SCIRT Rebuilding Infrastructure

LEARNING LEGACY

Lessons learned from one of New Zealand's most challenging civil engineering projects: rebuilding the earthquake damaged pipes, roads, bridges and retaining walls in the city of Christchurch 2011 - 2016.

Triumphal Arch presentation by site engineer

Story: Bridge of Remembrance and Memorial Arch

Theme: Construction

A presentation prepared by one of the site engineers restoring the Memorial Arch and Bridge of Remembrance, outlining the damage to the structures, the repair designs and the construction methodologies.

This document has been provided as an example of a tool that might be useful for other organisations undertaking complex disaster recovery or infrastructure rebuild programmes.

For more information about this document, visit www.scirtlearninglegacy.org.nz

Programme funded by
Christchurch City Council
New Zealand Government

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Christchurch City Council
New Zealand Government
city care
Downer
Fulton Hogan
McConnell Dowell
Fletcher

Triumphal Arch

2011 Earthquake Repair & Strengthening Works

Dave Kennedy – Site Engineer – Downer NZ

Established 1924 to commemorate soldiers of the Great War 1914-1918

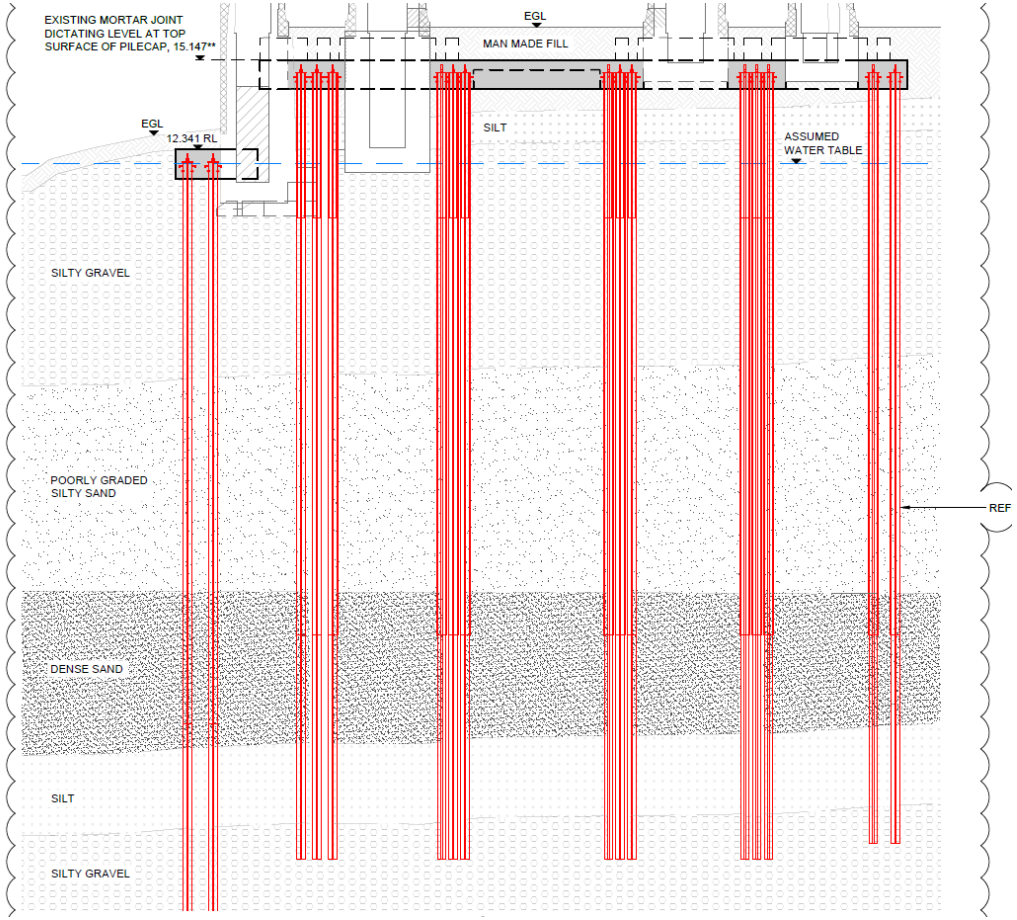
1965

2015

Original Construction & Ground Conditions

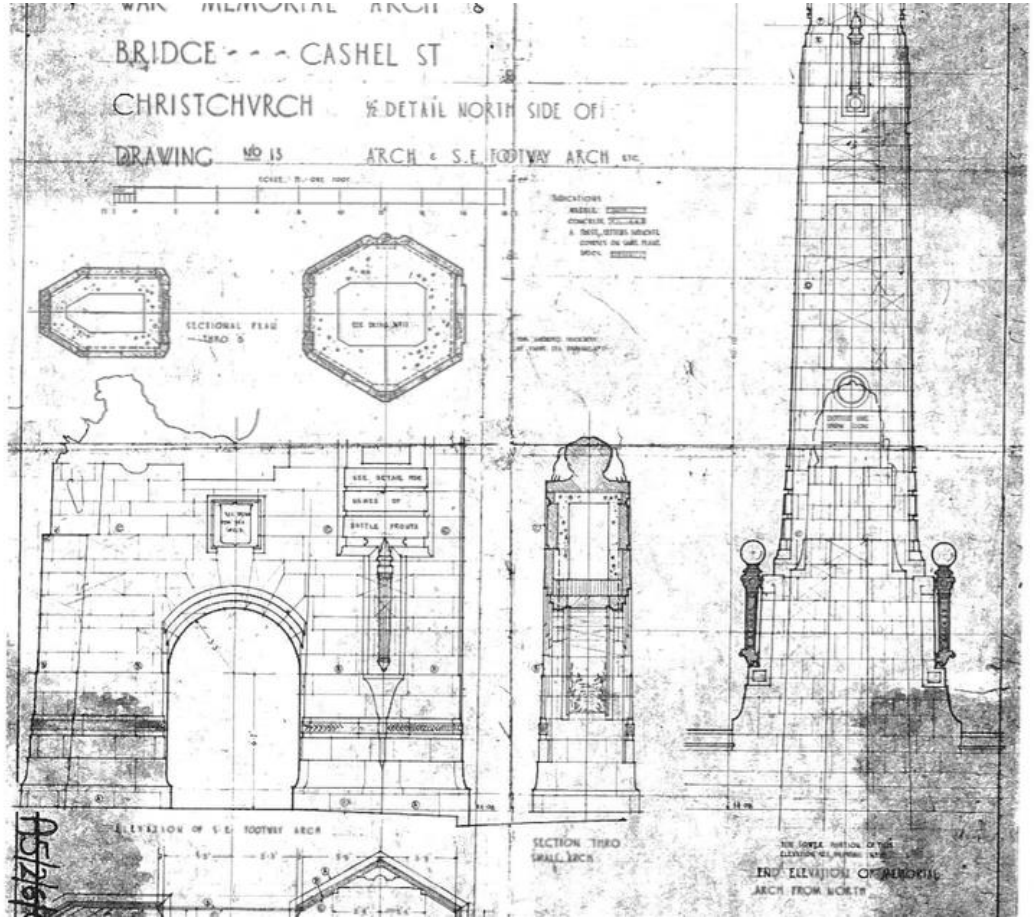
- Sandstone cladded concrete structure with a cavity at its core
- Cavity dimension approximately 400mm
- Constructed for £16078 over approximatly 21 months

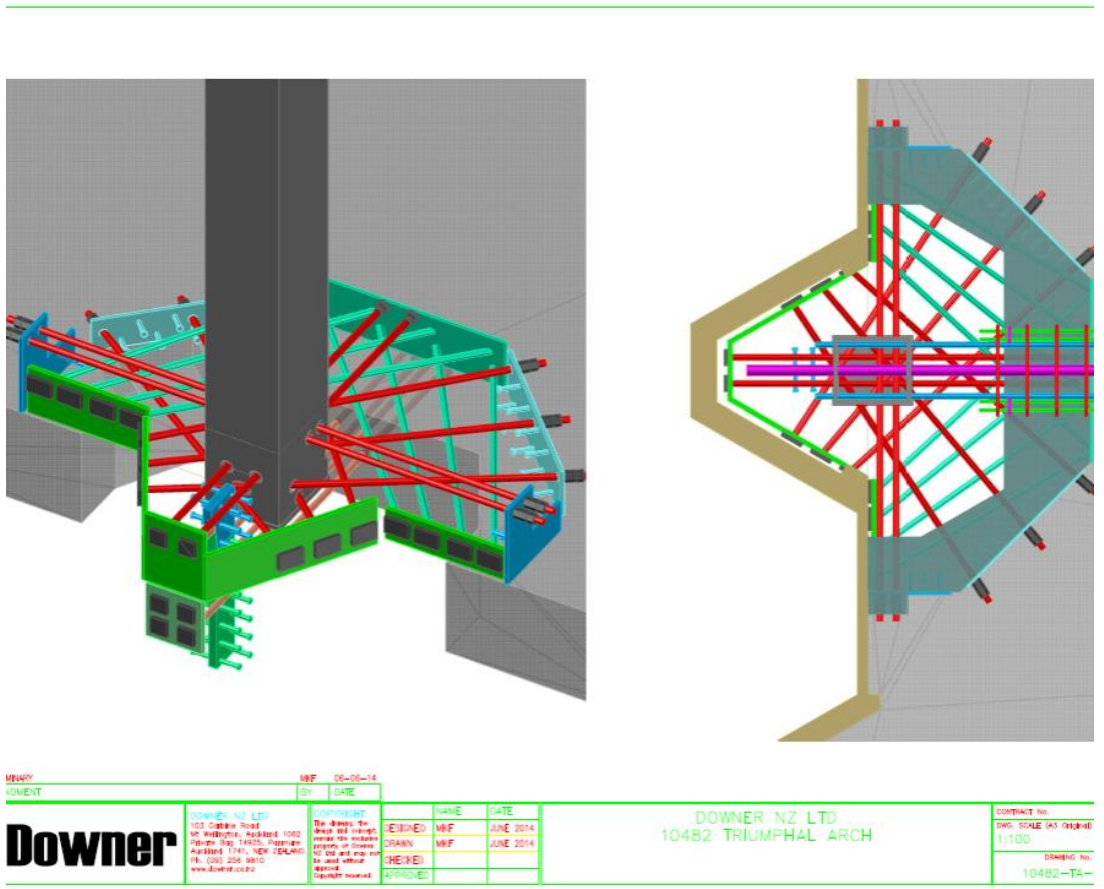
Ground Formation



- Bearing on existing pad foundations with deeper foundations to the North
- Ground type Silty Gravel - Dense Sand – Silty Gravel

