MATRIX OF OPTIONS CONSIDERED

APPROACHES TO REPAIR, STRENGTHENING AND RESILIENCE

In developing repair and reinstatement approaches for this building we have considered a broad range of materials and techniques. This section introduces this range of materials and approaches and intends to highlight the benefits and limitations of each as a basis for understanding how the options outlined in the subsequent sections have been arrived at.

It is important to note that strengthening & repairing a building such as this requires more than just one solution, as there are different parts of the building to address. The solutions outlined above are the main strengthening options for the primary lateral system.

<table>
<tr><th>ELEMENT</th><th>OPTION</th><th>PREFERRED</th><th colspan="2">COMMENTS</th></tr>
<tr><td rowspan="2"></td><td rowspan="2">Fibre Reinforcement Plastic (FRP)</td><td rowspan="2"></td><td colspan="2">• (1-2mm) Thin layer of high strength fibreglass.
• Typically applied as a wrap over the entire wall surface.
• Plaster usually removed, surface prepared and then plaster replaced.</td></tr>
<tr><td>Heritage Advantages:
• Retains wall masonry in original form without intervention or deconstruction.
• Plaster can be reconstructed to its original form.

Heritage Disadvantages:
• Process is not considered reversible.
• Loss of original plaster</td><td>Structural Advantages:
• Lightweight
• Can be incorporated under a plaster finish
• Can be chased deep into brick to gain some capacity in both directions for out of plane resistance
• Some systems can wrap damaged walls with little prior repair provided wall displacements are within suitable limits and surfaces are suitably flat

Structural Disadvantages:
• Low stiffness
• Removal of plaster, loose brick/mortar and careful preparation to a flat surface is required
• Generally, can’t be applied to the exterior façade where bricks are visible
• Relies on bond between FRP and brick
• Generally, not reversible
• Some complexity in fixing details to transfer load.</td></tr>
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ELEMENT	OPTION	PREFERRED	COMMENTS	
	Steel Brick Reinforcement (e.g. Helibar or equivalent)		• High strength stainless steel helical reinforcing bar which can be incorporated into a brick bed joint or installed in a chase either horizontally or vertically	
			Heritage Advantages: • Retains wall in original construction with minimal intervention, if plastered. • Plaster finishes can be reinstated or repaired. Heritage Disadvantages: • Process is not considered reversible. • Vertical bars are not possible with exposed brick masonry.	Structural Advantages: • Lightweight • Can be incorporated under a plaster finish • Can be chased deep into brick to gain some capacity in both directions for out of plane resistance • Can be used to stitch across cracks Structural Disadvantages: • Low stiffness • Removal of plaster and loose brick/mortar is usually required • Generally, can't be applied to the exterior façade if required for out of plane response where bricks are visible (as needed in vertical chase) • In a repair situation, it won't restore full capacity of masonry unless mortar can be replaced, pointing doesn't go deep enough • Generally, not reversible • Some complexity in fixing details to transfer load.
	Structural Steel Restraints and Frames		• Can be installed to provide in plane strength and stiffness with concentrically or eccentrically braced frames. Portal frames do not have stiffness compatible with masonry walls. • Can be used to provide out of plane resistance to masonry including walls, piers and window mullions • Can be used for ring beams, collector beams, restraints and chords of diaphragms	
			Heritage Advantages: • Steel is light and can be installed in components minimising adverse construction effects. • Installation is reversible with minimal adverse effects. Heritage Disadvantages: • If installed over fabric of significance, the steelwork • reduces visible and aesthetic value.	Structural Advantages: • Lightweight • Quite slender members can be used to minimise visual intrusion • Can be incorporated into wall or window framing for out of plane resistance if detailing and durability can be dealt with • Generally reversible Structural Disadvantages: • Generally moderate stiffness • May be visually intrusive

ELEMENT	OPTION	PREFERRED	COMMENTS	
	Reinforced Concrete Walls / Linings		• Generally installed on the inside face of a masonry wall by removing 1 or 2 wythes and replacing with a shotcrete or cast *in-situ* concrete walls dowelled into the existing brickwork • Can be used to provide in and out of plane resistance to masonry including walls, piers and window mullions • Can be used for ring beams and collector beams.	
			Heritage Advantages: • High level of protection of heritage value against future earthquake events. Heritage Disadvantages: • Invasive effects on masonry walls through loss of heritage fabric and irreversible consequences of the installation. • High level of loss of wall construction to effected walls with loss of construction and technological value. • Need to control migration of salts from the concrete to minimize risk of efflorescence on the exposed brickwork.	Structural Advantages: • Stiffness compatible with masonry walls • Can be incorporated within existing wall thickness • Adds both stiffness and strength • Relatively easy to tie into the existing structural load path. Structural Disadvantages: • Requires removal of brick fabric to maintain wall thickness. • Generally, not reversible
	Resin Injection		• Technique involves drilling a series of holes through the facing masonry and pressure injecting a resin or other binder material to fill voids, bind rubble/mortar fill material, and improve the strength of the masonry • Can be used to stabilise walls prior to drilling anchor rods or partial deconstruction • Not viable for this building as walls are solid brick, not rubble filled.	
			Heritage Advantages: • Works to improve the structural performance of a wall that has voids within its core construction, typically, stone masonry. • Low impact on heritage fabric with minimum intervention. • No adverse or visual effects. • Can improve moisture ingress issues through masonry walls where this is present. Heritage Disadvantages: • Need to control injectate to avoid slurry staining on masonry. • Not reversible. • It only works with random rubble fill with voids traditionally used as the fill between inner and outer wythes of stone. Has little practical advantage with solid, bedded brick construction.	Structural Advantages: • Stiffness compatible with masonry walls • Not visible apart from patches over holes • Can be incorporated within existing wall thickness • Adds both stiffness and strength Structural Disadvantages: • Cannot be effectively used to inject solid brick walls • Generally, not reversible

