Innovative seismic upgrade of Left Bank Art Gallery, Greymouth.

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ABSTRACT

The Grey District Council commissioned the strengthening of the C1910 Left Bank Art Galley building in 2018 to preserve its historical value and improve the building's seismic safety rating. Formally the Bank of New Zealand and situated in the Greymouth's new town square, the building was an entirely unreinforced masonry and heavy timber trussed construction. The building is approximately 240 metres square in plan, with a five metre floor to ceiling height for two-thirds of the building, the remaining being two storied. The strengthening methodology chosen increased seismic rating from approximately 20% NBS IL2 (earthquake prone) to 70% NBS IL3 (low risk), while preserving the full aesthetic character of the building. The seismic upgrades are not visible from either the exterior or the interior. Stage One prioritised making safe the unreinforced masonry parapet with the addition of steel angles and horizontal steel stays to the roof structure. Stage Two involved reinforced concrete foundation beams and columns cut into the brick walls in such a way that they did not protrude, which formed inverted portal frames. The masonry walls were also strengthened with closely-centred "Helifix" ties. The Stage Two structural work was completed on budget at a final cost $350,000. Other improvements include the strengthening of the rear two-storey section using steel girts and mullions in order to robustly connect all walls together with the roof structure.

1 INTRODUCTION

The Left Bank Art Gallery is a former Bank of New Zealand and landmark historical building in Greymouth. The building is well-positioned within the central business district, with views towards Mawhera Quay and the Grey River floodwall on the north side and the new town square on the west. A viewing platform recently constructed over the Grey River floodwall is positioned with views overlooking the Gallery. The building has been occupied as an art gallery for approximately 30 years in the capacity of displaying contemporary New Zealand paintings, print, photography and a nationally significant collection of pounamu.

This neoclassical style building was likely constructed after fire destroyed the original building in 1910 and prior to seismic strengthening, has remained substantially unchanged from its inception. In its original state the building had an approximate NBS rating of 20% and was therefore found to be a high earthquake risk (Class D). The main critical structural weakness of the building is its tall unreinforced clay brick masonry walls and parapet. Connections between the timber framed roof and walls were not of a standard that would withstand the lateral forces of a maximum credible earthquake event.

Figure 1: Left Bank Art Gallery after seismic strengthening view from the new viewing platform, 2020.

A parapet strengthening strategy was proposed by the author in 2013 and put into action by local contractors. The author was then commissioned by the Grey District Council *"GDC"* to lead the design of an innovative seismic upgrade for the overall structure with two essential requirements: while raising the life-safety of the building to its highest standard, the strengthening works should also not detract from the aesthetic value of the building and its suitability as an art gallery. This paper describes the design that met the specifications of the Council, owner and tenant to an exceptional standard and raised the NBS rating to 70% (Class B, Low Risk).

2 BUILDING DESCRIPTION

The Left Bank Art Gallery is an unreinforced rendered clay brick masonry *"URM"* construction which contains a former banking chamber and current exhibition gallery with utility rooms at the rear; a reinforced concrete vault accessed from the main chamber; and first-floor ablutions and storerooms.

As no drawings were discovered for the building, invasive investigation methods were relied upon to understand the building's 'as-built' construction. Some original bracket connections were discovered between the URM walls and the timber trussed and sarked roof diaphragm, which is clad with lightweight corrugated steel. Preliminary investigations revealed that the building did not contain structural reinforced concrete in the walls or roof. The exposed ceiling beams in the exhibition chamber were found to be non-structural.

The exhibition chamber, a large full height room boarded on three sides by URM external walls, was found to be especially vulnerable.

Figure 2 (left): North wall of the Art Gallery viewed from Mawhera Quay, photographed in 1988.
Figure 3 (right): As above, photographed in 2020.

Prior to strengthening, the URM walls would likely be heavily damaged in the event of significant earthquake-induced shaking. In the case of a maximum credible earthquake event, the former bank building could partially collapse from torsional effects, in response to a more substantial eastern end of the building moving comparatively less than the more flexible western end of the building.

The building's foundations comprised sound tongue and groove flooring supported on heavy timber bearers and short piles. The URM walls are supported on a concrete perimeter ring foundation. The first floor at the eastern section has a timber tongue and groove floor attached to the URM walls.

The neoclassical architectural decorative trims and features in the building's interior were important to retain in order to preserve the historic character of the building, such as the delicate plaster cornice mouldings. The chosen strengthening strategy outlined in the next section preserved the original look and feel of the building without visibly displaying incongruous metal structural elements.

