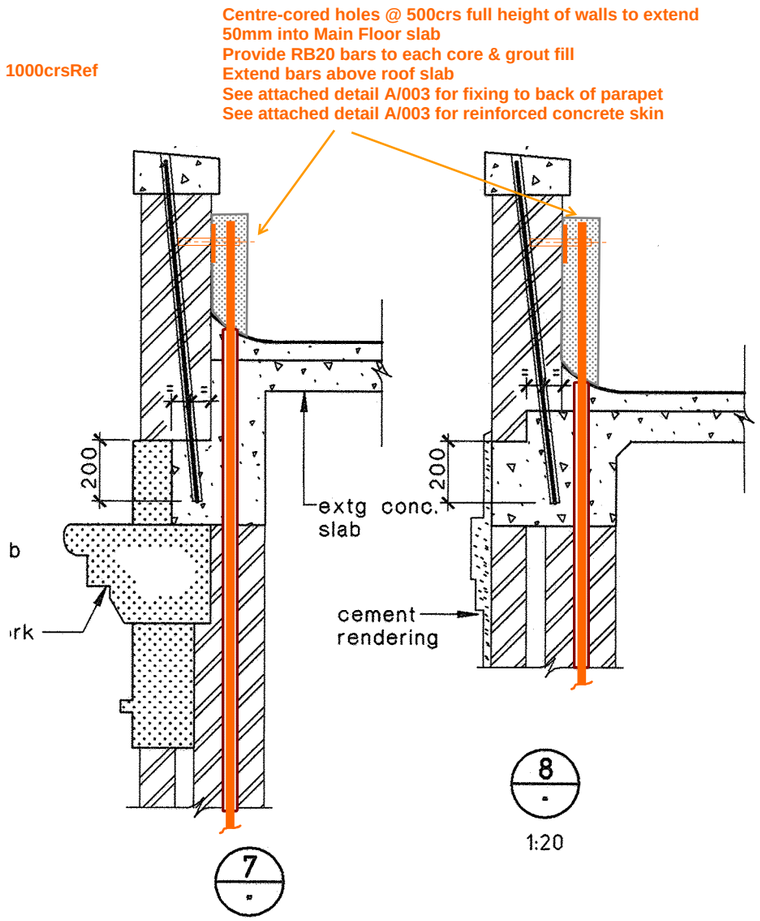
1:100

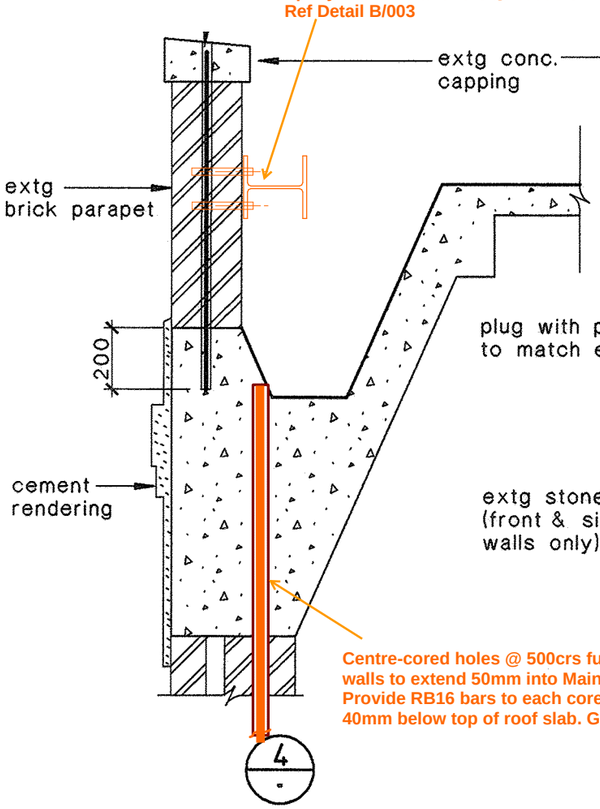
NOTE: Parapets to be strengthened are shown shaded

