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SEISMIC RESILIENCE – CHALLENGES FOR BUILT HERITAGE CASE STUDIES

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SEISMIC RESILIENCE – CHALLENGES FOR BUILT HERITAGE

5 CASE STUDIES:

1. **AGGS**: Implications of previous seismic intervention for maintenance
2. **UoO CAPS Building:** Redevelopment triggering seismic intervention
3. **Gisborne Cenotaph**: Major repairs and upgrading after 2007 seismic event
4. **Seddon Memorial**: Conservation work triggering seismic upgrading
5. **Domain Wintergardens:** Seismic upgrading (removal from EPB Register) triggering major replacement of fabric

Case Study 1: Auckland Girls Grammar School

Implications of seismic intervention for maintenance

2006 – asked to assess extensive deterioration of brickwork and defects internally

- Category 1 Heritage Building
- built of traditional cavity brick construction
- parapet walls /pitched slate roofs / cast iron downpipes

- extensive efflorescence (salts) externally
- water penetration – damp plaster internally
- failure of plaster internally (salt contaminated)
- blocked / broken downpipes - leaking

Case Study 1

Investigations – condition assessment and research

1990s seismic retrofit

Steel restraints to gable walls

Structural steel fitted at flashing /upstands level

52 penetrations to slate roof reliant on sealant

Cavities of brickwork had been filled with high strength concrete

Shotcrete (sprayed concrete on a galvanised steel mesh) applied to interior walls

Floor diaphragms installed

Case Study 1

1990s seismic strengthening

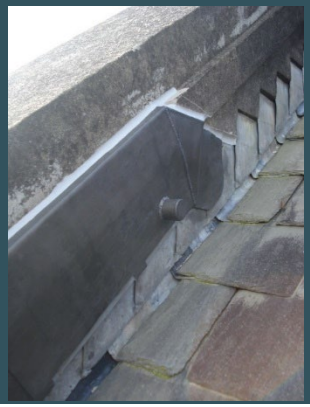
DEFECTS CAUSED BY:

1. Water penetration:
   - Blocked, broken rainwater pipes /Blocked drains;
   - Leaking parapet gutter linings;
   - Structural steelwork pierced flashings and upstands;

   Problem - No longer a drainable cavity

2. Soluble salts migration from cementitious grout filled cavity – causing failure of brickwork and the plaster

SOLUTION: Not maintenance….
but a major project and then continue to monitor.
Seismic upgrade 15years old – caused major implications for health and maintenance of this building

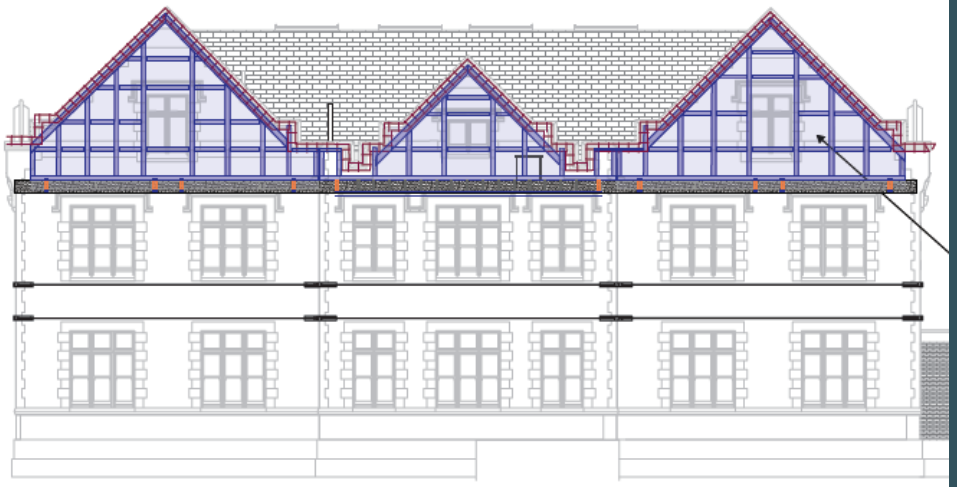


Case Study 1

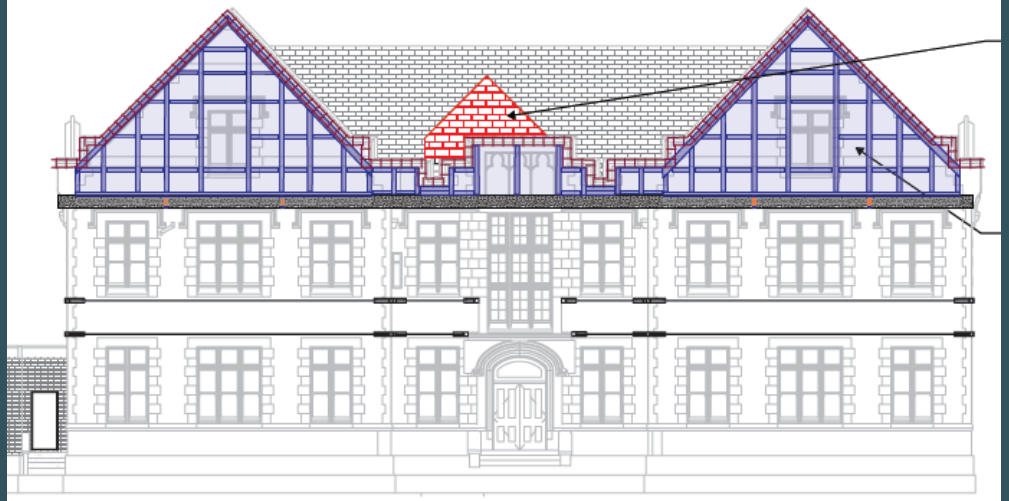
Defects and…… the Solution

Case Study 2: University of Otago Consumer & Applied Sciences Building: Redevelopment triggering seismic intervention

- 1918, solid mass masonry - URM;
- Category I – 1 of 6 significant heritage precinct buildings - rare examples of 19th /early 20th century gothic revival university architecture;
- Campus redevelopment – extend the CAPS by adding a new building with a link building;
- New building – to be designed to 100%NBS;
- CAPS seismically assessed as 10-15%NBS for IL2;
- University proceeded to developed design stage for both the new building and the CAPS – brief to the engineer was to achieve 100%NBS at IL2;



West Elevation



East Elevation

Resource Consent Stage:

Salmond Reed Architects asked to review the proposal and the impact on the heritage building just prior to submitting application.

The Proposal

- Dismantling all stone gable walls including windows
- New concrete ring beam
- Grouting of soft fill to the solid masonry walls (stone /brick)
- Rebuilding the gable walls - lightweight construction
- Removal of internal of timber walls replace with concrete
- External post tensioning
- Partial underpinning

Case Study 2

Heritage Impact – RC application stage

Case Study 2

Rebuilding the gable walls - lightweight construction??

Otago University's Seismic Strengthening Policy:

- " that all existing buildings, which are defined as Earthquake Prone, should be brought to at least **34%NBS**".
- "Heritage Buildings will be strengthened in accordance with the targets above, and with due respect to their heritage fabric and character". …..
- "All buildings, that are Earthquake Prone will have priority for strengthening to at least **34%NBS** in accordance with Building Act timeframes".

Otago University's Campus Master Plan:

Chapter 6: Design guidelines - Historic core

- "The restoration of this fine group of neo-gothic buildings should focus on stripping away later accretions to the interiors, to reveal the original spaces, architecture and ornament".

Dunedin CC District Plan

"prioritise protection of heritage values over compliance with other performance standards where there is a conflict"

A2.1.1.3 Principal threats to values:

d. The removal of original materials and features from heritage buildings

Final Assessment:

The proposal, as currently presented will:

- **cause significant loss of valuable heritage fabric;**
- **be in contravention of policy statement for achieving of min 34%NBS;**
- **adversely affect the integrity and authenticity;**
- **not satisfactorily balance engineering performance with heritage preservation and sustainability;**
- **result in the upper third of the building, with its most significant architectural features ending up as skin deep replicas, that have a shorter renewal period, and so will increase life-cycle costs of the building;**
- **ultimately devalue the heritage asset**

Recommendation

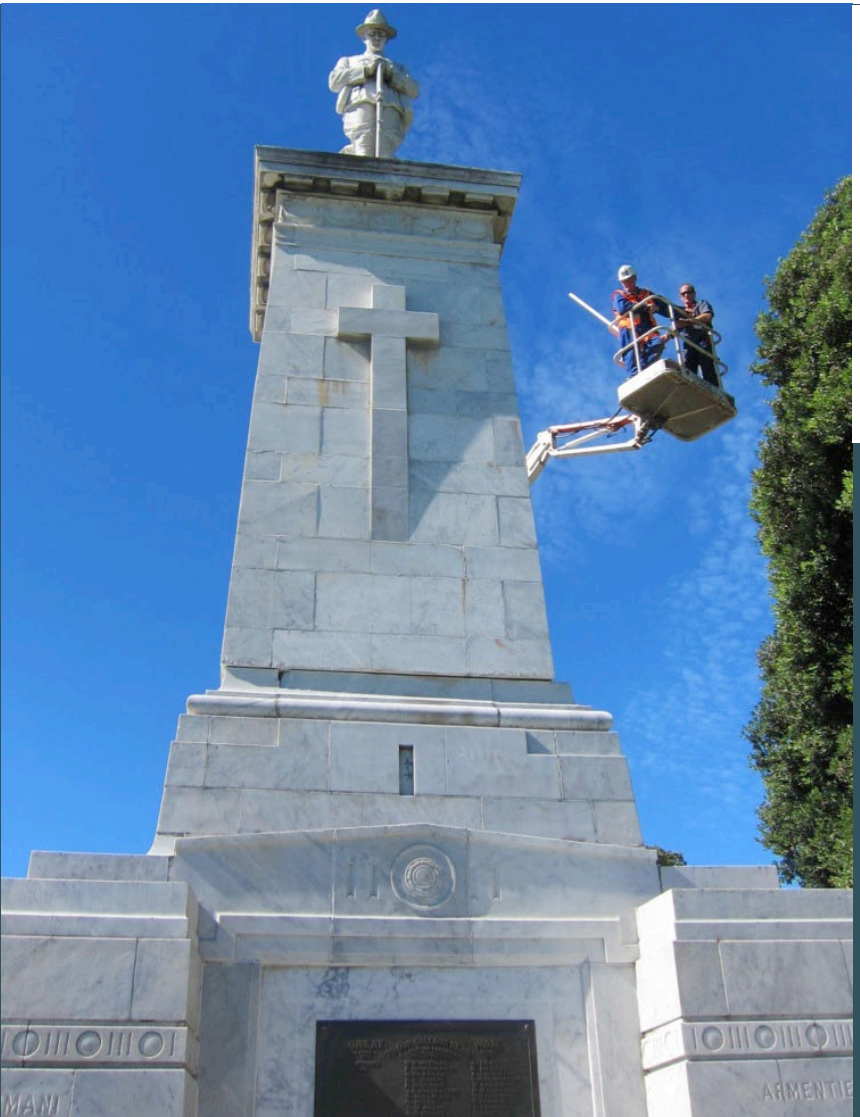
University review alternative structural options between a target of min 34%NBS and 67%NBS seismic resilience, in order to compare the adverse effects on the heritage fabric versus the overall benefits.

Final Outcome:

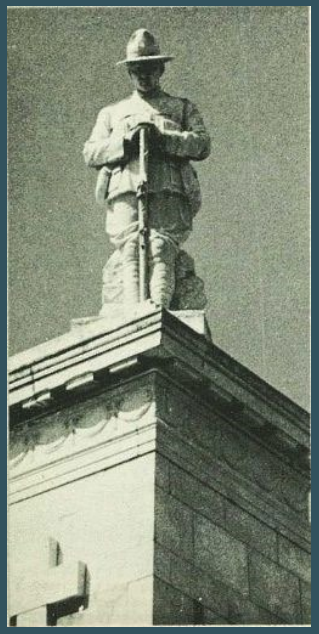
Revised substantially – reduced scheme to achieve 67%NBS at IL2

