Clendon Burns & Park Ltd
CONSULTING CIVIL & STRUCTURAL ENGINEERS

John Hollings Seismic Resilience in Practice Award - Submission

Project:	**Te Whare o Rehua Sarjeant Gallery – Seismic Strengthening**
Location:	**Pukenamu, Queens Park, Whanganui.**
Architect:	**Warren & Mahoney Architects (Warren and Mahoney)**
Engineer:	**Clendon Burns & Park Consulting Engineers, Wellington**
Client:	**Whanganui District Council**
Contractor:	**McMillan Lockwood, Palmerston North**
Completion:	**July 2024**
Opening:	**9 November 2024**

1.0 Introduction

Te Whare o Rehua Sarjeant Gallery is one of New Zealand's most important heritage listed buildings which also holds immense architectural value. It has stood as an iconic symbol at Pukenamu Queens Park in the city of Whanganui since 1919. The category one heritage listed building was built in the shape of a neo-classical Greek Cross on plan. It was also once revered as one of the best art galleries in New Zealand with a permanent collection of art works spanning some 400 years of art history.

The unreinforced masonry building, cladded in Oamaru stone, was closed in 2014, due to its earthquake prone status. It had a very low seismic rating and was a safety risk to staff and visitors, deemed unfit for storing the significant art collections.

Figure 1: Sarjeant Gallery and Mt Ruapehu

Warren and Mahoney Architects has been on an almost 30-year journey to revitalise the gallery, starting from winning the design competition in 1996, to embarking on a redevelopment project in 2019 to modernise and extend the gallery.

The Warren and Mahoney redevelopment design was based on reinforcing the clearly defined structure of the historic building which "**respectfully expands and enhances**" the original Sarjeant Gallery. A bridge suspended in the new entry foyer connects the new exhibition areas to the existing galleries. The bridge not only provides an access to the old and the new, it also highlights a link between two buildings of distinctive architectural styles.

Clendon Burns & Park (CBP) Consulting Engineers has been involved in the redevelopment project since 2014, working collaboratively with Warren and Mahoney Architects.

Figure 2 to Figure 6 shows the selected photographic views of the external and internal views of the original Sarjeant Gallery in 2014, when it was closed to the public.

Figure 2: Northern Elevation: Entrance at basement or road level (closed in 2014)
(This entrance was lifted in the redevelopment to be at the gallery level,
with the architectural features retained and a new link bridge
installed connecting the old and the new buildings)

Figure 3: 2014 South West Elevation (closed in 2014)

Figure 4: South Entrance (closed in 2014)

Figure 5: Architectural features at West Wall (closed in 2014)

Figure 6: Central Dome (closed in 2014)

2.0 Seismic Strengthening Scheme – Design Features

Between 2014 and 2019, CBP undertook a number of preliminary design schemes for consideration by the stakeholders and for costing to form the basis for fund raising. After much consideration of the seismic and the construction risk of the various schemes, the decision was made to strengthen the building to the seismic strength level corresponding to 67%NBS(IL3) or over 85%NBS(IL2) of the current code NZS1170.5.

Of utmost importance to Warren and Mahoney and to the Conservation Architect, is the need for the structural solution to be concealed and unobtrusive, to maintain the historic fabric and integrity of the existing Sarjeant Gallery.

Central to the adopted strengthening scheme was the use of prestressing applied to the masonry walls, to provide both out-of-plane and in-plane strength to the existing masonry walls to achieve the target seismic strength. The design utilised the building's unique multi-level cruciform plan layout to create effective load paths for the seismic load to be resisted.

Pre-construction tests and trials were commissioned during design development to develop the construction methodology with the contractor and the specialist subcontractor.

Over 300 stainless steel prestressing bars, up to 12 meters long were installed within vertical holes drilled in the walls with the bars anchored in the new reinforced concrete capping beams at the roof level and embedded in the existing concrete foundations. The bars were grouted in place and stressed to the design load.

Extensive investigations were carried out to establish the minimum bond lengths required for the prestressing bars to develop the prestress forces to meet design requirements. Where bond lengths were not able to be met, anchor plates bearing on the base of the foundation were used. On completion of drilling, installation and grouting of the bars, the prescribed prestress load was applied by hydraulic jacks. This effectively load tested all the anchors installed and formed the quality assurance process on site.

Prior to the strengthening work being carried out, the gallery level floor structure of the original Sarjeant Gallery comprised of polished timber floorboards supported on timber floor joists. The timber joists spanned between the perimeter concrete walls and internal brick arches with shallow foundations. There was no effective structural diaphragm at the gallery level, the timber floor joists were supported by simply bearing on corbels or on top of the brick arches, with no lateral ties or load paths to transmit the lateral load induced by seismic action.

The existing timber floorboards were lifted and stored to be reused, the timber floor joists and the brick arches were removed. A new composite floor, formed by casting concrete on metal decking supported on steel beams, was installed over the entire footprint of the building. The re-cycled timber boards were laid over the new concrete floor to reinstate the original interior architectural feel of the building, while providing a vital structural function of providing an effective structural diaphragm.

At the roof level, steel truss bracings combined with roof level capping beams tie the walls together for the in-plane and out of plane seismic loading. At the central dome area and the central core, a combination of carbon fibre, reinforced concrete coupling beams and prestressing were used.

