

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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August, 2011

Acknowledgements

This report has drawn extensively upon the published works of a significant number of current and former postgraduate students, whose involvement is acknowledged below:

- Dr Alistair Russell completed his doctorate at the University of Auckland in 2010 and is currently employed as a practicing structural engineer in Vancouver, Canada. Section 1.3 and section 2 of this document are derived with only minor modification from Russell (2010). Alistair's doctoral studies were funded by the Foundation for Research Science and Technology.
- Charlotte Knox is a doctoral candidate at the University of Auckland. Charlotte assisted in a range of activities associated with documenting damage to unreinforced masonry buildings in the Canterbury earthquake swarm and is the principal author of section 1.2. Charlotte's doctoral studies are supported financially by a University of Auckland Doctoral Scholarship.
- Lisa Moon is a doctoral candidate at the University of Adelaide. Lisa's doctorate will report on the damage to unreinforced clay brick buildings in the February 2011 earthquake, and Lisa made a significant contribution to section 3 of this report. Lisa's doctoral studies are supported financially by a University of Adelaide Doctoral Scholarship and her expenses in Christchurch were supported by the New Zealand Natural Hazards Research Platform.
- Ilaria Senaldi is a doctoral candidate at the University of Pavia in Italy, investigating the seismic behaviour of stone masonry buildings. Ilaria travelled to New Zealand to document the damage to stone masonry buildings in the February 2011 earthquake, and she has made a significant contribution to section 3 of this report. Ilaria is supervised by Associate professor Guido Magenes and her doctoral studies are supported financially by IUSS (Istituto Universitario di Studi Superiori, Pavia, Italy) and the EUCENTRE. Whilst in Christchurch, Ilaria's expenses were supported by the New Zealand Natural Hazards Research Platform.

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

- Dmytro Dizhur is a doctoral candidate at the University of Auckland. Dmytro has expertise in the field testing of unreinforced masonry buildings, and has played a major support role in collecting the data reported throughout this report. Many of the images presented in this report were provided by Dmytro, whose doctoral studies are supported financially by a University of Auckland Doctoral Scholarship.
- Ronald Lumantarna is a doctoral candidate at the University of Auckland. Ronald's doctoral studies are focussed on developing a knowledge base regarding the material properties of New Zealand's unreinforced masonry buildings, for use by practicing structural engineers in their seismic assessment and retrofit designs. Ronald's doctoral studies are supported financially by a University of Auckland Doctoral Scholarship.
- Najif Ismail is a doctoral candidate at the University of Auckland. Najif has assisted with a range of activities associated with data collection and reporting, and his doctoral studies focus on the development of new technologies for earthquake strengthening of unreinforced masonry buildings. Najif's doctoral studies are supported financially by the Pakistan Higher Education Commission.
- Cass Goodwin completed a Bachelor of Engineering and a Bachelor and Masters of Architecture degrees at the University of Auckland. Much of section 4 of this report is derived from Cass's M.Arch dissertation (Goodwin, 2008) and associated journal publications (Goodwin et al., 2009; Goodwin et al., 2011). Cass's M.Arch degree was financially supported by the Foundation for Research, Science and Technology. Currently Cass is employed as a practicing structural engineer engaged in seismic retrofitting of unreinforced masonry buildings, working for Abacus Engineering Ltd in Auckland.
- Temitope Egbelakin is a doctoral candidate at the University of Auckland. Temitope's doctoral studies are focussed on identifying impediments to the uptake of seismic improvements by the owners of earthquake prone buildings, and Temitope contributed to section 6.2 of this report. Temitope's doctoral studies are funded by the Foundation for Research Science and Technology.

Expertise associate with the seismic response of unreinforced masonry buildings was developed at the University of Auckland as part of the 'Retrofit Solutions' research project that was funded by the New Zealand Foundation for Research Science and Technology grant UOAX0411 during the period 1 July 2004 to 30 September 2010. The website associate with this project may be accessed at www.retrofitsolutions.org.nz

Expertise associated with the seismic response of unreinforced masonry buildings was developed at the University of Adelaide, in part, through research funded by the Australian Research Council over the period 1 January 2004 to 31 December 2010.

Data on the performance of unreinforced masonry buildings in the 22 February 2011 earthquake was collected as part of the Natural Hazards Research Platform Recovery Project 'Project Masonry'. The Natural Hazards Research Platform maintains a website at <http://www.naturalhazards.org.nz/>.