Case Study 3: Gisborne Cenotaph

Repairs and upgrading following a seismic event



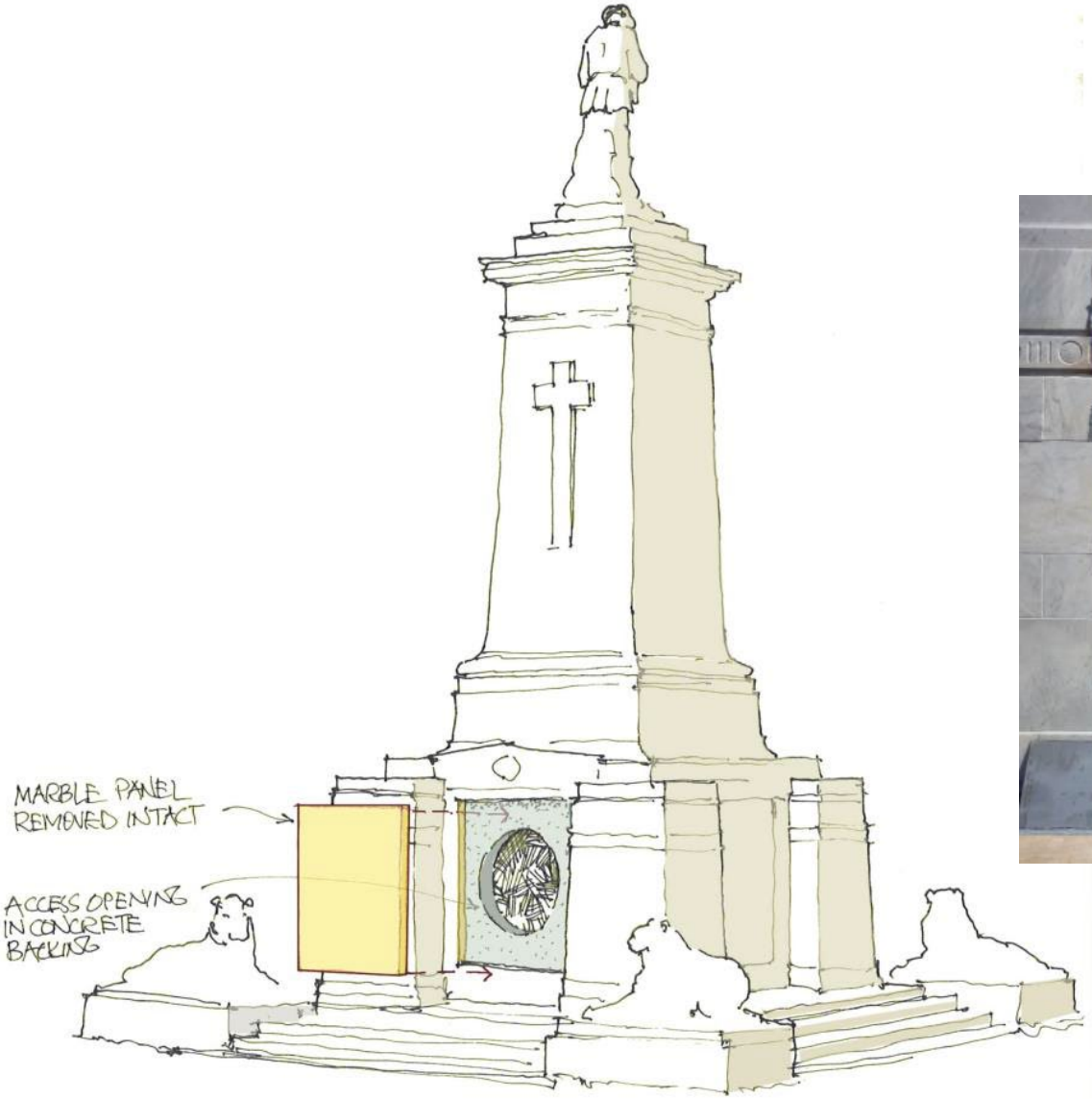
In 2007, an earthquake struck the Gisborne region, causing significant damage to a number of buildings in the central city. The Cenotaph itself was also damaged, with the upper shaft bearing the figure of a soldier dislocated from the base and moved about 65mm to the north-west. This is not the first instance of earthquake effects on the structure – an earlier event resulted in the figure of the soldier being rotated about 45 degrees.



Initial repair proposal being advocated:

Demolish and rebuild – around a new concrete core

Led to a long process of deliberations about the impact and costs



Case Study 3

Investigations – Multi-disciplinary Team

Case Study 3

Investigations – finding the hollow core

petrographic investigation, Gisborne Cenotaph concrete, Salmond Reed Architects

Figure 1: Photomicrograph, typical field of view of concrete from interior of Gisborne Cenotaph, showing fine aggregate particles of calcareous and other mudstone set in limey paste (higher relief, pale grey). Note oxidised rim to clast at top left. Colourless areas have lost friable paste during specimen preparation. Transmitted light. Scale: width of view is 6 mm.

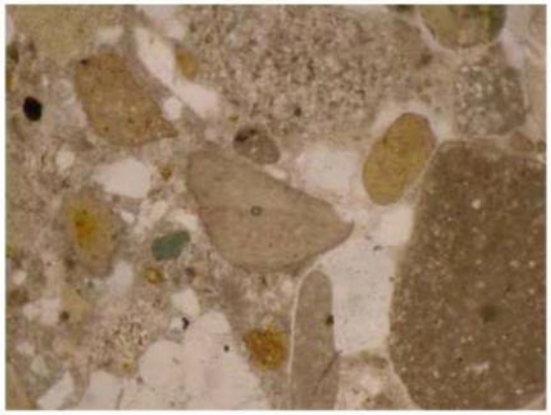
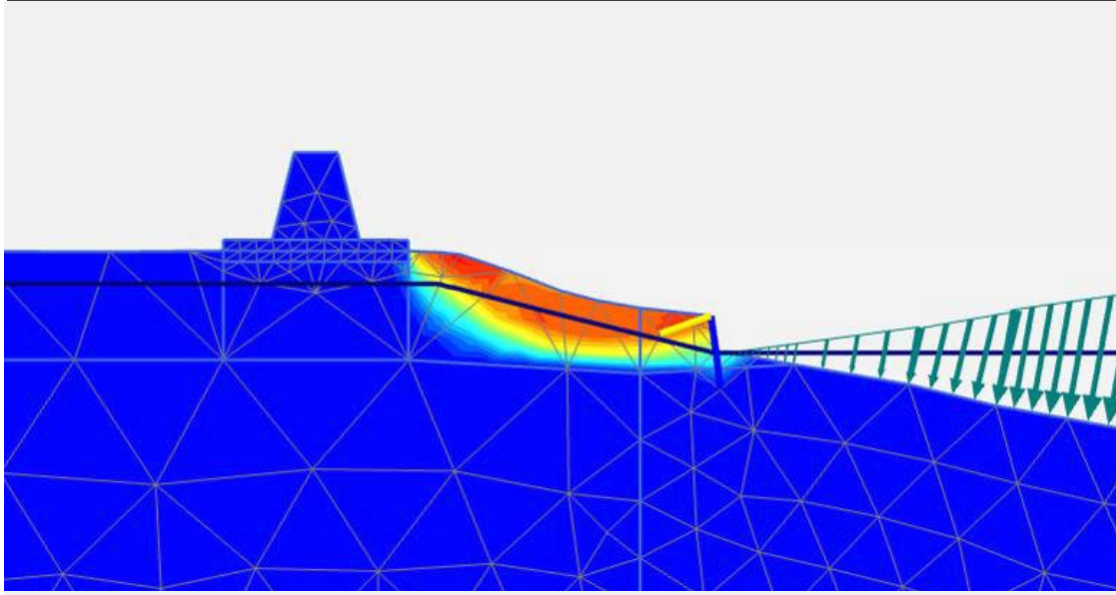
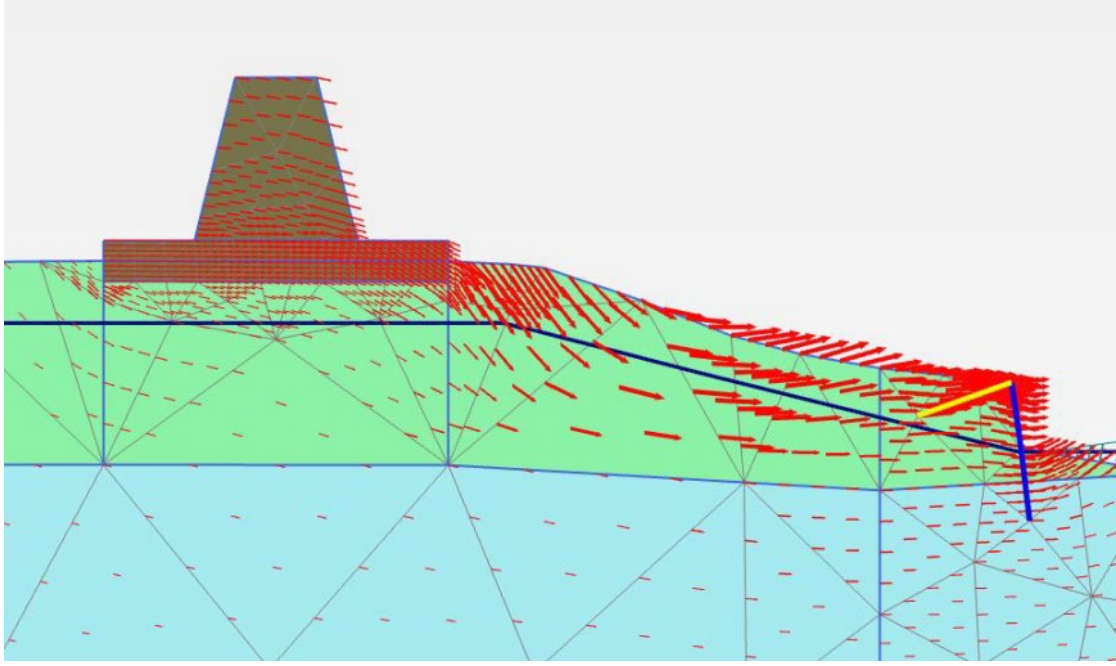


Figure 1: Photomicrograph, typical field of view of concrete from interior of Gisborne Cenotaph, showing fine aggregate particles of calcareous and other mudstone set in limey paste (higher relief, pale grey). Colourless particles are volcanic quartz and molluscan shelly material. Transmitted light. Scale: width of view is 6 mm.

Forensic & Industrial Science Ltd, PO Box 20-103, Glen Eden, Auckland, New Zealand tel 0800 28 99 99
industrial chemistry – contaminant tracing– analytical services – forensic science – corrosion prevention
industrial microscopy – process troubleshooting – cleaner production technology – component failure analysis

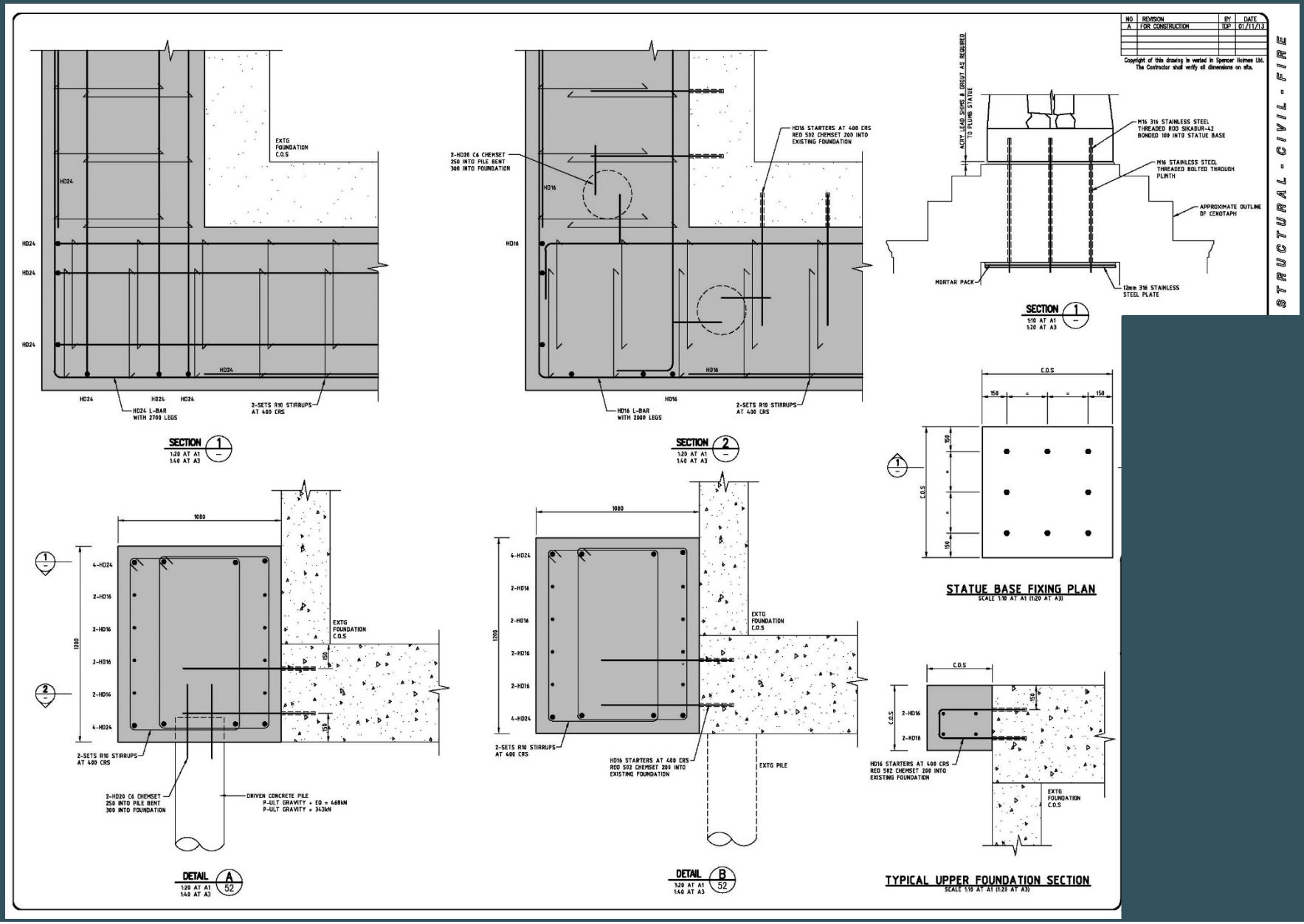




Case Study 3

Concrete Analysis / GPR and Modelling

- Removal and conservation repair of marble steps;
- Significant underpinning and connect to the existing piles;
- Repairs and repositioning of the shaft;
- Use of the void to provide seismic strength – meccano style stainless steel frame;
- Improve connection of the statue to the shaft