Figure 7 to Figure 11 shows the overall view of the structural scheme, with the structural steelwork shown in red, with the reinforced concrete capping beams and overlay slab around the dome shown in blue.

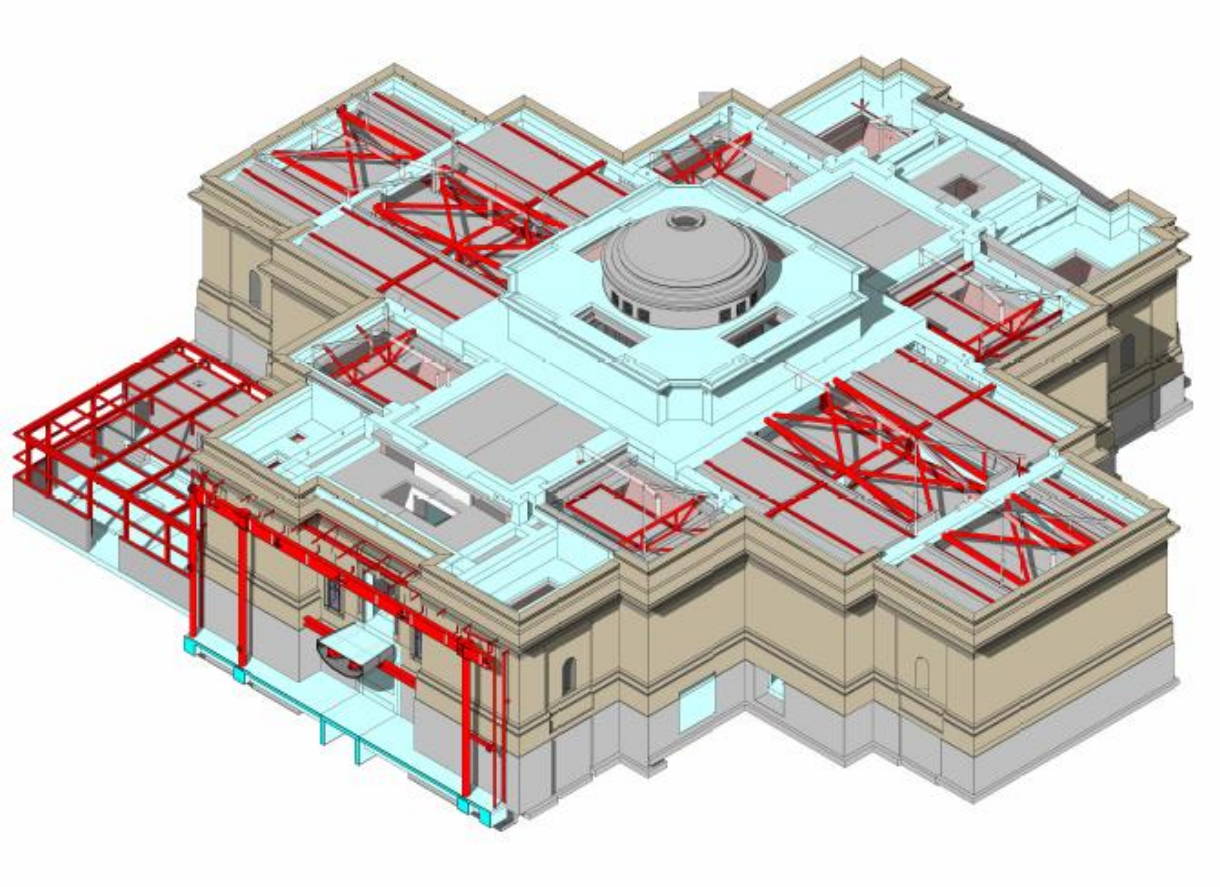

Figure 7: Overview of the strengthening elements installed (NW view)

