The Strengthening of Heritage Buildings – Construction Challenges

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Abstract
The task of strengthening and restoring heritage buildings is a challenging one as it is often difficult to strengthen a member without changing its dimensions or otherwise making the structure look different. Furthermore, the commercial realities sometimes dictate that adaptations to a building are needed to ensure its future usefulness. The task of supporting or moving the brittle fabric of heritage structures to accommodate these alterations can be even more difficult requiring thorough investigation and innovative methods. Between 1994 and 2011, the Auckland City Council strengthened and restored five major civic buildings and the author worked on two of these. This paper discusses some examples of the challenging construction aspects encountered in the strengthening and restoration of these heritage buildings.

1. Introduction

Five major civic buildings were seismically strengthened and restored by the Auckland City Council between 1994 and 2011. These were:

- 1994 – 1997 Auckland Town Hall
- 1998 – 1999 Civic Theatre
- 2002 – 2003 Chief Post Office
- 2004 – 2007 Auckland Museum
- 2008 – 2011 Auckland Art Gallery

Construction work on the Town Hall, the Civic and the Chief Post Office was carried out by Downer, and Hawkins Construction carried out the work on the Auckland War Memorial Museum and Art Gallery.

2. Auckland Town Hall

The Town Hall, located in Auckland's Queen Street, was constructed 1910–1911. The restoration which was carried out 86 years later included earthquake strengthening to modern design codes.

Figure 1: Auckland Town Hall, 2011.

Strengthening work included foundation piles, strengthening of concrete slabs and additional lateral support and concrete overlay strengthening to the unreinforced masonry walls.

Installation of the piles became difficult in that some areas had little headroom. Access by a piling rig of any sort could not be achieved, resulting in one of the piles being hand dug.

Figure 2: The Great Hall during refurbishment.

By contrast, the Great Hall was inconveniently large. In order to access the ceiling for painting and restoration, scaffolding of the entire auditorium was necessary.

Lateral support for the walls of the building was typically provided by tying the walls to a "diaphragm" floor or a (plywood strengthened) roof. A key to this philosophy is the anchors used to tie the brick walls to the diaphragm. In the course of the Town Hall project, Downer tested anchors and epoxy resins to destruction to verify their suitability.

A construction method which was new to New Zealand, and driven by the constraints of heritage work, was adopted for the strengthening of the mezzanine concrete floors in the main entrance. This entailed thin carbon fibre reinforced polymer strips, which were glued to the underside of the concrete slab. This resulted in an improvement in strength without significantly changing the depth so

that the architectural features, floor tiles and ceiling heights remained unaltered.

Figure 3: Strengthening work in progress, 1996.

3. Civic Theatre

The Civic Theatre was constructed in 1929 and was restored and strengthened in 1998–1999.

Figure 4: The 40c stamp of the Civic Theatre issued in 1998 while it was undergoing restoration.

The original Civic featured a Wintergarden that was open to the main auditorium's stage. The 1999 refurbishment (as did the 1975 conversion to a small cinema) featured the Wintergarden as a space separate from the main auditorium so that separate functions could run simultaneously.

For the 1999 refurbishment, this meant that some features of the interior had to be raised 2 metres (m).

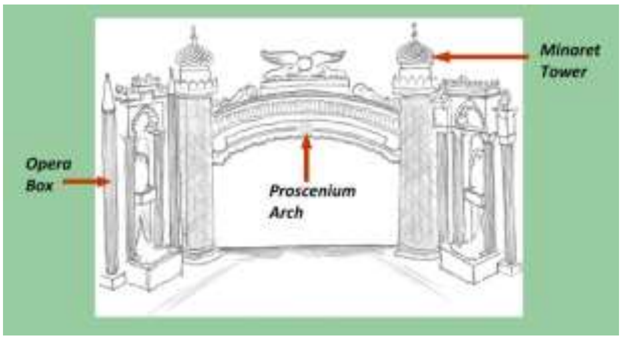

Figure 5: Interior features required to be raised 2 metres.