Case Study 3

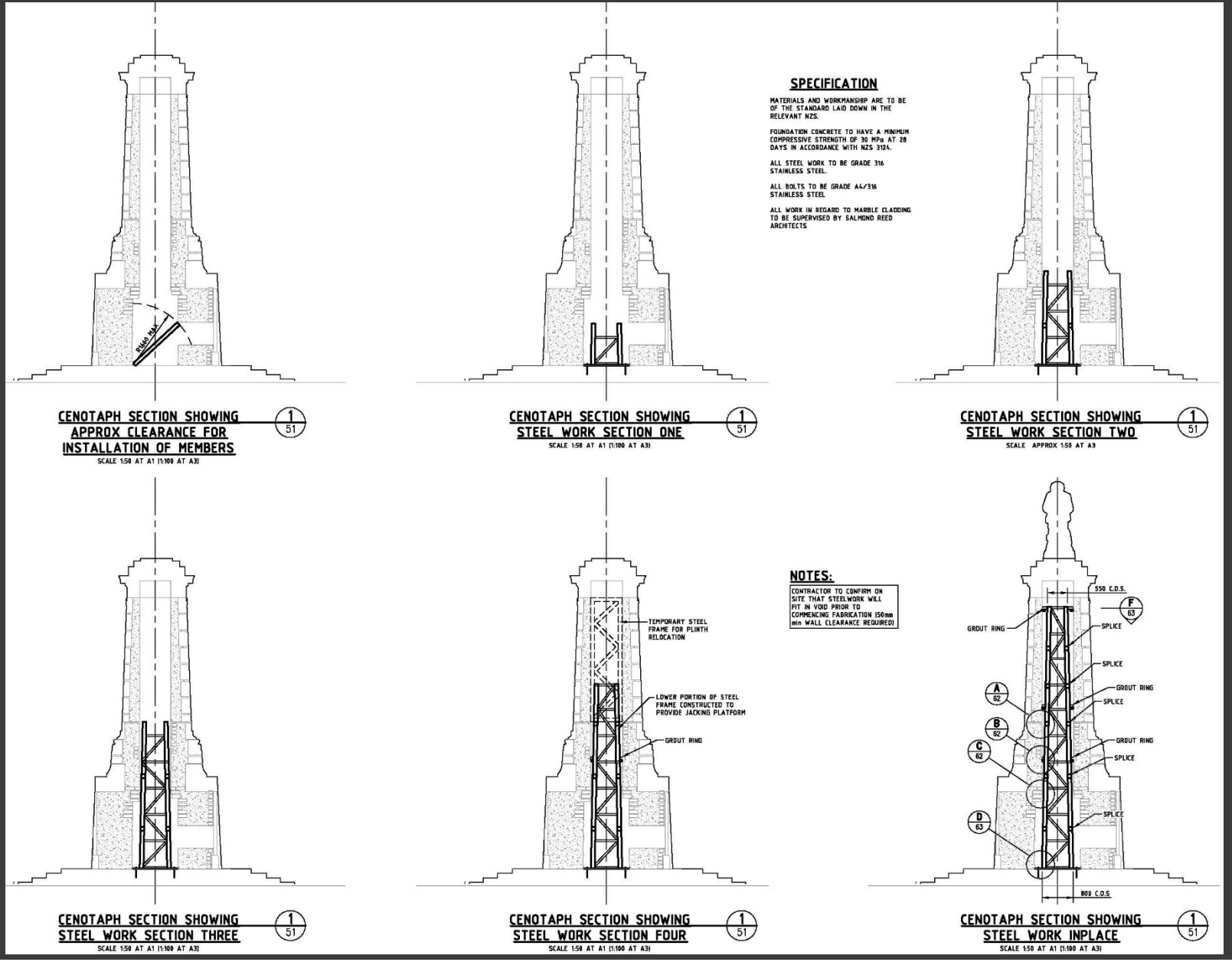
Strengthening: Underpinning and Statue Fixing

Case Study 3

Underpinning – Non ferrous reinforcing bars

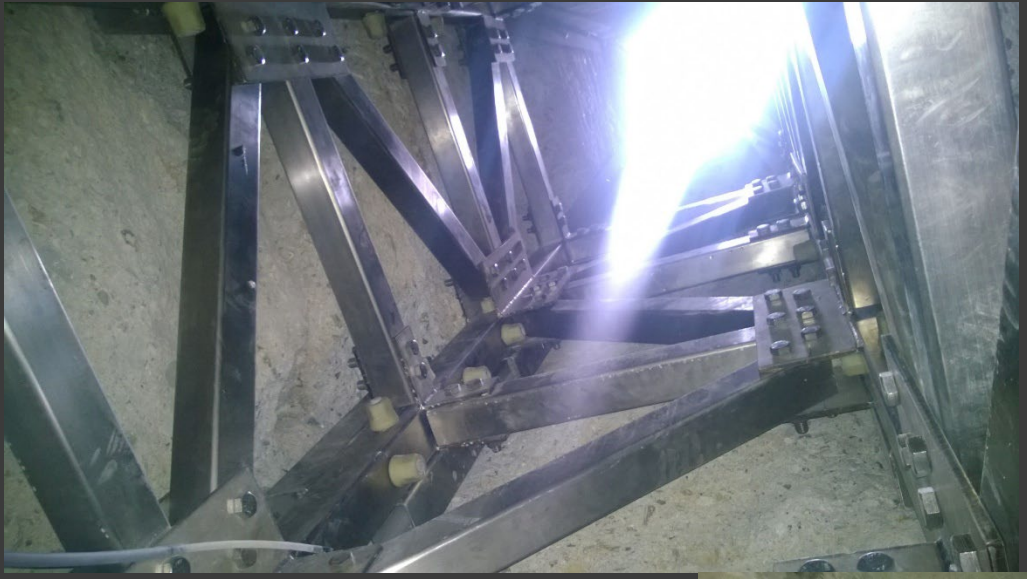
Case Study 3

Using the Void for Seismic Resilience



Case Study 3

Void Structural Frame

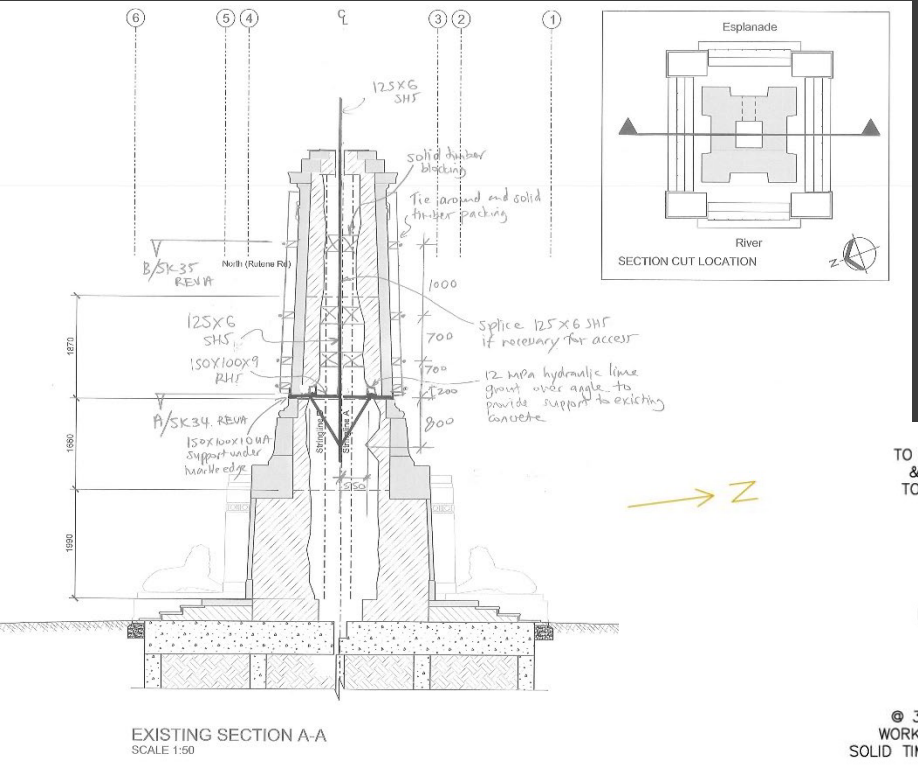


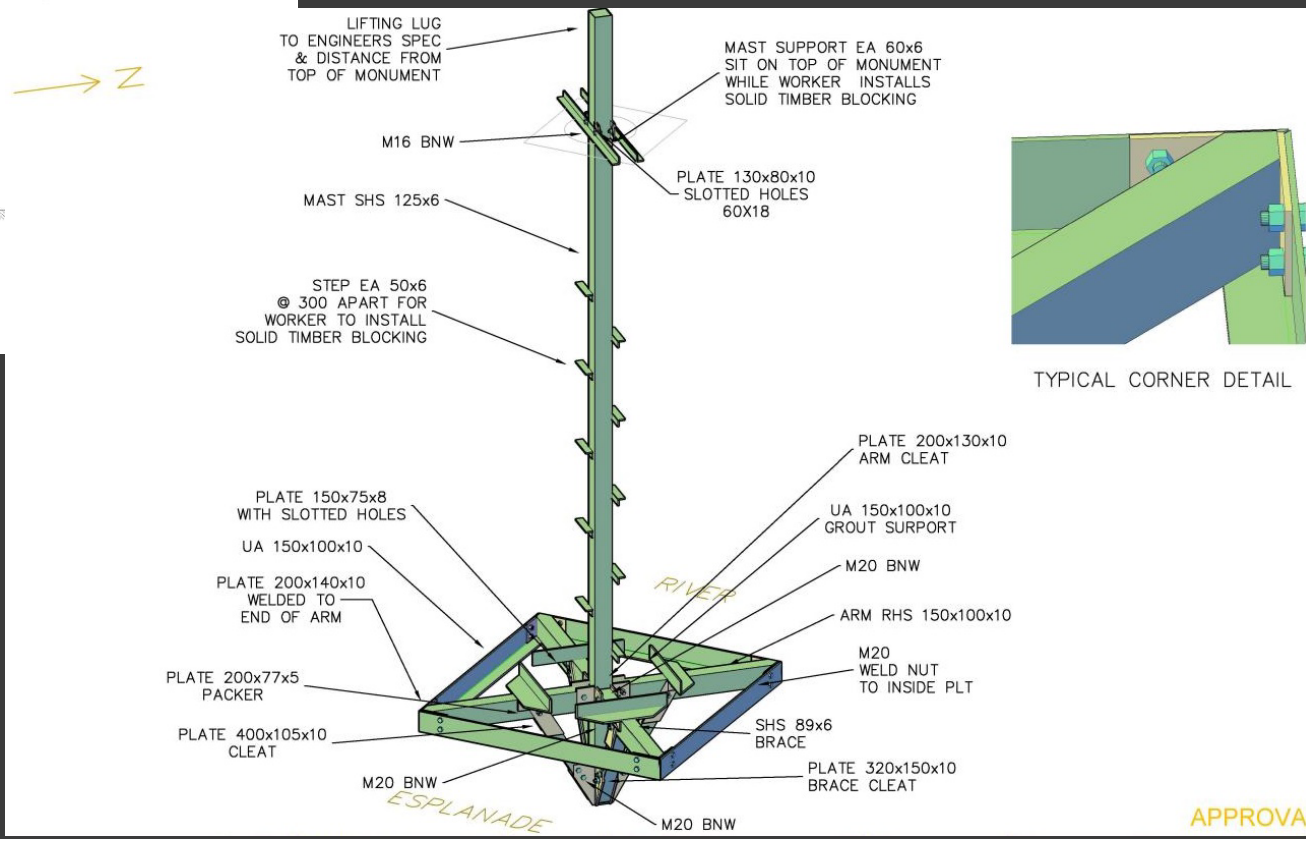
Case Study 3

Void Structural Frame

Case Study 3

Repositioning the shaft





TYPICAL CORNER DETAIL

Case Study 3

Lifting and Repositioning the Shaft

Case Study 3

Completion for Anzac Celebrations 2015

Case Study 4: Seddon Memorial, Wellington

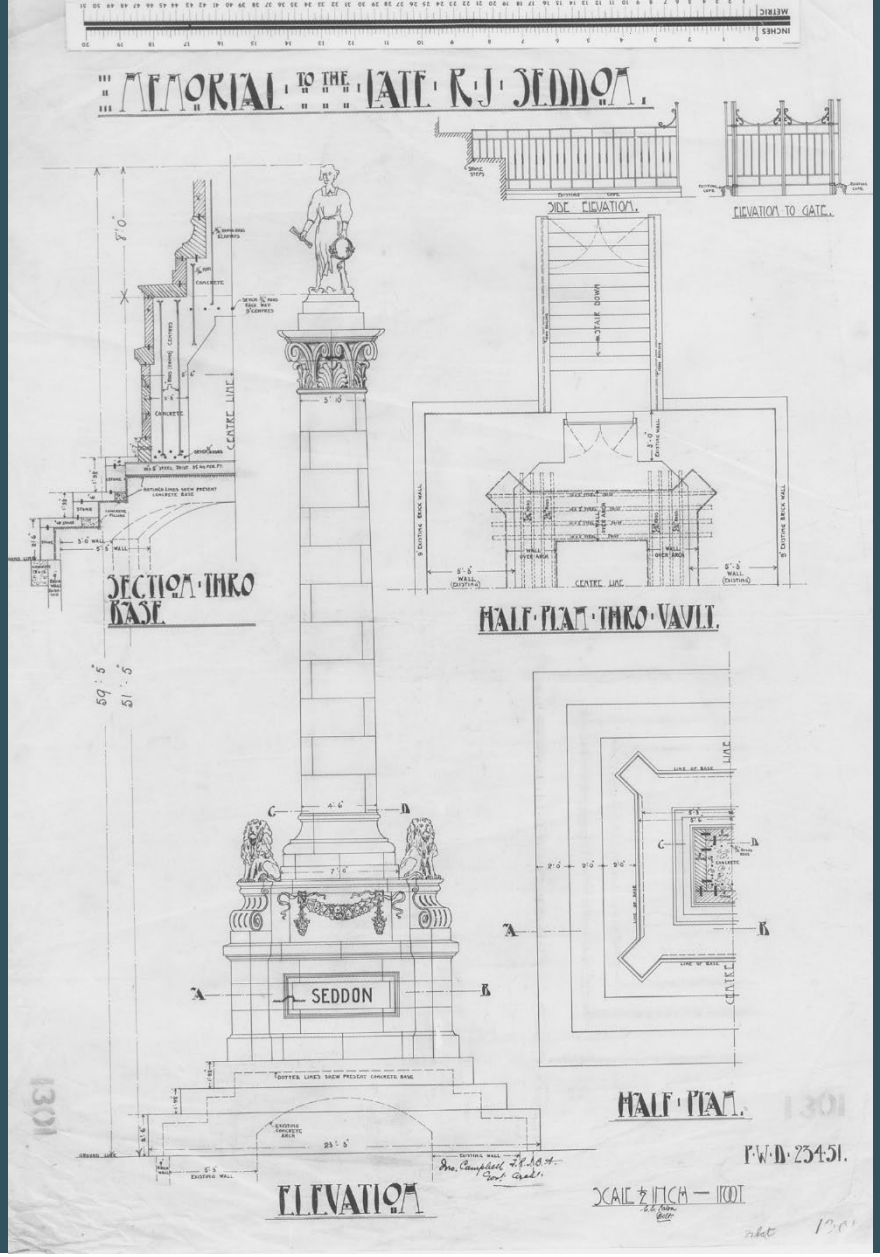
Repairs and maintenance triggering upgrading

