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RETROFITTING COSTS FOR URM BUILDINGS

Progress report

Michael Griffith and Jaroslav Vaculik
University of Adelaide
Bushfire and Natural Hazards CRC

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INTRODUCTION

In Australia, there is no requirement for owners of an existing building to seismically upgrade their building to comply with the provisions in the Australian earthquake loading standard, AS 1170.4 (SA, 2007). Some jurisdictions, in practice, may require a seismic assessment from an owner who is contemplating some form of structural alterations (eg, extensions to the existing building or removal or relocation of walls) or a 'change of use'. Depending upon the outcome of the seismic assessment, the building owner may be asked to bring the building's seismic resistance up to a negotiated % of the earthquake code's strength requirement for new buildings – hereafter referred to as %NBS. In many instances, the seismic improvements are implemented as much as possible as part of the structural alterations proposed by the building owner so that the cost for seismic upgrading is incidental to the total project cost. As a consequence, the source for data on seismic retrofit of URM buildings in this report has come from overseas examples.

In New Zealand, the government has been more proactive owing, no doubt, to the country's higher level of seismic activity. Indeed, the recent earthquakes in Christchurch and Kaikoura (2010, 2011 and 2016, respectively) have led to the government's enactment of legislation (Earthquake Prone Buildings (EPB) Amendment Act) that requires any building in the country which has a masonry parapet to have the parapet seismically restrained/strengthened (or removed) within the next 12 months. This act is now referred to as the Brower Amendment in recognition of Ann Brower who lobbied the NZ parliament vigorously for several years after the Christchurch earthquakes to take more decisive action (Brower, 2017).

Unfortunately, building owners are rarely moved to voluntarily strengthen their building when the main beneficiary is 'public safety'. Thus, seismic retrofit costs are a significant factor, even in countries where an improved seismic rating for a building can result in increased rental income and property values. In the following sections we describe the costs reported from neighboring countries where seismic rehabilitation work occurs regularly.

Egbelakin et al. (2011) reported that a high cost of retrofitting an earthquake prone building (EPB) is a significant impediment affecting owners' decisions to rehabilitate their EPBs. The New Zealand study conducted by Egbelakin and colleagues revealed that 90% of the interviewees across all the cases studied disclosed that seismic retrofit cost is generally high and can become an economic burden on property owners. Other costs associated with retrofitting EPBs were regarded as one of the main contributors to the high cost of retrofitting EPBs (EERI, 2003), resulting in difficulty when attempting to accurately estimate the overall cost of retrofitting EPBs. These costs relate to expenditure that cannot be estimated until the rehabilitation work commences or is completed (Bradley et al., 2008) and are characterised by several variations that depend on factors such as location, type of structure, building characteristics, rehabilitation scheme, the performance standard desired and other work(s) relating to the provisions in the building code that are triggered by the decision to retrofit. Both direct costs (seismic and non-seismic retrofit construction cost) and indirect costs (costs due to business disruption, loss of revenue) associated with seismic retrofit further complicate the cost estimation process (Bradley et al., 2008).

One way to overcome issues relating to seismic retrofit cost is to develop a strategy that will incorporate the seismic retrofit cost into a larger upgrade i.e. implementing seismic improvements during an on-going facility management program (EERI, 2003). Teamwork during the conceptual design stage in a rehabilitation project can also reduce cost, as all stakeholders can discuss and evaluate cost cutting measures (EERI, 2000). Likewise, Lindell & Perry (2004) highlighted that substantial financial aid and low-interest loans to owners of EPBs were significant motivators for improved seismic retrofit implementation. This was most recently demonstrated by the nearly unanimous response of owners of buildings with parapets in Wellington, NZ who have taken up the offer and applied for financial assistance to strengthen and/or remove the parapets on their buildings. A summary of the reported costs for seismic retrofit work on URM buildings follows.

Empirical Cost Data for Seismic Improvement of URM Buildings

The accurate determination of costs for the seismic improvement of the URM building stock requires expertise in quantity surveying. The authors acknowledge that they have no such expertise, but nevertheless present the following analysis based upon data presented at various locations throughout this report in order to trigger dialogue on the subject. The costings reported herein are just for the retrofit expenses, including labour. They do not cover additional costs for scaffolding, business interruption, road/pedestrian traffic rerouting, etc.

