Architectural Implications of Seismic Strengthening Schemes
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Abstract

Although over the past twenty years many unreinforced historic masonry buildings in New Zealand have been seismically strengthened, resulting architectural impacts have not been evaluated. In most cases strengthening schemes have been driven by engineering and economic concerns, rather than by architectural considerations. This paper seeks to redress the lack of architectural discussion and critique by studying three schemes that incorporate different structural strengthening systems: new concrete walls, steel braced frames and base-isolation. The impact of strengthening on exterior and interior architectural qualities is investigated and discussed from the perspectives of how the architectural experience of the building is changed, and how the upgrades relate to international guidelines.

The paper concludes firstly, that the most significant architectural implications of a seismic upgrade may arise from ensuing refurbishment, rather than the initial seismic upgrade; secondly that current New Zealand practice varies significantly from international guidelines; and thirdly, that in the process of upgrading, fundamental structural and architectural integrity is lost and this inevitability is currently unaddressed. Following this there is a need for debate and consensus concerning necessary amendments so that guidelines can be owned locally. Designers need to appreciate how understanding existing structural and architectural integrity can inform new strengthening schemes, and that any upgrade provides an opportunity to express any change to that integrity.

Introduction

This paper explores the architectural implications of seismic strengthening schemes. Frequently, at least in New Zealand experience, the approach to seismic upgrades has been driven by structural engineering and economic concerns, rather than by architectural considerations. In some cases the architectural outcomes are less than desirable.
This study takes three recently seismically strengthened historic buildings as case studies. After a brief description of each, architectural issues are identified and discussed. All three buildings chosen reflect the relatively recent European settlement of New Zealand in the late nineteenth century and the typical neo-Gothic or neo-Classical construction. Although they are of the same era and construction type, they illustrate different strengthening strategies, levels of strengthening, social significance and construction budget. In all cases they have continued to be used following strengthening. They are situated in Wellington a very active seismic zone by world standards.

Within the New Zealand context the architectural implications of seismic strengthening have received little attention. Although difficulties of strengthening historic buildings are considered briefly, the current earthquake risk building guidelines [1] do not raise architectural issues. Similarly, very scant treatment of design ideas occurred during a 1980 national symposium [2]. Certain architectural assumptions about the approach to seismic strengthening appear to have been made, and unfortunately, they have not engendered significant discussion or debate.

However, Bowman [3] raises local awareness of building conservation issues by highlighting relevant international recommendations from two sources; 1966 Venice Charter;

- “Article 5. The conservation of monuments is always facilitated by making use of them for some socially useful purpose. Such use is therefore desirable but it must not change the lay-out or decoration of the building.”
- “Article 9, ....any extra work which is indispensable must be distinct from the architectural composition and must bear a contemporary stamp.”

1977 ICOMOS meeting;

- “4. All interventions designed to strengthen monuments against future earthquakes should respect the character and integrity of the original structure.”
- “5. ... In general, interventions that can be undertaken in stages, that can be controlled by monitoring their effects, and that can be repeated, reinforced, or reversed as necessary, are preferable to those that are irreversible, ‘once for all’..... Retention of the existing structural system should be an essential part of the upgrading proposed, enhanced if necessary.”

Structural engineering concerns also dominate the international literature on strengthening historic buildings. Architectural issues are usually confined to case studies (e.g. Crosbie [4]), and there appears to be a general lack of specific consideration of architectural intentions beyond the idea that the building “look the same” after the seismic upgrade.

The following case studies are merely a vehicle for focusing on the architectural implications of seismic upgrades. The paper is not intended as a
criticism of individual outcomes but that specific issues raised during this study form the agenda for critical analysis of the impact contemporary strengthening has on historic buildings.

Case Studies

**Hunter Building, Victoria University of Wellington**

The *Hunter Building* is the most historic of all the campus buildings, with its neo-Gothic facades of exposed brickwork and white stone window tracery and decorative elements (Figure 1). Completed in 1906, the main building was contiguously enlarged to cope with an expanding university, right through until 1923. In 1974, due to the earthquake risk from its unreinforced masonry construction, it was vacated for many years until a two year construction contract period completed seismic upgrading and refurbishment in 1993.

Structural engineering studies of the building recommended that standard seismic design loads for strengthened buildings be adopted [1]. Consequently, the ultimate limit state lateral design load of approximately 20%g is similar to that required for a new building.

