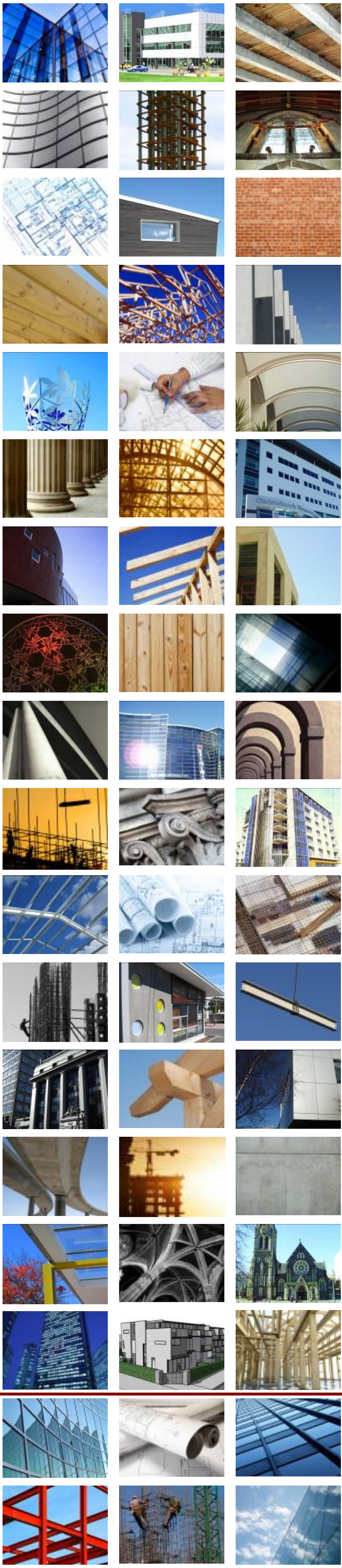

DETAILED ENGINEERING EVALUATION
OF AN EARTHQUAKE AFFECTED BUILDING

VICTORIA JUBILEE CLOCK TOWER
CORNER MONTREAL AND VICTORIA STREETS
CHRISTCHURCH

PREPARED FOR
CHRISTCHURCH CITY COUNCIL

September 29th 2011

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VICTORIA JUBILEE CLOCK TOWER
CHRISTCHURCH

DETAILED ENGINEERING EVALUATION OF AN EARTHQUAKE AFFECTED BUILDING

SEPTEMBER 2011

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2.0 Description of the Building
3.0 Description of the Structural System
4.0 Description of the Foundation System
5.0 Drawings Available and Prediction of 'Hot-Spots'
6.0 Summary of Damage Sustained
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Appendix A: Selected Photographs of Damaged Structure

Appendix B: Proposed Seismic Strengthening Work

Appendix C: Preliminary Geotechnical Assessment Report

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DETAILED ENGINEERING EVALUATION OF AN EARTHQUAKE AFFECTED BUILDING

For:
Victoria Jubilee Clock Tower

At:
Corner Montreal and Victoria Streets, Christchurch

September 29th 2011

1.0 Preamble

Ruamoko Solutions Ltd was engaged by Christchurch City Council to inspect the clock tower at the above address to assess the structural damage, and to advise on any structural repair and seismic upgrading work that may be necessary. This report is for the use of the building owners and the findings shall not be used by any other parties other than The Christchurch City Council (as owner and regulator) and its Insurer.

Several walkover assessments of the exterior and the interior of the clock tower were undertaken to assess the seismic damage from recent earthquake events, primarily the earthquake that occurred on February 22nd 2011, earthquakes on June 13th 2011, and the subsequent aftershocks up to the time of the inspections. The inspections were visual only and non-invasive. Photographs were taken of the cracks and other damage. A selection of the photos is attached in Appendix A.

This report considers an existing structure, and Ruamoko Solutions takes no responsibility for the original design or construction of the building. Comments regarding this building are limited by the nature of the inspection, and are not intended to be used outside the context of this major earthquake event, and re-inspection may be required following aftershocks. The findings are based on best engineering judgment and experience and are not intended to be used outside this context.

Our brief has included the seismic strengthening design and documentation to a level of 67% of current loadings code (Z=0.3) together with the preparation of this report covering the CCC and CERA requirement for the qualitative assessment of this building using the latest draft of DBH “Guidance on Detailed Engineering Evaluation of Earthquake Affected Non-Residential Buildings in Canterbury”, Part 2, revision 5, July 19th 2011.

Additionally, Ruamoko Solutions have designed, documented and construction monitored the internal steel stabilisation frame that has been erected inside the clock tower, in April 2010.

1.1 Qualitative/Quantitative Assessment

A Detailed Engineering Evaluation Procedure (DEEP) has recently been developed by CERA to provide consistent, comprehensive and auditable guidelines which help restore confidence in the remaining building stock in Canterbury. These guidelines will form the basis for our detailed engineering assessment.

The DEEP process follows a two-step process, firstly a qualitative assessment then a quantitative assessment, if necessary.

The qualitative assessment involves visual review of the structure and its conditions in order to ascertain whether the structure does or does not fall within required capacity limitations without completing any complex analysis.

The quantitative assessment involves analytically calculating the capacity of the structure in terms of the current code requirements, ie. to estimate the percentage of new building capacity available (%NBS).

The overall objective of this assessment, independent of the level of sophistication required, is to determine if a retrofit solution is required or not.

For the Victoria Jubilee Clock Tower a qualitative assessment was all that was required to determine that a retrofit solution would need to be developed.

2.0 Description of the Building

The Victoria Jubilee Clock is a cast iron clock tower designed by Benjamin Mountford and first imported into New Zealand from England in 1860. It was initially located at the Canterbury Provincial Buildings site then relocated to the Corner of Manchester and High Streets in 1897. It was finally relocated onto its new stone base at its present site on Victoria Street to coincide with Queen Victoria's Diamond Jubilee in 1930. It has a Category 1 heritage listing.

There was a restoration effort in the 1970's and a significant seismic strengthening and refurbishment project in 2003.

The Victoria Jubilee Clock is approximately 23m high from the bottom of the steps to the top of its finial. It sits on a stone and concrete foundation with steps in each direction. The foundation plinth is 7.3m square and extends from 0.7m above the ground level to 0.3 below ground level.

The stone lower section of the tower is 7.5m high and 3.7m square with four arch openings extending from the stone foundation plinth. Each opening is 3.0m high 1.8m wide.

The original upper cast iron framed section is approx. 12m high and 3.1m square. The finial extends 2.8m from the top of the upper iron clock tower roof.

3.0 Description of the Structural System

The gravity structural system consists of vertical load transfer through the upper level iron and steel columns through to the lower level stone walls and arches to the stone foundation plinth.

The lateral structural system consists of horizontal load transfer through the upper iron section via structural steel K braces installed as part of the 2003 seismic upgrade. Load transfer to the lower level stone walls is via extensions to the K brace corner columns into the lower stone section, connected (to the stone walls) via a series of embedded bolts.

Frame action of the stone arch buttress columns/beams (although in a damaged state) provides transfer of lateral load through to the foundation with overturning resisted by the self-weight of the tower and its foundation. The 2003 seismic upgrade included the installation of a grid of stainless steel rods installed in both horizontally and vertically in the stone walls and buttress columns.

4.0 Description of the Foundation System

The foundation system consists of a square stone and mass concrete pad approximately 1m deep, with the four buttress columns symmetrically placed upon it.

An existing artesian water bore located directly under the foundation pad has been reactivated with recent seismic activity. It is likely that the original cast iron bore pipe (approximately 200mm diameter) has been fractured by the in the June 13th 2011 earthquakes. It was not possible to repair the old pipe so instead a relatively crude concrete cap has been placed over the source of the 'spring' and the water currently discharges through collection pipes over the adjacent area. A permanent discharge pipe will be required to connect to the closest piped storm water outlet.