The two Minaret Towers were de-constructed by cutting them into 3 m high sections, removing them to storage and then restoring and re-constructing them on new, higher bases. This was the suggested method for other interior features, but the process was slow and destructive.

Therefore, the Proscenium Arch was treated differently. In an attempt to keep it in one piece, a pair of monorails was first installed under the roof trusses. The 8.5 tonne arch was then strengthened with steel and timber members and attached to the monorails with electric hoists. Its timber fixings were cut free from the proscenium wall and the arch was rolled towards the centre of the auditorium.

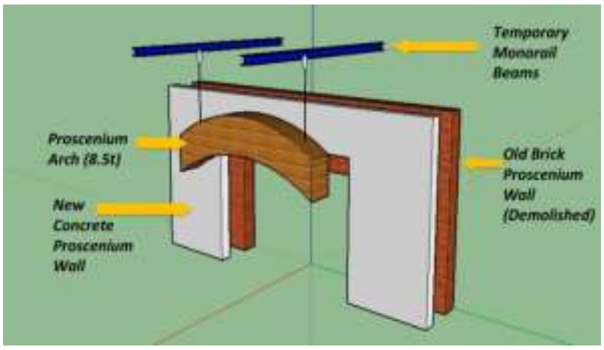

Figure 6: The temporary support, removal & re-attachment of the Proscenium Arch was engineered by Bob Mawdsley.

There it stayed until the new reinforced concrete proscenium wall was complete and the old brick wall demolished. The arch was then rolled back, raised 2 m and fixed to the new proscenium wall.

Figure 7: The Proscenium Arch is suspended from the monorails.

The raising of the Opera Boxes was equally innovative. Once again the objective was to keep the structures in one piece to eliminate time-consuming de-construction and re-construction.

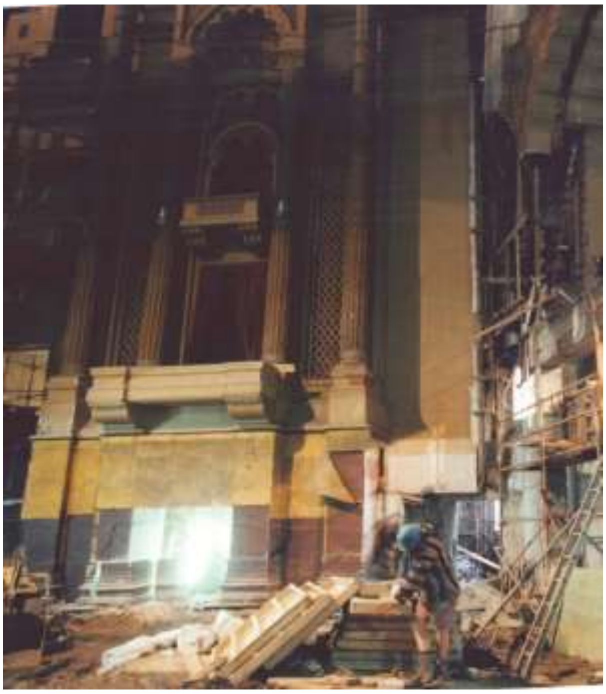

Figure 8: Opera Box Stage Right (before raising).

The proposed scheme involved steel brackets fixed to the walls and vertical rails attached to the structures, meaning the Opera Box could be slid up the wall. A captive shoe-and-channel detail ensured the Opera Box could not come out of its rails.

