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.

# Bridge of Remembrance poster for awards application

**Story:** Bridge of Remembrance and Memorial Arch

**Theme:** Construction

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A poster which was prepared to go with the award application for the Canterbury Heritage Awards 2016.

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

City Care Downer Fulton Hogan McConnell Dowell Fletcher

Programme funded by

# BRIDGE OF REMEMBRANCE TRIUMPHAL ARCH SEISMIC STRENGTHENING

Programme funded by

Christchurch City Council — New Zealand Government

Stronger Christchurch Infrastructure Rebuild Team (SCIRT) is responsible for rebuilding Christchurch's earthquake damaged horizontal infrastructure following the earthquakes of 2010 and 2011. SCIRT is made up of people from many organisations. The head contractual agreement within SCIRT is an alliance between owner participants and non-owner participants. The owner participant organisations are: Canterbury Earthquake Recovery Authority, New Zealand Transport Agency and Christchurch City Council. The non-owner participant organisations are: City Care, Downer, Fletcher, Fulton Hogan and McConnell Dowell. There are also many other Christchurch-based companies that play a vital role in helping to deliver the SCIRT programme of work of more than 500 projects completed from 2011 to December 2016.

| Location | Christchurch CBD |
|---|---|
| Client | Part of the SCIRT Programme, funded by Christchurch City Council and New Zealand Government |
| Structural Engineer | Opus International Consultants, seconded to SCIRT |
| Completion Date | November 2015 |

## Damage from February 2011 Earthquake

*Figure 1: Crack map and typical cracks recorded after the February 2011 Earthquake*

The Bridge of Remembrance Triumphal Arch suffered moderate damage in the February 2011 earthquake. This prompted seismic assessment by Opus Consultants on behalf of Christchurch City Council. The project was transferred to the SCIRT alliance with the Opus structural engineers seconded to SCIRT to develop the strengthening solution.

## Seismic Assessment

**Modal Analysis:**

- 1:500 year earthquake assessed
- Very low flexural & shear capacity in both out-of-plane and in-plane directions
- Very low ductility due to minimal reinforcement content
- Potential brittle failure modes
- Conclusion—earthquake prone

**Rocking analysis:**

- Potential to rock out-of-plane with capacity for 1:2500 year earthquake if a reliable rocking mechanism can develop
- Several issues exist which prevent the development of a reliable rocking mechanism
- No rocking can occur in-plane
- Conclusion—earthquake prone but there is an opportunity for significant improvement in performance by utilising rocking

**Issues to overcome to enable development of a reliable rocking mechanism**

- Integral wingwall only on the north side induces torsional effects (Fig. 5a)
- Inner columns are significantly wider than the outer columns preventing out-of-plane rocking at the base (Fig. 5a)
- Transfer of shear across the potential rocking plane relies on dubious shear friction interface
- Potential shear failure of supporting wall face due to minimal shear links in the columns and no reinforcement in the footings (Fig. 2b)