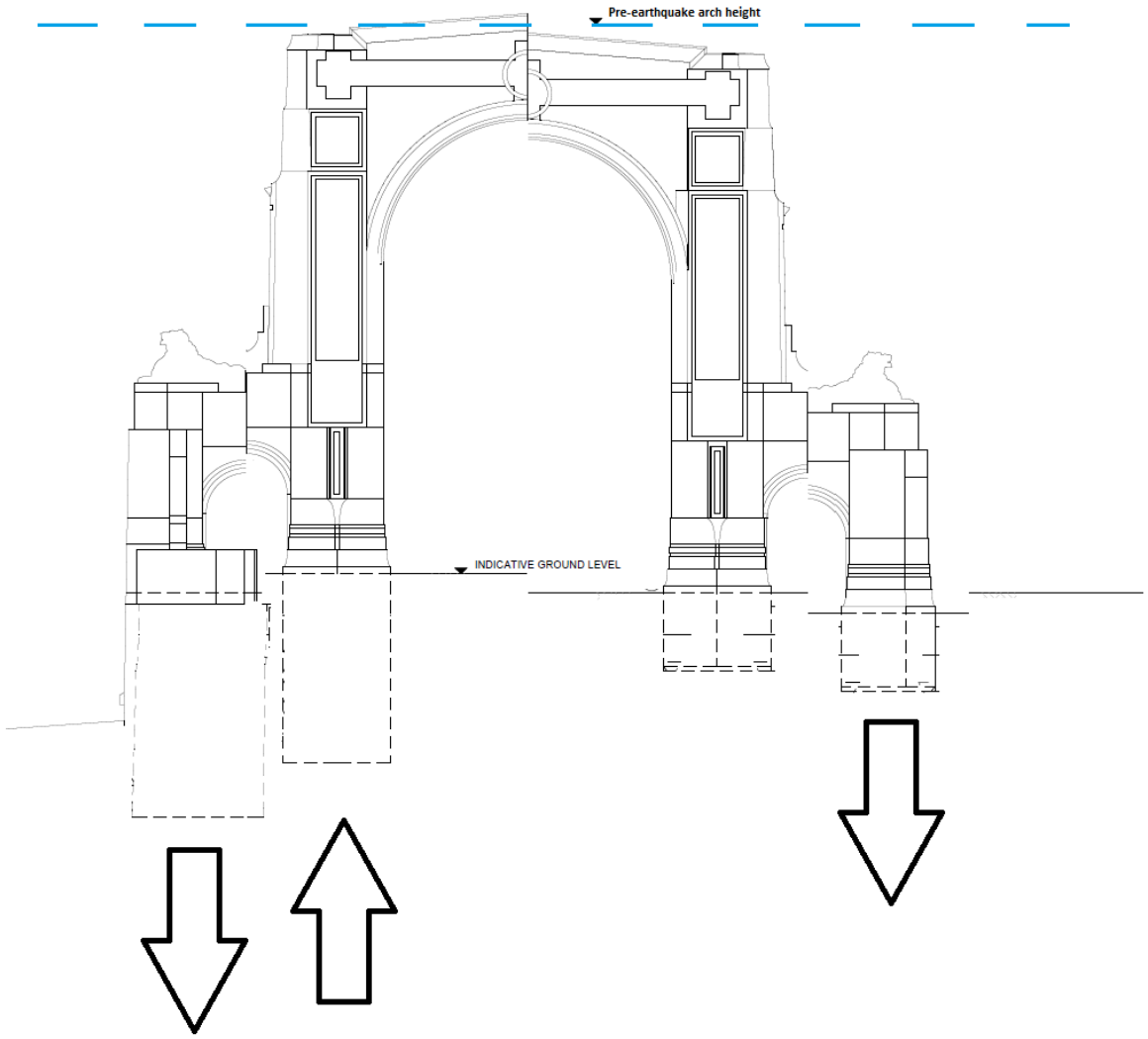
Planning & Designing





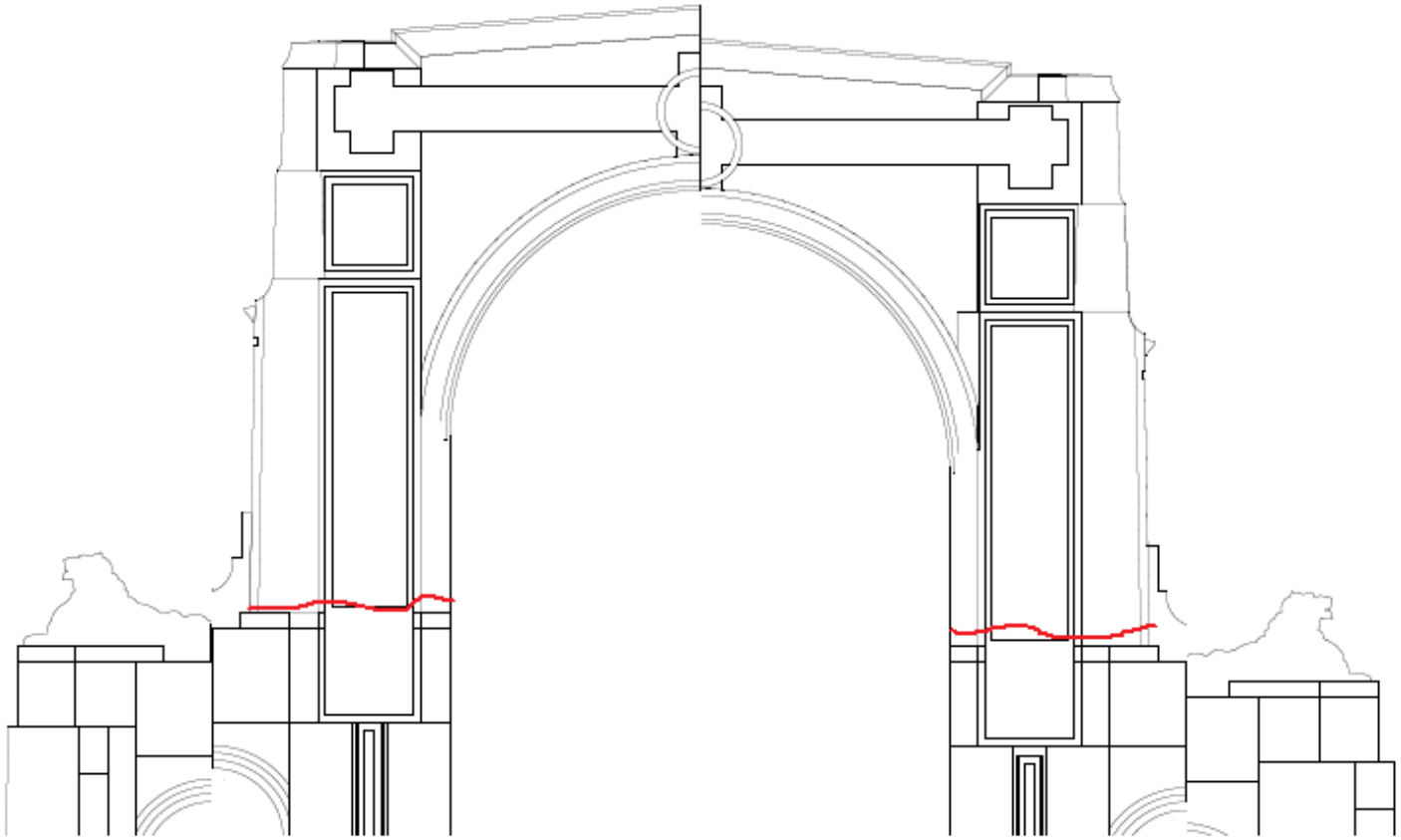
What happened the structure during the 2011 earthquake?

Differential settlement across the 4 columns



What happened the structure during the 2011 earthquake?

Horizontal displacement at the top half of the structure



What happened the structure during the 2011 earthquake?

