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New Zealand's unreinforced Masonry Buildings: Facing up to the earthquake.

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Abstract. The damage caused by the 2011 Christchurch earthquake has led to the introduction of compulsory seismic strengthening legislation for all unreinforced earthquake-prone masonry buildings (URM) within New Zealand. The legislation, passed in 2013, requires all such URM commercial, multi-unit and multi-storey residential buildings to be upgraded and strengthened to a minimum of 34% or more of the New Building Standard, irrespective of the earthquake zone within which they are located. Buildings so designated and in high earthquake zones will have a very limited time bring their buildings into line with these requirements. The proposal particularly affects old URM buildings. Some of these are buildings have a declared heritage value, many do not. Most were built around the turn of the twentieth Century. Together they make up a considerable portion of many small town commercial precincts. The legislation affects all parts of New Zealand, regardless of the particular region's exposure to earthquake risk.

The paper will background the current legislation, compare international legislation and study the financial effects of the legislation, case studying buildings within two distinct seismic zones. The findings suggest that where the cost of the upgrade puts the viability of the building as a rental investment at risk, the owner will most likely adopt demolition is the only feasible outcome. This could have far-reaching implications for the wellbeing of many small towns within New Zealand. An alternative strategy is examined and assessed.

1. Introduction

Seismic retrofitting of existing buildings remains a complex and often politically difficult area for governmental authorities. Issues of heritage, construction complexity, social upheaval and financial considerations including loss of rental income, can put the building owner to considerable disadvantage and threaten the commercial viability of any retrofit project. This disruption has to be balanced against the advantages of the nation's building stock becoming more resistant to earthquake damage, and hence providing a safer social environment for its citizens.

A OECD report, commissioned in 2006, states poor seismic retrofit solutions often arise from a lack of shared responsibility between local and national municipalities. There are also, in many examples, a lack of incentives that will convince owners to carry out the work [1]. Hassler (2009) suggests historic buildings will always be at risk because modern land-use regulations "regularly lead to considerable losses of historic substance in areas close to historic city centres because potential financial returns on future use are compared with the proceeds of a change of use of existing buildings." [2] Spence suggests a lack of financial incentive is also an issue. The cost of seismic retrofit varies from 5-50% of the total rebuilding cost and, according to Spence, with the return period of major earthquakes one hundred years or more, there is "...small incentive for the building owner to make the investment worthwhile" [3]. Other researchers, such as Fardis, agree the major threat to human life comes from existing (and hence older) buildings. In spite of this, Fardis suggests that new construction continues to remain foremost in the minds of legislators researching earthquake engineering and in the formulation of building codes. The redesign of an existing building to strengthen earthquake resistance is a significantly more demanding and technically complex activity than the design of a new structure. History, culture, heritage and building activity all combine to influence the hearts and minds of the



designers. Cost also is a significant issue. Limitation in funding inevitably mean “..the vast majority of the building inventory in seismic regions worldwide is [and remains], by and large, substandard and seismically deficient in the light of our current knowledge” [4]. Social considerations operate as well, suggest Wilkinson et al. Many building owners have a belief that spending money on seismic strengthening would be money better spent elsewhere, and hence have a subdued enthusiasm to part with the necessary funds required to make their buildings seismically safer [5].