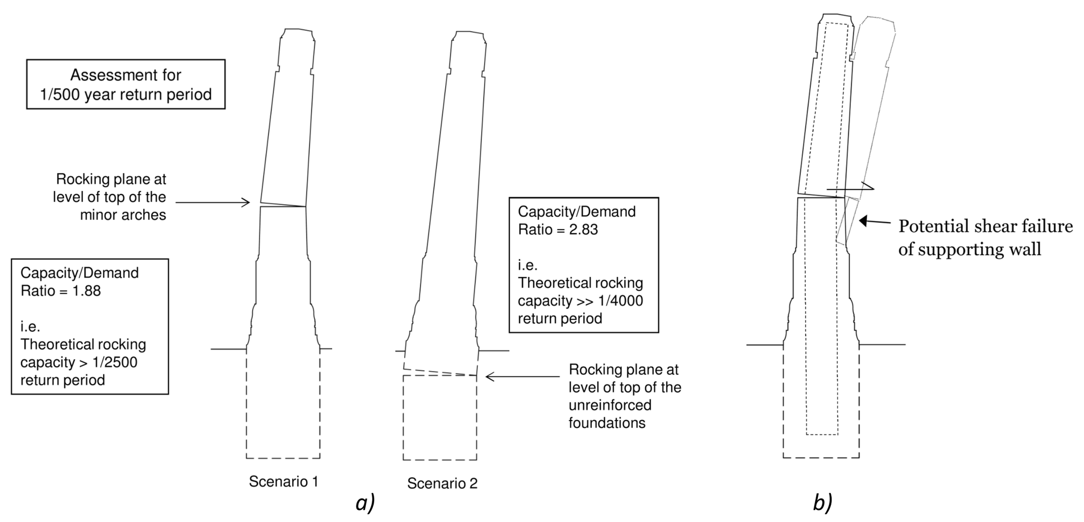


*Figure 2: a) Rocking scenario's considered in the assessment; b) Potential brittle failure mechanism during rocking*

## Additional factors affecting assessment and design

- Listed as Category 1 Heritage Structure with NZHTP and Group 1 with Council - significant restrictions on change to appearance and loss of heritage fabric
- Client wants to avoid/minimise future damage to heritage fabric
- Importance level 3 structure, 100 year design life - 1:2500 year design earthquake
- Perceived safety risk - internal access to the structure restricted requiring remote working practices
- Existing footings at different depths leading to torsional effects and differential settlement (Fig. 4a)
- Small voids within the structure - severe restrictions on size, location and access for placement of strengthening (Fig. 4a & 5a)

## Strengthening Solution

The strengthening solution enables a reliable rocking mechanism to form in any direction allowing significant reduction in seismic design loads through period-shift without reliance on conventional plastic hinges. The strengthening solution is temporarily intrusive but has minimal permanent impact on the appearance and important heritage fabric.

**Features:**

- The heritage structure above the rocking plane is internally reinforced with a fabricated steel box and concrete enabling it to remain elastic under a 1:2500 year earthquake (Fig. 3)
- Piles and pilecaps provide a solid foundation to rock on and allow for the increased dead loads from new concrete infill (Fig. 4b)
- Rocking collars provide a definite rocking interface and allow uniform out-of-plane rocking at the base (Fig. 5d, 5e & 5f)
- Tapered steel shear keys prevent sliding without restricting rocking (Fig. 6)
- Temporary access to the internal voids was provided by removal of the arch tops and the creation of temporary access holes at the column bottoms (Fig. 6a)
- Gap created to separate structure from integral wingwall (Fig. 7)
- Sliding joints located at the crown of the three arches enable in-plane rocking to develop enabling the benefits of rocking to be utilised for all directions of seismic shaking (Fig. 8)
- Transverse post-tensioning across the arches prevents pounding between columns and provides out-of-plane flexural capacity across the sliding joints (Fig. 8)
- Out-of-plane shear is transferred across the sliding joints using a stainless steel shear key pin located in a vertical slot to permit in-plane sliding (Fig. 8c)