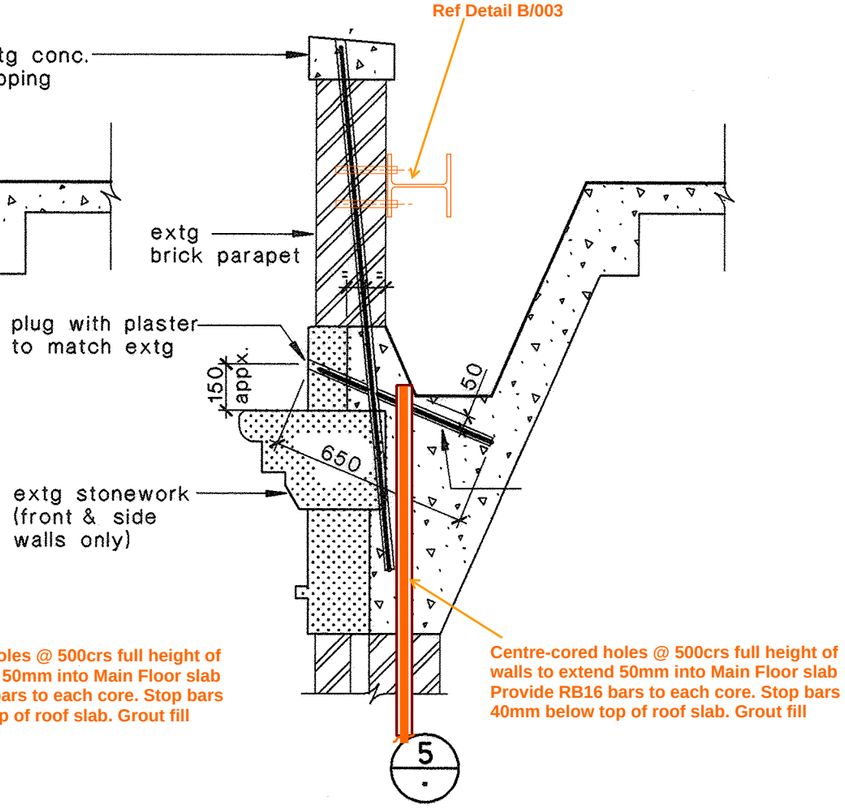
PROJECT:	RMAG
JOB NO:	104653.05
DATE:	24/10/2017
SSK:	001
REV:	1

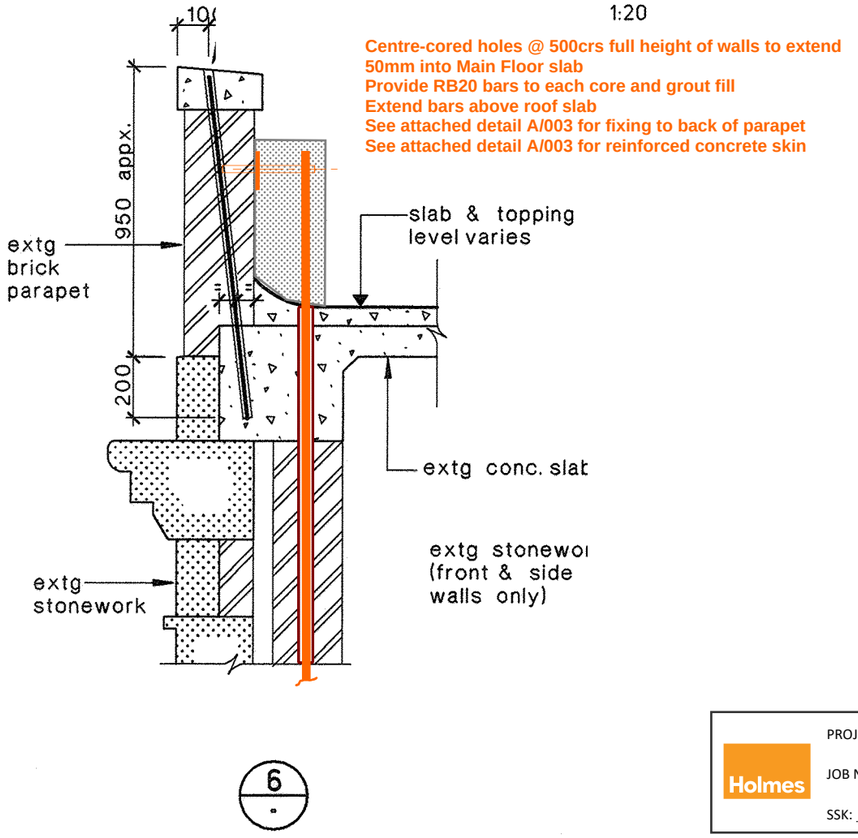










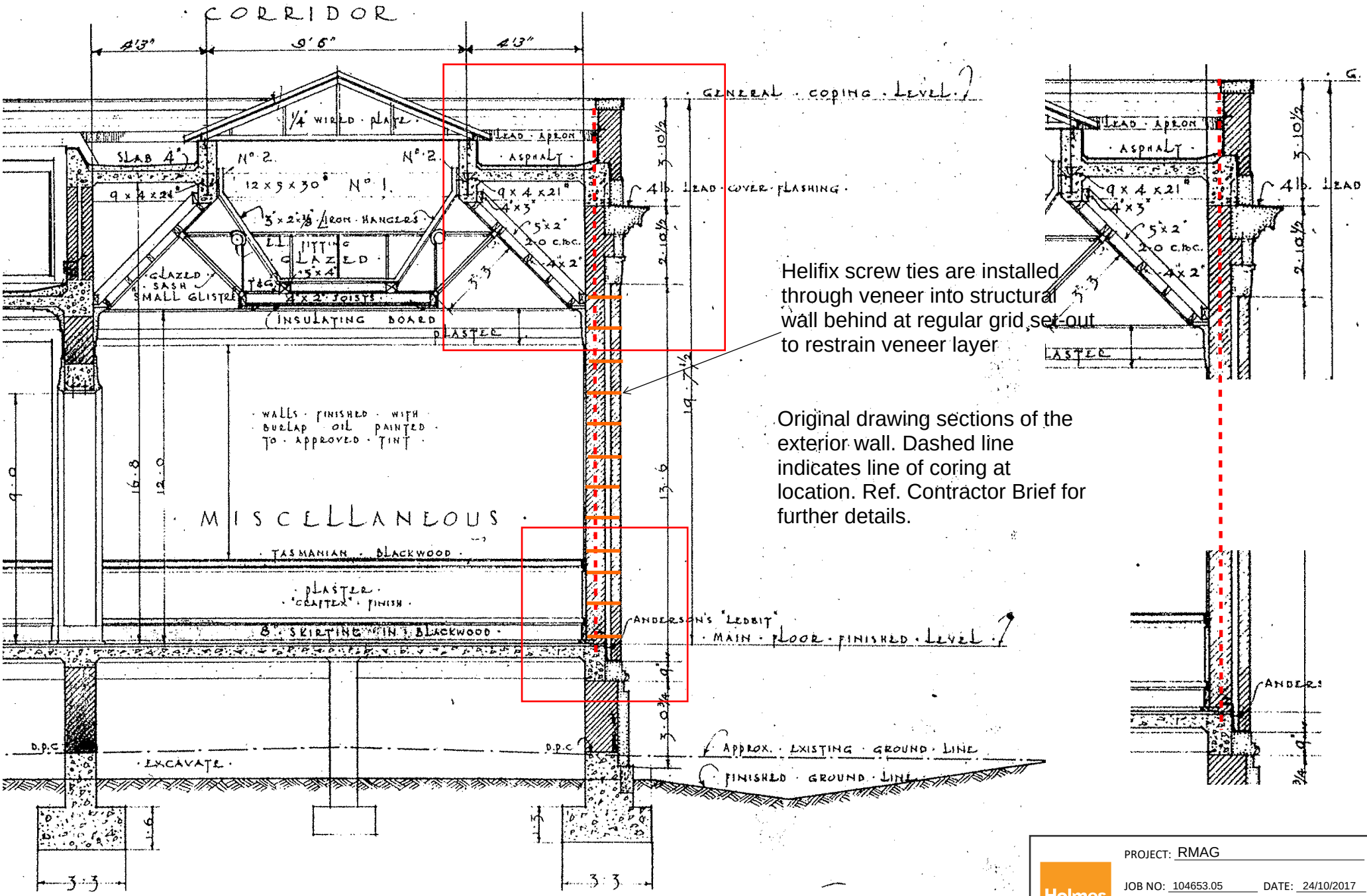


Holmes

PROJECT: RMAG

JOB NO: 104653.05 DATE: 24/10/2017

SSK: 002 REV: 1

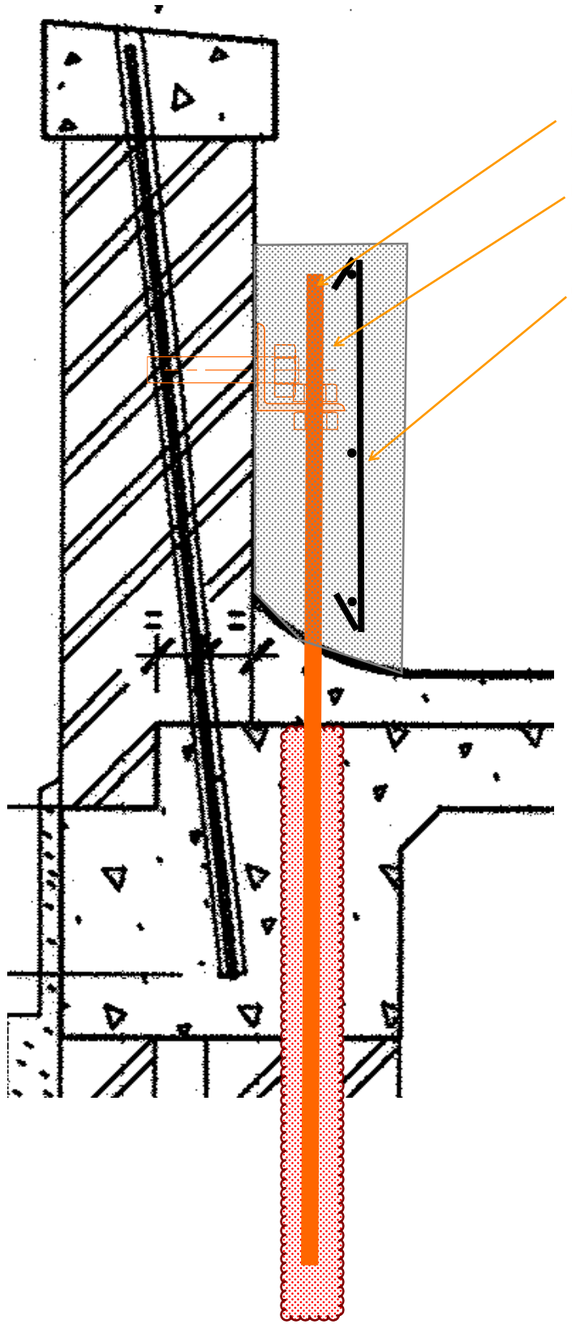


Helifix screw ties are installed through veneer into structural wall behind at regular grid set-out to restrain veneer layer