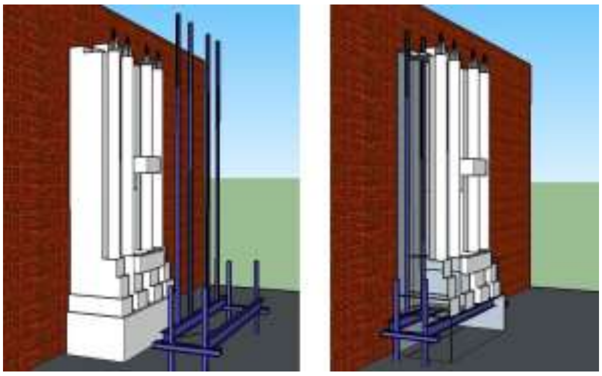

Figure 9: The temporary steelwork structure shown assembled both outside and inside the Opera Box

Whilst the initial concept was simple, the detail was not. Not only were the two Opera Boxes different in style, their make-up of framing timbers was rather random. It was also clear from an early stage that great care was needed to move a structure that was essentially made of flimsy film-set construction. Unless the Opera Box was fully strengthened and supported for the move there was the risk that only handfuls of plaster and wadding would be left attached to the new steel frame! All of the irregular and random timber framing was inspected, measured up and drawn to scale. A steelwork structure was then designed and detailed to suit.

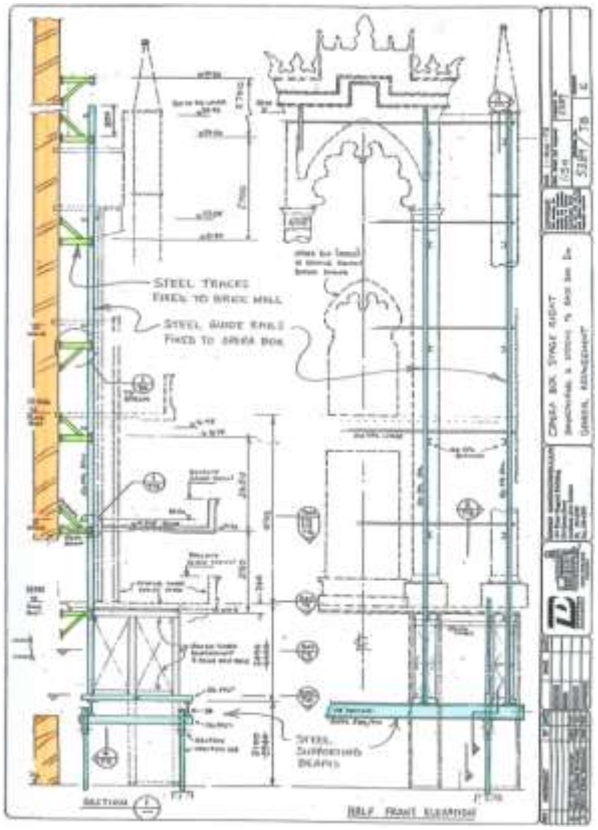

Figure 8: The Temporary Works design for the Opera Box raising, engineered by the author.

With all of the steelwork in place, it was then a straight-forward task to jack the structure up to its final position.

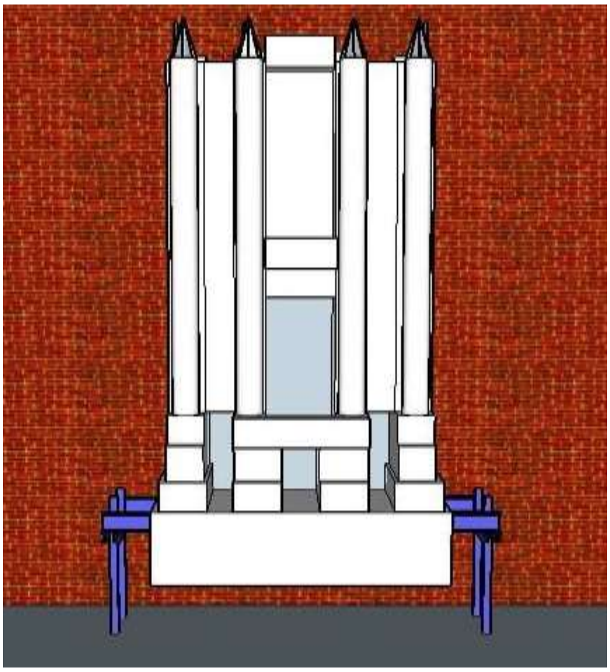

Figure 10: Schematic of the Opera Box immediately after jacking.