3 PROPOSED STRENGTENING METHODOLOGY

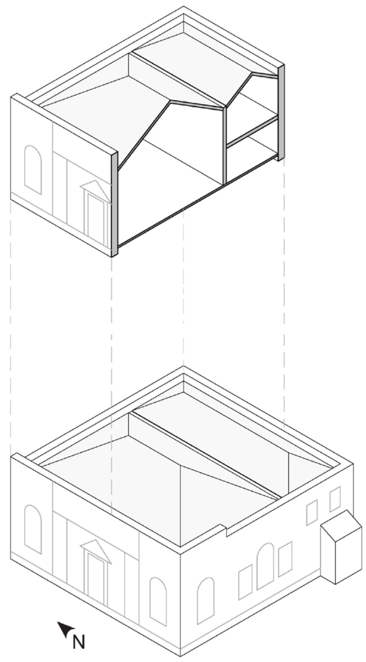
3.1 Parapet strengthening methodology

An investigation of the roof carried out in 2013 uncovered perimeter tie rods installed after the 1968 Inangahua Earthquake; however, these were corroded and needed to be replaced. The building's URM parapets were assessed as vulnerable to seismic shaking as has been well-documented in central Christchurch during the 2010-11 earthquake sequence.

The first strengthening improvements *"Stage 1"* were designed by the author and comprised reinforcing the brick parapets. Horizontal steel angles were attached to the inside perimeter of the parapets on the four sides of the building, which in turn were laterally supported with steel pipe strut / "tie backs" into the roof framing. Pipe stays were installed as close to horizontal as possible to negate vertical tension forces on the unreinforced masonry parapet. The underlying timber roof framing was strengthened with the addition of numerous angle brackets to improve joint strength between purlins, rafters and the heavy timber roof trusses.

3.2 Primary building strengthening methodology

The second stage *"Stage 2"* involved the consideration of several options to increase the strength of the west end of the building to prevent overall collapse. The two preferred options involved applying either internal steel framing or recessed concrete framing. Following discussions between the owner, the GDC and the tenant; the author proceeded with a detailed design of the recessed reinforced concrete option.



The concept of the design was to construct inverted moment resisting portal frames (north – south orientation) and half portals for the east – west orientation. The frames consisted of well-reinforced "ground beams" cast directly under the original timber framed floor and "mullions" cast into recesses created on the inside of the triple-wyth external walls. This had the effect of concealing the mullions and therefore retaining the original wall lining alignment. The inverted moment resisting portal frame, together with the portal frame over the main entrance combined to provide sufficient strength in the north – south direction at the west end of the building.

The overall building strength was increased by combining the primary strengthening system of inverted moment resisting portal frames and a secondary reinforcement strengthening system, as detailed below.

Figure 4: Architectural sketch of building layout.

3.3 Secondary wall strengthening methodology

The secondary strengthening system comprised the "reinforcement" of the URM mullions between the windows along the north and south facing walls by cutting a slot into the brickwork and cementing in steel "Tee" sections to provide reliable out-of-plane strength and robustness. These members spanned between the roof and ground floor.

Large steel plate corner mullions were installed at the north western and south western corners to tie the north, west and south walls together.

In addition to the above, "Helifix" wall ties were installed at approximately 600 centres each way to tie the single brick wyth to the adjacent double brick wyth across the cavity between them. This both supported the single wyth laterally and increased the overall out-of-plane strength of the wall.

3.4 Rear two-storey strengthening methodology

The two storied portions of the Art Gallery building were found to have retrofitted “strap and lined” lining with minimal heritage significance. This lining was removed to enable a steel angle “cage” system to be installed on the inside of all exterior and interior brickwork. This steelwork was used to tie the walls to the ceiling/roof and floor diaphragms. Additionally, steelwork tied the first-floor diaphragm to the robust concrete safe under the west end of the two-storied area.

This approach was used by Orion NZ Limited to strengthen over 100 URM network substations prior to the 2010 / 2011 Canterbury Earthquake events and was found to be very successful (Misnon, Dizhur, Mackenzie, Abeling, & Ingham, 2018).