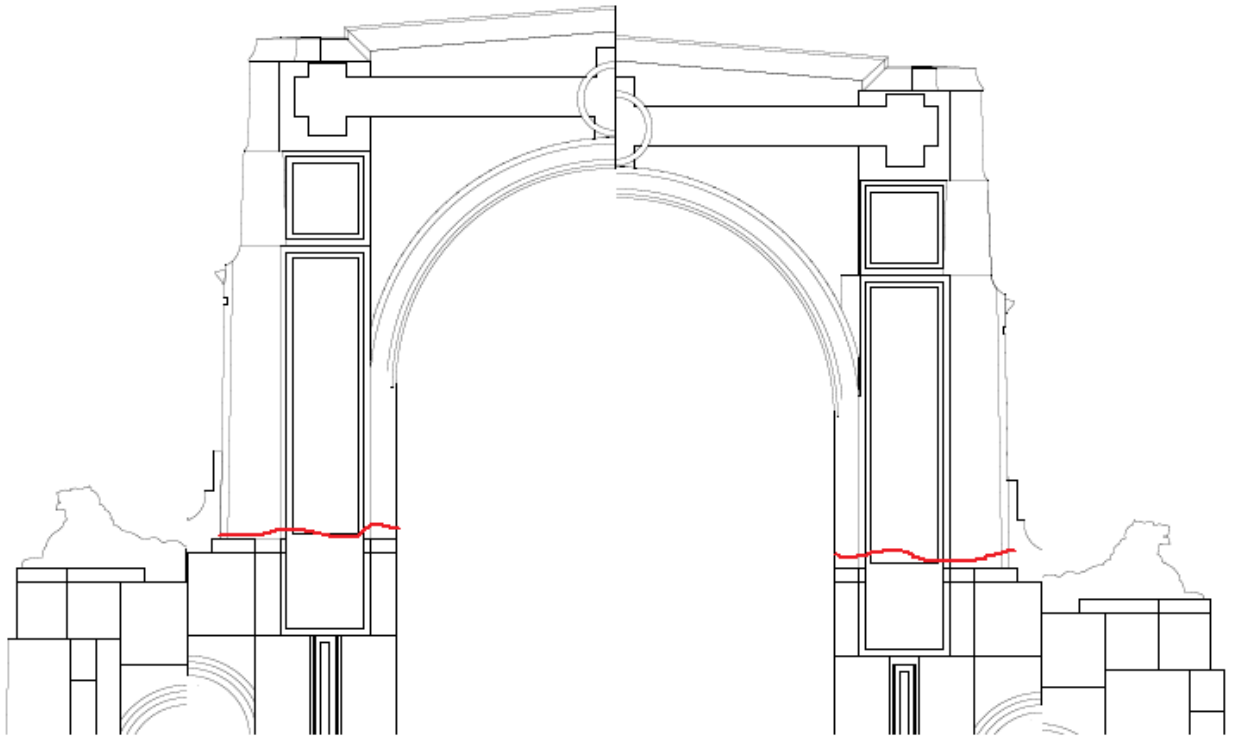
Cracking and spalling of stonework

Combination of all of the above deemed the Arch structure unstable forcing the Council to close the area from public use

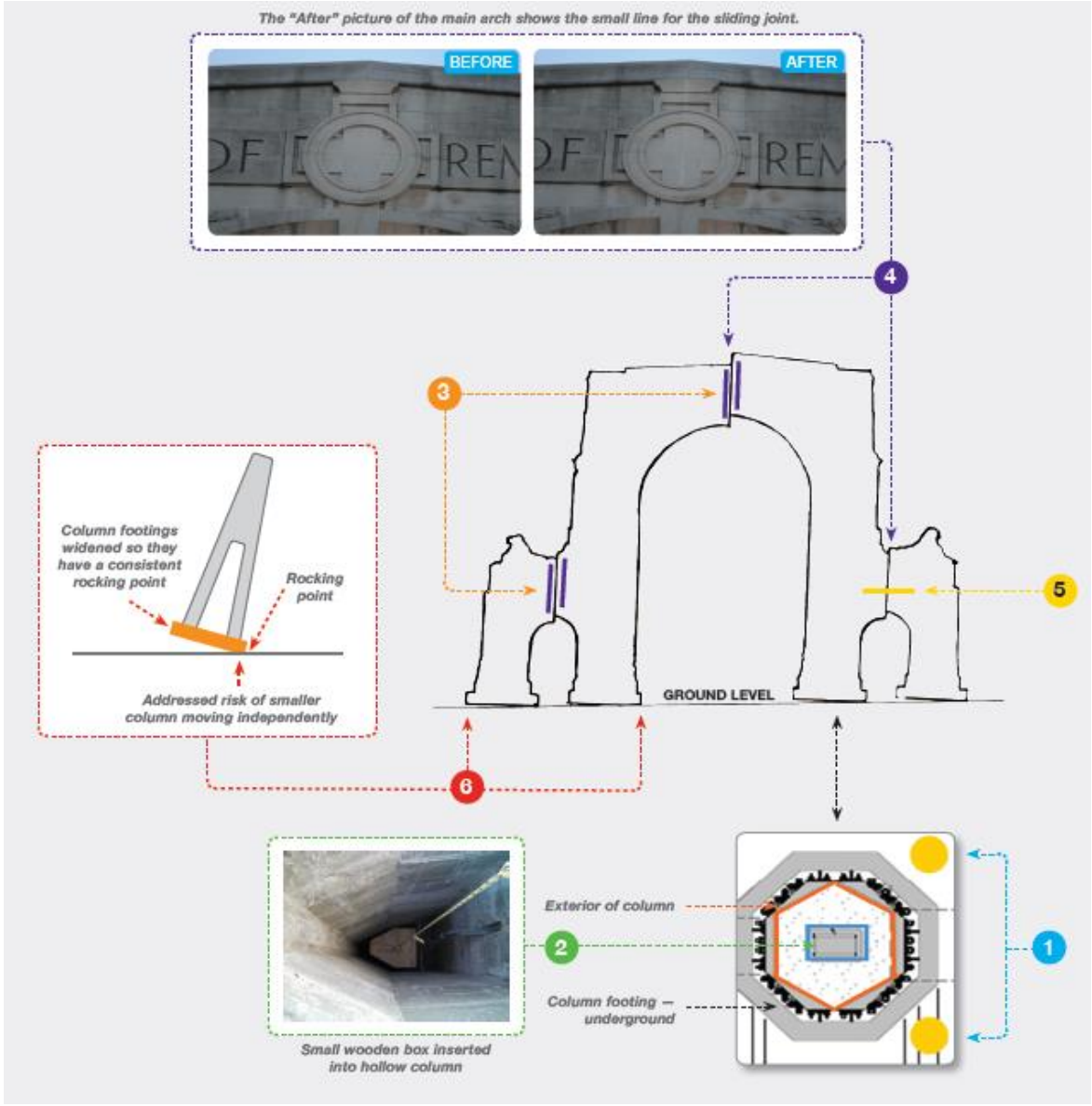
Work commenced by Downer in June 2013 to strengthen and repair the structure

Horizontal movement saved the structure

Designers have said that the horizontal movement/shearing along the top half of the structure saved it from total collapse occurring