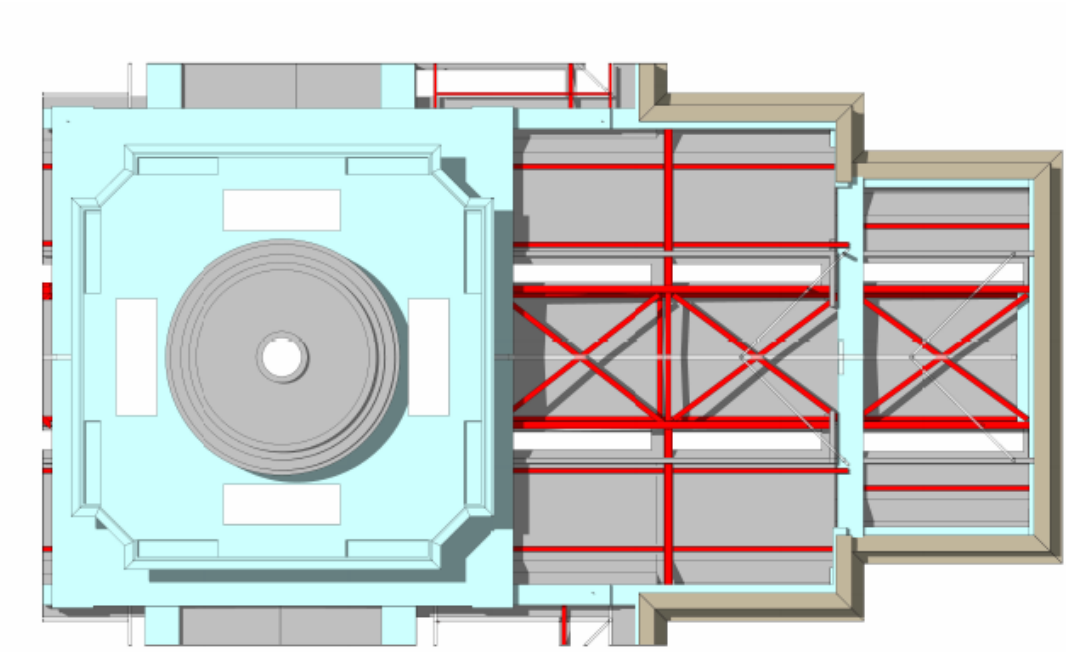

Figure 8: Part plan - view of the concrete works around the dome and steel roof bracings over the West Wing