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

The assistance of David Hopkins, Patrick Cummuskey, Richard Deakin, Russell Green, John Buchan, Claire Stevens, Katherine Wheeler, Neil McLeod, Bruce Mutton and Win Clark in providing information reported in section 1.3 and section 2.3 is gratefully acknowledged.

Tracey Hartley, a Chartered Building Conservation Surveyor with Salmond Reed Architects, is thanked for her assistance in providing information on aspects of the appropriate remediation of cavity construction as presented in section 4.2.3.

Sharon Weir of the Canterbury Earthquake Recovery Agency (CERA) is thanked for providing the data reported in Appendix C on buildings in Christchurch that were demolished during the period 1 May 2011 to 25 July 2011. Ceciel DelaRue is the Team Leader for Urban Design & Heritage at Christchurch City Council and is thanked for providing the information on costs of seismic improvement that is reproduced in section 6.3.

Paul Campbell and John Hare, both seconded to the Canterbury Earthquake Recovery Agency, are thanked for the time that they made available to discuss their observations pertaining to the performance of both unretrofitted and retrofitted unreinforced masonry buildings in the Canterbury earthquake swarm. The assistance of Will Parker, Jamie Lester and Andrew Brown of Opus International Consultants Ltd to provide supervision during a walking tour of the Red Zone that was conducted on Monday 18 July 2011 is gratefully appreciated.

Table of Contents

ACKNOWLEDGEMENTS.....	I
TABLE OF CONTENTS.....	IV
GLOSSARY AND ABBREVIATIONS	VII
EXECUTIVE SUMMARY.....	1
SECTION 1: INTRODUCTION AND BACKGROUND	3
1.1 SCOPE AND PURPOSE.....	3
1.2 EUROPEAN SETTLEMENT OF CHRISTCHURCH	4
1.2.1 <i>Early Christchurch construction</i>	4
1.2.2 <i>Rise and decline of unreinforced masonry construction</i>	6
1.3 THE EVOLUTION OF NEW ZEALAND BUILDING CODES	7
1.3.1 <i>Provisions for the seismic upgrade of existing buildings</i>	10
1.4 BRIEF COMMENTS ON THE SEISMOLOGICAL CHARACTERISTICS OF THE 2010/2011 CANTERBURY EARTHQUAKE SWARM	14
SECTION 2: THE ARCHITECTURAL CHARACTERISTICS AND THE NUMBER AND SEISMIC VULNERABILITY OF UNREINFORCED MASONRY BUILDINGS IN NEW ZEALAND	18
2.1 EARLY MASONRY CONSTRUCTION IN NEW ZEALAND	18
2.1.1 <i>The influence of the Wairarapa and Murchison Earthquakes</i>	21
2.1.2 <i>The 1931 Hawke's Bay Earthquake</i>	22
2.2 ARCHITECTURAL CHARACTERISATION OF NEW ZEALAND'S URM BUILDING STOCK	23
2.2.1 <i>Parameters for Differentiating Typologies</i>	26
2.3 NEW ZEALAND URM BUILDING POPULATION AND DISTRIBUTION	27
2.4 VALUE OF THE NEW ZEALAND URM BUILDING STOCK	28
2.5 SEISMIC VULNERABILITY OF THE NEW ZEALAND URM BUILDING STOCK	30
SECTION 3: OBSERVED PERFORMANCE OF UNREINFORCED MASONRY BUILDINGS IN THE 2010/2011 CANTERBURY EARTHQUAKE SWARM.....	34
3.1 DAMAGE TO URM BUILDINGS FROM THE 4 SEPTEMBER 2010 EARTHQUAKE.....	34
3.1.1 <i>Material properties</i>	36