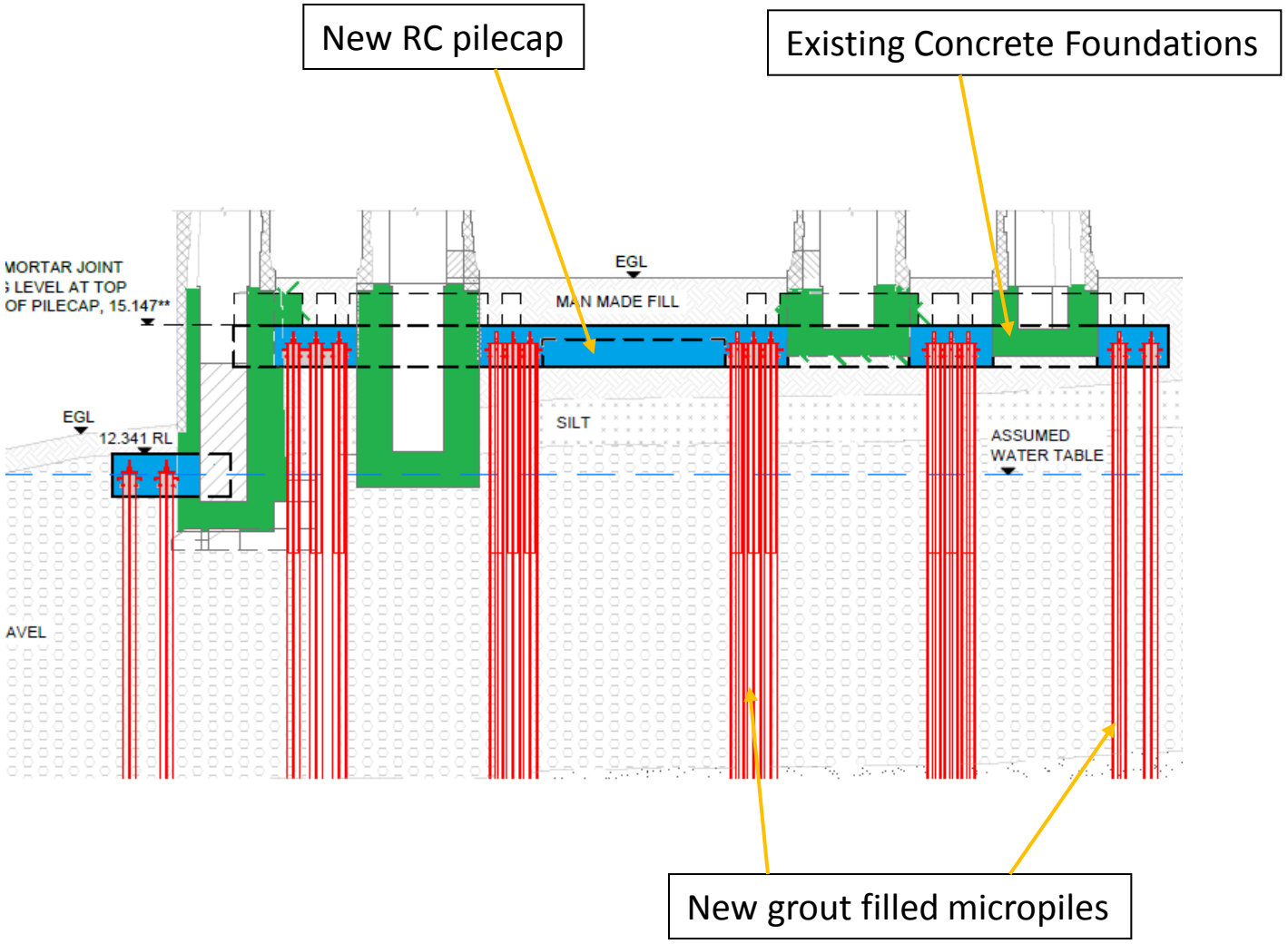


Design

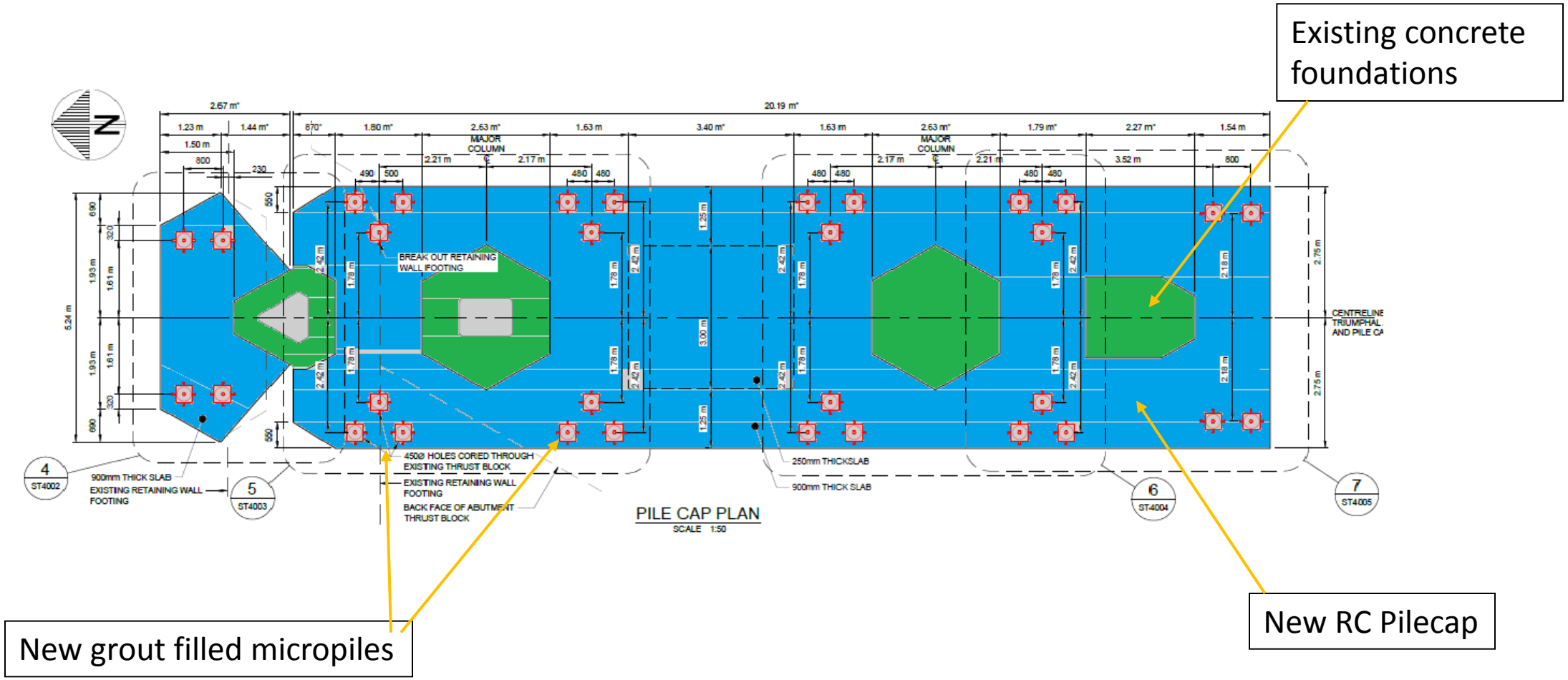

The "After" picture of the main arch shows the small line for the sliding joint.
BEFORE
AFTER
4
3
5
Column footings widened so they have a consistent rocking point
Rocking point
Addressed risk of smaller column moving independently
GROUND LEVEL
6
Exterior of column
2
Column footing — underground
1
Small wooden box inserted into hollow column

Design - Starting from the bottom

- Place grout filled ‘Micro Piles’ to dense sand layer – then “bulbing” occurs by injecting grout into the surrounding natural voids creating a stable base
    - Micro piles used as loading to ground around structure must be kept to a minimum
- Replace existing shallow foundations with new reinforced pile cap



Pile Cap Plan View



Micropiling explained

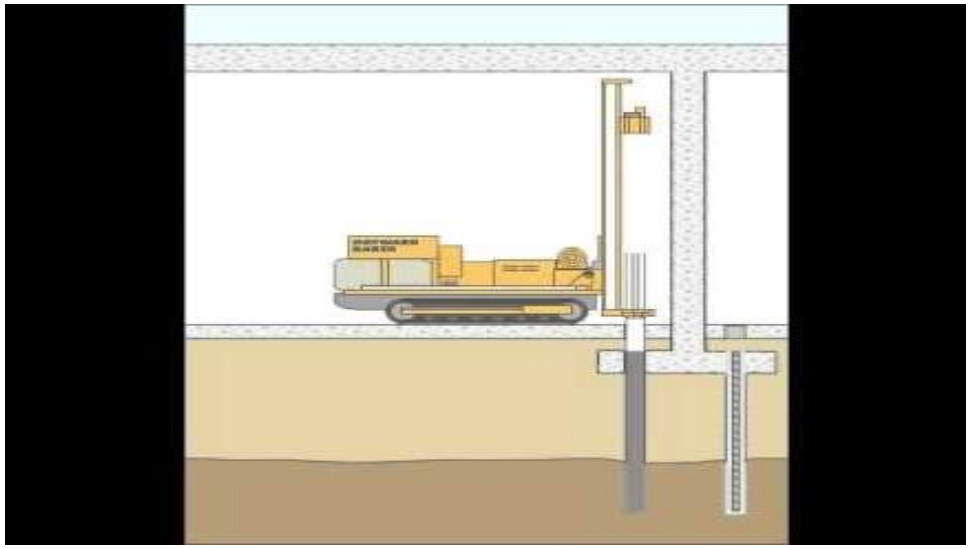
Micropiles are deep foundations constructed using high-strength, small-diameter steel pipe

- A casing is drilled to a required depth
- Reinforcing steel and grout is placed in the casing

Advantages:

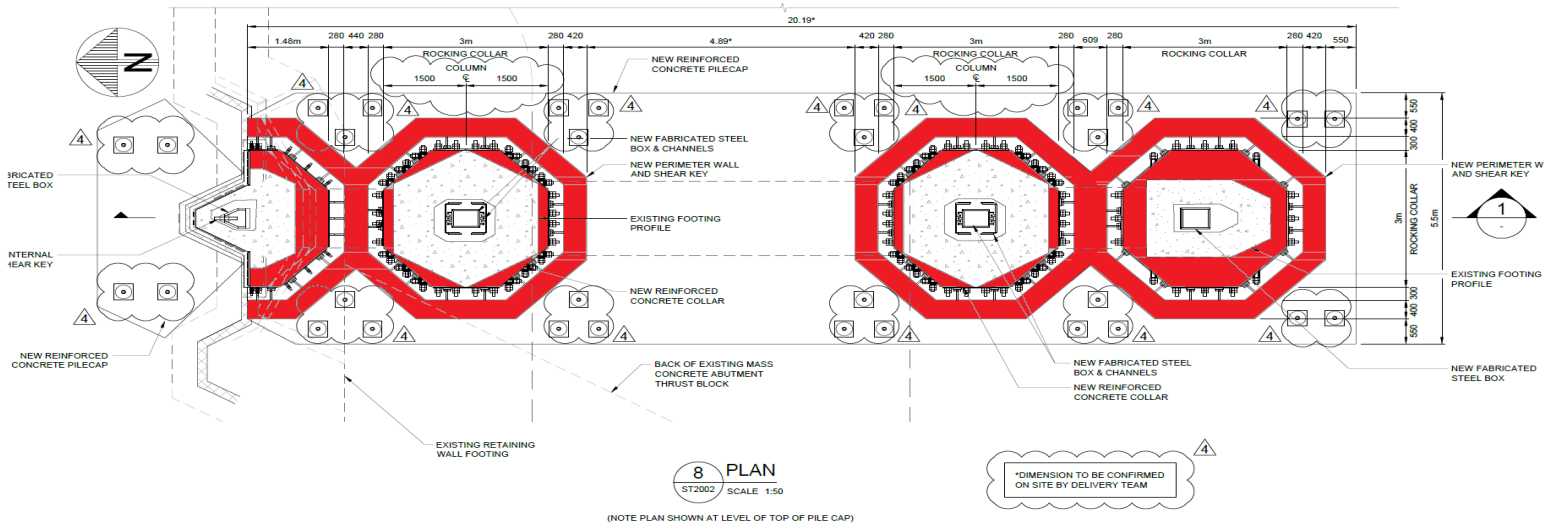
- Resists compressive, uplift/tension and lateral loads
- Drilling rigs allow installation in restricted access with minimal disruption to normal operations