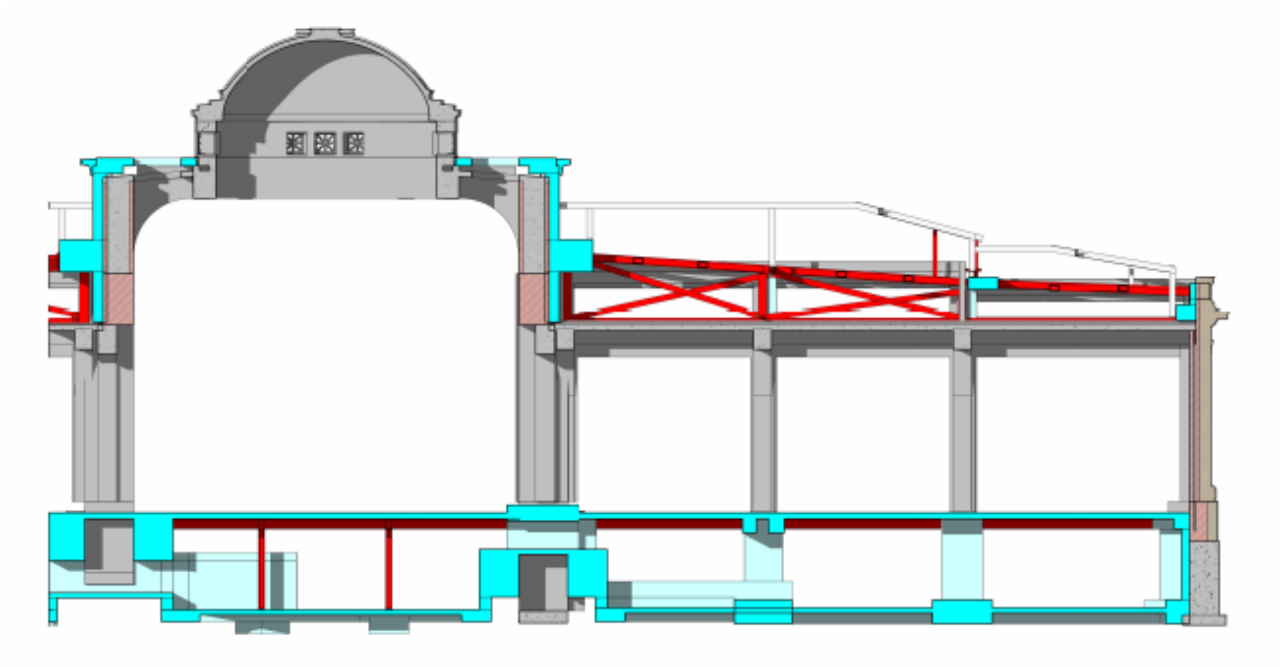

Figure 9: Part section through the core and the West Wing

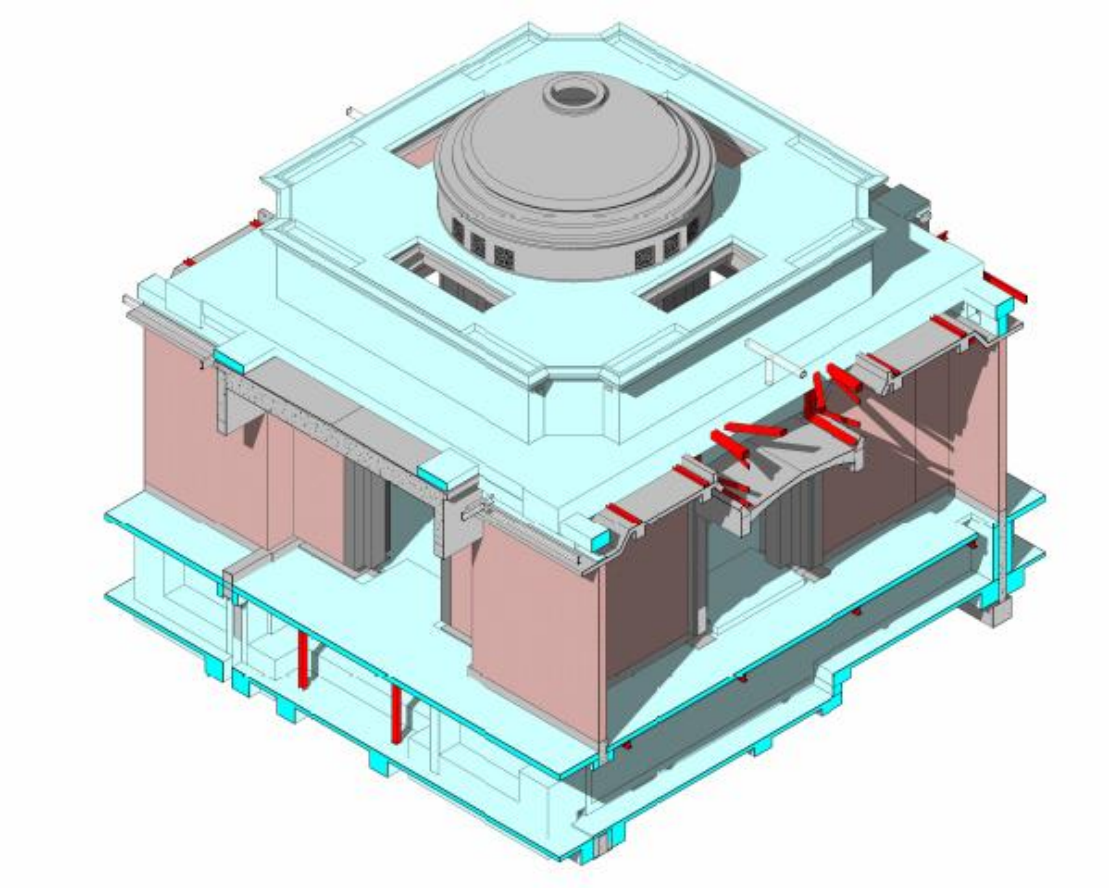

Figure 10: Close up view of the concrete works around the core and the dome

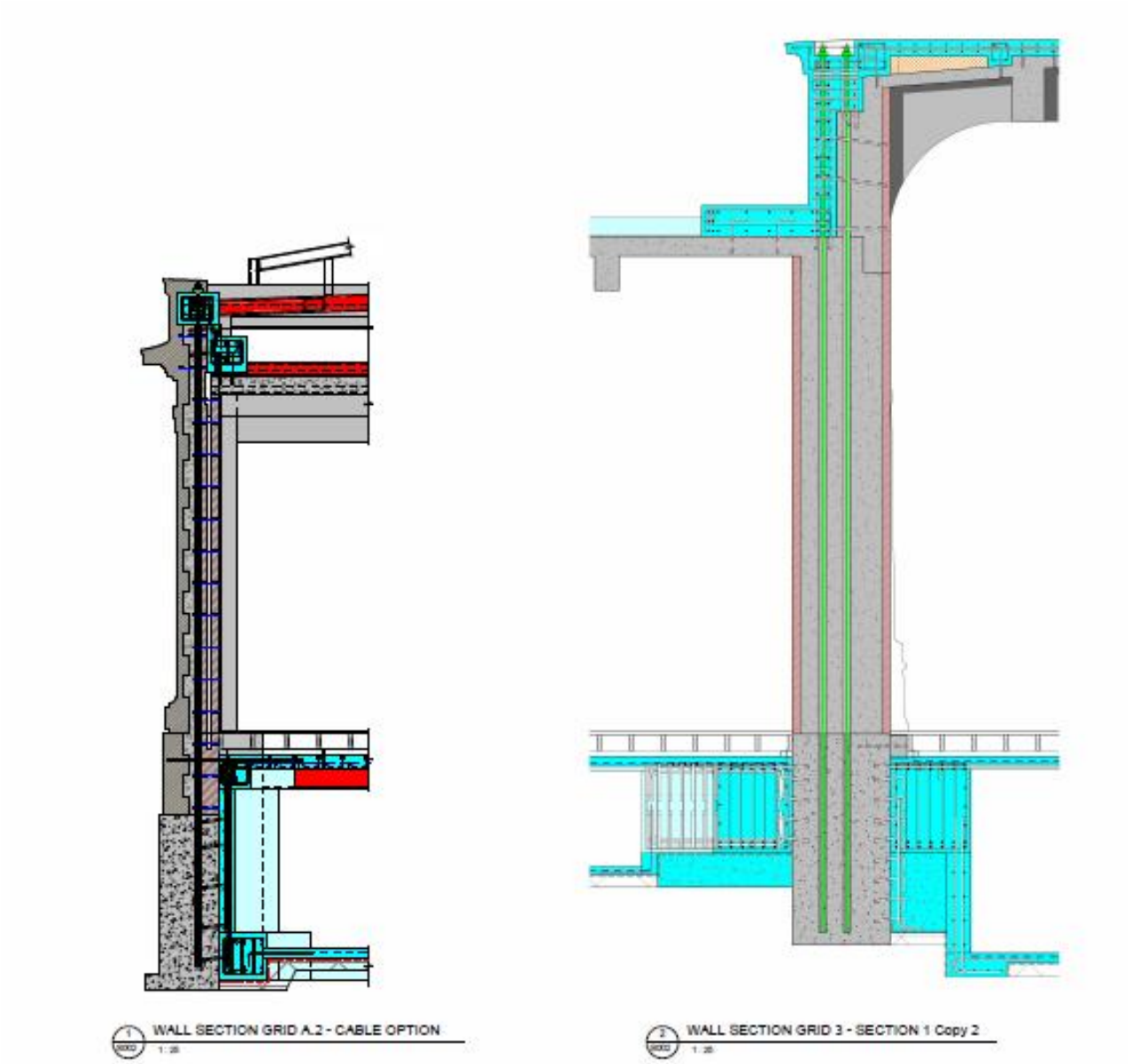

Figure 11: Sectional views of the perimeter and core walls, showing the prestressing and the concrete works