ELEMENT	OPTION	PREFERRED	COMMENTS	
	Post Tensioning		• Technique involves installing vertical high tension cables or rods to introduce additional compressive stress into masonry walls. This improves resistance to the flexural stresses created by earthquake shaking. • Can be used to stabilise walls prior to drilling anchor rods or partial deconstruction • Considered but not developed further for this building as walls are slender or perforated, there is a lack of solid piers and the mortar is weak	
			Heritage Advantages: • The strengthening rods and anchors can be concealed within the masonry wall thickness minimising any effects on aesthetic and architectural values. • Generally reversible. Heritage Disadvantages: • Invasive effects on masonry walls and other heritage fabric through core drilling with slurry run off requiring control to avoid staining of surfaces. • Requires walls to be in sound condition so damaged walls would require repair first. The system is not part of the damaged wall repair process. • Need to control core drilling to prevent blowing through the face of the masonry.	Structural Advantages: • Stiffness compatible with masonry walls • Visual impact low • Can be incorporated within existing wall thickness or beside piers Structural Disadvantages: • Only suited to some geometry, especially to walls • Adds compressive stress so not suited to weak masonry • Elastic, so once capacity is exceeded failure will be similar to unreinforced masonry

We have developed four options for consideration as shown in the below table. All options are to IL2. It is noted that some staging or deferral of works could be considered within the intervention options 1-7 to spread cost over time.

Option	Building Reinstatement Option	Description of Consequence	Indicative %NBS	Level of development of option
0A	Do Nothing	Building not occupiable and prone to further deterioration	30-40 with shoring (i.e. earthquake prone if shoring removed)	No further development included
0B	Demolish / Deconstruct and Store	Loss of building including significant heritage values to the community. Recording and storage of heritage items will incur some cost. Opportunity for new riverside development.	N/A	No further development included
1	Minimal heritage intervention and building and structural resilience	Least possible intervention to Heritage values but with low resilience against future earthquake damage. The building would be occupiable.	35	No further development included
2	Minimal intervention and very high resilience with base isolation	The least possible intervention to Heritage values and with the highest level of resilience that would preserve Heritage values.	>100	No further development included
3	Moderate intervention and resilience	The building is strengthened to a level to withstand moderate earthquakes. Earthquake damage would be expected, but the strengthened building would provide life safety for occupants. There is a higher level of intervention required to Heritage fabric.	67	Developed Design
4	High intervention and resilience	The building would provide high resilience against future earthquake damage but requires the complete installation of a concrete structure into all of the masonry walls with high levels of interventions required to the Heritage fabric and values of the building.	100	No further development included

OPTIONS 3: Elemental Breakdown

Option 3 is shown in the sketches in the accompanying reports. A construction sequence with accompanying notes has been developed for Option 3 and this information is also in the reports.

Brief comments on the Option 3 are provided in the below table.

Note: that these comments have not yet been reviewed internally, by the team or the peer reviewer.

ELEMENT	OPTION	PREFERRED	COMMENTS
Structural	3 - Moderate intervention and resilience	Developed Concept	Installation of concrete lined walls on all main walls provides consistent stiffness around the building. Wall repairs are provided in areas that do not require lining to reach upgrade objectives. Foundations are upgraded beneath concrete lined walls and the majority connected to create a reasonably well tied foundation grid 67% NBS broadly aligns with CCC and minimum New Zealand Society for Earthquake Engineering requirements. Performance in future earthquake good, noting that in a severe earthquake there will be moderate damage, including damage to heritage fabric, especially to walls not lined, and features.
Buildability	3 - Moderate intervention and resilience	Developed Concept	An outline methodology has been developed to ensure the work can be reasonably expedient and efficient and be treated in a similar way to a small-scale construction project. First a 'top down' approach to secure the building sufficiently to work on the ground floor by installing strength and stiffness to the western side of the building. Once this work is carried out, the full building footprint can be repaired and strengthened using a 'bottom up' approach.
Heritage	3 - Moderate intervention and resilience	Developed Concept	Moderate Intrusion into damaged masonry walls by removing 1-2 wythes of brick and replacing brick with reinforced concrete. Processes require strengthening of more walls, some of which would not otherwise require deconstruction for repair. Breathability of concrete lined walls a concern, although walls have been shown to be durable, for example Chch Boys High strengthened in the late 1990's. Proven performance in protection of heritage fabric in Canterbury Earthquake sequence.
Services	3 - Moderate intervention and resilience	Developed Concept	Allowance for services penetration will need to be included in Detailed Design stage for two approach.
Costs	3 - Moderate intervention and resilience	Developed Concept	Likely costs for delayed stage 2 restoration outlined in cost report