https://www.youtube.com/watch?v=TNXd577IReE



Design - Rocking Collars

- Base of columns widened to create the same footprint for each column

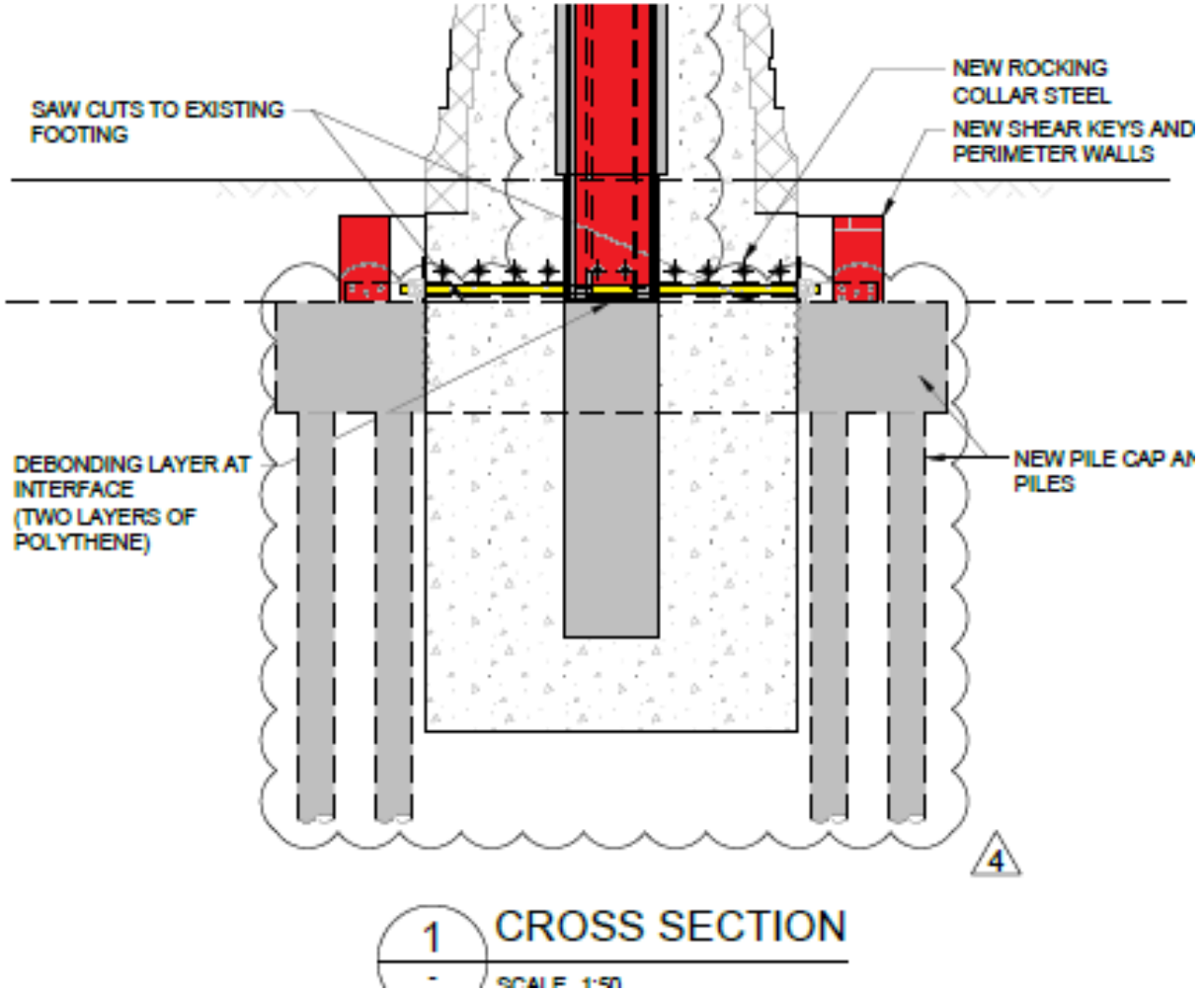


Design - Rocking Collars

•M64 steel bars cored through base restrained at both ends to steel plates

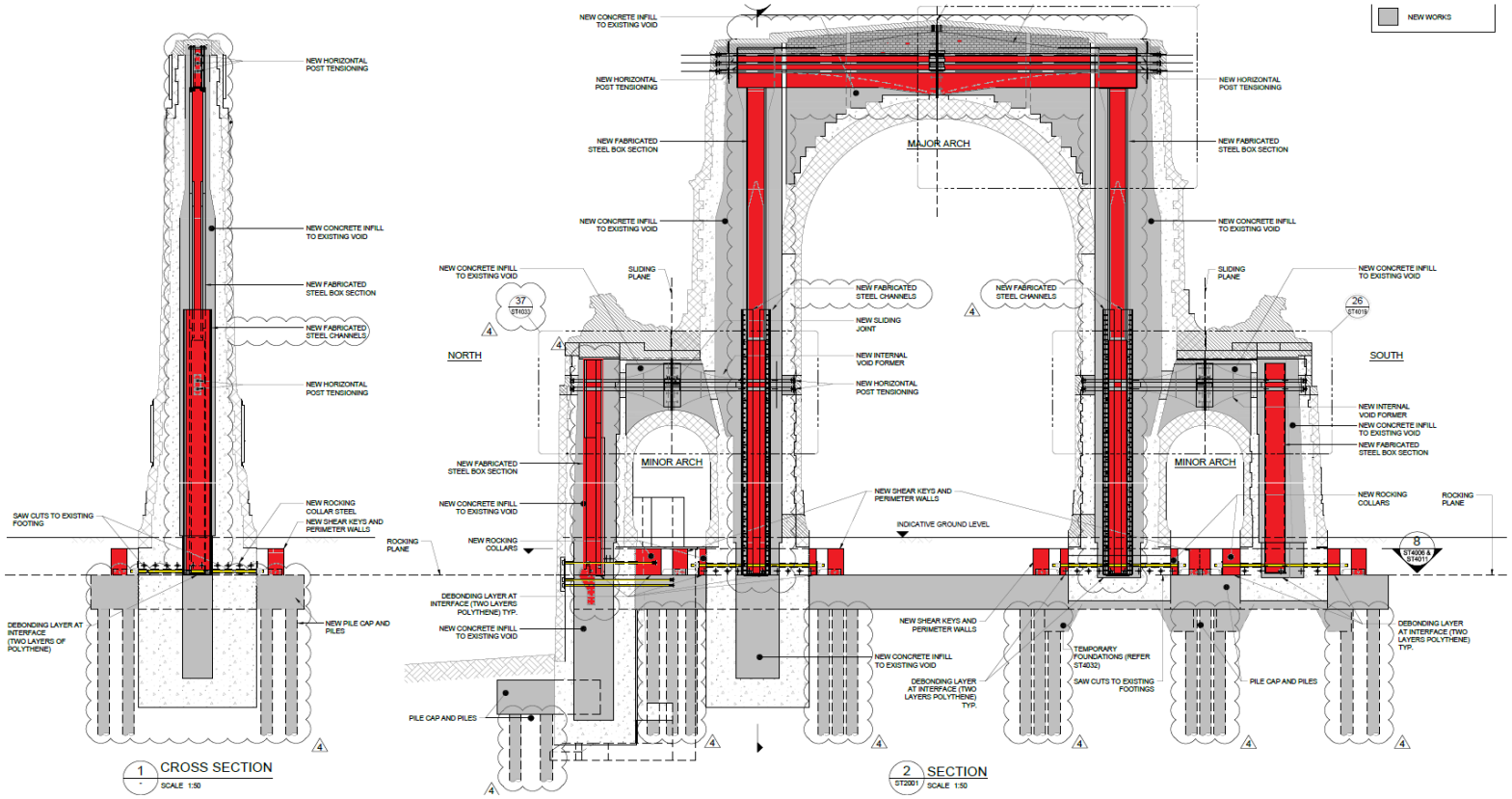
•Horizontal 200mm deep gap cut between existing concrete and base of column

•Perimeter wall constructed around base with steel members to “clamp” the base in position from horizontal shear movement