2. New Zealand’s earthquake legislation

The Building (Earthquake-prone Buildings) Amendment Bill 2013 was introduced into the New Zealand Parliament on 13th December 2013. The intent was to upgrade and improve methods of managing New Zealand’s older and often earthquake-prone buildings. The legislation arose out of the recommendations of the Canterbury Earthquake Royal Commission, [6] a body formed to look at the reasons for the collapsed buildings following the two earthquakes that struck Christchurch city over a six-month period. An earthquake of magnitude 7.1 struck on September 4th 2010. This was followed by another earthquake on the 11th February 2011, this time of magnitude 6.3. The latter earthquake caused extensive damage across the city and caused the deaths of 185 people. Included in the damage were many small, URM retail buildings commonly referred to as “home shop” or “house shop” buildings, the main focus of this paper (Fig 1). This building typology, so called because the shop owners retailed their wares on the ground floor and lived with their families in the upstairs portion of the predominantly two-storey building, formed the core of the many urban streetscape settlements that grew up around the larger cities in New Zealand, mostly between the years 1880+ to the 1920-1930s. In Auckland for example, such centres as Grey Lynn, Ponsonby, Herne Bay, parts of Dominion Rd, Mt Eden, Papakura and old established areas such as Otahuhu all have URM “home shop” buildings as an integral part of the retail streetscape. Other centres are similar. In regional towns further south, such as Wanganui or Marton (one of the case study focuses of this paper), as much as 50% of the streetscape are URM buildings of varying heritage or non-heritage quality. External construction was single, double or of cavity brick construction, often with protruding parapets elaborately adorned. Floors were constructed of timber, with strip timber tongue and groove flooring. Access to the upper floor, where the owner and family lived, was usually by internal stairway (Fig 2).

Figure 1 Grey Lynn Auckland (Source: C Murphy)



Figure 2 Ponsonby Rd Auckland (Source: C Murphy)



2.1 *Criticisms of past earthquake policy*

Whilst the previous act required Local Authorities to develop policies around earthquake-prone buildings, there was, according to the Ministry of Business Innovation and Employment (MBIE) Consultation Document, large discretion in the system as to “how actively they identify and deal with these buildings.”

Individual local authorities have very different approaches to implementing current policy requirements. Some local authorities are not actively identifying earthquake-prone buildings or requiring building owners to deal with them. Other authorities have taken some action, but have given building owners very long timeframes to resolve problems. A number of authorities have taken strong action, including requiring higher strengthening than required by law. [7,16]

The MBIE suggested some 15000-25000 buildings fell into the earthquake-prone category but acknowledged this figure was a very broad estimate as only a few local authorities “can provide good data”. [7,6]

Of the 66 local authorities, only 23 were able to provide any information on the number of earthquake-prone buildings in their districts, and much of the information received was incomplete. [7,12]

2.2 *Risk Analysis and Time frames*

The proposed legislation originally treated the whole of NZ as a uniform risk, with the upgrading of URM earthquake-prone buildings required within a specified time frame (15 years) applied uniformly across the whole of New Zealand. This stance has since been changed, with the MBIE document acknowledging the original proposal had met considerable resistance from submitters. Submissions from the Auckland Council, the largest Territorial Authority in New Zealand, help to change this stance. They were based on a risk analysis survey from GIS Science, a research consultancy commissioned by the Auckland Council, which looked at the statistical probability of a significant earthquake and the likely costs, number of collapses, and number of deaths that could result. [8]

GIS Science suggested the risk levels to life from an earthquake were for Auckland statistically very low, even for earthquakes with a return period of 500 years or more (0.002 annual probability), with the number of deaths in the Region from this return period estimated as 7, with 2 deaths within Auckland city itself. Auckland, the location of many URM buildings has, suggests the GIS report, rarely experienced even low-level earthquake shaking “since Europeans first settled there in the early 1800s and there appear to be no historical earthquake casualties”. The Modified Mercalli intensity (MMI), an indication of earthquake intensity, has never been exceeded in excess of MM6, with only occasionally localized intensities of MM4 and MM5 shaking, and one instance only of MM6 shaking in 1891 (the Waikato Heads earthquake), located some 50 km south of Auckland near the mouth of the Waikato river. [8]

As it stands, the legislation now acknowledges different time frames for different zones, and the timeframes for assessment and strengthening varying between 15 and 35 years, depending upon the risk zone.