Georg Winkler, geotechnical engineer, of Land Development & Exploration has made a site inspection and has issued a Preliminary Geotechnical Assessment Report dated July 11th 2011. LD&E have advised that they do not consider that any further geotechnical work will be required, unless new foundations for the structure are proposed. Refer to Appendix C for a copy of that assessment report.

A level and verticality survey shows little evidence of differential settlement and the proposed seismic upgrade will have negligible effect on the subsoil.

5.0 Drawings Available and Prediction of 'Hot-Spots'

Drawings from the restoration in the 1970's and the seismic upgrade in 2003 were available at the time of seismic retrofit design.

Hot spots include the damaged columns and arches in the lower stone section. An inspection of the upper iron section revealed no damage apart from the permanent deformation of the upper finial.

6.0 Summary of Damage Sustained

The structural damage sustained is generally limited to the dislocation of the stones forming the arches and buttress columns at the tower base. Some individual stones are significantly dislodged and held loosely in place pending the repair and seismic strengthening project commencing. Other non-structural damage includes the bending over of the finial spike. Refer to Appendix A for selected photos of the damaged clock tower.

7.0 Intrusive Investigations

The thickness and general integrity of the stone and mass concrete foundation plinth was checked during the drilling of groups of cored holes for the anchor rods to the temporary stabilisation frame. That confirmed that the foundation plinth was at least 900mm thick.

Extensive core holes through the stone buttress columns and the stone walls above the arches, both horizontally and vertically were drilled for the 2003 seismic upgrade for the installation of the stainless steel threaded rods. The stone was generally found to be competent throughout with limited voids or rubble between individual stones.

No other intrusive investigations were carried out following the earthquakes, but detailed inspections of all damaged and dislodged sections of the tower were made.

8.0 Implications / Reasons for the Damage

The reason for the damage was high seismic loading – well beyond the capacity of the 2003 strengthening capacity – resulting in brittle stone deformation and dislocation between stones. That led to tension failure of the diagonal stainless steel bars placed inside the buttress columns in 2003 and spreading and dislocation of the arch stones.

Due to the very high level of damage to the buttress columns and stone arches we have concluded that the strength of this structure has been severely reduced to a level where it is likely to be 'dangerous' as defined in the Canterbury Earthquake (Building Act) Order 2010.

9.0 Generic Building / Material / Configuration Issues

The major issue with this structure is a lack of strength and ductility in the old stone masonry type of construction.

10.0 Elements Specifically Reviewed versus Elements Simply Inferred

The new reinforced concrete structure has been designed for 67% Code seismic loading. The existing stone at the buttress column and arch level has not been relied upon for any strength. The stone at that level is being re-laid as a veneer.

The existing structural steel K braces in the upper section have been reviewed for available strength. Sufficient strength is available to meet the 67% Code seismic loading used for this project.

11.0 Original Lateral Load Resistance

If we neglect the strength contribution from the embedded stainless steel rods we rate the existing stone structure as having approx. 25% Code strength when we assume a stone/mortar dependable shear stress of 0.05MPa before it was damaged by the earthquakes.

12.0 Post Earthquake Damage Capacity

With the failure of the retrofitted stainless bars, the initial low level of strength in the stone/mortar joints and the high level of damage incurred we expect that the capacity of the damaged building will be well below 33% Code, rendering it "dangerous" as defined in clause 7 of The Canterbury Earthquake (Building Act) Order 2010.

13.0 Failure Mechanisms

The failure mechanism observed was frame action of the buttress columns and arches at the tower base resulting in tension failure of the retrofitted stainless bars and gross movement of the stones in the buttress columns and arches.

14.0 Temporary Stabilisation Work

Immediately after the February earthquake a thorough inspection of the tower was completed and a stabilisation concept developed and implemented. The stabilisation concept consisted of a four sided and two level braced structural steel frame connected to the existing upper level steel braced frame columns.

That braced stability frame is anchored down to the tower base plinth with bolts embedded up to 900mm into the plinth. The braced frame has provided an alternative lateral load path to reduce the lateral loads in the damaged buttress columns and arches at the base of the tower.

15.0 Items to be Repaired and / or Strengthened

The badly damaged sections of the tower are to be repaired and strengthened as outlined below.

16.0 Design Feature Report

The seismic retrofit of the Jubilee Clock Tower involves sequential deconstruction of the lower stone arches and buttress columns and reconstruction of those elements with a new internal reinforced concrete structure. Refer to Appendix B for drawings of the proposed seismic strengthening work.

Before deconstruction commences a steel PFC beam is to be placed on the outside of the stone face immediately above the level of deconstruction and connected through the stone walls with stainless rods to an internal steel angle girdle which in turn is connected to the new concrete skin walls to be cast on the inside surface of the stone tower.

The new reinforced concrete skin will connect to the existing stone with embedded stainless steel pins. The new reinforced concrete skin wall in conjunction with the external steel PFC "girdle" will provide support to the upper level of retained stone during sequential deconstruction of the buttress columns and arches.

Each buttress column and adjacent arch is to be deconstructed sequentially. Immediately after deconstruction of each column a steel SHS post is to be placed as an additional prop to the upper level stone wall and is to be cast centrally within the new reinforced concrete column. One by one the buttress columns are to be deconstructed and re-built with reinforced concrete.

When all buttress columns have been re-built, the arches are to be cast in reinforced concrete. Starter bar reinforcing that is cast into the concrete skin walls above will be cast into the new arches.

The buttress columns are to connect to the existing foundation using a series of reinforcing bars embedded into the existing foundation pad.

The existing foundation pad is to be strengthened with four post tensioned tendons placed at mid depth of the existing foundation, with a tendon located under each column in both directions.

Once the new reinforced concrete structure has been constructed the existing internal structural steel stabilisation frame and temporary stabilisation slab topping is to be removed so that the plaster finish to the inside of the tower and placement of a cut stone veneer can be completed. The cut stone veneer is to be made from the existing deconstructed stone and is to match the existing stone surface and coursing patterns exactly.

16.1 New Load Paths

Once works are complete the new lateral load path will be through frame action in the new reinforced concrete buttress columns and arch together with shear wall action in the new reinforced concrete skin above the arch level. Post tensioned clamping across the existing stone foundation from the four post tensioned tendons will provide the foundation pad with enhanced flexural and shear strength.

Vertical load paths will be through the new reinforced concrete buttress columns and arches.

16.2 Load Levels and Coefficients

The seismic design of the tower has been based on the CCC Earthquake Prone Building Policy, 2010, which requires this building to be strengthened to 67% new seismic code. Vertical load paths have been designed for elastic response under ultimate limit state conditions.

The basic seismic design parameters are listed in the table below.

μ	Z	R	Sp
1.25	**0.3**	**1.0**	**0.7**

Table 1: Elastic site spectra multipliers for structural strength

16.3 New Structural Elements

New structural elements include the SHS posts cast centrally within the new reinforced concrete buttress columns, the new concrete skin walls within the tower walls, the new concrete arches and the post tensioned tendons installed in core drilled holes through the existing foundation pad.

17.0 Recommended Timeframe for Strengthening

As this structure is already stabilised, retrofit does not need to be implemented as a matter of urgency. However, the stone components of this clock tower can be expected to deteriorate further if it is subjected to more large seismic events.

18.0 Retrofit Sketches or Drawings

Refer Appendix B for the detailed plans showing the seismic upgrading and repairs intended for this tower.