The strengthening strategy included weight reduction by selective demolition. In some areas the wall thickness was reduced and brick partition walls removed. All existing load bearing walls were strengthened by new sprayed concrete walls, typically 125 mm thick, and vertical ribs or columns chased into the existing brickwork to resist wall face loads. As exterior walls were of cavity construction, a large number of ties were required to connect the outer veneer to the new walls. Upgrading floor diaphragms proved necessary, and several new areas of flooring around the back of the building were added. As well as providing necessary additional accommodation, they enhanced the seismic performance of the diaphragm by eliminating some plan notching.

![Figure 1 Hunter Building](image1.png)

![Figure 2 Hunter Building Interior Council Chamber](image2.png)
Harbour City Centre (formerly the DIC Building)

This is a well known building located in the heart of Wellington’s business and shopping area. Although its neo-Classical facade contributes significantly to the street scape, the seismic strengthening responded less to historical value than to Council pressure to mitigate seismic risk (Figure 3). While the ground and mezzanine floors provide for retail usage, the upper six floors are mainly offices. Originally the building consisted of two independent structures, completed in 1928 and 1912 respectively, but through the strengthening scheme they are now tied together. Floor diaphragms have been upgraded on each floor level to transfer loads to the front area that has been strengthened to resist the seismic loads from the whole complex. The existing concrete encased steel frame, built approximately five years before the introduction of New Zealand’s first seismic design code, required strengthening.

Figure 3 Harbour City Centre

Figure 4 Harbour City Centre
Dominant Steel Bracing

Figure 5 Parliament House

Figure 6 Parliament House
Horizontal Isolation Plane
New diagonal steel bracing elements are connected to the existing frame forming several cross-braced bays that rise up through the building. Strengthening was completed in 1981, several years before the publication of the current guidelines. The level of strengthening is therefore significantly lower than that adopted today.

The focus of this study is on the architectural impact of the new steel bracing with its unique dominant visual and spatial influence (Figure 4).

Parliament House

*Parliament House*, completed in 1922, is the central of the three buildings comprising New Zealand Parliament Buildings (Figure 5). The unreinforced masonry and stonework seismic upgrade and refurbishment was completed in 1995. In the preceding design competition, entrants submitted schemes for three levels of conservation while treating the building, in seismic terms, as a National Monument. This requirement was interpreted by the winning team to mean minimal damage during MMIX intensity shaking, which, for Wellington has a return period of between 220 to 350 years. The building has been base-isolated and also cast-in-place reinforced concrete structural walls added. Although the base-isolated scheme was 3% more expensive than a conventional solution, it provides an outstanding degree of protection to the building occupants and the fabric of the historic and nationally important building.

Base-isolation is the most significant aspect of the scheme. As at the Salt Lake City and County Building [5], all walls and piers have been cut through. After localized strengthening they have been placed on horizontally flexible rubber bearings. The level of the isolation plane is in the basement, just below the suspended ground floor structure.

Above the isolation plane new reinforced concrete beams and structural walls are the major strengthening elements. These have been cast directly against the existing masonry walls, and subsequently concealed by mouldings and finishes.

Discussion

During the study three main areas worthy of consideration emerged, first, how the upgrade has affected users’ experience of the building; secondly, how schemes relate to International Guidelines; and finally, whether there has been a loss of fundamental structural integrity. Whilst the first is primarily a local issue, the latter two have a broader agenda, questioning whether it is possible to uphold the guidelines and retain structural and architectural integrity, particularly when local conservationist agendas favour visual integrity.

The changed architectural experience

One outcome of the study is concerned with the impact of the seismic upgrade on the architectural experience of the building. As explained by Rasmussen [6] our
experience of architecture is multi-faceted and involves most of our senses. To what extent then might a seismic upgrade affect building users’ experience of, for example, scale and proportion, textural effects, daylight and hearing?

Awareness and impact was found to vary greatly from non apparent to highly visible. In the latter category the Harbour City Centre displays an uneasy clash of structural systems. Diagonal members have been inserted into a three dimensional framed structure without apparent integration into a coherent architectural strategy. Their infrequent occurrence, orientation and relationship to how the spaces around them are occupied are unfortunate. Awkward juxtapositions fail to contribute positively to the making of architectural space. Certainly their insertion is a challenge to interior designers who must contend with the disruptive spatial influence of the braces. The crude exposed detailing and use of industrial steel sections perhaps indicates inadequate architectural involvement. These details may be satisfactory structurally, but where exposed, they detract from the surrounding interior fabric.