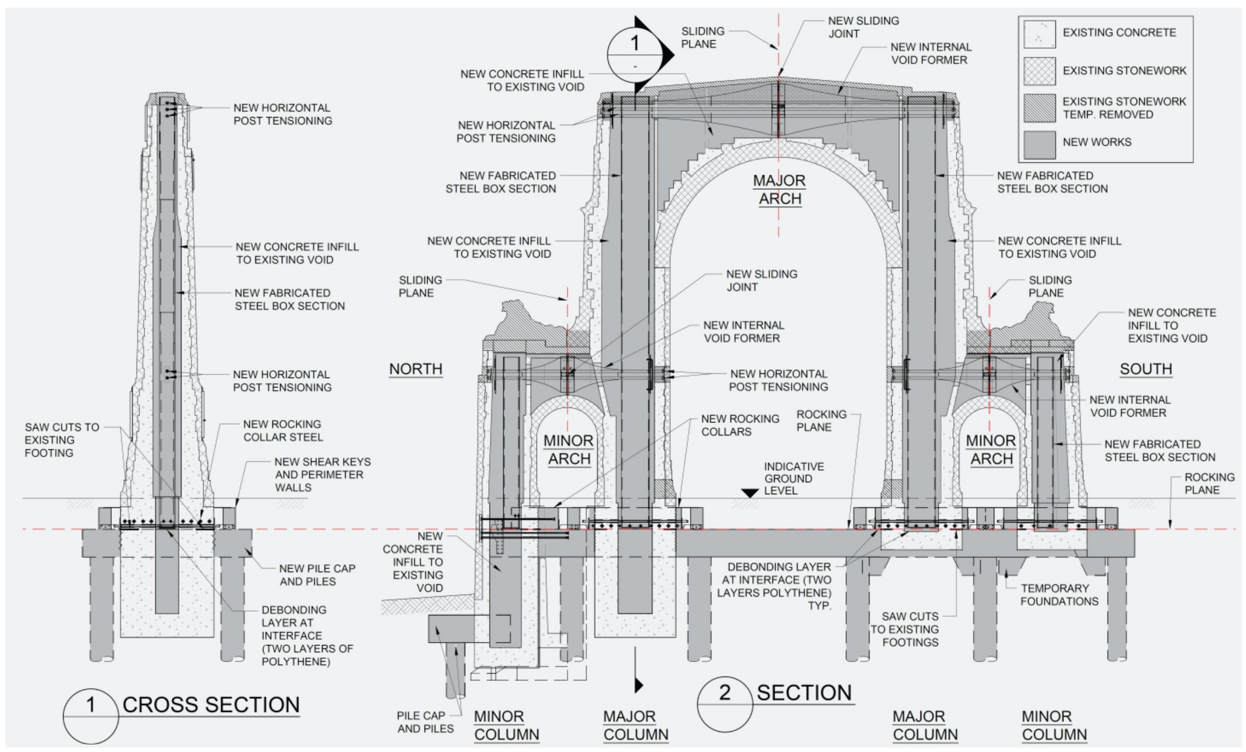


*Figure 3: Summary of seismic strengthening works*

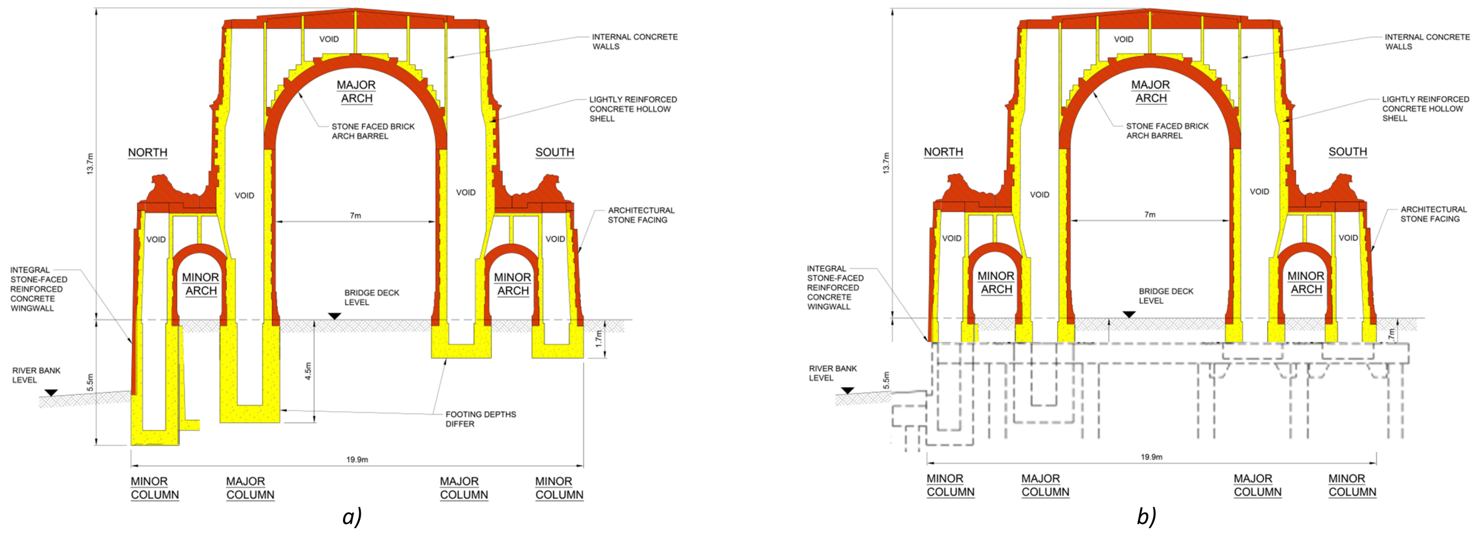

*Figure 4: Cross section through existing structure indicating: a) varying existing foundation depths; b) new piled foundation*