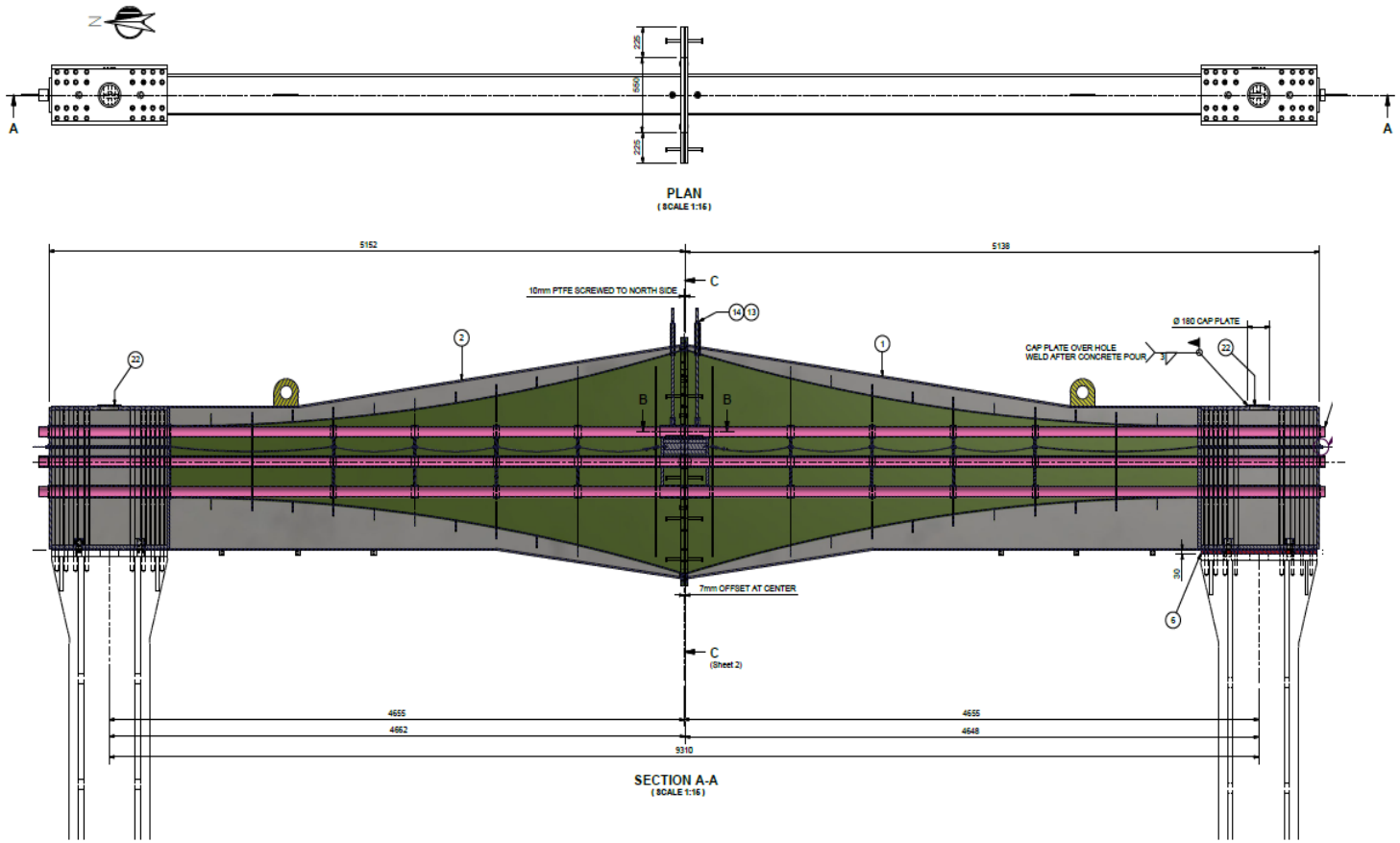
Design – Steel Columns

Built up box sections placed in cavity's to carry movement safely to the base and strengthen the structure



Design – Sliding Plates and Post Tensioning

Sliding plates pressed against each other to create a movement joint at the crown of each arch



Design – Sliding Plates and Post Tensioning

- Due to each archway being cut through the centre post tensioning was necessary to retain the shape and integrity of the arches during seismic activity

- Carried out by placing woven steel strands into a ‘dry’ duct and tensioned from both ends

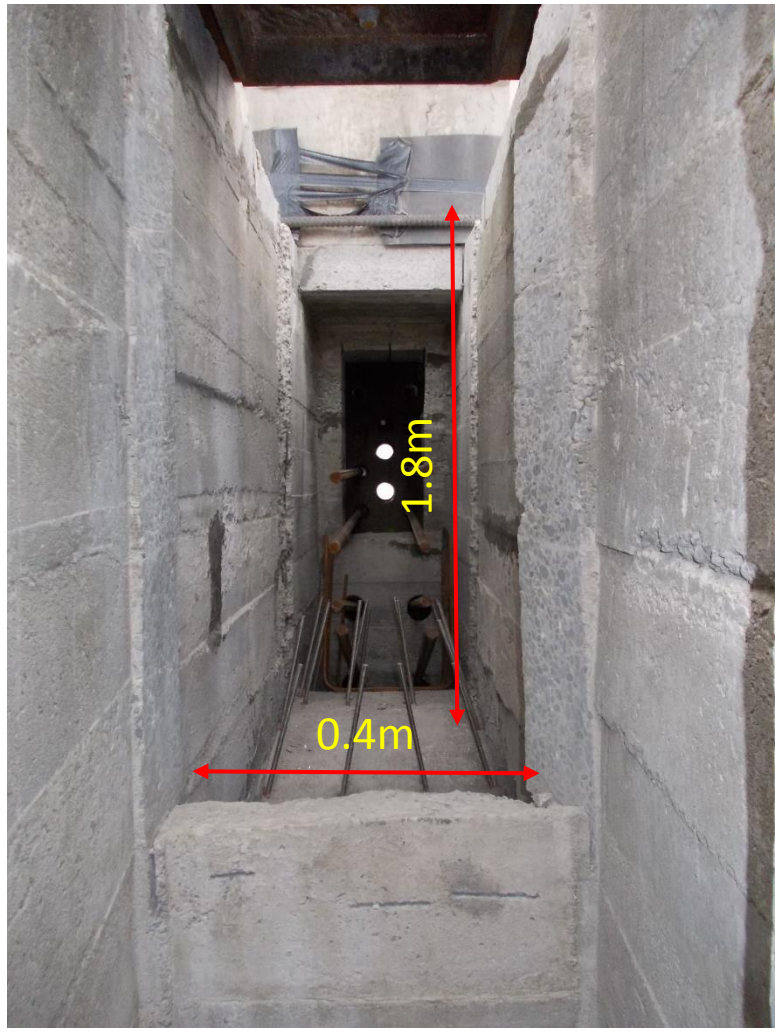
- Process can only happen once the surrounding new concrete has reached its design strength – 40mpa

Constructability - Typical Working Environment

Restricted work environment = high operative turnover

Working in confined spaces whilst operating heavy dust emitting power tools

Risk to accuracy of installation



Constructability – Opening up works

1. Remove stone

2. Install structural elements

Constructability – Opening up works

3. Encase in concrete

4. Reinstate existing stone

Constructability Issues – Pouring Concrete

- Concrete requires certain size gaps in order to flow and compact to form a solid and void free element

- Standard aggregate and concrete additives weren't suitable for the narrow spaces within the Arch voids hence a highly flowable mix was agreed upon

Typical Mix Design

- Glenium 79 – improves workability and finishing

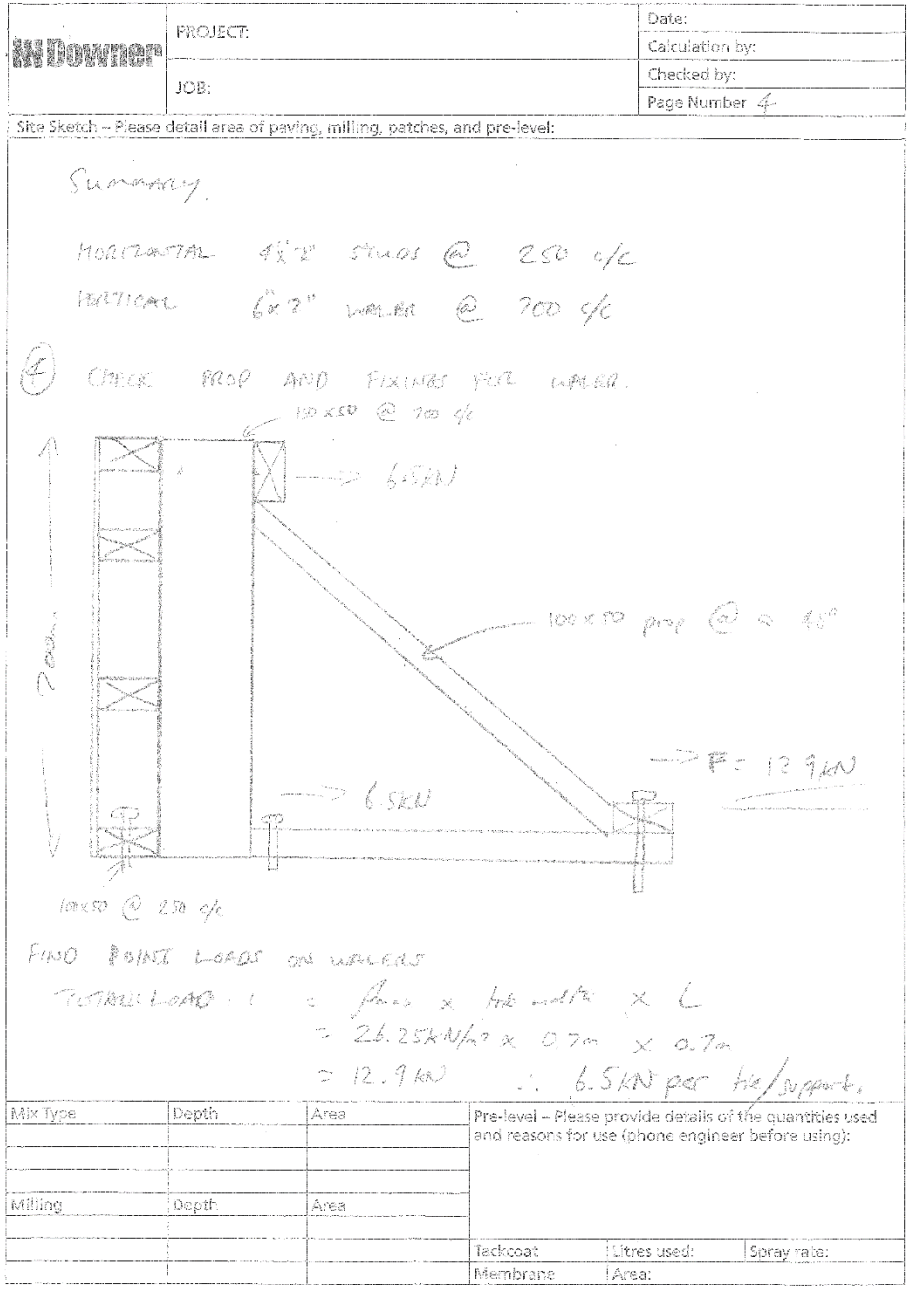
- Rheomac 362 – enhances viscosity and minimizes concrete deforming elastically during pour