3.0 Geotechnical Design and Foundation

Extensive geotechnical investigations were conducted between 2011 and 2015, these included cored drilled holes and cone penetration tests. The site was identified as potentially prone to liquefaction and lateral spread based on these early investigations.

In 2018, Ian R Brown Associates Ltd (IRBA) assisted by Professor Nicholas Sitar (University of California, Berkeley), were engaged to undertake a review of the earlier geotechnical assessment. The geological setting, age of sediments, as determined from radiocarbon dating of wood recovered from drillholes, discontinuous nature of sandy layers, past seismic history of the area and depth to potentially liquefiable soils were aspects which informed IRBA's assessment.

IRBA concluded that there is a very low risk of liquefaction in the soils beneath the Sarjeant Gallery. This significantly reduced the predicted ground deformation due to liquefaction and improved the design bearing capacity.

The foundation strengthening was to provide a structural skin with new footings stitched to the existing concrete basement walls and tie beams to support the gallery level diaphragm floor slab. This provides a robust substructure that can tolerate the predicated lateral spread and settlement in an ultimate design level earthquake.

4.0 Temporary Works and Construction Challenges

During construction it was necessary for CBP to develop some innovative temporary works with the contractor. The following temporary works were particularly challenging and interesting:

- **Underpinning of walls and staging excavation.**

In the Eastern Wing of the Sarjeant, it was essential to underpin some of the existing walls and columns by approximately 1.3m to deepen the basement. Access was particularly confined, and the underlying material of sand made this challenging.

After several discussions with the contractor, it was decided that a unique form of sheet piling, using interlocking 300PFC and a network of waler beams would be used. The rationale for using 300PFC's was that these were able to be carried into the confined space manually. The PFCs were installed into the sand by vibration using modified jack hammers. The interlocking PFC's prevented any sand leakage. The underpinning was staged to minimize construction risk.

- **Battered excavation at perimeter of the existing Sarjeant Gallery**

On the north side of the Sarjeant Gallery, excavation was required to a depth of approximately 4.5m to construct the basement for the new extension building. Due to the relatively high gravity bearing loads on the perimeter wall and the strip footings being supported on existing sandy ground, particular care was taken to prevent collapse of the building into the excavation and potential excessive settlement causing damage to the existing building.

Through discussions with IRBA, temporary staged excavation support was developed which involved a reinforced concrete apron, Titan Ischebeck anchors and regular monitoring was carried to detect any potential movement of the building. The excavation and supporting apron

were undertaken in three vertical and five horizontal stages to help manage risk. Refer Figure 1.10 for a photo of the excavation and the temporary retaining wall.

- **Removal of the north wall feature and reinstatement at a higher elevation**

The Warren and Mahoney design has a link that connects the original Sarjeant Gallery to the new extension at the first floor Gallery Level at its north side. The link is a steel bridge that spans between the original and the new building, requiring the entrance to be lifted to a new elevation. To allow the existing entrance with the North Wall features to be retained and lifted to the new elevation, required meticulous planning of the temporary works and careful construction sequencing of the permanent works. Refer Figure 1.11 and Figure 1.12.

- **Repair of the corner cracks due to corroded cast iron pipes**

At 16 corners of the original building, there were cast iron downpipes within the external wall providing roof drainage which were severely corroded. The corrosion of these cast iron down pipes was the leading cause of vertical cracks at these locations. Steelwork installed providing the temporary horizontal stitching, together with cautious sequencing, allowed the successful removal and replacement of all the cast iron downpipes.

5.0 Conclusion

The innovative design has resulted in an effective, yet visually unobtrusive strengthening solution to this grand historic building, helping to restore to its place as a national and architectural treasure.

Appendix 1

Construction Photos

Figure 1.1 Excavation in progress – timber floor removed.

Figure 1.2 Excavation completed.