2.3. Barriers to revitalization and enhancement of URM buildings

2.3.1. Excessive strengthening requirements

Whilst the time allowances for upgrade have been eased, the requirement for URM and other earthquake prone buildings to be upgraded to a minimum of 34% of the NBS remains, regardless of the location of the building. This effectively means, suggest researchers such as Tailrisk Economics, the safety standard for a building in Auckland (a low risk earthquake area) is about “three thousand times stronger than the one applied in Wellington (a high risk area) [9]. What is more, suggests the Tailgate report, compliance with the minimum standard for Auckland will result in a cost in excess of three billion dollars, (Tailgate’s own report puts it as high as \$10 billion) “but is expected to take 4,000 years to save a single life” [9]. The report suggest that the definition of what constitutes an “earthquake-prone” building should be urgently revisited and based on evidence of risk and not graded according “to their estimated strength relative to the new building code”. [9]

Other submitters responding to the Consultative document also criticised the excessive life safety standard applied to earthquake prone buildings.

Smoking alone kills 20 times as many people each and every year as were killed in Christchurch. The total number of Kiwis killed by earthquake is one tenth of those killed by smoking and the same for obesity... [7, 12]

2.3.2 Insurance and financial barriers

Submitters responding to the original Consultation document documented concerns about the lack of insurance for such URM buildings impacting on the ability to obtain bank finance to upgrade, assuming of course the loan-to-value ratios support a loan in the first place. Where in areas of low value and low rent they do not, as the case study in this and a previous paper by the writer suggest, financial support is required.

2.4 The Heritage EQUIP funding source.

The Auckland Council’s submission recognised the problems a lack of funding could result in and suggested to the Commission that “bank loans be guaranteed for owners needing to upgrade buildings and for the cost of a seismic retrofit (just that component) be deemed “repairs and maintenance” rather than capital expenditure for tax purposes [7].

A recent change in government policy has recently resulted in revised regulations that address in a very limited form the concerns of Auckland Council and others. Owners of selected buildings are now able to make application to Heritage EQUIP for funding to “...give them more options to manage the unique earthquake strengthening challenges they face.” [10] This limited source of funding was instigated in 2016 as an incentive to supporting the refurbishment of New Zealand’s heritage building stock. The funding comes in the form of grants for 1) professional advice and 2) grants to upgrade the works.

2.4.1 Professional Advice Grants:

These are limited only to eligible owners of Category 1 or Category 2 heritage buildings but only in regional centres that have a medium or high seismic risk, and for up to 50% of professional advice to a maximum of \$50,000. The grants cover initial assessments costs such as professional engineering and architectural advice, geotechnical reports, conservation reports and are designed to encourage professional input resulting in compliant-feasible solutions that are cost effective. (11)

2.4.2. Work Upgrade Grants:

Again, the grants apply only to eligible owners of Category 1 or Category 2 heritage buildings but covers this building type in all risk seismic centres. It covers up to 50% of the seismic strengthening cost and to a maximum of \$400,000. Should the heritage building be location in a regional centre within a medium or high seismic zone, the percentage support has been recently increased, from

50% to 67% and can now be applied to buildings upgrading from their initial Earthquake-prone status to a structural level equivalent to 67% of the NBS. (11)

3. A comparison: International Retrofit Strategies

The seismic upgrading policies within other jurisdictions such Turkey, Japan and parts of the United States, in particular that of California, make an interesting comparison with those of New Zealand

3.1 Turkey

Interactions between the Anatolian plate and surrounding plates ensure earthquakes are by far the most significant natural hazard within this country (12). The risk is compounded by a rapid population growth, a history of illegal settlements and illegal structures and ongoing inertia on the part of the authorities to remedy the situation (13). The Van earthquake of 2011, suggest Gunes, was a “wake-up” call for concerted action. The passing of the Law No 6306, commonly referred to as the Urban Transformation Law, was implemented by Parliament within six months of the earthquake. Contrary to the very limited compensation available to effected building owners in New Zealand, there is significant recompense for the effected owner or renter under this new Law in that, if high risk and within the selected high risk area undergoing seismic renewal and approved for demolition, the recipients of the effected structure are given credits that enable them to own/occupy an equivalent upgraded or new building within, or close to the area undergoing seismic regeneration (14). The legislation is relatively new and whilst there are implementation problems, such as the lack of clarity surrounding the high risk designation processes they are, suggest Candas et al, faults within the implementation process that can be remedied (13). There is no doubt, in spite of considerable teething problem, the legislation is giving new impetus to the very significant task of retrofitting or renewing the infrastructure within the high risk seismic areas within the next 20 years