19.0 Disclaimer and Limitation of Liability

Ruamoko Solutions Ltd conditions of contract are the standard ACENZ/IPENZ "Short Form Agreement for Consultant Engagement," July 2011 version. These conditions can be downloaded from the ACENZ website www.acenz.org.nz. Ruamoko Solutions is liable to the building owner only to the extent of that agreement. That commercial engagement is not bound by the Consumer Guarantees Act.

Report prepared by

Joe McGlrr
BE (Hons) (Civil)
STRUCTURAL ENGINEER
Written on 30 08 11

Report reviewed by

Grant Wilkinson
BE (Hons) (Civil), FIPENZ (Structural, Civil), CPEng
MANAGING DIRECTOR

APPENDIX A

VICTORIA JUBILEE CLOCK TOWER
CHRISTCHURCH

SELECTED PHOTOGRAPHS
OF DAMAGED STRUCTURE


View of the south arch shortly after the February earthquake showing the dislodged arch keystone and damaged columns


View from the east during stabilisation


Elevation of the entire tower from the south, finial bent at top


Internal view of the tower stone lower section


View of the dislocated southern arch keystone


View from the north after stabilisation showing damage to the columns including the failed internal stainless rods

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APPENDIX B

VICTORIA JUBILEE CLOCK TOWER
CHRISTCHURCH

DRAWINGS OF THE PROPOSED SEISMIC STRENGTHENING WORK

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COORDINATION ISSUE
AUGUST 2011

PROJECT NUMBER : 603
DRAWING INDEX

S1-1 Cross sections

S2-1 Plan sections

S3-1 Details

JUBILEE CLOCK TOWER
STABILISATION AND STRENGTHENING
VICTORIA STREET, CHRISTCHURCH

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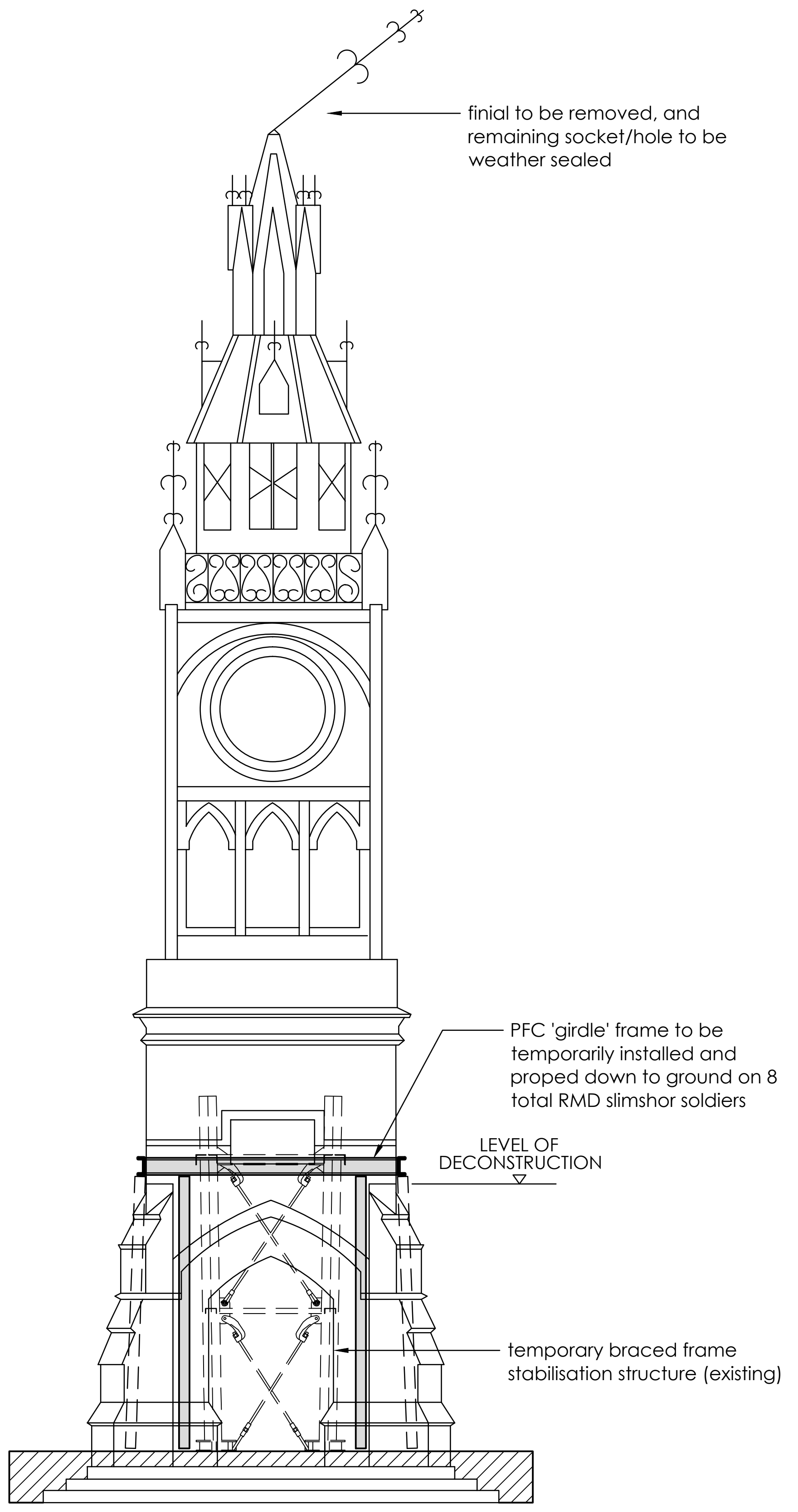
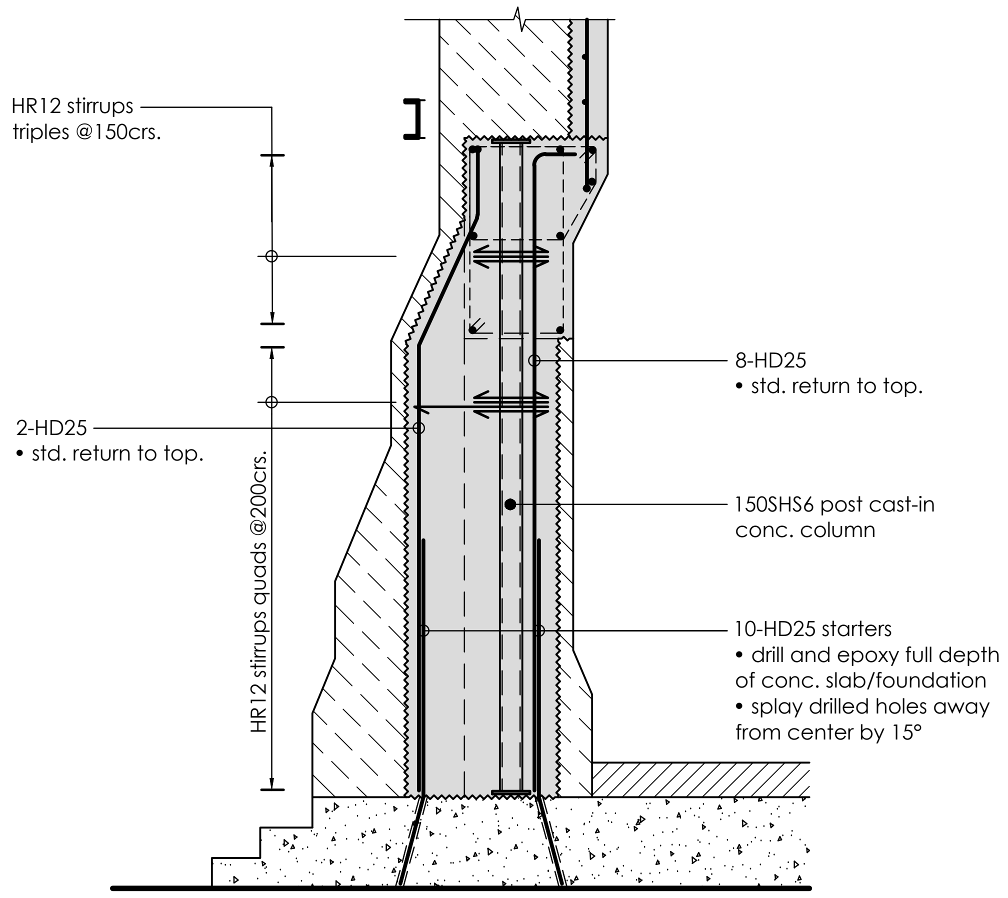