<u>Christchurch, NZ Data:</u>
Christchurch City Council has published information on the projected cost of seismic improvement of URM buildings (NZ Government, 2010). This document identifies that the cost to strengthen a typical URM building to 33% NBS and 67% NBS is in the range of $400/m^2$ (AUD$360/m^2$) and $1000/m^2$ of building floor plan area, respectively (refer Table 1). These rates are consistent with values contained in a report by Holmes Consultants (2009) who were the principal structural engineers involved in a number of seismic retrofit projects in Christchurch.

<u>United States Data:</u>
FEMA (1994), on the other hand, estimates seismic rehab costs at 15.29$/ft^2$. Adjusted for inflation and into AUD$ equates to approximately 15.29/ft^2 x 10.76ft^2/m^2 x 1.85(2018$/1994$) = $304/m^2. This cost was for an average across the US and did not specify any particular performance target.

<u>Victoria, B.C. Canada Data:</u>
Retrofit costs from Paxton, Elwood and Ingham (2017) for a case study of URM buildings in downtown Victoria, British Columbia in Canada give 'Benefit to Cost' ratios > 0.8 for parapet retrofits on all soil site classes and for partial retrofits for buildings on site classes D & E.

	US (2014$)	Australia
Parapet bracing	$6/ft^2	$65/m^2 x 1.6 US to AUD$ = $100/m^2
Partial retrofit	$10/ ft^2	$107/m^2 x 1.6 US to AUD$ = $171/m^2
Full retrofit	$33/ ft^2	$355/m^2 x 1.6 US to AUD$ = $568/m^2

Costs from the Victoria, BC study are per roof area (for parapet retrofit) and total floor area (partial and full retrofits). The value of a statistical life was taken as $9.1M in their benefit-cost calculations as compared to $4.2M reported by Australian government (Department of the Prime Minister and Cabinet, 2014).

<u>Wellington NZ City Council Data:</u>

The Wellington city council data (Vallis, 2018) is from a list that is still being compiled but to date consists of parapet retrofit costs for 31 URM buildings. When broken down into the retrofit cost divided by the roof plan area the average works out to be $96/m^2 or in terms of cost divided by length of parapet is, on average, equal to $1350/m of parapet. As noted, this data is a 'work in progress' and may be further inflated due to an increase in demand for such work as a result of recent earthquakes and the deadline to complete the work. Further work is ongoing to clarify the Wellington data.

Summary of Retrofit Costs

This data is summarized in Table 1 where it can be seen that there is reasonably consistent cost estimates reported for seismic retrofit work across 3 independent sources and countries with the US and Christchurch costs covering work beyond just parapets.

To put this into an international context, the earthquake hazard in Christchurch, NZ and Victoria, BC Canada are similar whereas hazard in New Zealand is roughly double that in Australia. The implication being that if Australia wants to simply remove life-safety falling hazards in a design magnitude earthquake (10% chance of occurring in 50 years), it might be sufficient to simply strengthen parapets and gable end walls and provide some wall-to-floor ties.

Table 1. Seismic retrofit costs for URM buildings (AUD$)

	Parapet retrofit ($\$/m^2$ roof plan area)	Partial retrofit ($\$/m^2$ floor plan area)	Full retrofit ($\$/m^2$ floor plan area)
Christchurch City Council	NA	$360 (parapets and some floor-wall ties)	900
FEMA	NA	$300 (parapets and some wall ties)	NA
Victoria, BC, Canada	$100 (parapet only)	171	568
Wellington, NZ	$96 (parapet only)		

As a further reference point, the cost to build a parapet wall in Australia, rendered on one side, without bracing is given by Rawlinsons 'Australian Construction Handbook' (2007) as $\$450/m^2$. Note – these are in 2018 dollars as adjusted according to CPI. Further research is on-going to break the retrofit costs down further according to the various techniques that can be used.

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