- Xypex – waterproof characteristics closing up pores in concrete/crystallising

Engineers Role

Temporary works

- Formwork calculations and checks



Downer	PROJECT:	Date:
		Calculation by:
	JOB:	Checked by:
		Page Number 4

Site Sketch – Please detail area of paving, milling, patches, and pre-level:

Summary.

HORIZONTAL 4"x2" studs @ 250 c/c

VERTICAL 6"x3" WALER @ 700 c/c

4 CHECK PROP AND FIXINGS FOR WALER.

100x50 @ 700 c/c

6.5kN

100x50 @ 250 c/c

100x50 prop @ = 45°

F = 13.9kN

6.5kN

2.8m

FIND POINT LOADS ON WALERS

TOTAL LOAD = = load x tributary x L

= 26.25kN/m² x 0.7m x 0.7m

= 12.9kN ∴ 6.5kN per tie/support.

Mix Type	Depth	Area
Milling	Depth	Area

Pre-level – Please provide details of the quantities used and reasons for use (phone engineer before using):

Tackcoat	Litres used:	Spray rate:
Membrane	Area:	

Engineers role – Temporary works

PROJECT:		Date:	
JOB:		Calculation by:	
		Checked by:	
		Page Number	

Site Sketch – Please detail area of paving, milling, patches, and pre-level:

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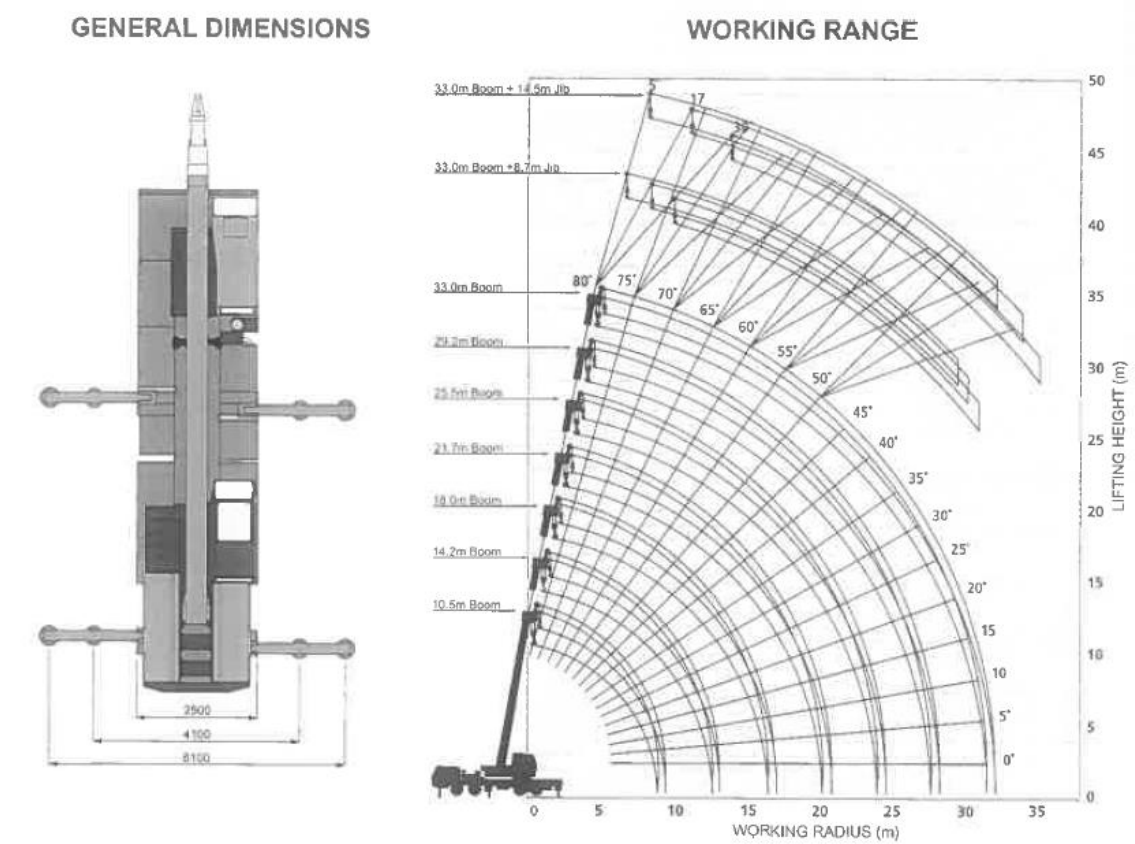
Milling	Depth	Area

Pre-level – Please provide details of the quantities used and reasons for use (phone engineer before using):

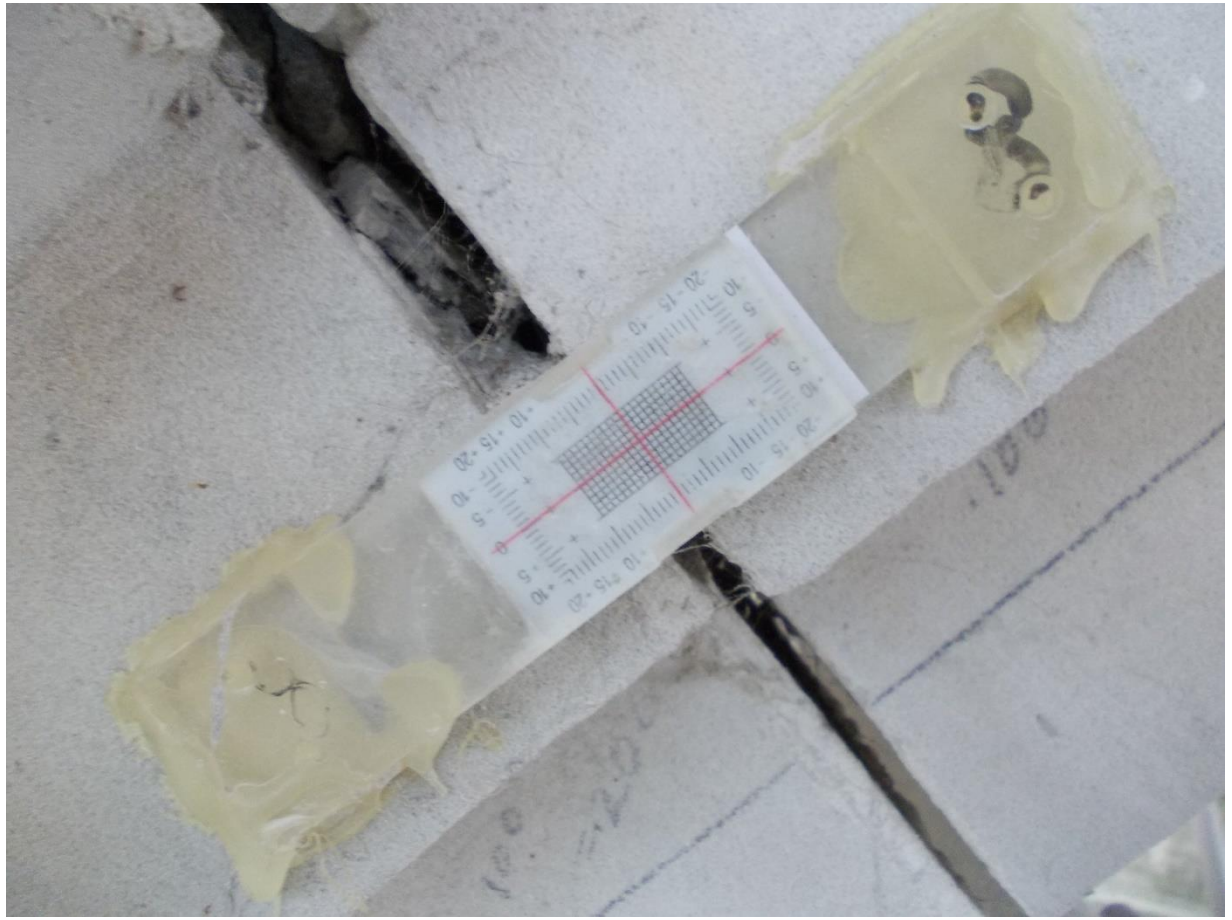
		Tackcoat	Litres used:
		Membrane	Area:
			Spray rate:

Engineers role – Lift Plans



www.titancranes.co.nz email: enquiry@titancranes.co.nz FreePhone: 0800 848 262

Engineers role – Movement monitoring



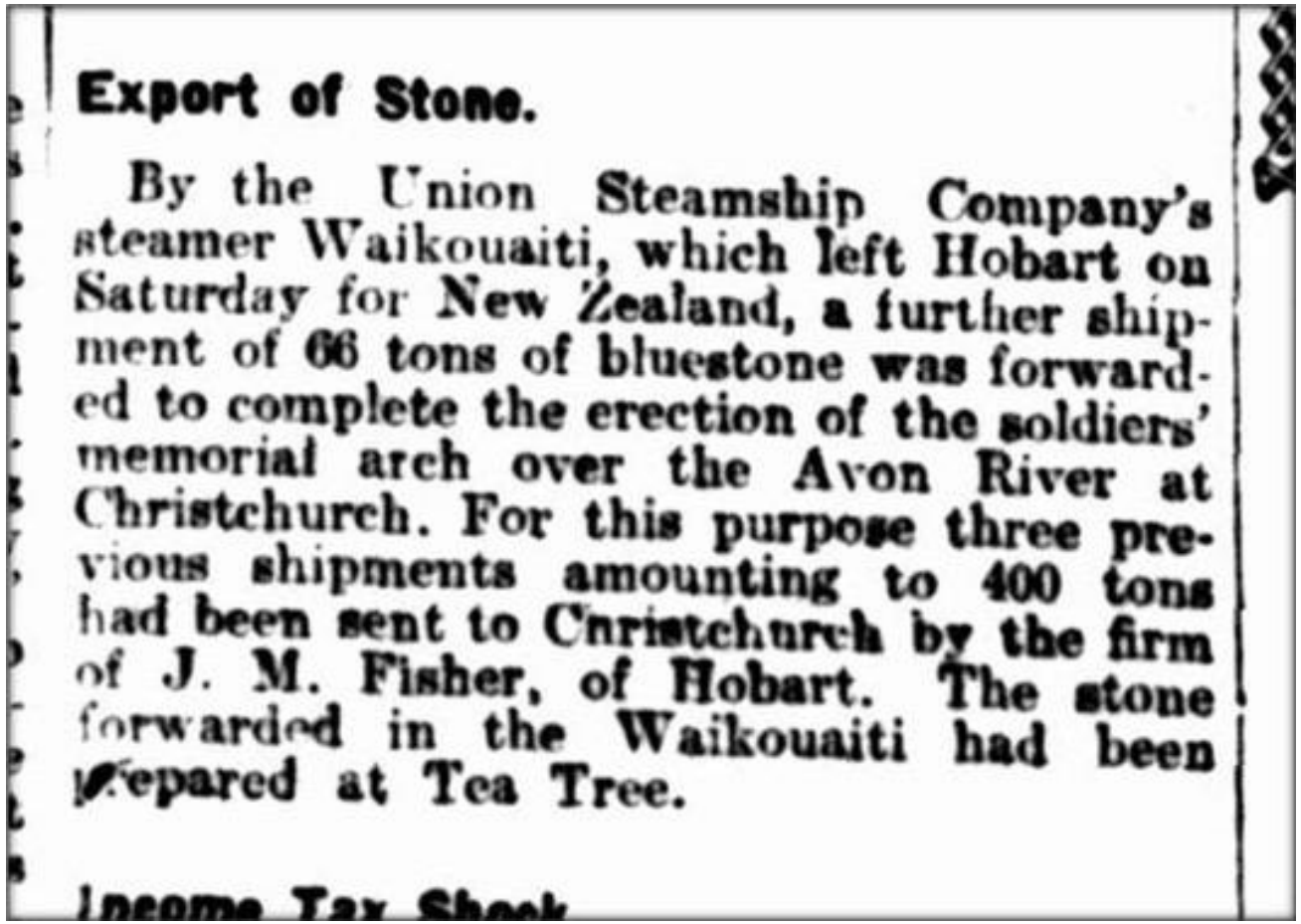
Engineers role - SWMS

Job Step	Identified Hazards What could result in harm *** Refer to Annex 1 for Hazard ID Checklist*	INITIAL Risk Level Likelihood Certain Likely Moderate Unlikely Rare	Severity Major Serious Medium Minor	Risk High-H Med-M Low-L	Control Measures In order of preference, can hazards be: 1. Eliminated? 2. Substituted for a safer alternative? 3. Controlled by physical barriers, guards or mechanical aids? 4. Controlled by training and work procedures? 5. Controlled by the use of PPE? **Note:** Refer to appropriate Work Instruction/Management Procedure when detailing controls.	RESIDUAL Risk Level Risk High-H Med-M Low-L	Responsibility for Control Measures
Crane Set Up & Delivery of Stage 2 sliding plates • Crane to arrive onsite first and position itself in correct location onsite. Crane will reverse into Oxford Tce off Lichfield Street with the use of spotters to stop traffic. Spotters will guide the Crane while reversing down Oxford Tce and into site compound. • The Crane will be positioned and set up by Titan Crane operatives. • The Sliding Plate Assembly is to be delivered to site by Semi-Trailer and is to enter the site in the same procedure as for the Crane. • Lifting operation is to be undertaken early in the morning to avoid strong winds and to minimise plant/pedestrian interface when crane and semi-trailer arrive onsite. • Toolbox to be held onsite before beginning lifting operation to go over lift plan and roles of each operative.	Moving Plant & Equipment (Generic for whole SWMS)	Moderate	Medium	Moderate	• Toolbox meeting to discuss job and hazards. • Plant/personnel segregation or exclusion zone. • Spotter guiding plant at all times. • Daily Plant Checks. • Licenced, Trained and Competent operators. • Operators are not to use mobile phones while operating equipment. • Exclusion zone in swing area of plant. • Correct PPE to be worn at all times. • Suitable guards in place over all moving parts. • Reversing should be minimised where possible and use spotters. • Make eye contact with operator before approaching machine. • Only use plant and equipment for tasks that they are designed for. • Only operator and spotter to be present in excavation area.	Low	All Operator
	People/Plant Interface	Likely	Medium	Moderate	• Ensure all fences and gates are locked. • Perform all tasks in a professional manner (you are being watched). • Spotter to guide crane & trucks into site & stop pedestrians where required.	Low	All
	Oil leaks from machinery (Generic for whole SWMS)	Moderate	Medium	Moderate	• Spill kits on site and workforce briefed to all affected and signed acceptance. • Daily Plant check sheets completed.	Low	Operator All
Removal of Existing Stones to top of Major Arch Procedure for removing stones: PART 1 – Preparation: **1st Row Stones** • Cut front face mortar joints and proceed to "explode" stones (method of breaking down existing stones to be replaced) • Place strops around top of arch to ensure stones do not fall out before crane hooks on – strops to be in contact with all faces of stone - if not in contact place timber off-cuts with foam underneath	Lifting/Suspended Load	Unlikely	Major	High	• Lift plan to be in place & signed off • Lifting Chains & Gear to be tagged with current lifting cert. • Steel sections lifting eyes designed by Downer Temporary Works Engineer. • Crane to have correct certification. • Crane Operative to be correctly trained and competent. • Load to be rigged by Titan's Rigger. • Tag Lines to be attached to Steel Boxes and controlled by operatives on the ground. • Steel Boxes to be positioned in place by dogman using radio communication. • No ground worker to be below suspended load. • Monitor weather conditions and delay lift if winds are too high. • Exclusion zone set up around crane while it is operating. • Ensure safety strops are in place until crane is fully hooked onto stone.	Moderate	Operatives Crane Driver Dogman/Rigger Engineer
	Manual Handling	Moderate	Minor	Moderate	• Assess any loads before lifting and follow manual handling procedures. • Ensure crew members are fit for task. • Mechanical lifting where possible. • 2+ man lift for loads over 25kg. • Correct PPE to be worn including gloves. • Ensure hands are kept well away from pinch points and areas where they could be crushed.	Low	All
	Working at height	Moderate	Serious	High	• Working at height permit to be in place. • Harness to be worn when on top level of scaffold. • Weekly scaffold checks	Moderate	All

Engineering/Construction Facts

Heating of existing voids: stone is naturally porous therefore a poor insulator – each void had to be heated prior to each concrete pour to assist curing time

Matching new replacement stone to existing stone: refurbishment requires removed material to be replaced like for like. The replaced stone at the arch was sourced from the original quarry in Tasmania, Australia



Export of Stone.

By the Union Steamship Company's steamer Waikouaiti, which left Hobart on Saturday for New Zealand, a further shipment of 66 tons of bluestone was forwarded to complete the erection of the soldiers' memorial arch over the Avon River at Christchurch. For this purpose three previous shipments amounting to 400 tons had been sent to Christchurch by the firm of J. M. Fisher, of Hobart. The stone forwarded in the Waikouaiti had been prepared at Tea Tree.

Income Tax Shock

Extract from Bridge of Remembrance Committee Report - 1924

rays of the rising sun, and also the last rays of the sun as it sinks in the West.

Masonry Construction.

In this Memorial there is none of the simplicity of regular sized, square-shaped stones, and the work of the masons has, therefore, been exceedingly difficult. Thought and labour and skill there have been, and it is my happy position to know that the masons, and especially the foreman, have entered into the work and carried it to completion with all the enthusiasm, care and craft required to imbue it with the living quality it should possess.

Time the contract has certainly taken, but my Committee has felt that this Memorial is to speak not only for and to this generation but to countless generations yet to come; and that the few extra months spent upon the work are as nothing compared with the result it is hoped to obtain.