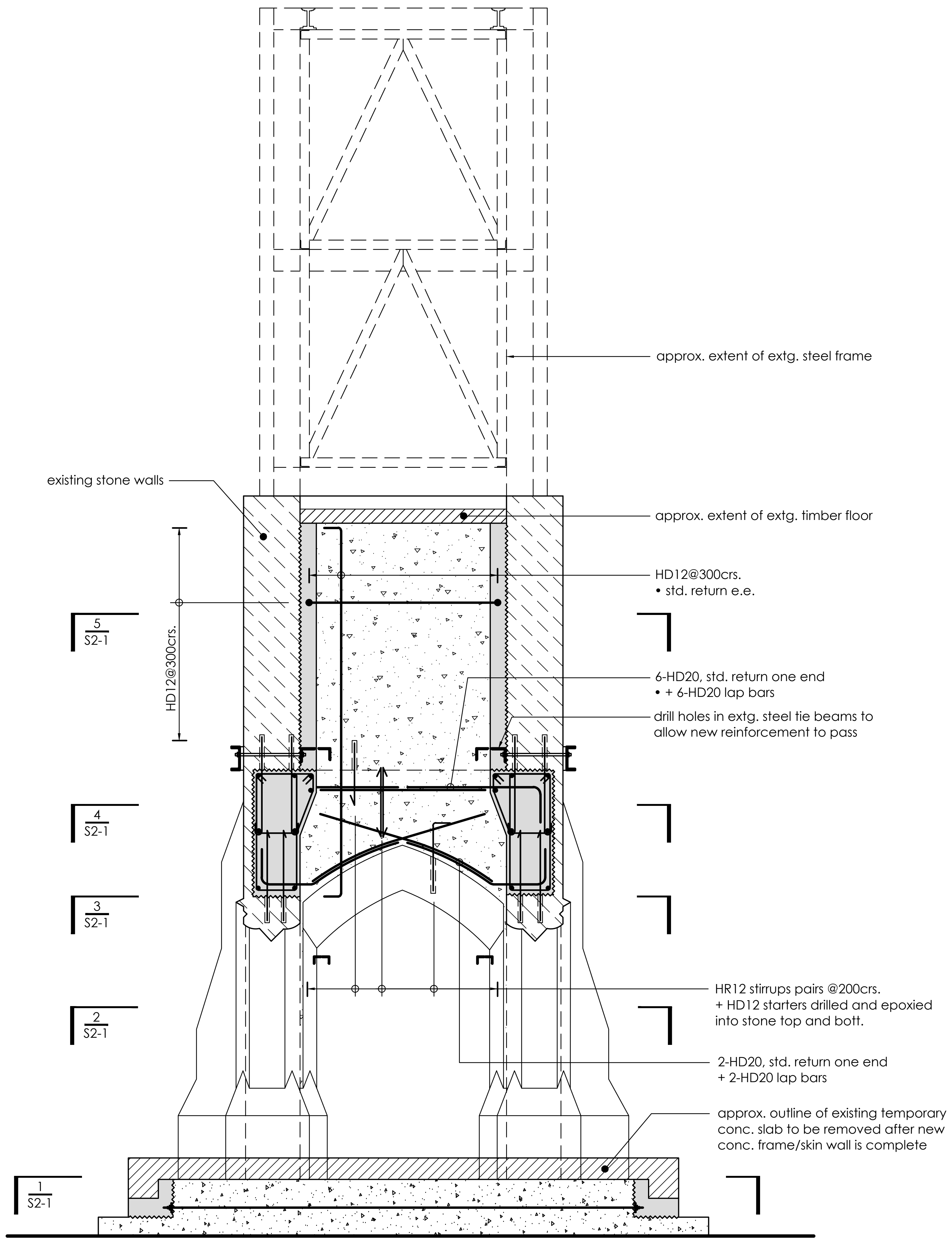
TYPICAL EXTERNAL ELEVATION
SCALE 1:100

PROPOSED CONSTRUCTION METHODOLOGY:

- place PFC 'girdle' exterior frame and bolt in place, including props to base slab
- post-tensioned cables to be placed to slab foundation
- place reinforcement, wall starters and boxing for concrete skin to the internal face of the stone walls. Cast internal concrete skin
- jacking as required to base of temporary frame to be carried out, to ensure tower is plumb and to offset any settlement to the existing columns during seismic movement
- deconstruct stone legs one at a time to level indicated, place internal SHS prop, column starters, column reinforcement and boxing as required. Cast structural concrete column. Continue leg-by-leg until all four are complete
- place falsework to support reinstated arch stones, starters, beam reinforcement and formwork to concrete beams. Cast beams.
- cut and remove temporary support frame, treating exposed steel as specified
- 'veneer' stones to be relaid around new concrete columns and arches with veneer ties as specified, finial reinstated with instruction given by engineer on site



1
S2-1
TYPICAL COLUMN ELEVATION
SCALE 1:50



TYPICAL CONCRETE SKIN ELEVATION
SCALE 1:50

rev	by	date	revision details
A	JDM	31.08.11	coordination issue

consultants

project title: JUBILEE CLOCK TOWER
VICTORIA STREET
STABILISATION AND STRENGTHENING

drawing title: TYPICAL ELEVATION
NEW STRUCTURE ELEVATIONS

design	JDM
drawn	JBM
date	AUG 11
scales	AS SHOWN
file no	603
size	A2
dwg	S1-1
rev	A

All dimensions are to be verified on site before commencing any work or shop drawings

