Report to the Royal Commission of Inquiry

The Performance of Unreinforced Masonry Buildings in the 2010/2011 Canterbury Earthquake Swarm

by

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Glossary and abbreviations

Acceleration response spectra	A diagram that shows the peak ground acceleration that a building of a specific period will be subjected to. The spectra can be used to assess both the seismic inertial forces induced in an elastically responding structure and the amount of induced displacement relative to the ground
Cavity	A method of wall construction where there is an inner and an outer leaf (or layer) of masonry and a central gap (cavity) that has the function of providing ventilation and a pathway for moisture to exit the wall (see also solid construction)
Diaphragm	A horizontal or inclined structural element within a building that has the function of providing stiffness and stability to perpendicular walls and to transmit loads to these walls. In unreinforced masonry buildings this term is normally applied to mid-height floors and to roofs, which in both cases are usually constructed of timber
Ductility	The ability of a building or a structural element of a building to be able to plastically deform without losing strength
Earthquake Prone Building	A building having an expected earthquake performance that is less than 33% of that of an equivalent new building correctly designed to current standards and located at the same site (see also %NBS below)
Earthquake Risk Building	A building having an expected earthquake performance that is between 34% and 67% of that of an equivalent new building correctly designed to current standards and located at the same site (see also %NBS below)
Fibre Reinforced Polymer (FRP)	A high strength lightweight material composed of synthetic fibres held within a polymer layer than can be used to improve the earthquake performance of a building
Iconic buildings	Historically or culturally significant buildings
Importance Level	The importance of a building in and after an earthquake. Buildings that are expected to contain large numbers of people or buildings that are expected to have an emergency

	function after an earthquake have higher importance.
In-plane behaviour	Behaviour that occurs in the direction parallel to the orientation of the structural element, which is typically a wall. The term is often used to describe failure, where for instance door and window openings in a wall may no longer have right angle corners (see also out-of-plane behaviour)
Intensity	A measure of the effect of an earthquake at a particular site, often measured in terms of the maximum ground acceleration at that location
Magnitude	A measure of the total energy released by the earthquake, originally based upon the Richter Scale but now determined using a revised technique
Near Surface Mounting (NSM)	An earthquake strengthening technique where slots are cut into a masonry wall and strengthening elements are inserted into the slots. The reinforcing element can then be covered over such that it is located near the surface rather than on the surface of the wall
Out-of-plane behaviour	Behaviour that occurs in the direction perpendicular to the orientation of the structural element, which is typically a wall. The term is often used to describe failure, where for instance a wall may deform outwards or completely collapse into the adjacent street or alley (see also in-plane behaviour)
Period	A property that describes how the building will shake in an earthquake. The period is measured in seconds and is dependent on a building's mass and its stiffness. The term describes the time taken for a building to complete one full cycle of lateral deformation
Seismic zone factor	A factor that numerically describes the seismicity of a region
Solid construction	Wall construction where multiple leafs (or layers) of masonry are used to create the wall thickness, without including a cavity
Unreinforced masonry (URM)	Construction of clay brick or natural stone units bound together using lime or cement mortar, without any reinforcing elements such as steel reinforcing bars
Territorial Authorities	Territorial authorities are the second tier of local government in New Zealand, below regional councils, and are based on community of interest and road access. There are 67 territorial authorities
%NBS	Percentage New Building Standard: A number that scores the expected earthquake performance of a building compared to that of an equivalent new building correctly designed to current standards and located at the same site

Executive Summary

The scope and purpose of this report were established at a meeting on 19 July 2011 with the members of the Royal Commission of Inquiry into Building Failure Caused by the Canterbury Earthquakes. The purpose of this report is to provide a resource, both for the members of the Royal Commission of Inquiry and for other parties wishing to make a submission to the Commission when hearings begin. It was established that the scope would include:

- Details of the characteristics and value of the New Zealand unreinforced masonry (URM) building stock and of the assessed seismic vulnerability of this building stock;
- Details of the performance of URM buildings within the Christchurch Central Business District (CBD) in the 2010/2011 Canterbury earthquake swarm;
- Information on technologies (including costs) available for the seismic improvement of URM buildings, and on the hierarchy of improvements that may be applied in order to improve the seismic performance of URM buildings;
- Identify URM buildings that are or were representative of their class of building and whose observed earthquake performance was representative of how that class of building would behave during earthquake actions throughout the rest of New Zealand;
- Comments on the adequacy of current practices and methodologies that may be adopted in response to the events in Christchurch.

In an effort to provide the information required by the Royal Commission, the authors have drawn on information obtained during their work with building damage assessment teams following the 4 September 2010 and 22 February 2011 earthquakes as well as data and information collected from reference material that is acknowledged in the report. Two items of interest to the Commission:

a) URM building damage statistics from the 22 February 2011 earthquake; and

b) costings for various seismic retrofit technologies that have been shown to be effective

are still being compiled and are not provided in this preliminary report. It is expected that this information will be available in time for inclusion in the final report.

In brief, the main recommendations of this report are:

- All URM buildings should be improved so that the public is protected from all falling hazards such as chimneys, parapets, gable end walls and out-of-plane wall failures. These parts of URM buildings should be improved to the full design strength required for new buildings in New Zealand. If required, further building improvements should aim for 100% of the requirements for new buildings with lower values negotiable on a case by case basis. However, a minimum of 67% is recommended.
- There should be a single, national policy for URM building maintenance and seismic strengthening rather than multiple regional policies.
- The estimated cost to upgrade all of New Zealand's approximately 3867 URM buildings to a minimum of 67% of the NBS requirements is approximately $2 billion. This is slightly more than the estimated value of $1.5 billion for the total URM building stock. Clearly, a cost effective strategy is needed to direct the limited resources available to tackle this problem.
- Field testing of a limited number of existing URM buildings in the Christchurch CBD or nearby (that have been listed for demolition) would improve the current understanding of the seismic capacity of these buildings as well as offer an opportunity to develop and validate more cost-effective seismic strengthening/retrofit technologies. Such testing would focus on global structural performance characteristics and how loads are transmitted through buildings, and would be undertaken using such techniques as snap back testing to generate lateral loads and deformations that simulate earthquake effects. The performance of structural elements either extracted from such buildings, or tested in place, would also provide important new information.
- In view of the estimated cost to upgrade all URM buildings to a minimum of 67% of the NBS, it is proposed that first priority be given to ensuring public safety by securing/removing falling hazards as outlined in section 7: Recommendation 3, Stage 1 and Stage 2. The cost to do this is unknown but would be substantially less than the amount to fully upgrade all buildings.