At the other end of the scale, upgrading at Parliament House has essentially been hidden. It is non-apparent to the casual observer. On the exterior there is no explicit reference to the extreme protection measures that have been undertaken. The isolation plane is detailed as either a sealant filled horizontal joint, or elsewhere as a horizontal slit running under a plinth used as a footpath that is cantilevered from the base-isolated superstructure (Figure 6). The philosophy seems to be one of seamless accommodation, with no attempt to express the new condition.

Inside the building, and throughout the basement walls only, the isolation plane is visible, expressed rather crudely as a negative joint infilled with compressible material. Far more complex “crumple” zones, with piano hinged sections that open out to accommodate horizontal movements in excess of 300 mm, are plastered over and concealed. Other details, such as movement joints between the isolated lift well, that cantilevers down below ground floor to the basement floor, are exposed.

New structural walls have reduced room and corridor internal dimensions but this is not noticeable except in several areas where the additional walls thickness has affected the symmetrical spacing of some original decorative details. Whilst these dimensional changes may not seem important, they nevertheless destroy any original proportioning system, which is further eroded by wall thickening to accommodate services.

In the case of Hunter Building the outcome is that its external architectural character has been preserved and that there is little visual evidence of the extensive interior works. The overall approach reflects the prevalent conservationist view that the “preservation of the exterior facade” is all important. Inside, the designers selected areas, such as around the ornate main stairwell, to remain unaffected, while large lengths of brick partition walls and widths corresponding to the thickness of the new concrete walls on most bearing walls were demolished. All new structure is plastered and painted in a sedate and conservative manner to match the existing. Therefore the potential aesthetic
richness inherent in the new construction, such as referencing the tightly gridded pattern of new cavity ties remains unexploited. Despite this, it must be acknowledged that in most areas the new construction is very respectful and of the same visual character as the existing fabric.

For all three buildings, due to either a period of unoccupancy, long refurbishment time or high staff turnover, it has been difficult to assess how the strengthening has affected other architectural qualities such as interior space, lighting and acoustics. New construction such as refurbished office space with reduced ceiling heights (Hunter Building), not directly related to the seismic upgrade, is likely to have a far more significant impact.

Another general comment concerns the lack of expression in the structural solutions. That is, from an architectural perspective, the structural solution has failed to capitalise on the aesthetic possibilities of its form and its ability to enhance the existing structure. The Harbour City Centre could have taken cues from other buildings such as the Lyon School of Architecture design studios (albeit a new building) [7] as a suggestion on how repetitive diagonal struts can influence space definition positively.

**Relationship to International Guidelines**

With respect to international guidelines the three buildings show distinctly different attitudes, that vary from adhering to or disregarding them, whether intentionally or otherwise.

Of the three buildings considered in this paper the Harbour City Centre comes closest to respecting the guidelines. Not only is the primary strengthening reversible by unbolting and cutting the steel braces, but its construction is clearly more modern than that existing. However, at another level, aspects of the scheme are disturbing. The spatial dislocation and crudity of detailing has been discussed.

Parliament House on the other hand, displays a dramatic irreversible means of upgrading in which the whole building is sectioned at basement level and new concrete beams and walls are tied to the existing construction. Above ground floor an opportunity has been taken to enlarge the existing floor area around a light well utilizing new shear walls. Their inclusion in the building has been through a seamless incorporation into the existing classical idiom making it difficult to discern the old from the new. No attempt has been made to present a contemporary solution.

In essence the Hunter Building has also been strengthened by the irreversible addition of a structural layer to its walls. Though in its execution the layer occasionally appears in a subtle contemporary manner, as advocated by the guidelines. For example, where the new layer has been applied without prior width reduction, it is held back deliberately and chamfered to the existing brickwork in a detail that does bear a "contemporary stamp." Other areas such as the Council Chamber prove more problematic. Here concrete is applied to the existing surface in a manner that fuses contemporary surface graphics (following
an orthogonal pattern) with a termination of surface along the stone quoin. Despite being read as an applied surface, the termination accentuates construction irregularities and bears witness to the difficulty or uncertainty in knowing "how far to go." Likewise, two new structural columns engage the existing arcade as contiguous full height elements but whose bulk and location destroys the rhythm of the pointed arches and any vestige of shadowy ethereal space (Figure 2). In both cases contemporary and necessary additions have been diluted to 'acknowledge' the existing condition.