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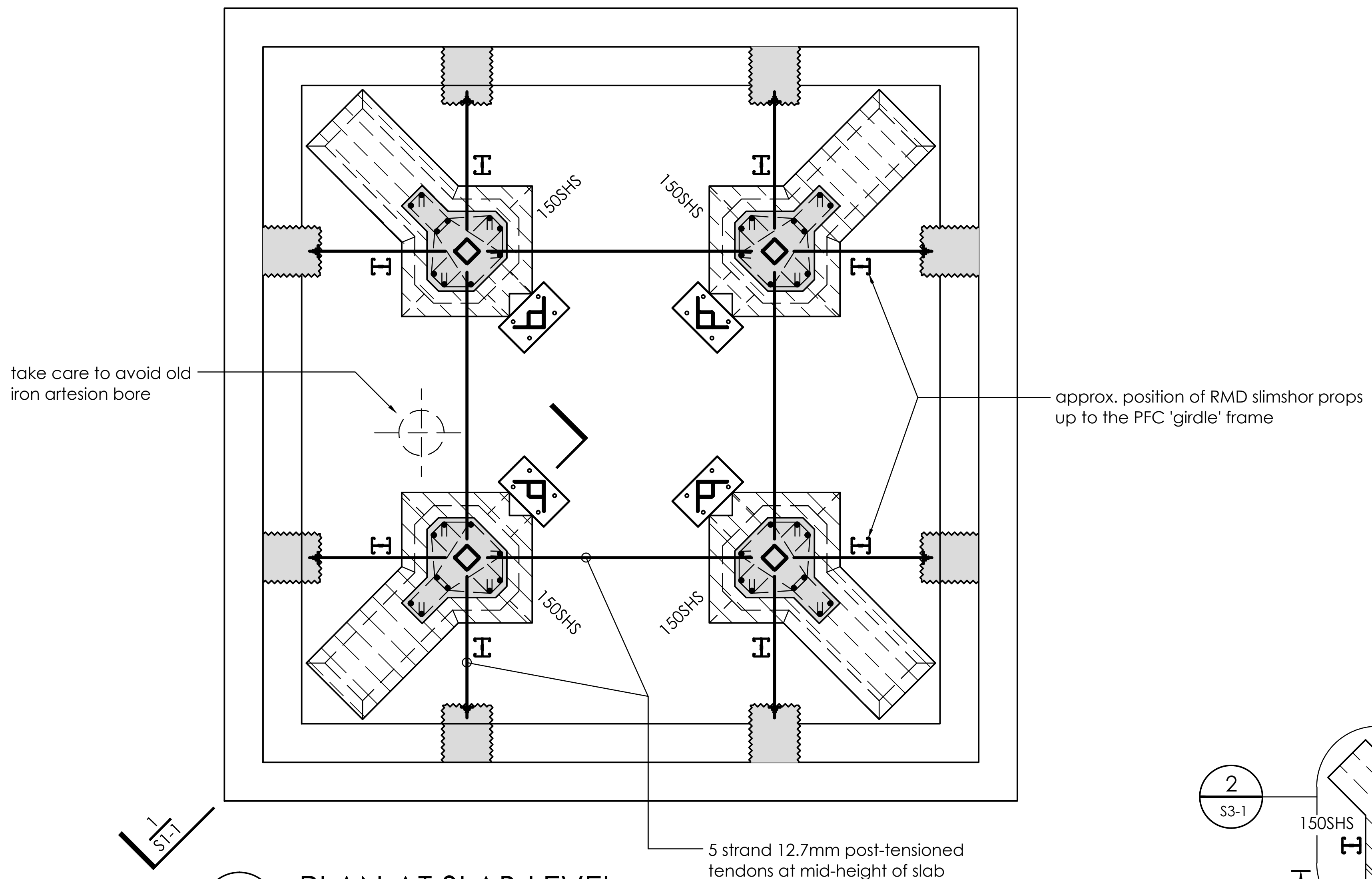
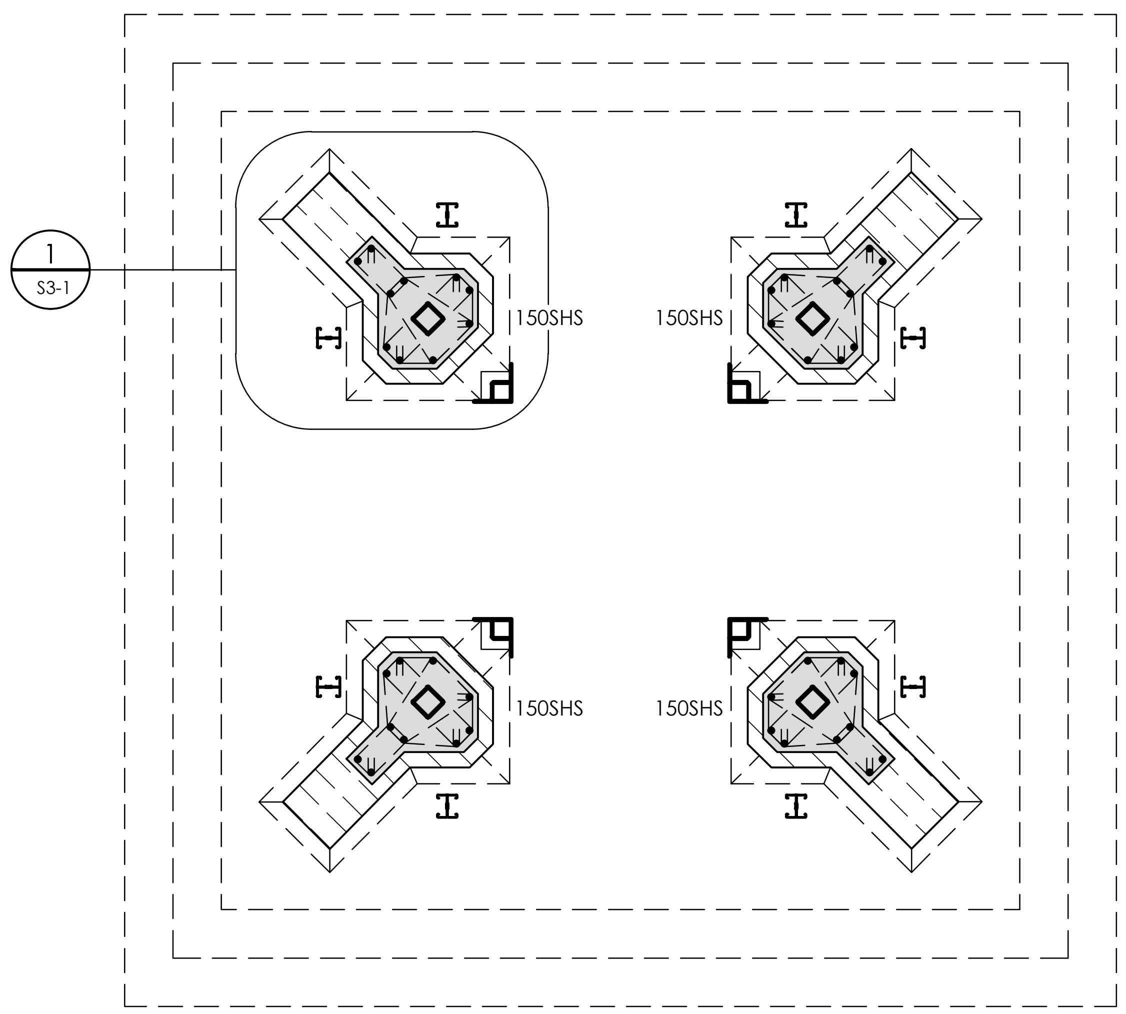
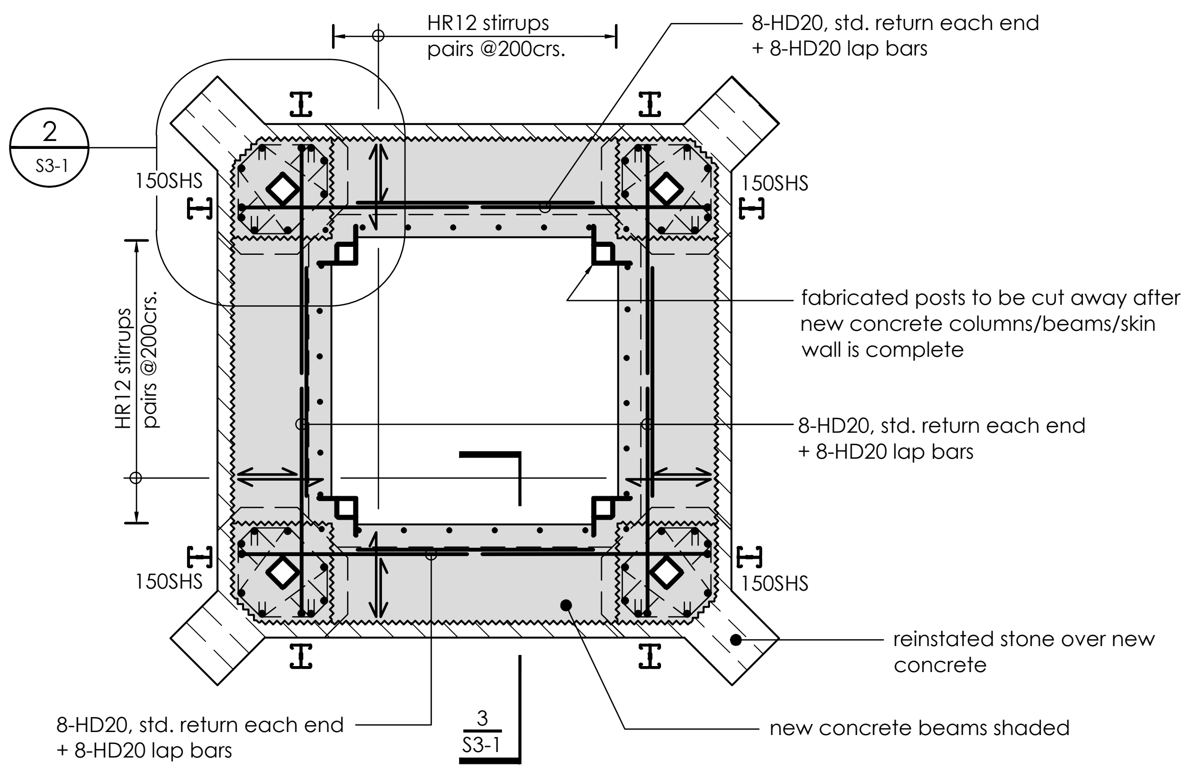