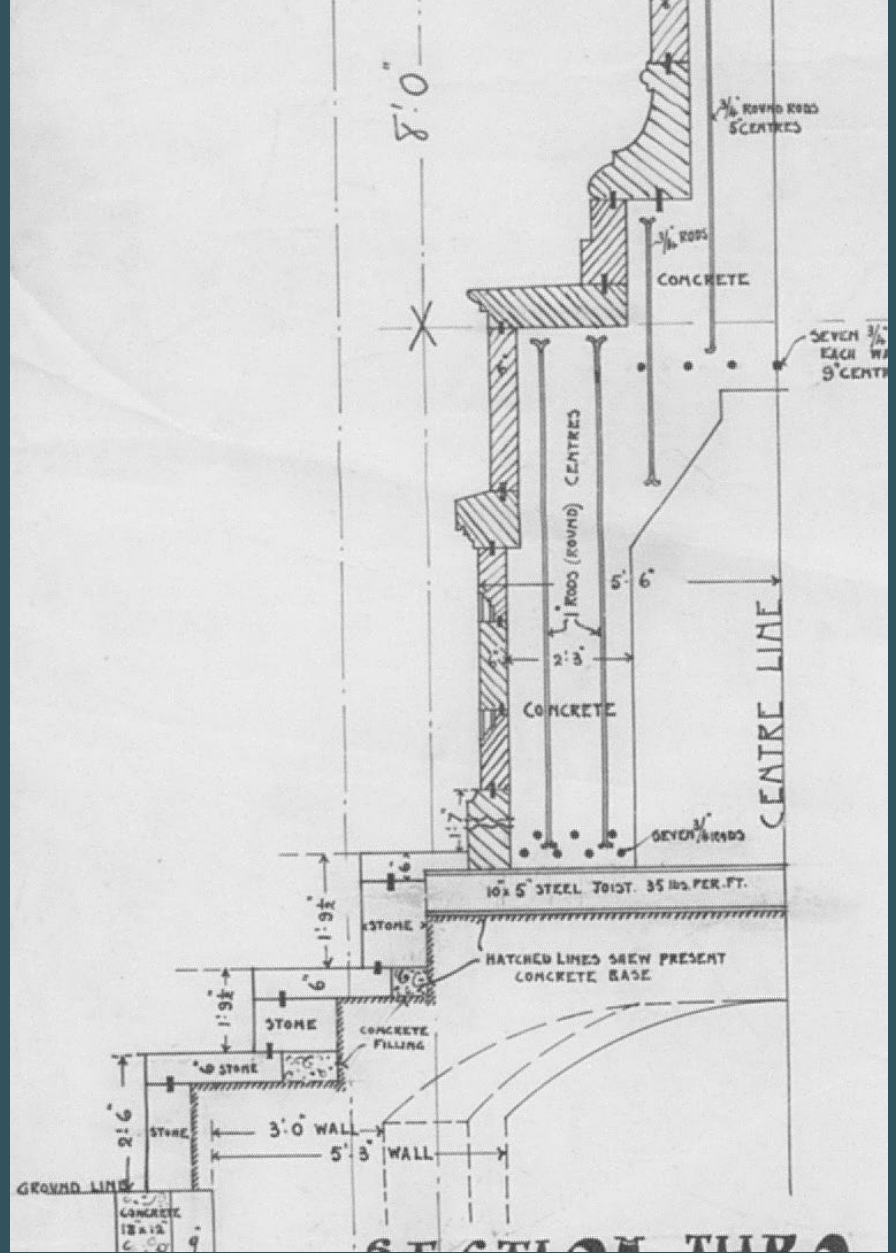
Case Study 4

Concerns about condition and water penetration

Case Study 4

Corrosion staining/water leaching – first noted 1930s





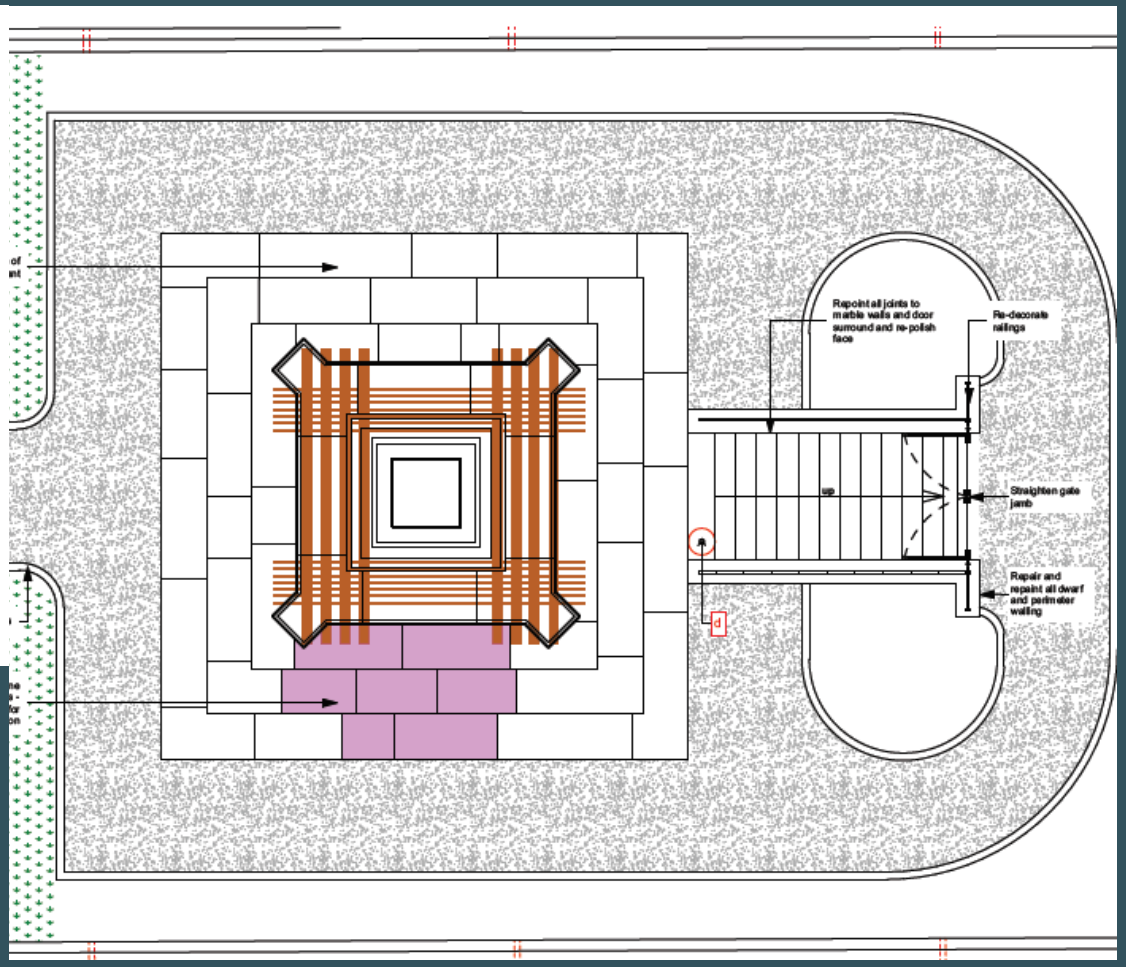
Case Study 4

Research – original drawing / history of condition

Seddon Memorial
Wellington

FINAL ISSUE

Conservation Statement
and Recommended
Scope of Repairs



Key Recommendations:

1. DSA be undertaken;

2. Physical investigations - reason for corrosion and establish condition and size of the void

Case Study 4

Conservation Statement and Condition Assessment

Assessed - designation of IL2

Structural weaknesses:

- Statue potential for toppling;
- Column anchorage to plinth 15% (Critical);
- Column bending capacity 25%;
- Column pedestal overturning resistance 30%;
- Crypt overturning resistance 100%;

Classified - very high risk

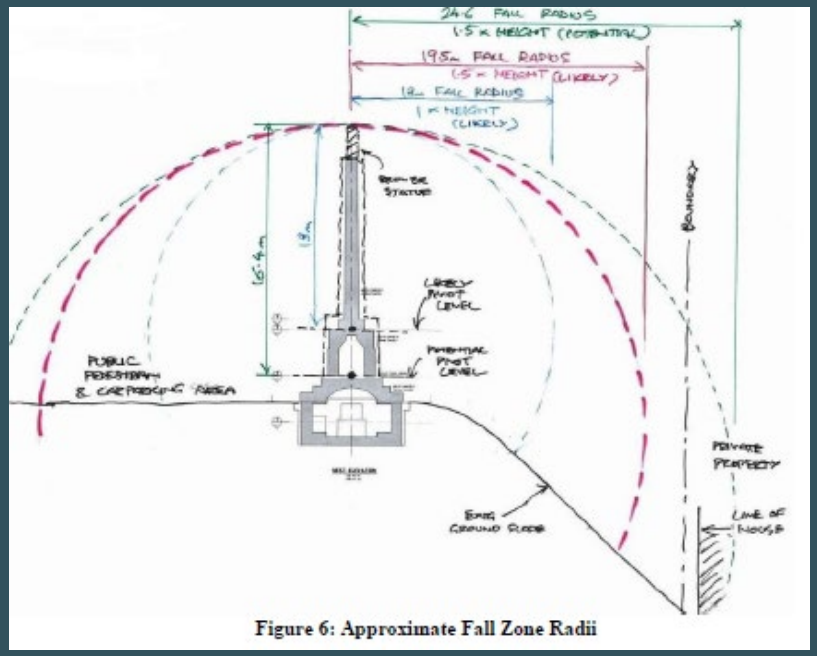


Figure 6: Approximate Fall Zone Radii

Option 1: Height Reduction of column

Reduction in height to 12.5m - 38%NBS

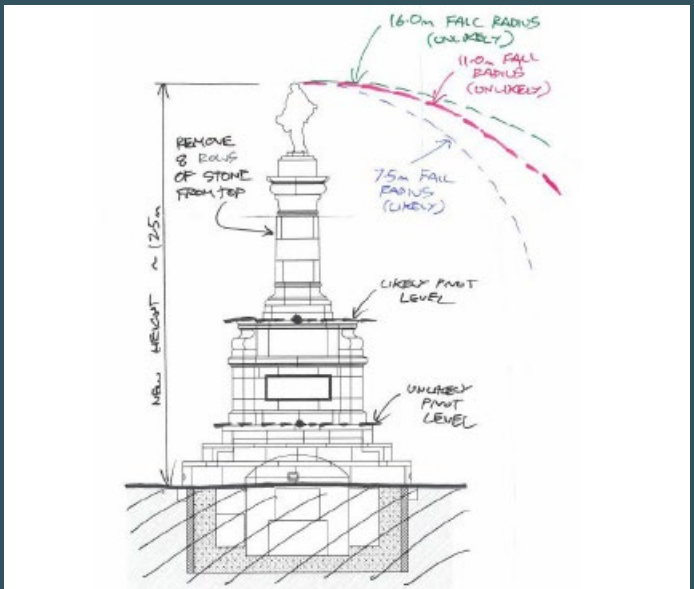


Figure 8 (Left): Reduced likely fall radius range to 7.5-11.0m, seismic rating 38%NBS(IL2)