Most of the supplementary steelwork designed for the jacking operation was retained, providing increased strength for seismic loads.

4. Chief Post Office

The catalyst for the restoration and strengthening of the Auckland Chief Post Office (CPO) was the construction of the massive Britomart underground railway station. For this project, the CPO was to be the main thoroughfare from Queen Street to the underground linking the trains to the buses and ferries.

Figure 11: Front view of the CPO (2011).

The upper 3 levels were strengthened but not refurbished and leased until a later date. However, the ground floor and basement were both strengthened and modified to become the Britomart Interchange.

The ground floor was originally half a storey above street level with the basement floor half a storey below. In the new configuration, this was changed so that the ground floor was approximately at street level, providing easy pedestrian access to and from the building. A new basement was constructed a full storey below ground with an underpass to the other side of Queen Street.

The challenges for the Contractor with these alterations were:

- Ground water. As the original higher-level basement had already experienced flooding problems, the construction of a deeper basement was even more difficult.
- Careful management of the lateral support systems as the floor slab and basement were demolished around the internal columns.
- Monitoring of the structure and temporary supports whilst sections of the perimeter foundation beam and piles were removed.

One of the major undertakings was to create an opening 20 m wide by 10 m high in the rear brick wall of the building. This was needed to provide a spacious and naturally lit opening for the escalators and stairs from the platforms below.

Figure 12: The new columns & beam in the rear wall.

Temporary support was needed for the opening in the rear wall while the new columns and beam were cast. The trick was to design a support system that would not get in the way of the new work!

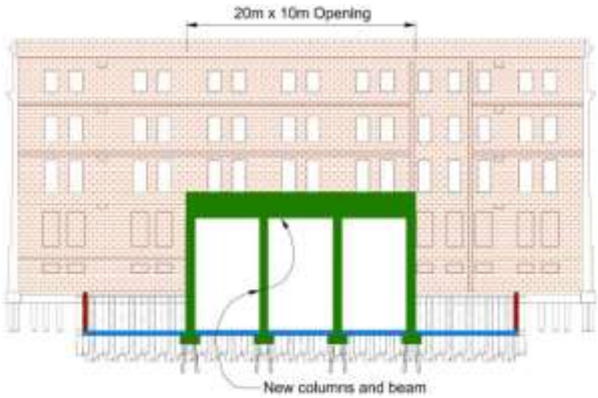

Figure 13: Schematic showing the new columns & beam.

The columns were constructed by cutting vertical slots in the wall. This required very little temporary support as the brickwork was able to arch over the relatively narrow slots.

The beam was more challenging, requiring an innovative approach to support the estimated 350 tonnes of floors and walls above. The method used involved casting the beam in two halves with a vertical construction joint. The first half of the beam (the part inside the building) was notched into the wall and cast while most of the brick wall was still in place and still providing a good vertical load path. Steel columns and beams were then fastened to the outside face of the wall so in tandem with the first half of the beam they provided vertical wall support whilst the second half of the beam was cast. The beam was designed with a set of stirrups for its first duty (that of temporary support during construction) and a second set of stirrups for its permanent load cases. The second set of stirrups, fully enclosing the longitudinal bars, consisted of two "C" shaped bars that were site welded to form a closed loop.