3.2 California

The Californian building legislation, referred to as the Uniform Building Code (UBC), contains only one passive “trigger” requiring a structural upgrade to a suspect building. That trigger is a change in use of a particular building, with discretion given to building compliance officers to determine if the change of use is to a more hazardous occupancy. Most cities within the area have however instigated additional regulations that reflect the communities concern over safety issues associated with existing buildings, especially those constructed in URM. For this reason, suggest Hoover, California continues “...to be a leader within the USA in the field of seismic mitigation” [15]. The active “triggers” require seismic retrofitting for certain building types, with the state mandating that the seismic hazards of unreinforced URM buildings in particular must be mitigated in a proactive manner, particularly in the area of parapet hazards, where the parapet upstand has often deteriorated and is not well secured to the structure. All regional building codes offer a standard for the seismic strengthening of URM buildings –viz. the Uniform Code for Building Conservation. The policy hence has similarities to the just passed legislation for URM buildings in New Zealand. Unlike New Zealand however, which is implementing a national policy with specific timeframes and retrofit requirements, there is within California a wide variation in the standards utilized within the different cities making up the Zone 4 earthquake area (the zone of highest risk). This is an unfortunate situation says Hoover, resulting in “...an uneven level of life safety between jurisdictions, unfair requirements of building owners, and inequitable economic competition between jurisdictions” [16]. There is a strong need, suggests Hoover, for “uniform life safety standards for the assessment and retrofitting of existing buildings” [16]. The New Zealand nationwide policy of seismic retrofitting regulations for earthquake-prone buildings would hence be seen by Hoover as a desirable outcome in the task of providing minimum life safety for building users in California.

The issue of compulsory retrofit within a specific timeframe remains a challenge in California, just as it does in New Zealand. An example of this would be the issue of hospital seismic safety. The Senate Bill in 1994, which requires a specific time frame, comes up against the social consequences of demolition and closure for non-complying buildings not capable, through lack of funds, of meeting the requirement to “survive earthquakes without collapsing or posing a threat of significant loss of life.” In the case such as the hospital, where continued use is essential, the recommendation is for public funding for genuine hardship, but with a recommendation “to encourage new construction over retrofitting” [19].

3.3 Japan

Japan has of recent years subsequent to the Kobe earthquake revised its building code, moving to the adoption of a performance based document, similar to the nation-wide performance based code adopted by New Zealand in 1991 [17]. The hope is the introduction of this form of legislation will provide a greater degree of flexibility, innovation and design freedom in the realm of material use in building construction. [18]. Seismic upgrading has traditionally be allocated a low priority in Japan. Although the damage and cost of the Kobe earthquake has change minds, an OECD report indicates up to 30% of Japan buildings remains constructed to outdated building codes and building standards. [1]. Whilst it may be a leader in seismic hazard mitigation technology for new construction, the performance based code does not provide for existing buildings, except when there may be additions to the building in question that involve changes to structural members. There is also, unlike California, no code requirement for building strengthening where a change of use is proposed for a building, and unlike New Zealand, no compulsory requirement to strengthen or mitigate the hazards unreinforced (URM) buildings, with the decision to upgrade an optional one for the building owner. Should the owner decide to seismic strengthen, the seismic force level for which the upgrade is to be designed can be determined by the same owner[19]. Financial aid for seismic retrofit is available, with the supporting financial legislation introduced after the Kobe earthquake. [20]. Although the financial aid is modest, estimated between the range 13-16 percent, its presence along with other incentives such as reduced housing loans, taxation relief and reduced interest rates ensure widespread takeup. The monetary incentive is across all manner of buildings, unlike New Zealand, where financial loans are available to a restricted few buildings that rate a high valued Category 1 or Category 2 heritage category.