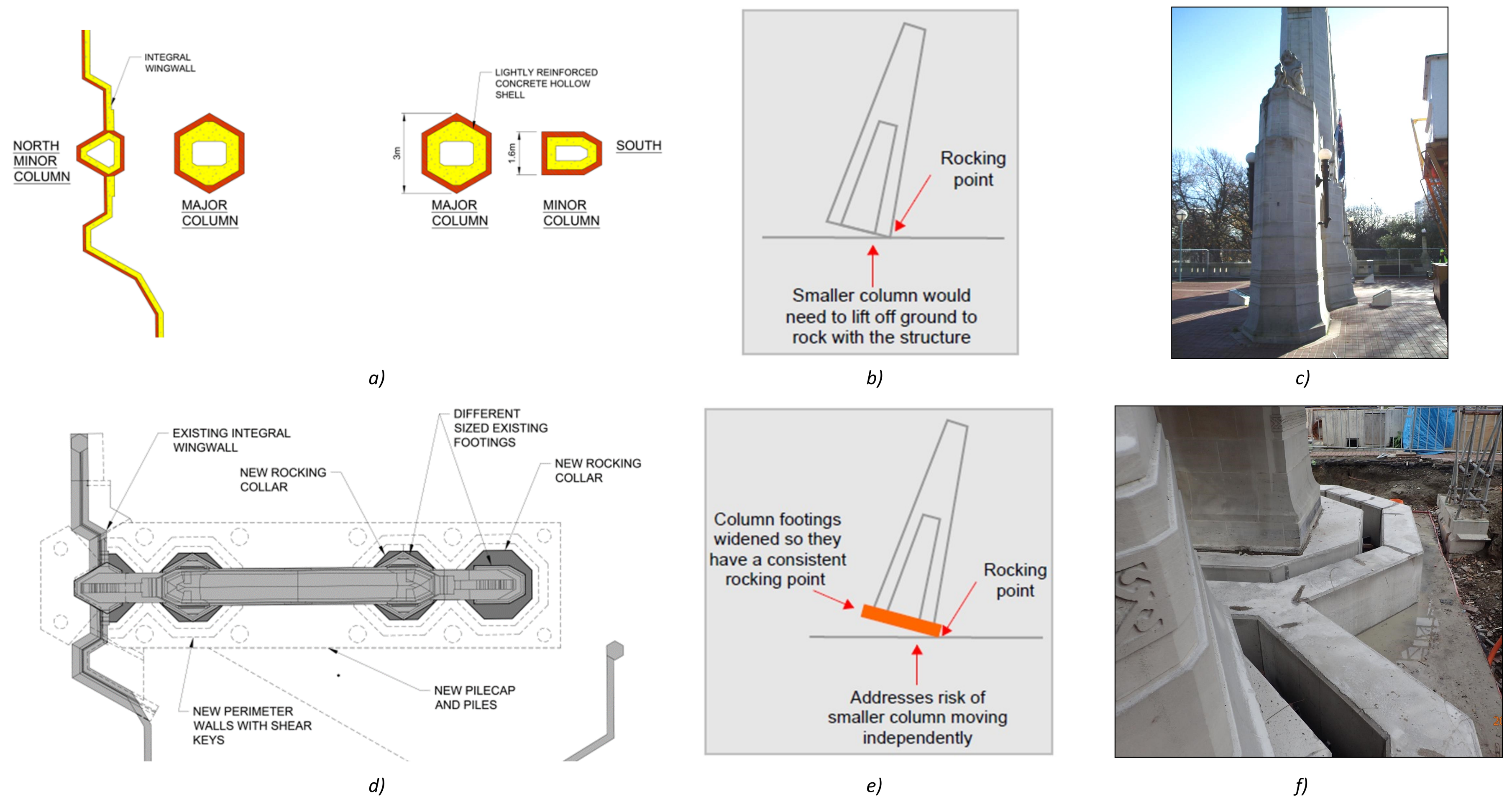


*Figure 5: a) Plan section through existing columns indicating varying size columns and integral wingwall; b) Sketch indicating that the existing column dimensions are not compatible with rocking; c) Side elevation highlighting varying column dimensions; d) Plan on strengthened structure indicating new rocking collars which provide uniform footing dimensions compatible with