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

3.1.2	<i>Building damage statistics</i>	36
3.1.3	<i>Chimneys</i>	38
3.1.4	<i>Gable end wall failures</i>	39
3.1.5	<i>Parapet failures</i>	40
3.1.6	<i>Anchorage failures</i>	41
3.1.7	<i>Wall failures</i>	42
3.1.8	<i>Successful wall anchorage</i>	45
3.1.9	<i>In-plane wall failures</i>	45
3.1.10	<i>Partial wall failures</i>	47
3.1.11	<i>Diaphragm deformations</i>	48
3.1.12	<i>Return wall separation</i>	49
3.1.13	<i>Pounding</i>	50
3.1.14	<i>Special buildings</i>	50
3.1.15	<i>Building damage due to ground deformation</i>	53
3.1.16	<i>Summary</i>	54
3.2	DAMAGE TO STONE MASONRY BUILDINGS FROM THE 22 FEBRUARY 2011 EARTHQUAKE	55
3.2.1	<i>Post-earthquake assessment and building damage statistics</i>	56
3.2.2	<i>Damage mechanisms in stone masonry buildings and churches</i>	59
SECTION 4: TECHNIQUES FOR SEISMIC IMPROVEMENT OF UNREINFORCED MASONRY BUILDINGS		67
4.1	TYPICAL EARTHQUAKE FAILURE MODES IN URM BUILDINGS	67
4.2	TECHNIQUES FOR SEISMIC IMPROVEMENT OF URM BUILDINGS	70
4.2.1	<i>URM material stabilisation (poor maintenance)</i>	70
4.2.2	<i>Parapets and other falling hazards</i>	71
4.2.3	<i>Wall strengthening to restrain out-of-plane bending</i>	74
4.2.4	<i>Floor and roof diaphragm stiffening</i>	78
4.2.5	<i>Connection of structural elements</i>	80
4.2.6	<i>Shear walls</i>	81
4.2.7	<i>Insertion of internal frames</i>	84
4.2.8	<i>Removal of mass and/or geometric/stiffness irregularities</i>	86
SECTION 5: SET OF REPRESENTATIVE BUILDINGS		87
5.1	STONE MASONRY BUILDINGS	87
5.1.1	<i>Christchurch Cathedral</i>	87
5.1.2	<i>Christchurch Basilica</i>	88
5.1.3	<i>Canterbury Provincial Council Buildings</i>	89
5.1.4	<i>Christchurch Arts Centre</i>	90
5.1.5	<i>Former City Malthouse</i>	91
5.2	RETROFITTED CLAY BRICK MASONRY BUILDINGS	92
5.2.1	<i>The Smokehouse, 650 Ferry Road</i>	93
5.2.2	<i>TSB Bank Building, 130 Hereford Street</i>	93
5.2.3	<i>X Base Backpackers, 56 Cathedral Square</i>	95
5.2.4	<i>Vast Furniture / Freedom Interiors, 242 Moorhouse Avenue</i>	96
5.2.5	<i>Environment Court Ministry of Justice, 282-286 Durham Street North</i>	97
5.2.6	<i>Shirley Community Centre, 10 Shirley Road</i>	98
5.2.7	<i>Review of performance of retrofitted clay brick URM buildings</i>	99
5.3	UNRETROFITTED CLAY BRICK BUILDINGS	100
5.3.1	<i>127-139 Manchester Street</i>	100
5.4	CLAY BRICK URM BUILDING THAT HAVE BEEN PARTIALLY OR FULLY DEMOLISHED	102

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

5.4.1	192 Madras Street.....	102
5.4.2	Joe's Garage Cafe, 194 Hereford Street	103
5.4.3	Welstead House, 184-188 Manchester Street	104
5.4.4	Caxton Press, 113 Victoria Street	106
5.4.5	Cecil House / Country Theme Building, 68-76 Manchester Street.....	107
SECTION 6: DEMOLITION STATISTICS AND INFORMATION ON THE COST OF SEISMIC IMPROVEMENT		108
6.1	CHRISTCHURCH BUILDING DEMOLITION STATISTIC	108
6.2	COSTS OF SEISMIC IMPROVEMENTS.....	110
6.3	COST OF SEISMIC IMPROVEMENT OF THE NATIONAL URM BUILDING STOCK	111
6.3.1	Approximate cost of seismic improvement of national URM building stock	111
SECTION 7: RECOMMENDATIONS AND CLOSING REMARKS		113
7.1	RECOMMENDATIONS.....	113
7.2	CLOSING REMARKS	114
SECTION 8: REFERENCES.....		116
APPENDIX A: TERMS OF REFERENCE – ROYAL COMMISSION OF INQUIRY INTO BUILDING FAILURE CAUSED BY THE CANTERBURY EARTHQUAKE		123
APPENDIX B: ESTIMATION OF URM BUILDING POPULATION AND DISTRIBUTION		127
APPENDIX C: LIST OF DEMOLISHED BUILDINGS.....		133

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

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

	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

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

- 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.