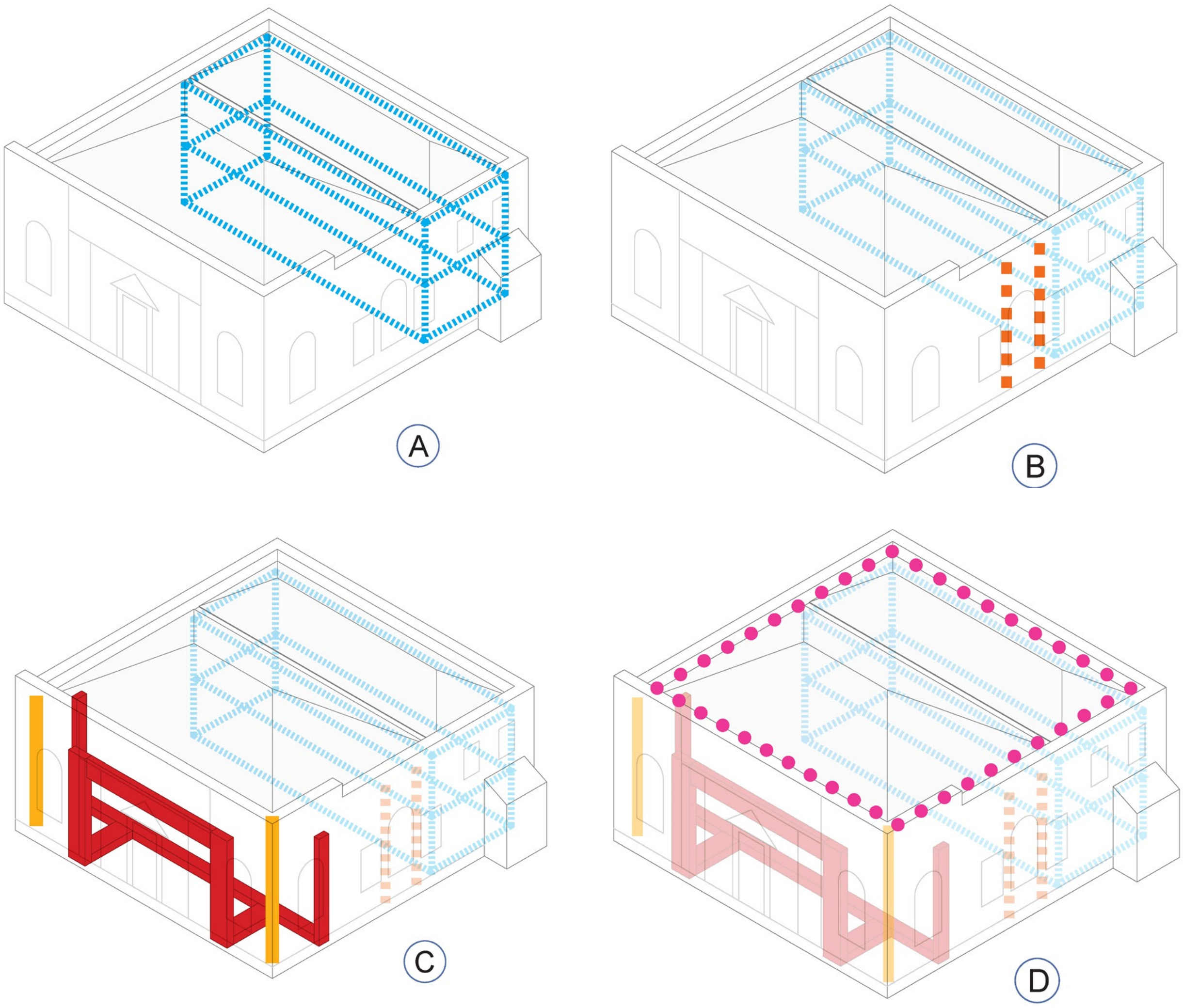


Figure 5a: The steel skeleton “cage” system installed on the inside of all brickwork in the two-storey section of the building.

Figure 5b: The secondary strengthening system shows the reinforcement of the URM walls with mullions between the windows along the north and south facing walls.

Figure 5c: The primary strengthening system shows inverted moment resisting portal frames oriented north south and over the main entrance.

Figure 5d: Steel brackets connect the roof to the top of the reinforced masonry walls.

3.5 Geotechnical considerations

Geotech Consulting were consulted regarding the ground conditions in the area, as it was not practical at the time to undertake a specific ground investigation. Their conclusion, after consulting all relevant geotechnical data for the immediate area was that it was very likely the building was bearing on substantially medium density sandy gravels with a low probability of significant liquefaction induced settlement (Geotech Consulting Limited, 2017).

3.6 Other work

The ground floor north east corner of the building was "opened up" to increase the usable public area.

4 IMPLEMENTATION OF THE STRENGTHENING STRATEGY

4.1 Parapet strengthening implementation

The strengthening of the parapet was carried out in 2013 by an experienced local contractor and proceeded without any complications. The overall cost for the parapet strengthening was approximately $15,000. Refer to figures 4.1 and 4.2.