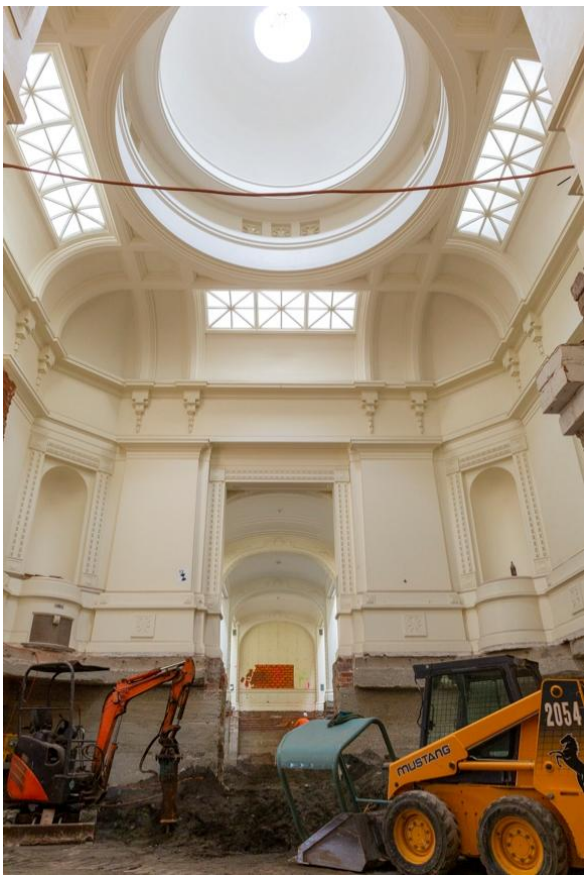

Figure 1.3 Excavation in progress – Core area.

Figure 1.4 Ground beam reinforcing installed, wall starters to be placed.

Figure 1.5 Foundation wall reinforcing placed.

Figure 1.6 Floor slab reinforcing placed.

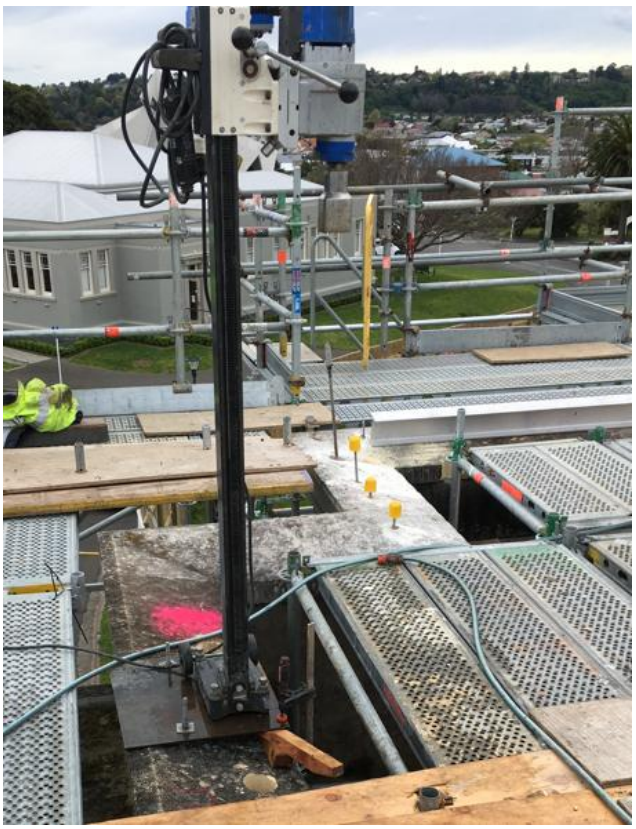

Figure 1.7 Drilling of holes for a prestress bar at roof parapet.

Figure 1.8 Reinforcing for concrete works around the dome and core roof with prestressing bars installed.