**Loss of Fundamental Structural Integrity.**

Both the Venice Charter and the ICOMOS document offer a philosophical problem epitomised by "Retention of the existing structural system should be an essential part of the upgrading proposed, enhanced if necessary." Both upgrading and enhancing a structural system may cause changes to structural principles and design ideas behind the building. The various recommendations seem to err in favour of "visual continuity" and fail to address the dilemma as to whether the integrity of a structure can be maintained, or whether the structure becomes something different, in which case should that difference be expressed?

When analysing the outcome of contemporary seismic intervention, success seems dependent on the degree to which the intervention is rendered invisible, and hence 'visual' presence is afforded greater hierarchical status. Indeed Crosbie [6] confirms that strengthening should be accomplished "with a minimum of intrusion into their historic fabric" whilst acknowledging the difficulty of protecting "without destroying the very qualities that make it worth saving." Despite these intentions, burying steel and concrete within existing masonry of the Stanford Memorial Church, Crosbie fails to respect the character and integrity of the original structure.

Base isolation is offered as a means of providing "minimum intrusion", however in *Parliament House* "minimum intrusion" is at the expense of sectioning through all basement structure. All masonry load bearing walls are supported by 'new' ground beams, loads are transferred through point contacts (isolators) and transmitted back to 'enhanced' foundations. The building is no longer built out of the ground, evoking its classical legacy; it is now dislocated from the earth and the separation is maintained by flexible bearings. Moreover, on the exterior, the separation is heavily disguised with the addition of a plinth around the base of the building.

The *Hunter Building* seems to privilege the retention of the exterior and exterior surface at the expense of the interior and interior surface. Removal of the inner brick skin and its replacement with sprayed concrete means the structural system has been changed. New structural walls with supplementary structural columns, have further obviated the need for exterior buttresses though their original structural effectiveness is in doubt. Loss of an example of neo-Gothic construction for the sake of the visual image, is a consequence of a conservationist attitude that overrides other considerations.
Inside the building, sprayed concrete surfaces lock the whole building together *shadowing* the masonry and solidifying the form. The idea of a building comprising walls of two different materials running in parallel was clearly not part of the original design intention. There has been the loss of original structural integrity and design intention following the upgrade, though acknowledgement and expression of this is non-apparent.

Whilst the *Harbour City Centre* building has been upgraded more in line with the guidelines (whether by an accident of economics or not) than the other buildings, the upgrade shows little respect to the original frame structural system. The new braced frames represent an insertion of a totally different nature. Undoubtedly the chosen solution was the most economical and structurally efficient, but one is left wondering how the outcome might have been if the existing frames had been “upgraded” or “enhanced” and not, at least for lateral loads, made redundant.

**Conclusions**

Although the exterior of all the buildings studied had not been significantly visually affected by the seismic upgrades, the impact upon the interiors ranged from indiscernible to significant. In most cases, the changed quality of interior architecture was more related to the subsequent refurbishment than any seismic strengthening.

New Zealand seismic upgrade practice varies considerably from recognised international guidelines. More debate of their relevance and application to New Zealand is needed, enabling local practice needs to be re-evaluated and discussed in the light of any ensuing local amendments made to the guidelines.

On a broader scale, however, the discussion hints at the potential impossibility of retaining the “existing structural system” whilst at the same time upgrading “enhanced if necessary.” The problem is that fundamental ideas (philosophical positions) and materials (physical properties) are likely to be altered, suggesting that the action of saving the building/monument inevitably causes the loss of its original and fundamental structural and architectural integrity. This is seen as a dilemma or paradox that is unaddressed by current guidelines and forces a difficult choice between the level of intervention and the architectural expression of that intervention. It becomes more problematic knowing that guidelines favour not changing the “decoration of the building” whilst upgrading. This tends to favour the physically “hidden” interventions over any “overt” expression of the idea. With “hidden” interventions, where appearance is little changed, public awareness is informed not by recognising ‘what is needed to retain a building in seismic circumstances’ but by reinforcing a myth that these building are ‘constructionally survivable’ in these conditions.

Perhaps upgrades should recognise this dilemma unshackled by a desire to retain visual integrity and to accept alternatives that express and support ideas inherent in the building. It is in the recognition of existing structural systems, as a prelude to intervention, that “original” proposals can emerge. Particularly if
they are considered architectural interventions that *add to* the building as a second layer of structure.

**References**