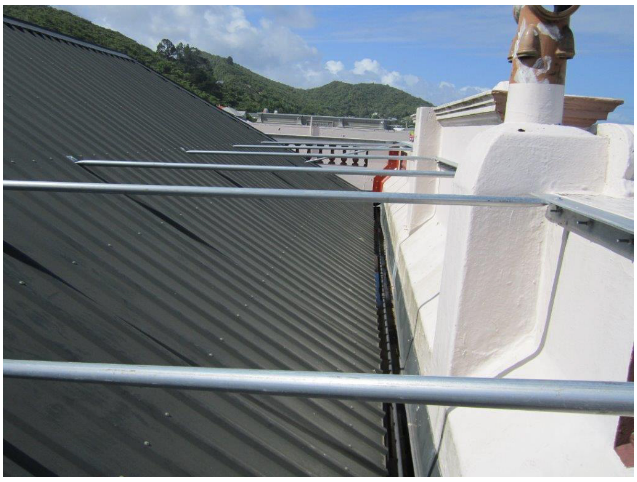


Figure 6 (left): Steel plate corner bracket and horizontal angle girts.

Figure 7 (right): Pipe stays tie back unreinforced masonry parapet to roof bracing diaphragm system.

4.2 Primary building strengthening implementation

The implementation of the strengthening strategy proceeded substantially as planned due to the extent of the research carried out prior to construction, resulting in very few unexpected problems. Sufficient monitoring took place to ensure that critical details such as beam column joints were correctly reinforced**.**

The practicalities of saw-cutting into a century-old building must be carefully reviewed prior to the work being carried out. Small sections of the brickwork were removed in stages with sacrificial props used to hold brickwork until the concrete was poured. The ground floor perimeter skirtings and part of the floorboards were partially removed to allow for installations of the reinforced concrete columns and ground beams. The original floorboards could not be saved, however new timber flooring was matched to the original boards.

Additionally, sections of the cornice plasterwork were removed as required for installation of steel mullions. Moulds were made of cornice while insitu to allow exact replicas to be made by a professional experienced plasterer. With the completion of the works, each new cornice was fixed around the reinforced mullions.

The cutting into the existing brick wyths to effectively recess in the cantilevered concrete mullions also was carried out without any substantial problems. Numerous starter bars were used to tie the brick walls to the new mullions. The mullions were poured in several lifts to minimise the effect of concrete aggregate segregation and to minimise the pressure on the formwork. Any gaps between brickwork were effectively filled with cement paste from the concrete. The new reinforced concrete "lintel" above the main doorway was carefully formed up to avoid damage to the original features of the front wall of the building. The slotting in of the steel T section into the unreinforced masonry window mullions was also carried out without any real challenges.

Figure 8: Sufficient monitoring took place to ensure that critical details such as beam column joints were correctly reinforced.

Figure 9 (left): Unreinforced masonry above the main entrance is potentially unstable in out-of-plane loading.

Figure 10 (right): The inverted moment resisting portal frame over the main entrance increases strength in out-of-plane loading.

4.3 Secondary wall strengthening implementation

The rear area of the building was stripped out to permit the installation of the angle steel "framework" that tied the walls to the first floor and the roof along with tying the external walls together at the corners – often an area of high stress during seismic events. The original linings were more recent than the original construction and therefore had minimum historic value.

The installation of perimeter wall to roof brackets was made possible by the available access between the sloped roof and ceiling. This was carried out as per the design.

Once the above had been carried out, the wall linings and decorative fixtures were reinstated in such a way that after completion, it was hard to tell what had changed aesthetically from the original interior. See Figures 11 and 12 for a comparison.

Figure 11: "Before" photo of original building prior to strengthening works being carried out.

Figure 12: "After" photo of seismically strengthened building from same view.

5 CONCLUSION

The seismic upgrade of the unreinforced masonry Left Bank Art Gallery was carried out in 2018-19 to preserve the original character of the building and to increase the seismic rating from approximately 20% *NBS* IL2 (earthquake prone) to approximately 67% *NBS* IL3. A case study of successful seismic upgrades made to unreinforced masonry Orion substation buildings was adapted in conjunction with an inverted steel portal frame system, which does not protrude from the wall and is entirely concealed. As public safely has remained the priority, the first stage of strengthening carried out was to reinforce the masonry parapet. This seismic upgrade was completed within the allowed budget for the structural works. Both the client and the tenant are very satisfied with the result and the building continues to operate as a public Art Gallery and key landmark building in Greymouth.

5.1 References

Geotech Consulting Limited. (2017). *Greymouth CBD – Geotechnical Conditions for Elmac Consulting.*

Misnon, A. N., Dizhur, D., Mackenzie, J., Abeling, S., & Ingham, J. (2018). Multidisciplinary Post-Earthquake Critique of Masonry Substation Retrofits. *Earthquake Spectra, 34*(3), 1363–1382.