rocking; e) Sketch indicating how the new collars enable rocking; f) Photo of new rocking collars with movement moat and perimeter wall on the new pilecap during construction*

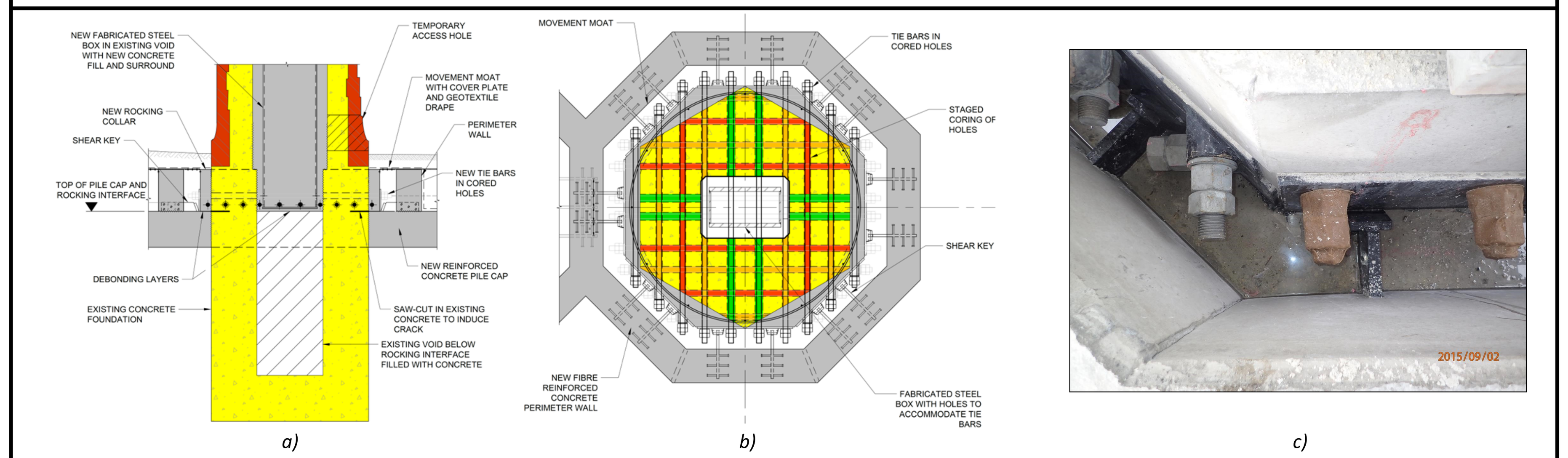

*Figure 6: a) Section through strengthened column showing shear keys, perimeter wall and rocking collar tie-bars; b) Plan showing the same; c) Photo within movement moat showing shear keys and rocking collar tie-bars*