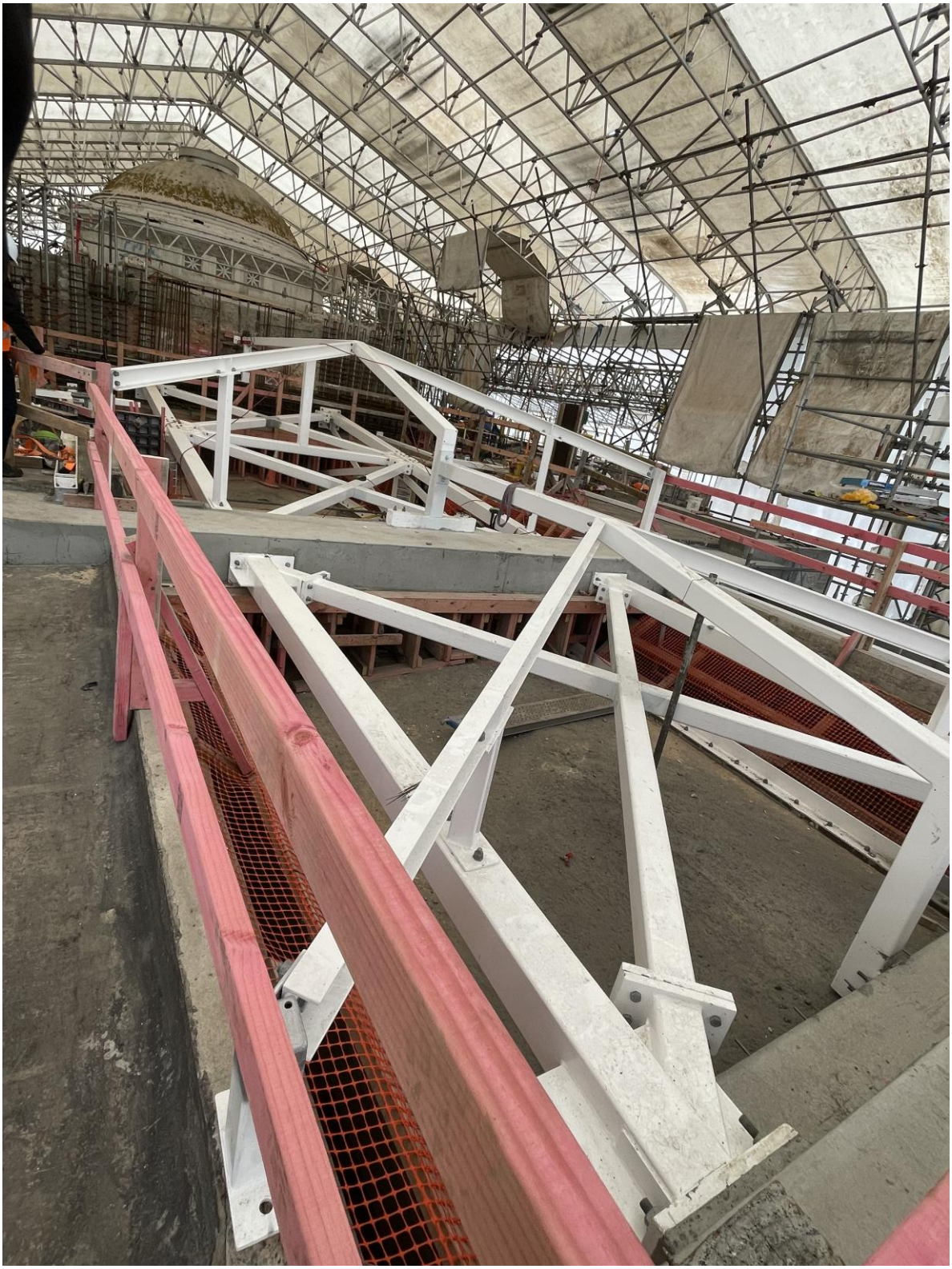

Figure 1.9 Roof steelwork and steel truss bracings over West Wing.

Figure 1.10 Temporary retaining wall at the north side of the original Sarjeant Gallery building nearly completed to accommodate the basement of the new extension building.

Figure 1.11 Temporary steel work to stabilise the north façade to allow relocation of the north entrance from the basement level to the gallery level and to allow a bridge structure to be installed. (Refer Figure 2 and Figure 1.10 for the original north entrance location)

Figure 1.12 Bridge structure being installed amongst the temporary works at the north façade prior to being cladded in Maori carving.

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Appendix 2

Completion Photos

Figure 2.1 Sarjeant Gallery new entrance at the north end of the original building.