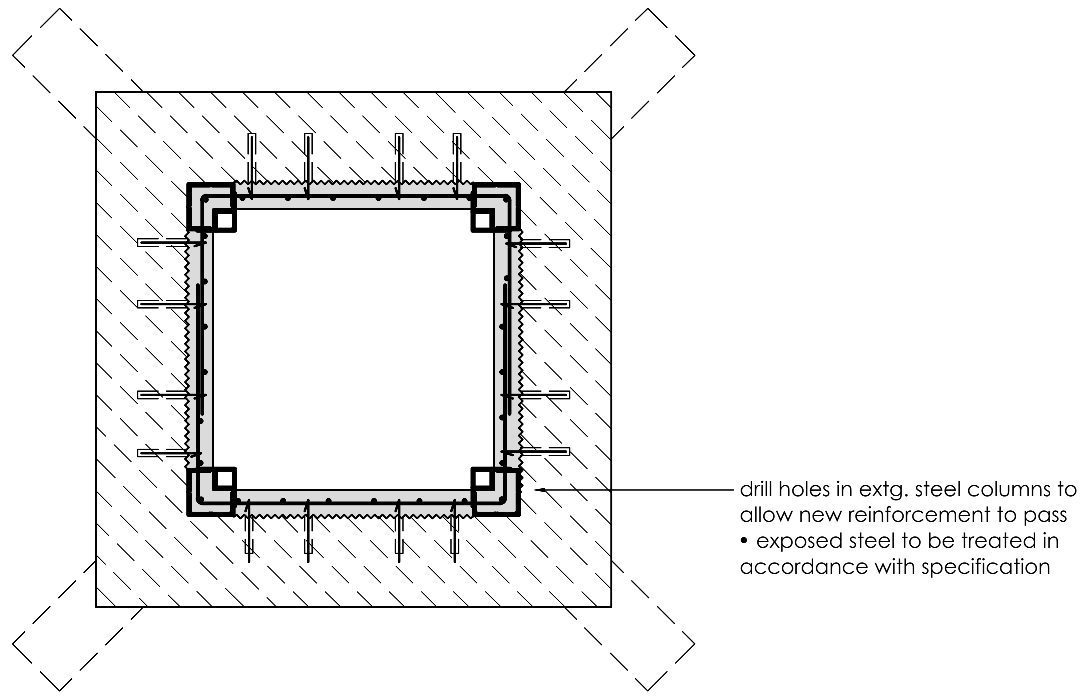
1 S1-1 PLAN AT SLAB LEVEL
SCALE 1:50



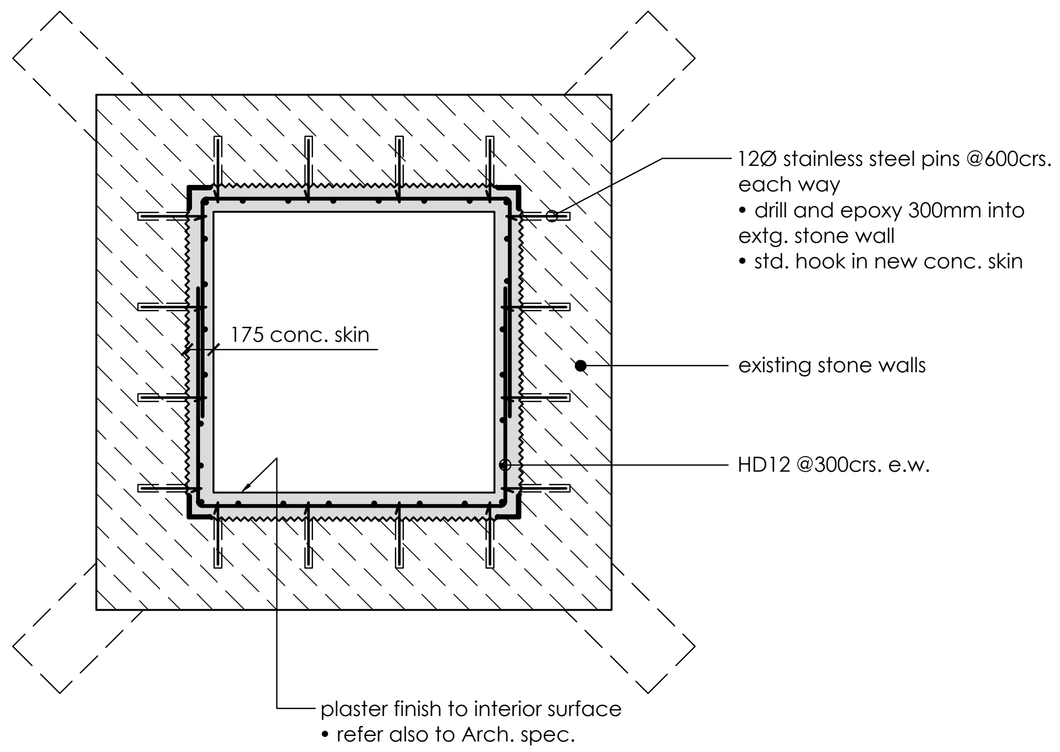
2 S1-1 PLAN AT COLUMN LEVEL
SCALE 1:50



3 S1-1 PLAN AT CONCRETE BEAM LEVEL
SCALE 1:50



4 S1-1 PLAN AT CONCRETE SKIN
SCALE 1:50



5 S1-1 PLAN AT CONCRETE SKIN
SCALE 1:50

rev	by	date	revision details
A	JDM	31.08.11	coordination issue

consultants