Reduction in height to 10.5m - 100%NBS

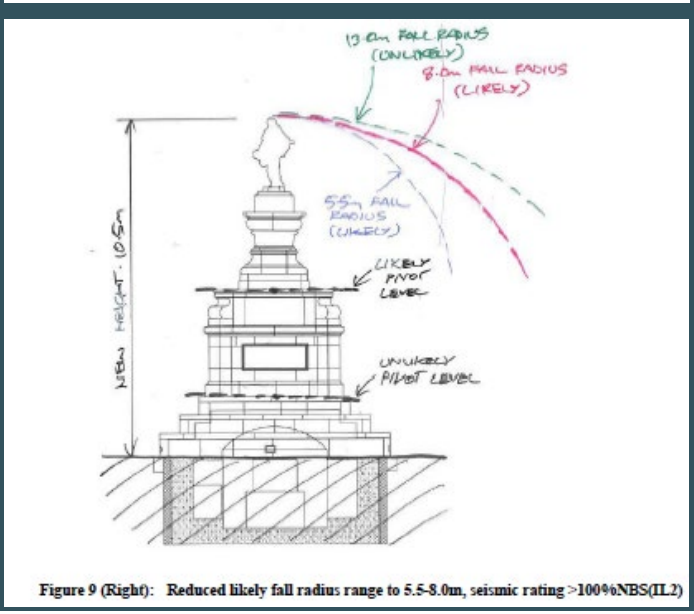
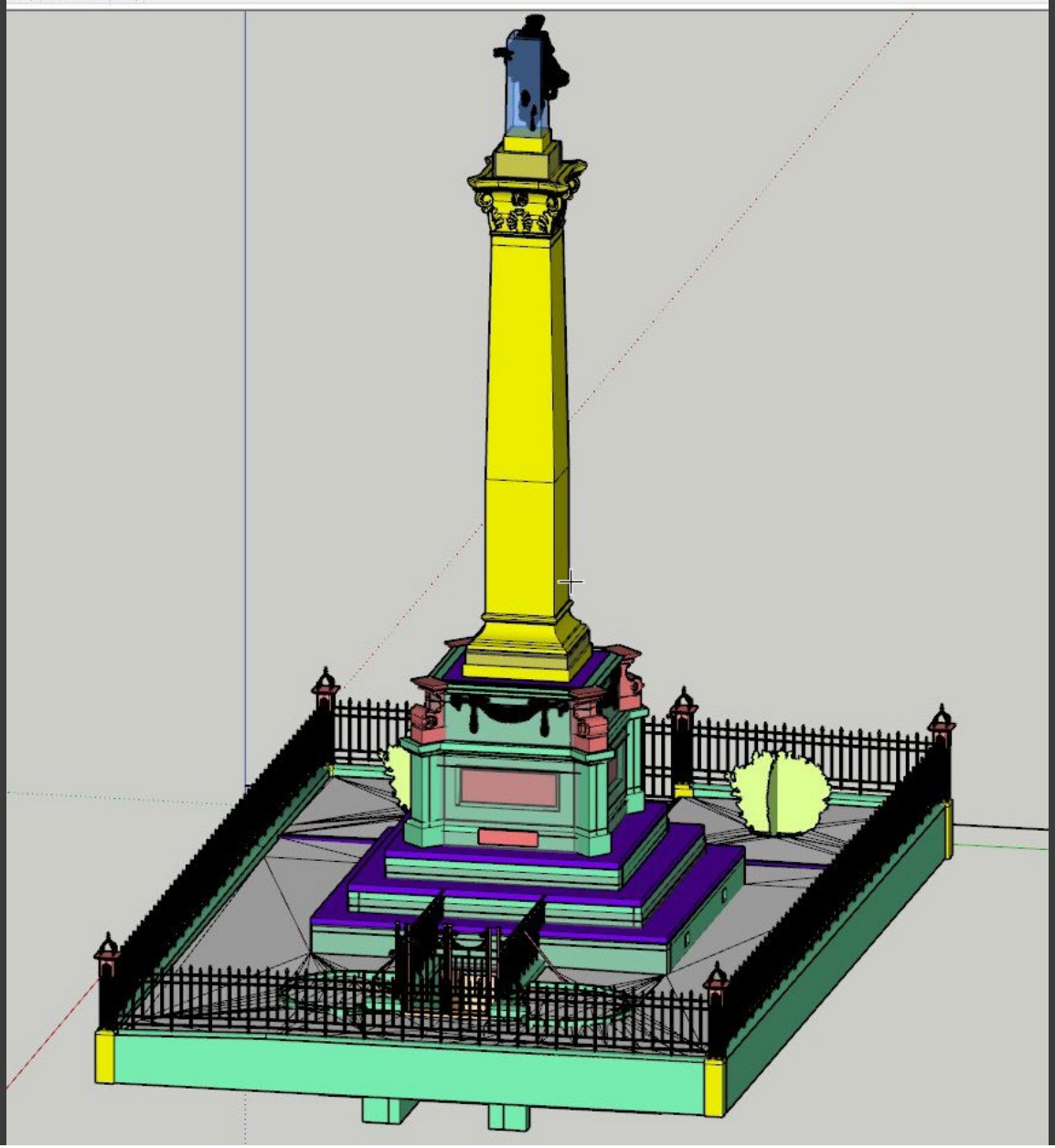
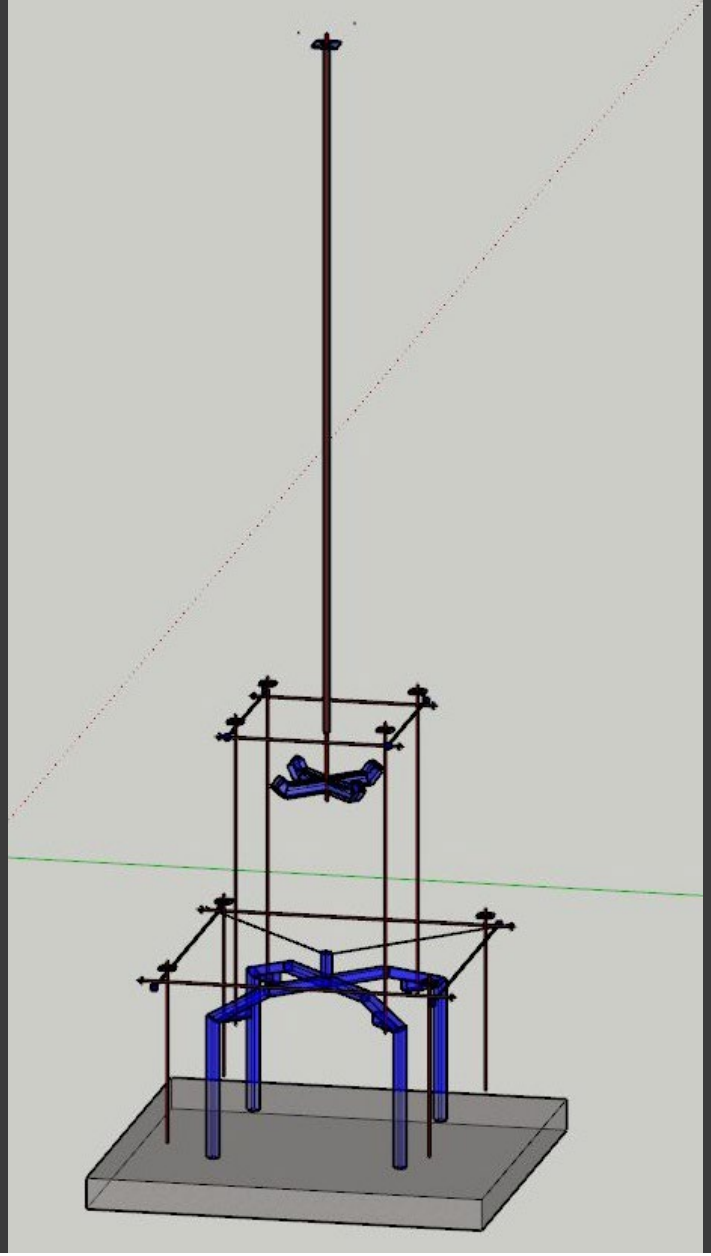


Figure 9 (Right): Reduced likely fall radius range to 5.5-8.0m, seismic rating >100%NBS(IL2)



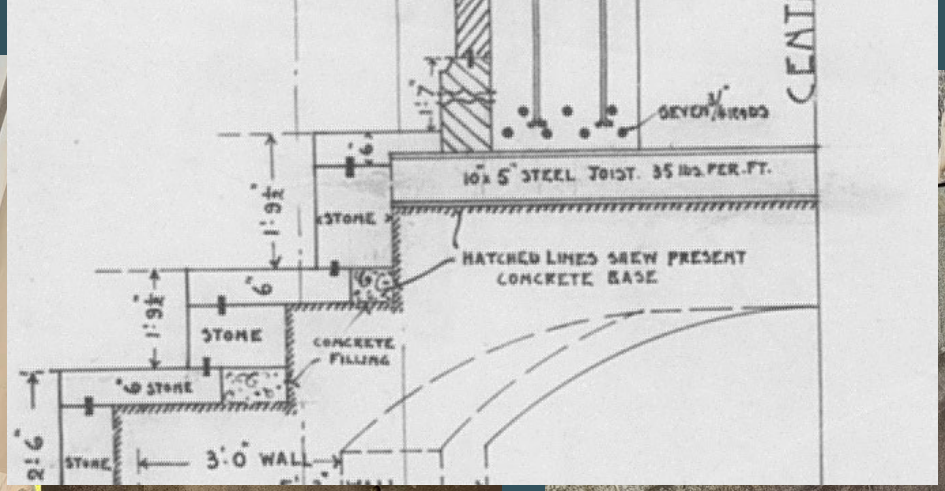


Case Study 4

Option 2: Strengthening to min 34%NBS

Case Study 4

Stage 1: Remove highest risk – the statue & investigate fixings



Case Study 4

Investigating the corrosion

Case Study 4

Breaking through to the void

Case Study 4

Saturated Void

Case Study 4

Corrosion ? Never assume anything!

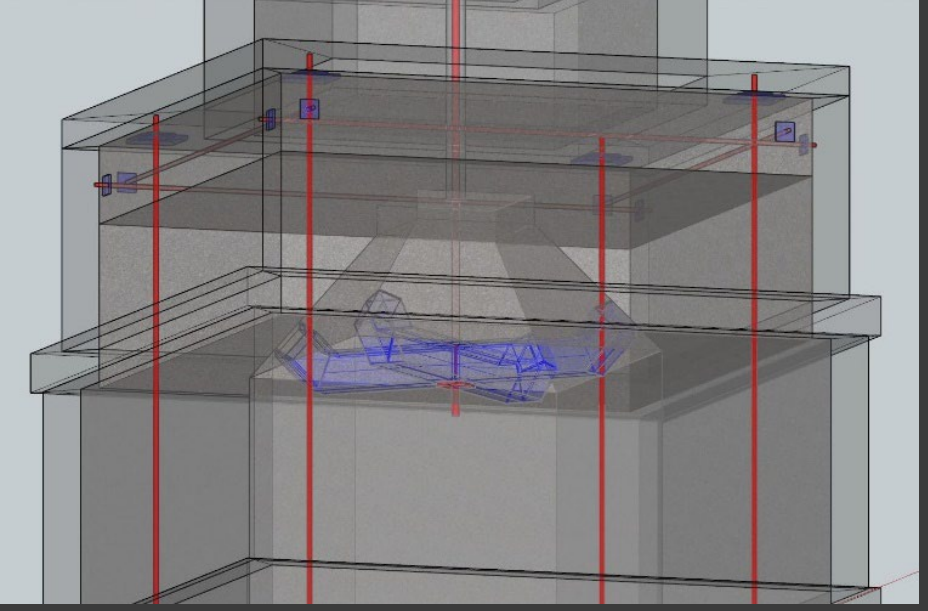
Case Study 4

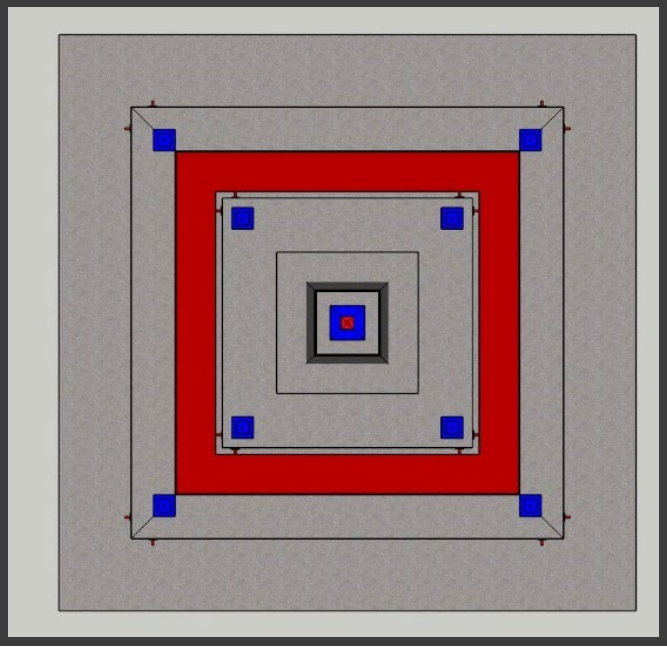
Rotted timber – Tannins causing staining

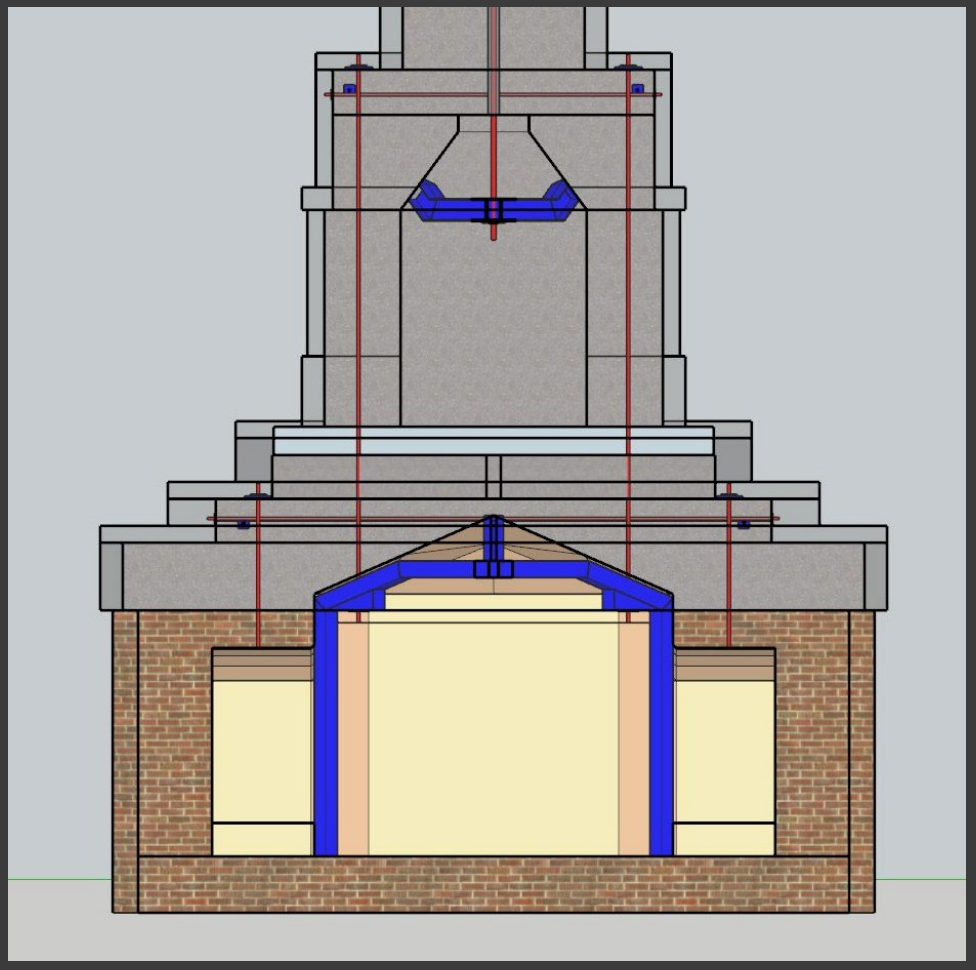
Figure 1: Core sample 4-21/563A before and after testing.