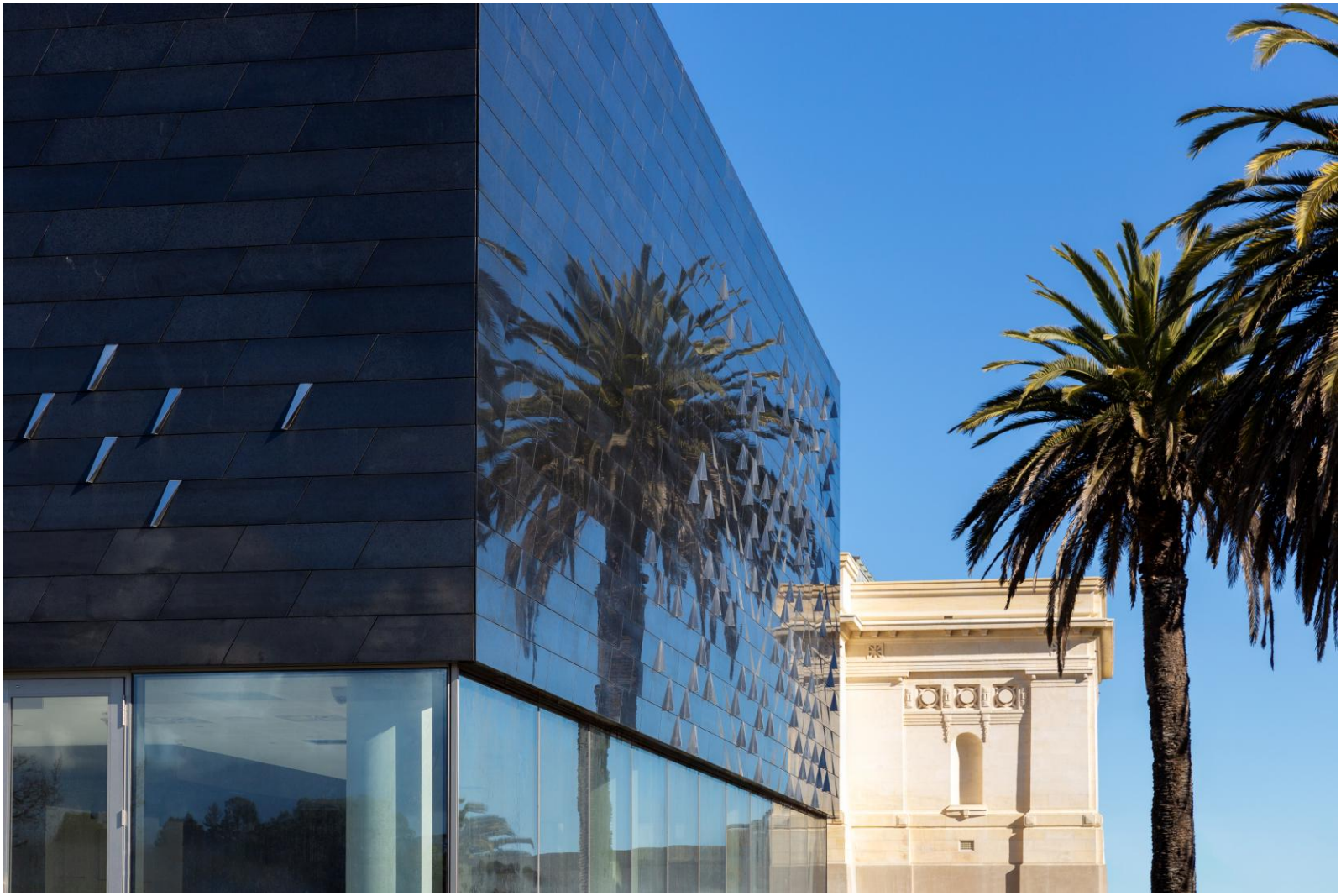

Figure 2.2 View towards the north west corner of the original Sarjeant Gallery building.

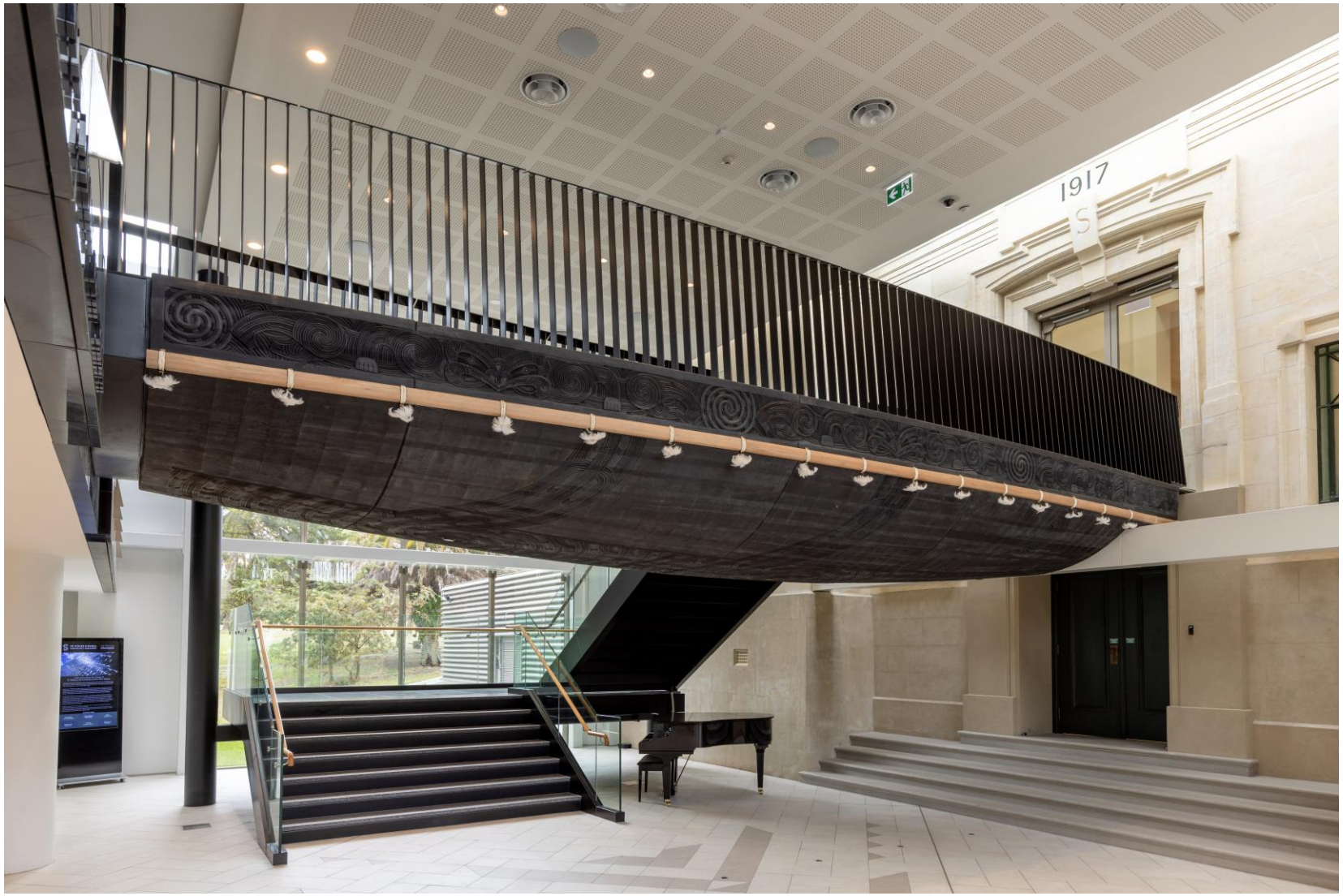

Figure 2.3 View of the bridge cladded in Maori carving with the relocated north entrance to allow connection between the original building and the new extension at the Gallery Level.

Figure 2.4 View of the dome roof and core area,
with no structural interference inside.

Figure 2.5 View of the interior with the original timber floor boards reinstated and laid over the new concrete floor.