Original drawing sections of the exterior wall. Dashed line indicates line of coring at location. Ref. Contractor Brief for further details.

Section through South and North Elevation walls

PROJECT:	RMAG
JOB NO:	104653.05
DATE:	24/10/2017
SSK:	003
REV:	1

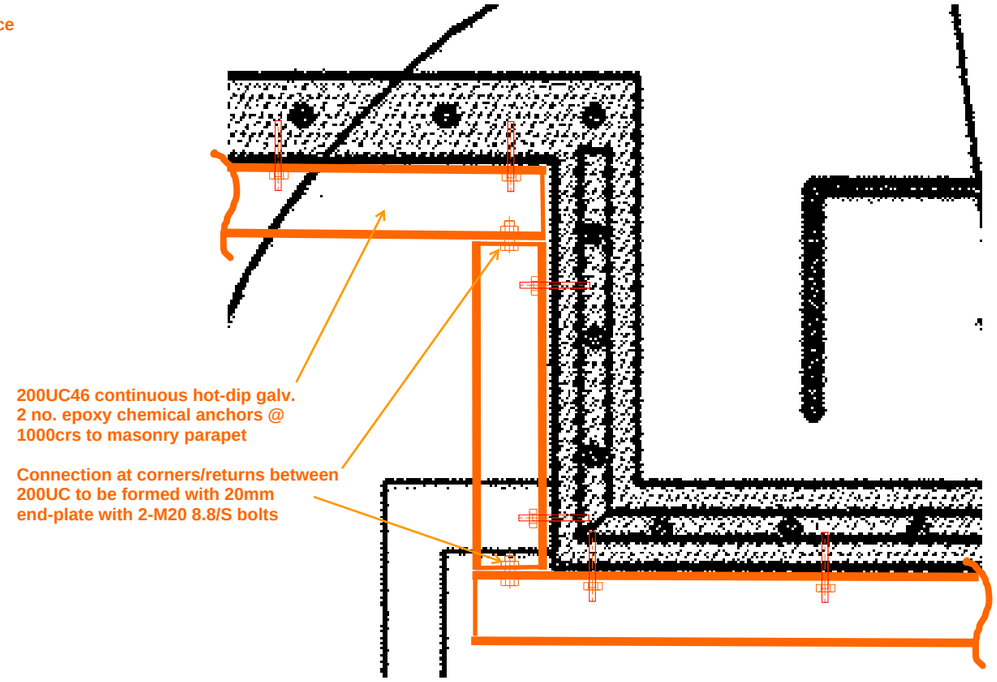


Centre-cored holes @ 650crs full height of walls to extend 50mm into Main Floor slab
Provide RB20 bars to each core and grout fill
Extend bars above roof slab

Provide mild-steel unequal angle to accept RB16 vertical + RB flange nuts above/below
UA to accept 2 no. M12 threaded rods epoxy fix into masonry

Concrete skin wall to be formed with 40mm cover. Reinforce with one layer of D10@200crs each way

Detail A/-



200UC46 continuous hot-dip galv.
2 no. epoxy chemical anchors @ 1000crs to masonry parapet

Connection at corners/returns between 200UC to be formed with 20mm end-plate with 2-M20 8.8/S bolts

Detail B/-

Holmes

PROJECT: RMAG

JOB NO: 104653.05 DATE: 24/10/2017

SSK: 004 REV: 1