Case Study 4

Drying the void, testing concrete, fine tune proposal

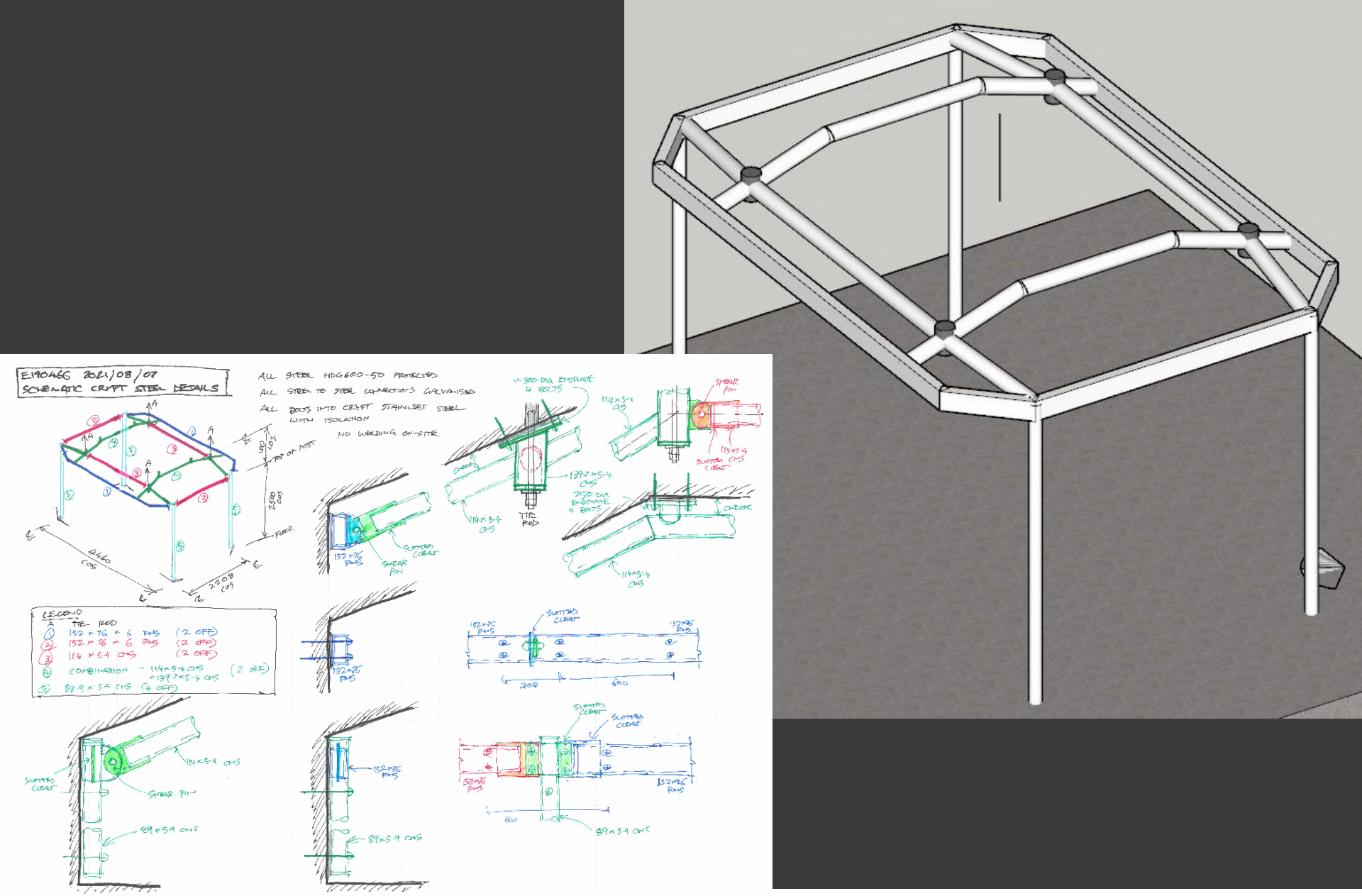






Case Study 4

Structural steel and Post-tensioning – simple on paper

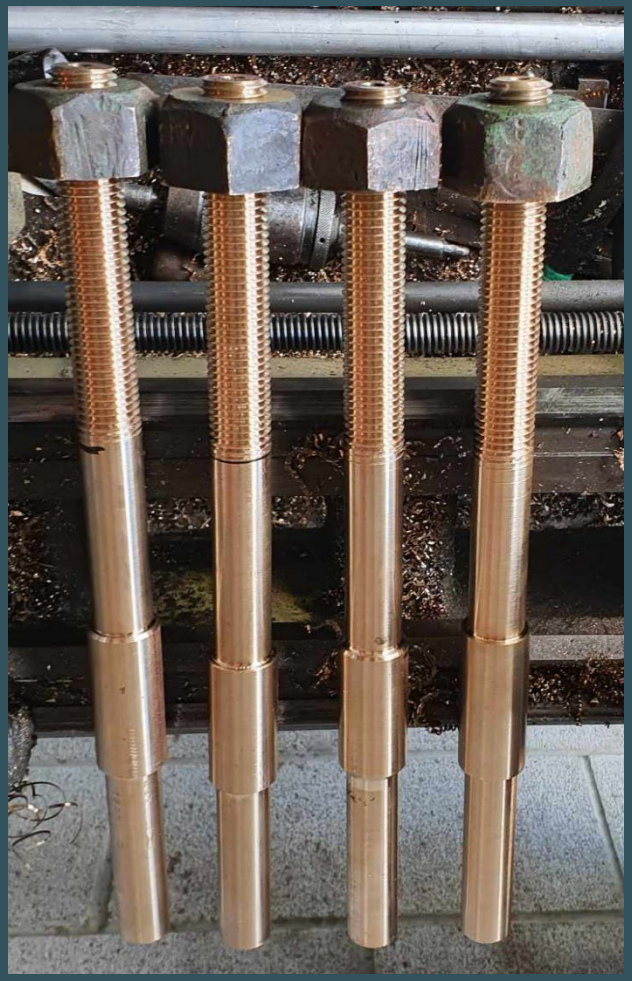


Case Study 4

Crypt Steel Frame Design – Finalised documents

Case Study 4

Stage 2 – Seismic Upgrade and Restoration

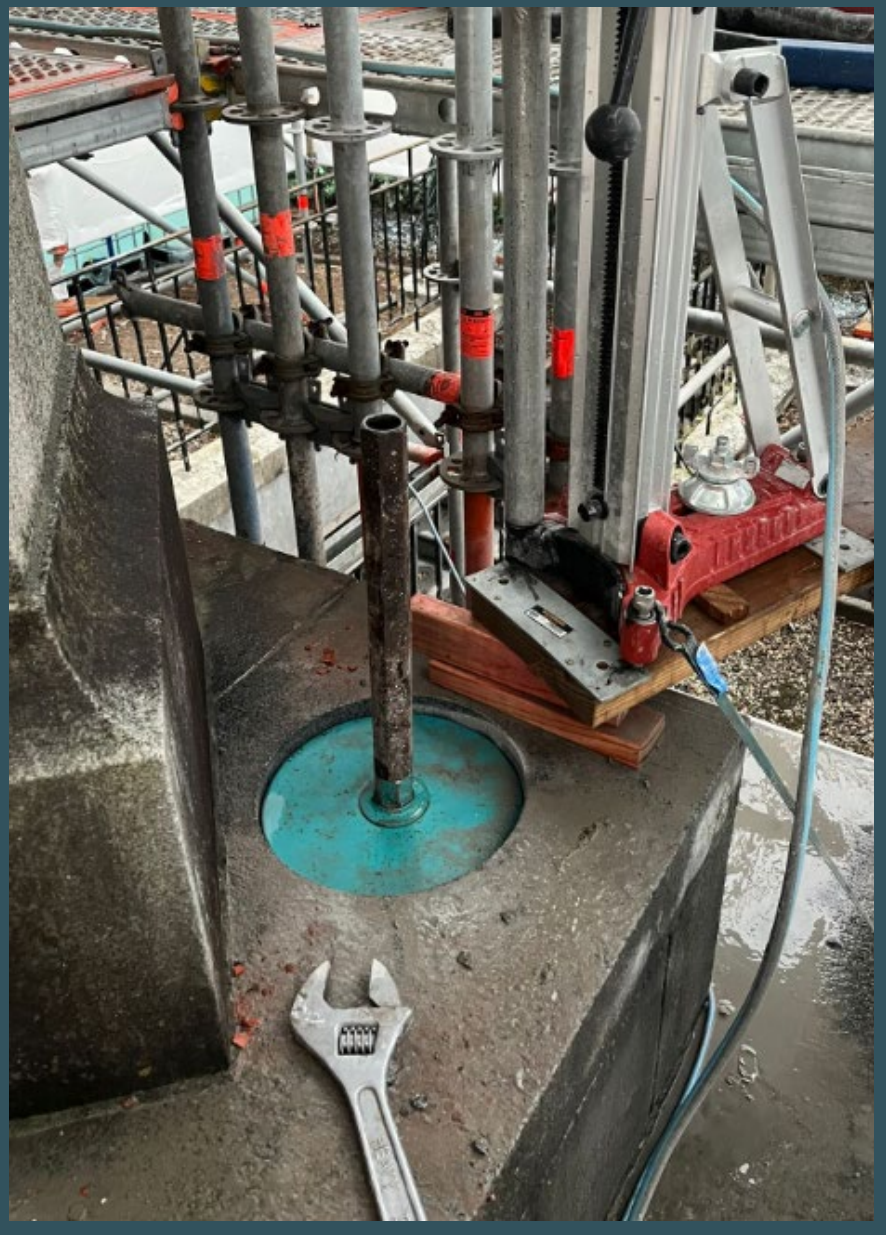


Case Study 4

Statue Fixings

Case Study 4

Coring the Column and the Iron Girder Issue



Case Study 4

Coring the Monument - 2 stages

Case Study 4

Coring – 8 vertical & 8 horizontal cores to monument

Case Study 4

Void Steelwork

Case Study 4

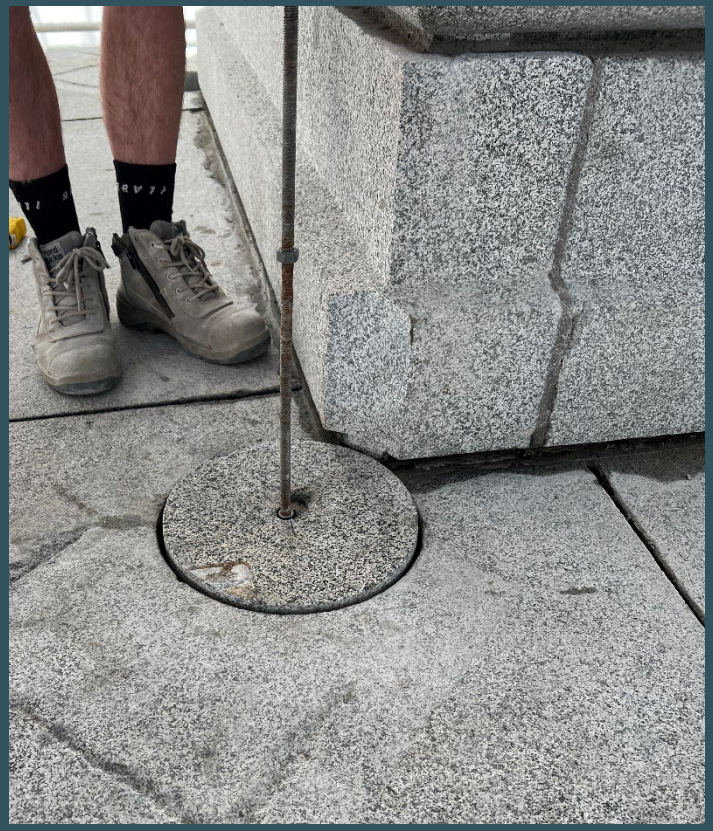
Installing the Crypt Steelwork

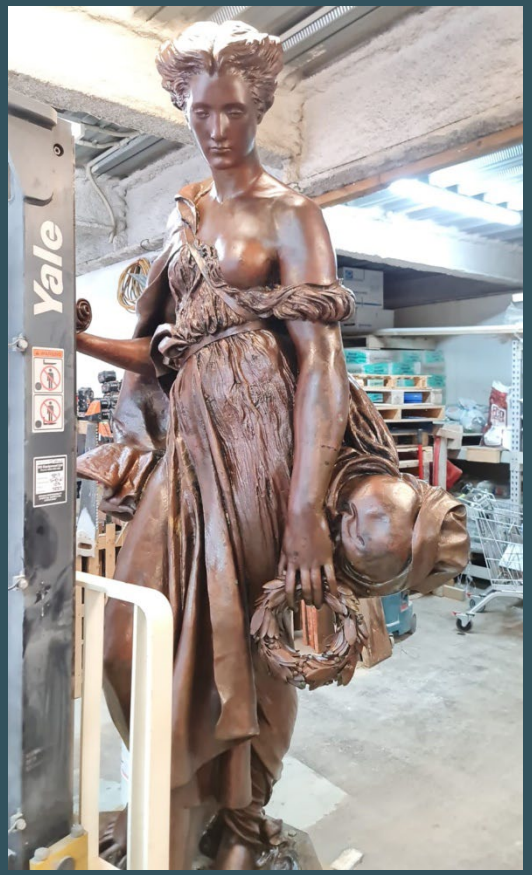
Case Study 4

Installing the Crypt Steelwork

Case Study 4

Completed ready for tensioning and replastering





Currently completing - cleaning, repointing, lead capping, replastering the Crypt, statue being reinstatement next week!