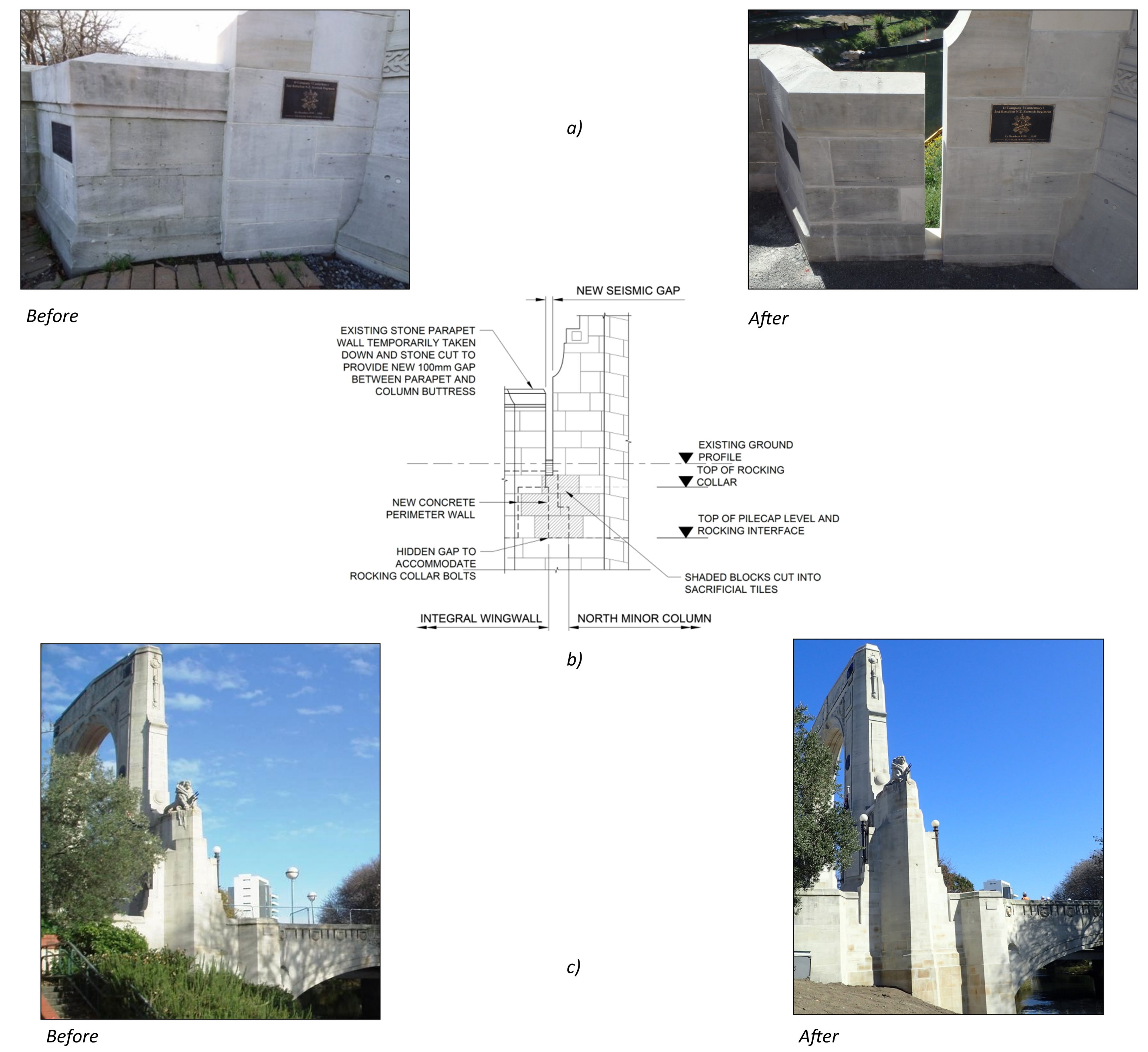


*Figure 7: Modifications to address restraint from integral wingwall—introduction of seismic gap: a) view of parapet from on the bridge; b) summary of modifications to wingwall; c) view of parapet from river bank*

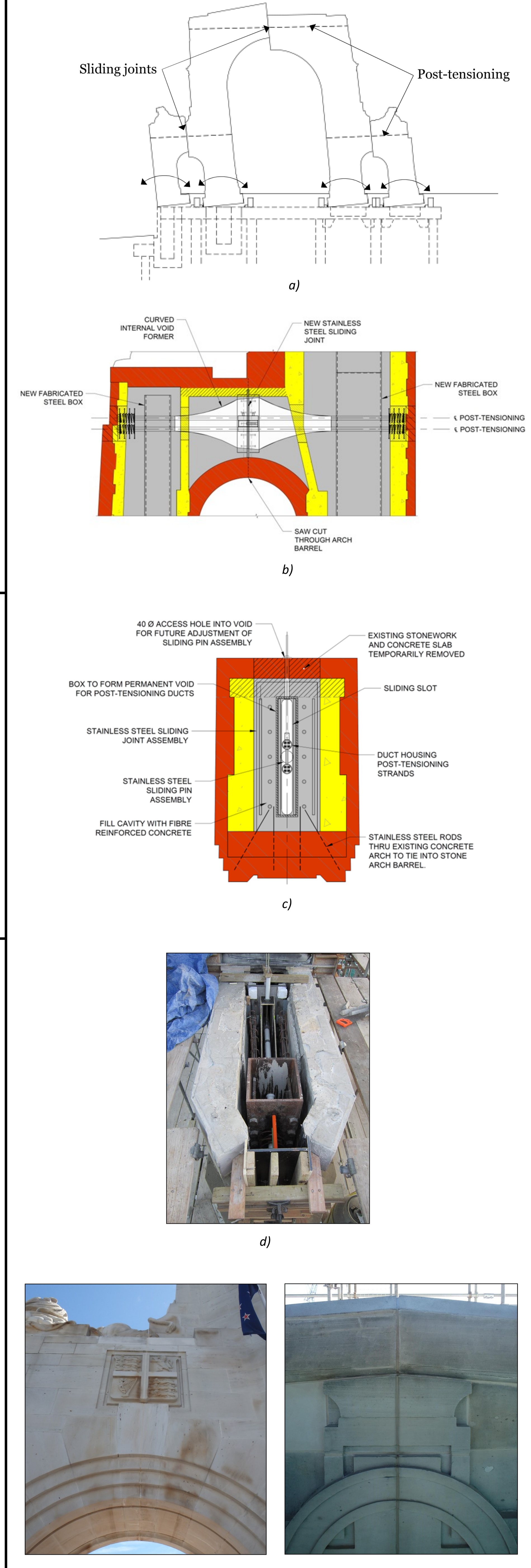


*Figure 8: a) Sketch indicating how the introduction of sliding joints at the crown of the major and minor arches enables in-plane rocking; b) section through strengthened minor arch showing new sliding joint and post-tensioning details; c) section through typical sliding joint; d) photo showing top of minor arch (immediately below the temporarily removed stone lions) prior to concreting; e) photo showing final appearance of stonework on the minor arch at the new sliding joint; f) photo showing the final appearance of stonework on the major arch at the new sliding joint*