project title: JUBILEE CLOCK TOWER
VICTORIA STREET
STABILISATION AND STRENGTHENING

drawing title: PLAN SECTIONS

design	JDM
drawn	JBM
date	AUG 11
scales	1:50
file no	603

dwg S2-1
A2 rev A

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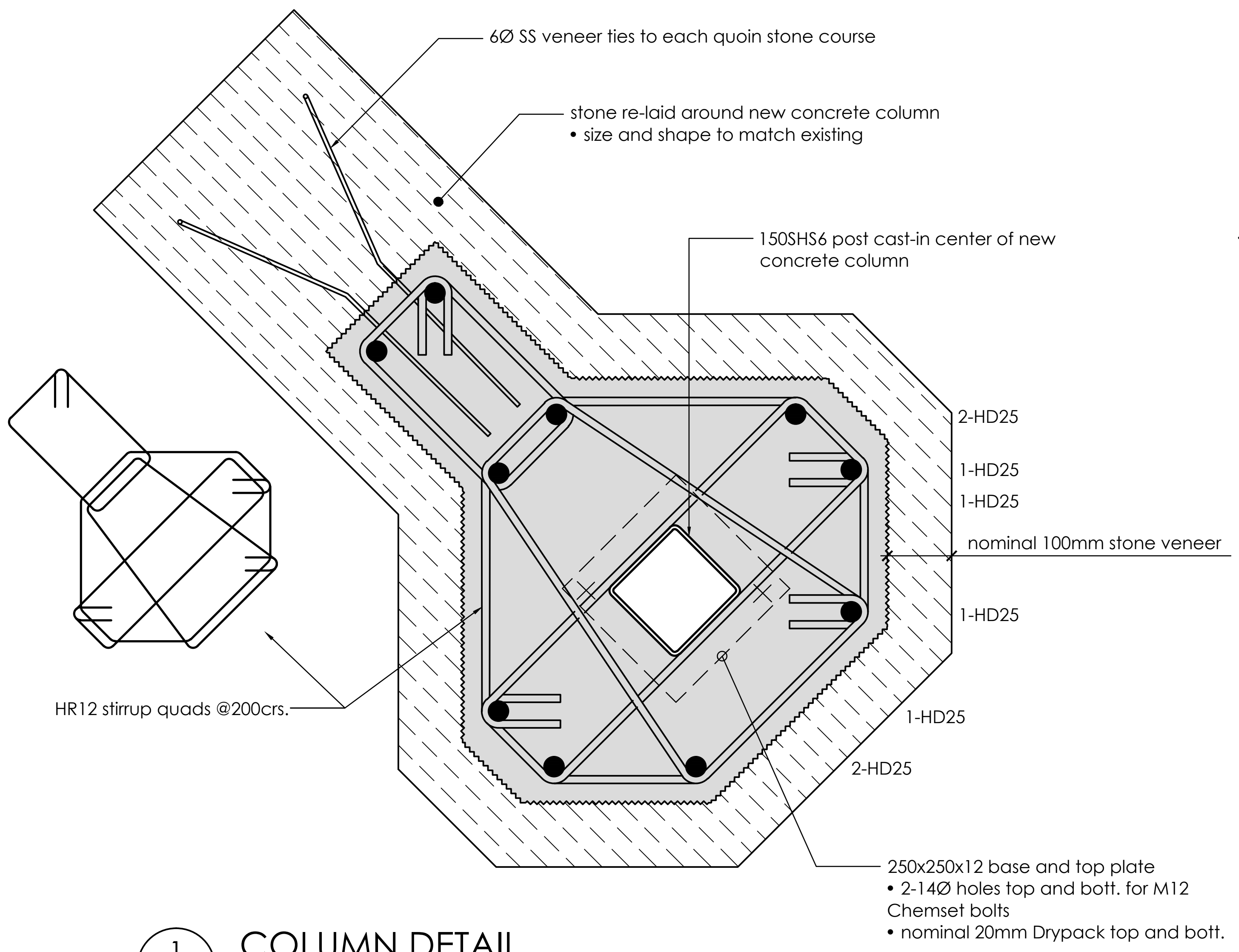
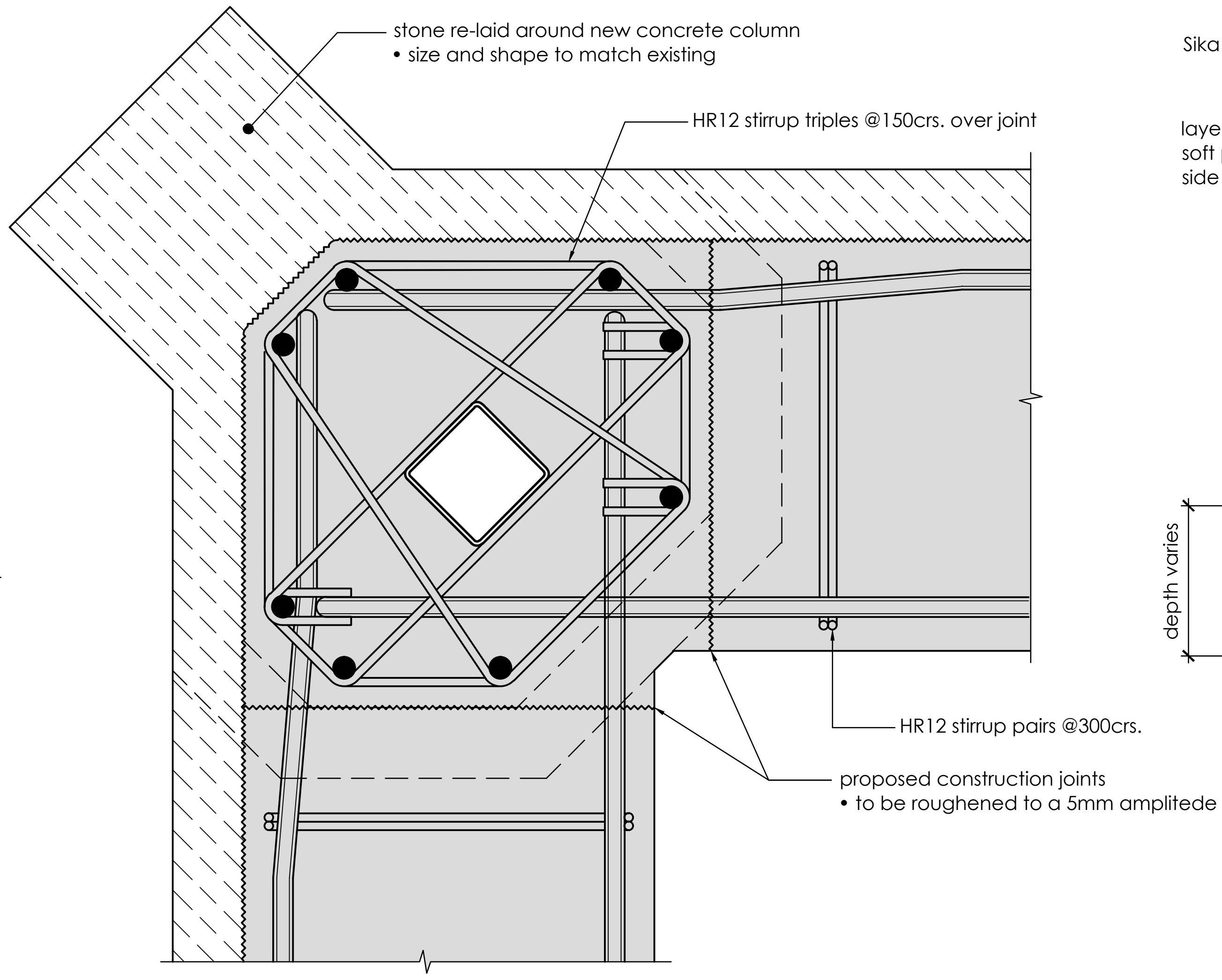
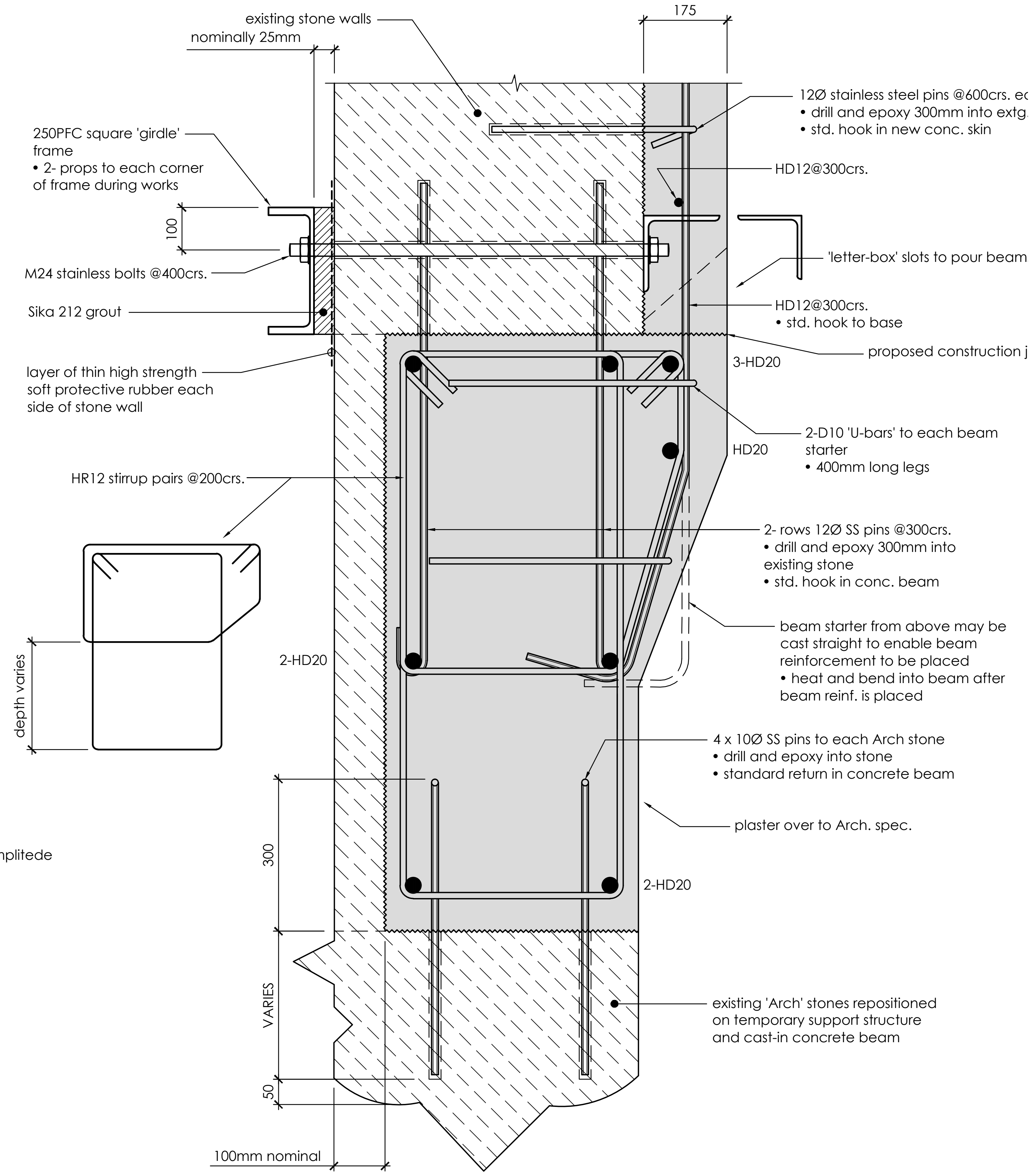