Case Study 4

Completion

Case Study 5: Wintergardens: Seismic upgrading (removal from EPB Register as a trial project) triggering major replacement of fabric

2015 Detailed Seismic Assessment Findings:

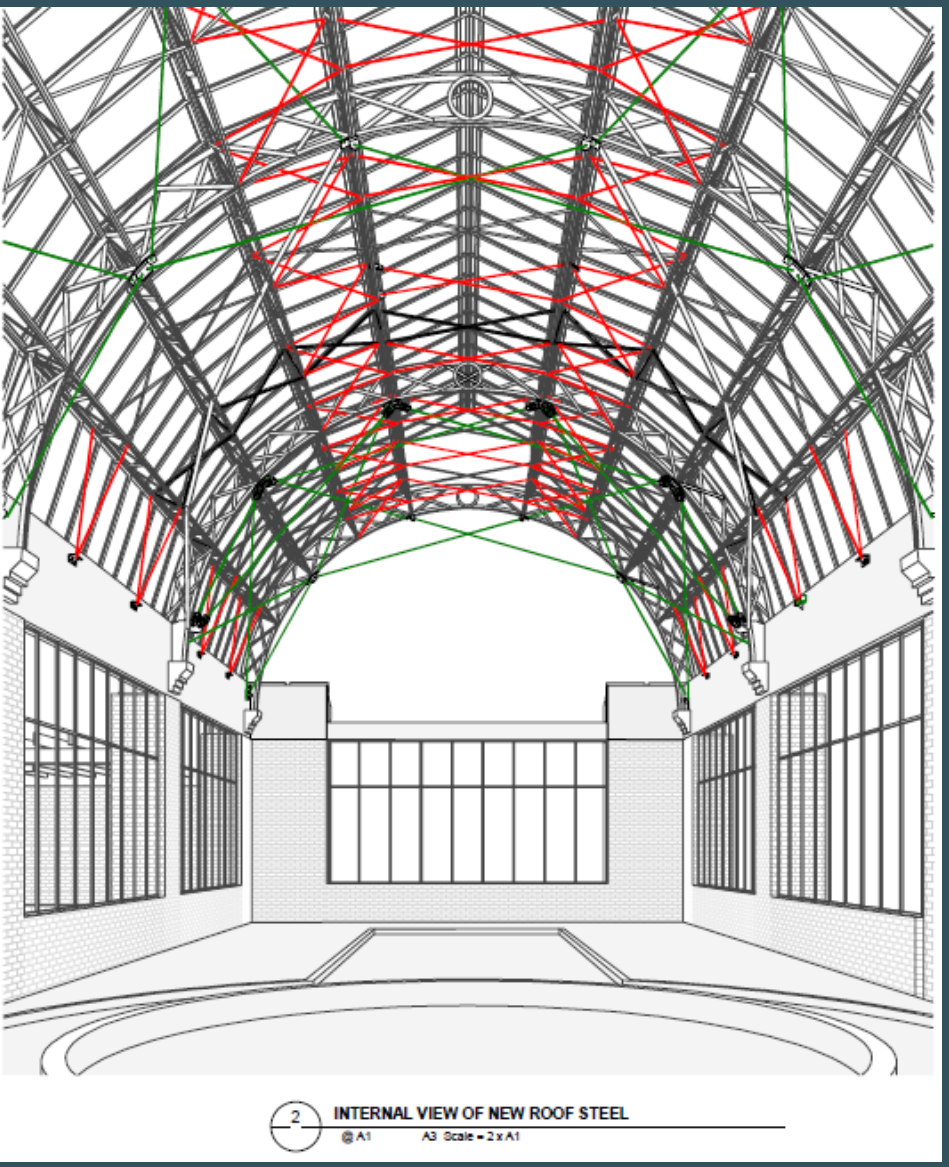
- Walls/piers – 67%NBS;
- Roof system excessively flexible and members insufficiently sized;
- Potential for cracking /shattering of brittle glass to roof – fall hazard;
- Tropical House chimney - potential fall hazard;
- Boiler House roof required a diaphragm;

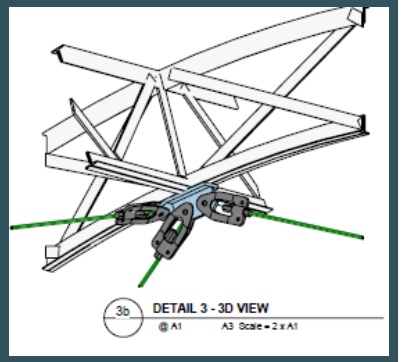
Recommendations:

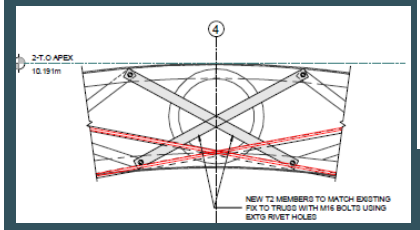
1. Install diagonal tension bracing to the iron roof structure;
2. Supplement critical iron roof members;
3. Upgrade and underpin the chimney;
4. Add diaphragms to the Boiler House.

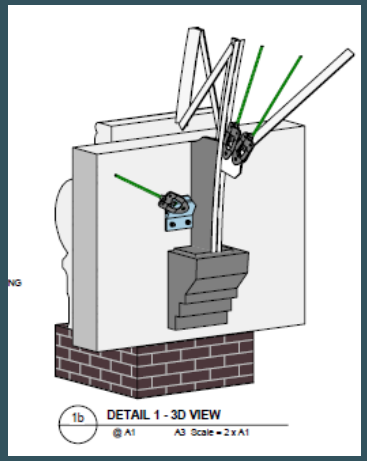
Case Study 5

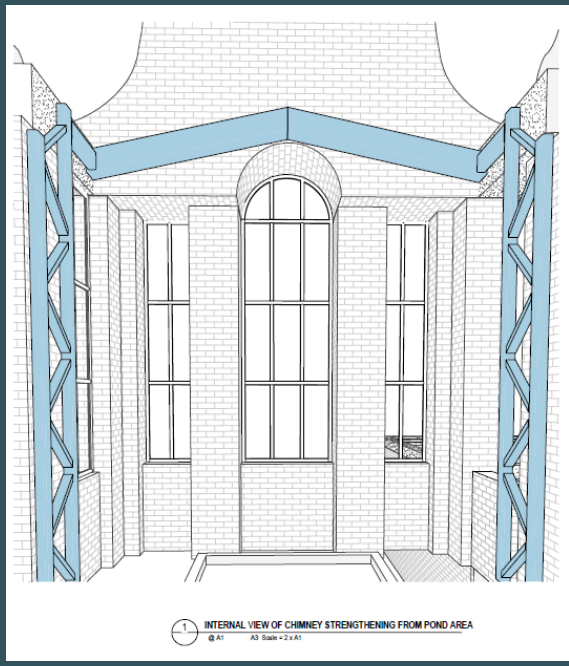
Condition Report

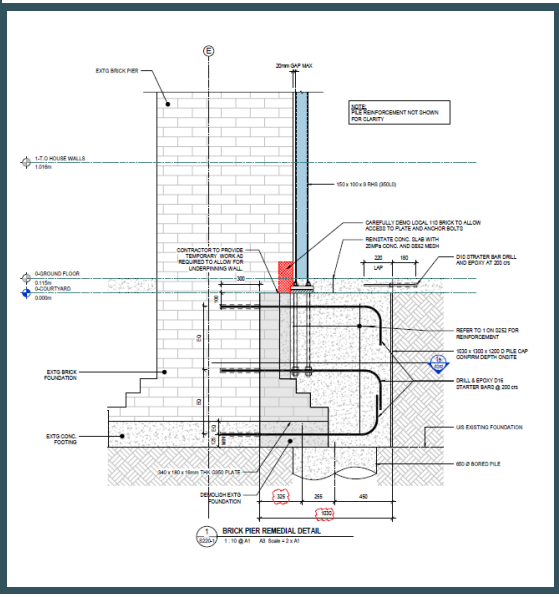












Case Study 5

Consents obtained by the engineer and tendered

Case Study 5

Contractors queries about repairs and the glass

2017 - SPECIALIST GLAZING ENGINEER - ADVISED COUNCIL:

- Existing sloped roofs – 6mm toughened safety glass in AL bars - non-compliant – should be 8.76mm heat strengthened laminated glass (HSL);
- Even if no live load allowance (for maintenance), min. requirement is 6.76mm HSL glass with glazing bars having min. 13mm purchase;
- All vertical glass above 5m and over fire exits - minimum 6.76mm HSL glass with deeper rebates to meet code;
- Replace glass and joinery should be replaced to accommodate movement or, provide catchment nets;

SERIOUS HEALTH AND SAFETY IMPLICATIONS –

Major replacement of glass and glazing bars to roofs, gables and porches at high level;

SALMOND REED APPOINTED AS LEAD CONSULTANT:

- Seismic retrofit;
- Major repairs;
- Glazing renewal;
- Improvements to the buildings;

Stage 1
2018/19 Contract - most urgent fabric repairs, without extensive scaffold;

2019 Finalise the design of the new glazing and review the seismic strengthening;

Stage 2
2019/20 Obtain new consents / tender documentation/ appoint contractor

Stage 3 – On site in 2 separate phases Temperate House first and then Tropical House

HSL Glass – 3mm layers of HS glass with an EVA film layer (double mechanical strength of annealed)

Supply issues:
1 overseas manufacturer of 3mm HSL Stippolyte

Clear glass readily available in NZ

Case Study 5

Glass and Glazing Issues

ALLUMIUNIUM GLAZING

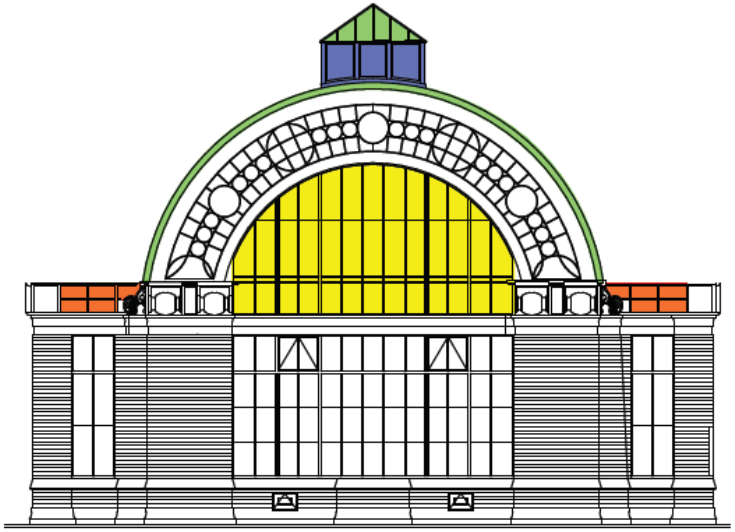
New 6.76mm heat strengthened CLEAR laminated glass with new glazing bars.

New 8.76mm heat strengthened STIPPOLITE laminated glass with new glazing bars.

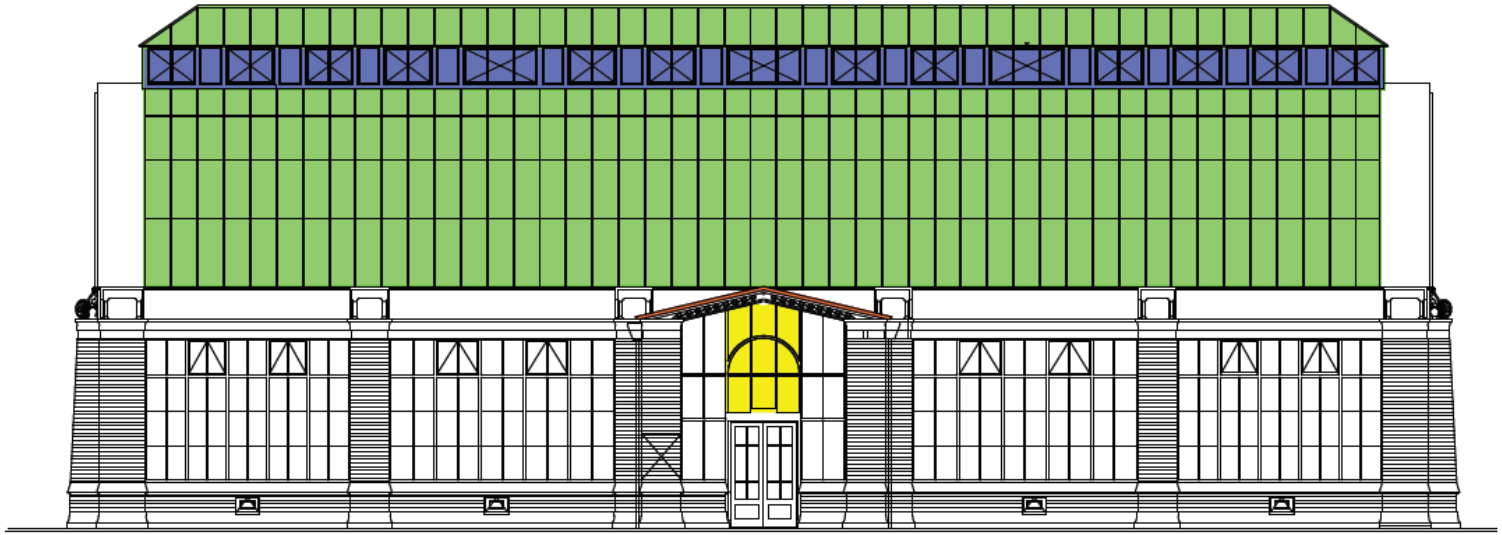
TIMBER GLAZING

New 6.76mm heat strengthened CLEAR laminated glass with new rosewood beads.