3.4 Comparison

A summary of the variation between international legislation can be compared in broad terms by reference to the following Table 1

Table 1. Seismic Strengthening Comparison

Requirement	New Zealand	Turkey	Japan	California
Upgrade compulsory?	Yes – to 34% of NBS within 7-25yrs for high risk seismic zones	Yes, within designated areas.	No	Yes, but to certain URM building types only
Upgrade required-change of use?	Yes	Yes	Unknown	Yes, but only if to a more hazardous use
Upgrade required-structural alterations	Yes	Yes	Yes	Yes
Financial incentive	Limited to selected Category 1, Category 2 heritage buildings only.	Yes, if within designated areas	Yes, 13-16%	Public funding for certain building types and if personal hardship

4. Case Study Comparison:

Two further case study examples calculating the likely expenses for the retrofit of a typical small scaled URM building are examined. The case studies builds on previous analysis that considered rental returns for a North Island town and a South Island city, Dunedin [21]. As stated, the seismic upgrade is necessary to ensure the earthquake prone URM building comes up to the required minimum New Building Standard (NBS) of 34%, this being the new minimum allowable percentage required by the new legislation.. Costs are rated against rental values subsequent to any upgrade and the viability of the resultant financial situation accessed. The building selected is located in the inner-city suburb of

Mt Eden, a prosperous secondary rental location with a street heritage substantially effected by the legislation (Fig 3). The plan areas are typical of such buildings, with prime ground floor retail space of a limited size, ancillary spaces to the rear of the ground floor (storage) and the upper floor area, originally given over to “home shop” accommodation for the owner and family, but now predominantly used for a variety of activities, either related to the shop activity or sublet to other tenants. Values are estimates only and variations, depending upon location and condition, can be expected.

Figure 3: Mt Eden URM Building



4.1 Case Study 1: Mt. Eden, Auckland

For the Auckland case study rental values were based on valuations for the building and other equivalent building valuations from similar areas. Summary values are indicated in Table 2. Building costs were derived from Contractor estimates. Auckland is a low risk earthquake zone. Strengthening is required within a 35year time frame.

Table 2. Building Strengthening Estimates –Auckland

Location	Area sm	Rental Value \$	Estimated Upgrade Cost Excl. Tax \$
Ground floor	65.00	\$700psm - 45,500	231,000
Rear ancillary area	38.33	\$258psm- 9,890	84,000
First Floor	77.22	\$175psm - 13,520	126,000
Total	~180 sm	~\$68,910.00	\$441,000.00

4.2. Case Study 2: Marton

The region is renowned for its non-heritage and heritage structures and is designated a high-risk earthquake zone. As a result, any strengthening requirements are required within the 15year maximum time frame. Rental values have been estimated from real estate data for a regional town retail location and have been estimated in the region of \$180-190 per square metre overall, depending upon location. Building rates are suggested as marginally cheaper than the Auckland rates, with savings to undertake the same amount of construction upgrade in the order of \$50,000.00

Table 3: Building Strengthening Estimates -Marton

Location	Area sm	Rental Value \$	Estimated Upgrade Cost Excl. Tax \$
Ground floor	65.00	\$340psm -\$22,100	220,000
Rear ancillary area	38.33	\$125psm - 4,791	80,000
First Floor	77.22	\$100psm- 7,700	100,000
Total	~180 sm	\$34,590.00	\$400,000.00

4.3. Findings

The comparisons from the case study investigation can best be illustrated by reference to Table 4 below. Bank finance costs, interest only, at 5.6% is assumed across the total upgrade cost. An improved lease/rental ability factor of 10% is assumed subsequent to strengthening.