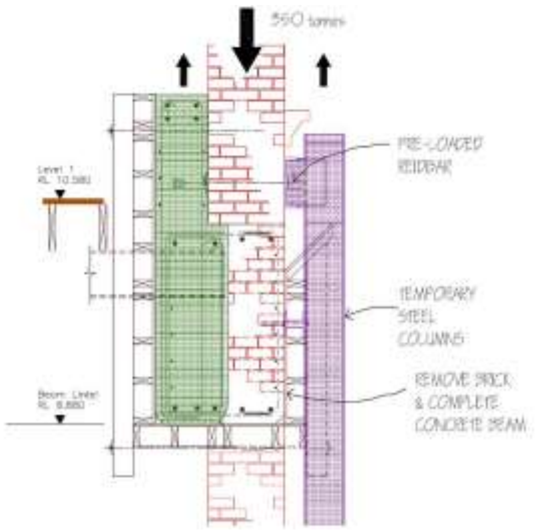

Figure 14: Schematic showing the partly constructed lintel beam in the rear wall of the CPO.

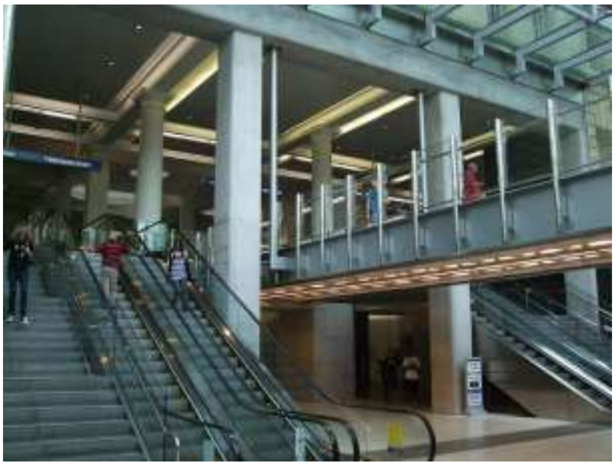

Figure 15: The new columns and beam in the rear wall of the CPO.

A detailed survey of the existing cracks in the wall was carried out and their condition monitored before, during and after the construction of the new columns and beam. No change was observed.

5. Auckland Museum

The Auckland War Memorial Museum was originally built in 1929.

Figure 16: The Auckland War Memorial Museum (2011).

During the restoration and strengthening of the Museum in 2004–2007 new utility and exhibition spaces were constructed. This included underground car parking and a Grand Atrium constructed within the semi-circular courtyard at the rear. This was a challenging task described as constructing a 7-storey building within the confines of a heritage building.

Figure 17: The wave-like roof of the new Grand Atrium is just visible in this photo of the rear of the Museum.

A major challenge for the Contractor was the construction of a truck dock entrance to a new underground loading bay.

Figure 18: The new truck dock entrance.

A section of the perimeter foundation beam had to be removed and new beams cast. Self compacting concrete was used under the existing structure so that full load bearing contact could be achieved. When the concrete for the new beams had hardened, it was post tensioned with high strength stressing wires.

6. Auckland Art Gallery

The Auckland Art Gallery was the oldest of the recently refurbished civic buildings. The original building with the clock tower was built in 1887 and subsequent extensions were constructed in 1913, 1916, 1971 and 1981.

Figure 19: The original building from Kitchener St.

As with many similar buildings, the floors and roof were strengthened with layers of plywood and tied into the perimeter walls to brace the walls for seismic loads.

Figure 20: The original building from Wellesley St.

New electrical, plumbing, air conditioning, fire protection and security systems were installed as part of the upgrade. Some of the more recent additions to the Art Gallery were demolished to make way for a new 5-level extension featuring a glazed atrium.

The refurbished and strengthened Auckland Art Gallery was completed and opened in 2011.

Figure 21: The new glazed atrium extension during construction.

7. Conclusion

The five buildings recently strengthened and refurbished by the Auckland City Council provided some interesting challenges for Contractors. In particular, the refurbishment frequently involved adaptations to improve the buildings' usefulness. These changes required innovation and complex temporary support structures to protect the delicate heritage fabric.

8. Acknowledgements

Much of the information for this paper was researched and published by the author in the book *Evolving Auckland – The City's Engineering Heritage* (Christchurch: Wiley Publications, 2011).

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