New 6.76mm heat strengthened STIPPOLITE laminated glass with rosewood beads.



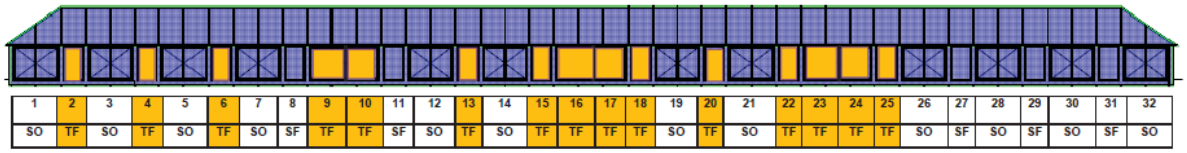
1 - SOUTH ELEVATION



2 - EAST ELEVATION

Case Study 5

2019 – Glazing Design



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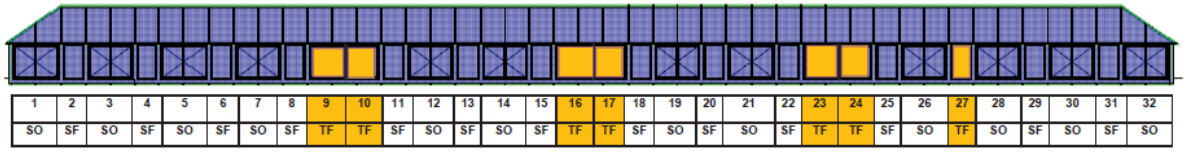
SO	TF	SO	TF	SO	TF	SO	SF	TF	TF	SF	SO	TF	SO	TF	TF	TF	TF	SO	TF	SO	TF	TF	TF	TF	SO	SF	SO	SF	SO	SF	SO

TROPICAL HOUSE - WEST ELEVATION LANTERN

TIMBER:
9 NARROW FIXED GLASS PANELS
6 WIDE FIXED GLASS PANELS

STEEL:
12 OPENING CASEMENTS
5 STEEL FIXED PANELS



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
SO	SF	SO	SF	SO	SF	SO	SF	TF	TF	SF	SO	SF	SO	SF	TF	TF	SF	SO	SF	SO	SF	TF	TF	SF	SO	TF	SO	SF	SO	SF	SO

TROPICAL HOUSE - EAST ELEVATION LANTERN

TIMBER:
1 NARROW FIXED PANELS
6 WIDE FIXED GLASS PANELS/ TIMBER

STEEL:
12 OPENING CASEMENTS
13 STEEL FIXED PANELS

LEGEND

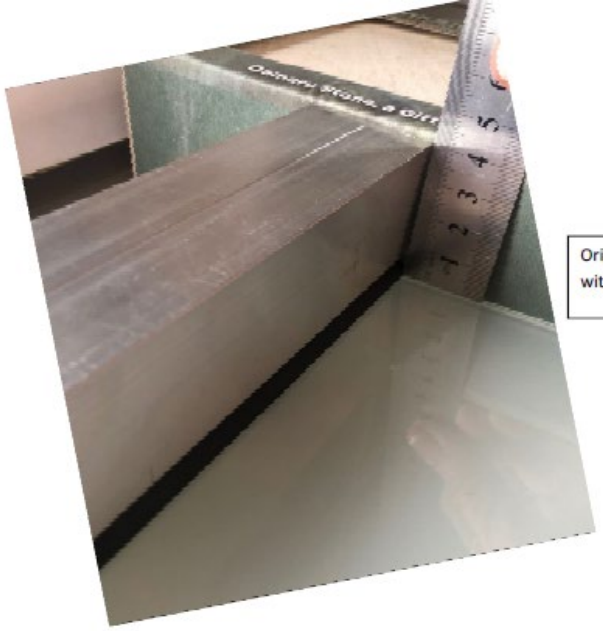
DENOTES TIMBER BEADS FIXED GLASS PANEL
SF STEEL FIXED CASEMENT
SO STEEL OPENING CASEMENT
TF TIMBER FIXED CASEMENT

NORTH AND SOUTH ELEVATIONS:
6 STEEL FIXED CASEMENTS IN TOTAL

SRA/ SK/ 01 - TROPICAL HOUSE LANTERN BEADING

Case Study 5

2019 – Glazing Design



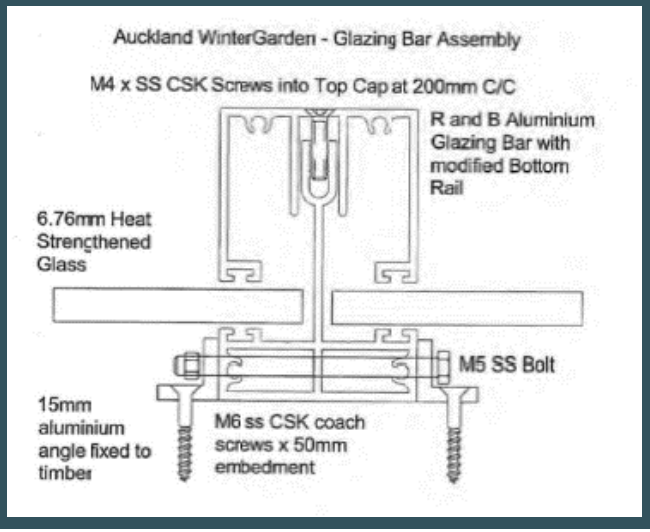
Original Design of New Roof Glazing bar with gasket

Original standard glazing 38mm high above glass

Re-designed, reduced height (reduced by 8mm in total when gasket in place)

New Roof Glazing bar – note gasket missing

Redesigned to reduce the height of the bar by 8mm

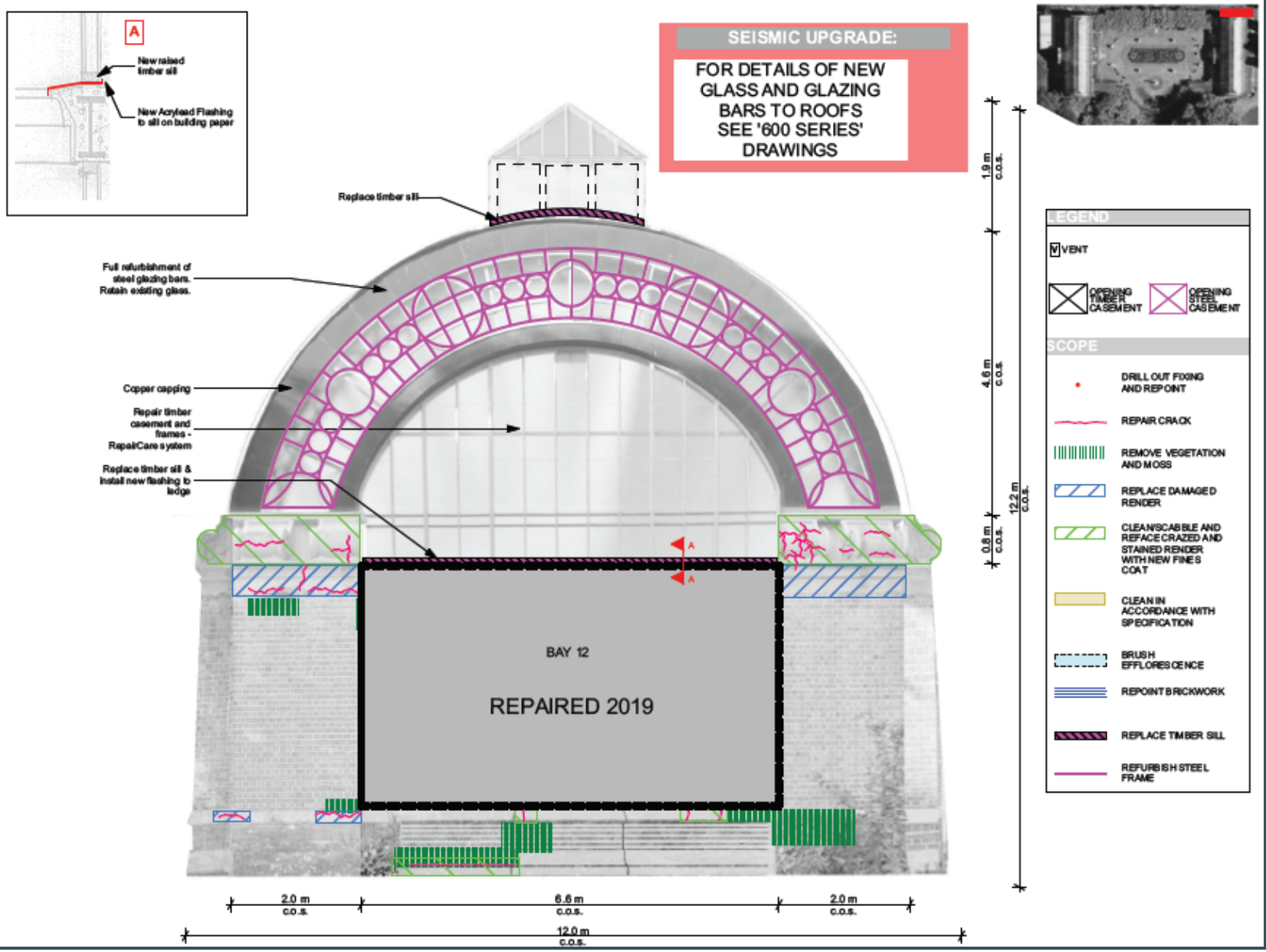


Case Study 5

2019 Developed Design – Glazing bars

Case Study 5

Trial panel



Case Study 5

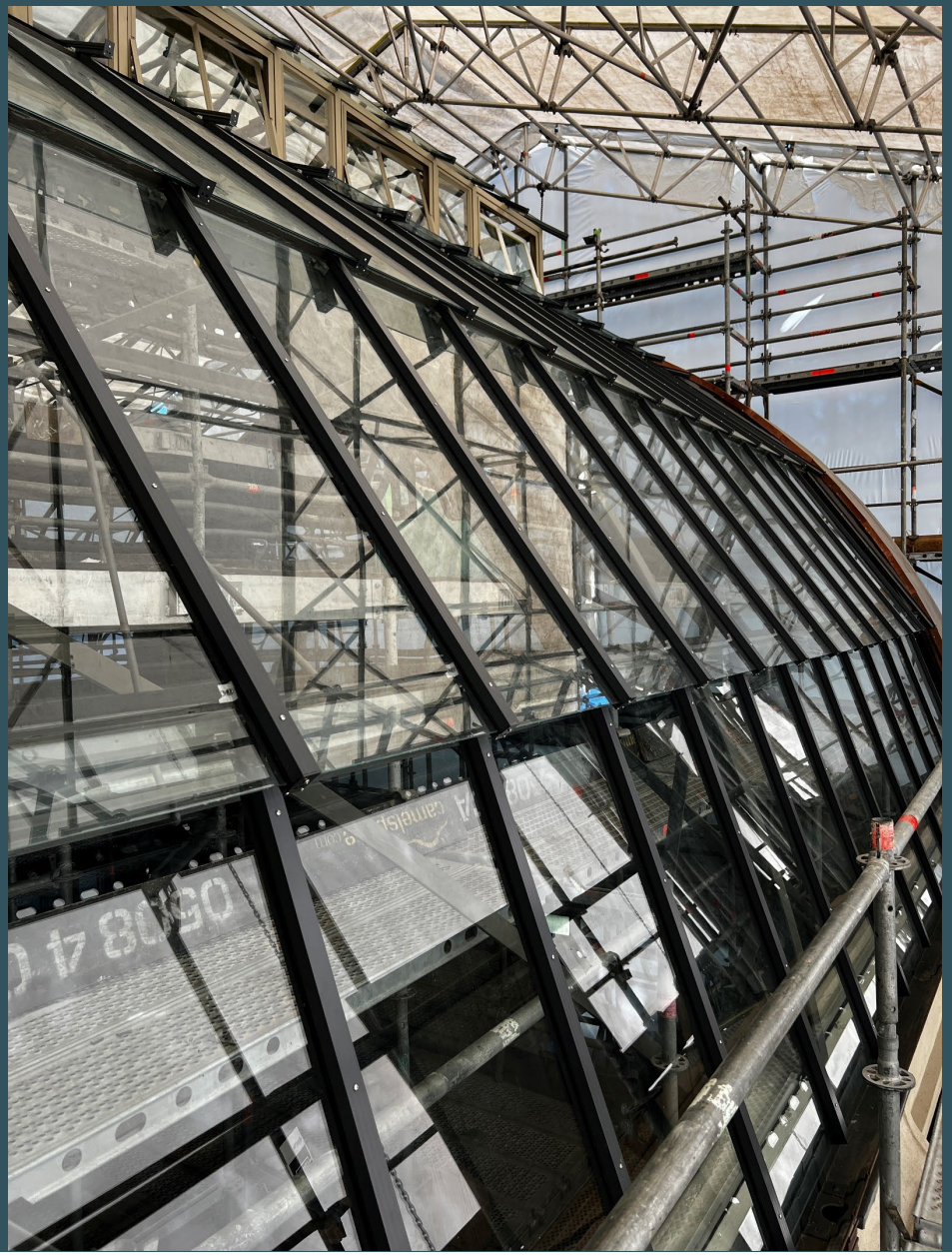
Repairs documentation

Case Study 5

Temperate House

Case Study 5

Temperate House



Case Study 5

Tropical House in progress – completion Feb 2023