Table 4. Cost breakdown summary analysis

Item	Auckland \$	Marton \$
Existing Rental	68,910	34,590
LESS Bank Finance cost per annum (Interest only-5.6%)	(24,700.00) [\$441,000 x 5.6%]	(22,400.00) [\$400,000 x 5.6%]
PLUS Improved lease ability (10%)	6,890	3,450
Gross rental income pa after deduction of strengthening costs	51,100.00	15,640.00
Income LOSS due to strengthening pa.	(17,810.00) ~26%	(18,950.00) ~ 55%
Estimated Gross Valuation loss. ¹	~21% ²	~50%
(Estimated Captilisation rate prior - after (%))	(7.5%-7%)	(10% - 9%)

Rental income is gross excluding tax and assumes costs for rates and insurance is the responsibility of the tenant. Both locations suffer loss of income. The most extreme loss related to value situation remains the Martin example, with income reduced from an estimated gross income of \$34,590 to an effective \$15,640.00 p.a. after bank loan costs for strengthening are subtracted from gross income. For properties such as this, the final return of \$15,640, and assuming a upgraded capitalisation rate of 9%, reduces the book value of the property from an original \$345,900 to \$173,770, a loss in valuation in the order of 50%. If per annum maintenance costs are included in the Martin example, say \$4000.00, the effective nett rental profit *before* tax would be in the order of \$11,640.00 p.a., a sum that equates to a return on the original investment of less than an equivalent bank term deposit rate.

5. CONCLUSIONS

This case study outlines the challenges for the building owner of complying with the new legislation and still maintaining a viable business operation. In the town of Marton, costs suggests the income loss (57%) and resultant nett income would render the retrofit and strengthening option marginal. Compounding this is the relatively short strengthening period as Martin, together with other towns in the region, such as Taihapi and Bulls, are within a high risk earthquake zone. The only other option to avoid paying the \$200,000 fine for non-compliance is to demolish the building. Demolition for these

¹ Valuation loss: (Est.V. Price prior = 68910/7.5 x 100) – (Est. V. Price after = 51100/7 x 100)

² Percentage loss = Est Valuation loss/Original Est Valuation prior x 100

non-heritage buildings seems the most likely course of action. To date, with the exception of minor government loan advances for parapet and veranda repairs to buildings in high earthquake zones requiring immediate repair, and the Heritage EQUIP funding for selected Cat 1 or Cat 2 Heritage quality buildings, the funding to support any substantial retrofit has not been forthcoming from the state.

In the Auckland example, high rental values ensure this particular building remains financially the lesser effected by the legislation. In addition, the high value of land in similar inner city suburban locations within Auckland, such as Ponsonby and Devonport, and the prospect of a greater building intensification under new zoning regulations could present an attractive alternative in favour of demolition/rebuild over retrofit and strengthening, to the detriment of energy savings. In other outer suburb and less wealthy fringe areas of Auckland however, such as Otahuhu or Papakura, the decision as to what direction to proceed is less clear, At stake for all suburbs is the quest to preserve the heritage streetscapes the presence of these small urban URM brick “home shop” these types of buildings currently achieve.

Additional research is needed to develop and test alternative compliance processes, similar to the risk matrix assessment process used to determine cladding profiles and capable of being used, at least for low risk zones, by non-engineer professionals. The aim would be to secure these small-scaled heritage building in such a way that fixes the most dangerous parts of a building and allows it to “fail safely” in a significant earthquake, but by the same token limits upgrading costs to levels where on-going occupation of these URM structures continues to be viable. If however, Government policy remains in its present form, and the lack of financial support for the non-heritage building continues, mass demolition of street heritage will most likely happen. With that the appeal of a neighbourhood will be diminished, and with it the financial and community rewards associated with that same appeal.

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