1 S2-1 **COLUMN DETAIL**
SCALE 1:10



2 S2-1 **BEAM/COLUMN DETAIL**
SCALE 1:10



3 S2-1 **CONCRETE BEAM DETAIL**
SCALE 1:10

rev	by	date	revision details
A	JDM	31.08.11	coordination issue

consultants

project title
JUBILEE CLOCK TOWER
VICTORIA STREET
STABILISATION AND STRENGTHENING

drawing title
DETAILS

design	JDM	
drawn	JBM	dwg S3-1
date	AUG 11	
scales	1:10	
file no	603	A2 rev A

APPENDIX C

VICTORIA JUBILEE CLOCK TOWER
CHRISTCHURCH

PRELIMINARY GEOTECHNICAL ASSESSMENT REPORT

BY: **LAND DEVELOPMENT & EXPLORATION LTD**
DATED: **JULY 11TH 2011**

Project Reference: 10048
11 July 2011

Christchurch City Council
C/o Insight Unlimited
P.O. Box 1219
GISBORNE

Attention: John Radburn

Dear John

JUBILEE CLOCK TOWER

PRELIMINARY GEOTECHNICAL ASSESSMENT REPORT

1 INTRODUCTION

Land Development & Exploration Ltd was engaged by Insight Unlimited on behalf of Christchurch City Council to undertake a visual assessment of the buildings and land forming the Jubilee Clock Tower which was damaged by the February earthquake event. The purpose of the work was to provide a preliminary assessment as to what geotechnical issues contributed to the damage to the property, and what geotechnical engineering work may be required to reinstate it back to a satisfactory condition. Provision of possible engineering solutions to minimise damage to the assets from future earthquake events was also an objective.

2 ASSESSMENT

The visual assessment was undertaken by Georg Winkler; a senior Chartered Professional Engineer with a background in engineering geology and geotechnical engineering, and the director of a team responsible for the mapping and understanding of earthquake-induced lateral spreading throughout Christchurch for the Earthquake Commission. Georg was accompanied by John Radburn of Insight Unlimited (Project Manager).

3 SITUATION

The Jubilee Clock Tower comprises a stone masonry tower located at the intersection of Montreal and Victoria Streets.

The damage to the structure appears to be mostly a result of earthquake shaking. However, it is noted that the adjacent building has subsided as a result of underlying liquefaction, indicating that liquefaction-induced settlement of the tower may have also occurred. This inference is supported by the tilting of some of the paving towards the tower.

The tower may be located within a zone of slight lateral movement towards Hagley Park, although the surface damage to land associated with this appears to be largely negligible, especially with respect to the subject site.

There is a reasonably significant volume of water emanating from the core of the tower. We understand that it is may be an artesian well rather than a broken water main, which is plausible given the slight settlement of the ground directly beneath the tower. We understand that a chemical analysis of the water has been carried out to determine whether it is artesian water or town supply water, although we do not know the outcome of this.

Based on our visual assessment we consider that further settlement is possible with future large earthquake events, although the risk of adverse settlement or differential settlement is considered to be low.

4 Recommendations

We do not consider that further geotechnical work will be required, unless new foundations for the structure are proposed.

5 Other Considerations

This report was prepared for Christchurch City Council with respect to the particular brief given to us. Information contained in it can not be used for other purposes or by other entities without our prior review and written consent.

It should be appreciated that the report is based on a visual assessment and observations made in a regional context and that the nature and behaviour of the subsurface materials may vary from that described following further investigation and analysis.

Yours faithfully

LAND DEVELOPMENT & EXPLORATION LTD

Georg Winkler

MIPENZ, CPEng

Geological-geotechnical engineer

\\sbs\documents\LDE Projects\10000 to 10100\10048 Insight Chch Building Investigations\Jubilee Clock Tower\10048gew08072011 Jubilie Clock Tower Preliminary Assessment Report R1.docx www.ruamoko.co.nz

Rūamoko
Maori god of earthquakes and volcanoes. Youngest son of Rangi And Papa (Sky father and Earth mother). Alternate sp Rūaūmoko