

The performance of unreinforced masonry buildings in the 2010/2011 Canterbury earthquakes

Jason Ingham



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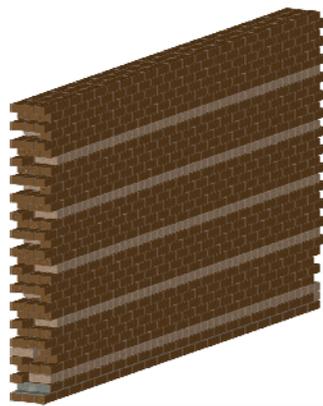


Definitions

- **Masonry unit:**
 - Clay brick or natural stone element used to construct masonry
- **Mortar:**
 - Binding element used to connect masonry units, typically composed of lime or cement, or both



Definitions



- Stretcher, header
- Bond pattern
- Bed, head, collar joint
- Leaf (wythe)
- Cavity



Types of construction:
Clay brick **UnReinforced Masonry (URM)**



Types of construction:
Natural stone unreinforced masonry



Types of construction:
Reinforced concrete masonry – not considered here



Types of construction:
Concrete frame with masonry infill – not considered here



Format of presentation

- Part 1: Background to URM buildings in NZ
- Part 2: Observations following the 4 Sept 2010 earthquake
- Part 3: Earthquake failure modes and strengthening techniques
- Part 4: Observations following the 22 February 2011 earthquake
- Part 5: Closing remarks

Format of presentation

- Part 1: Background to URM buildings in NZ
 - History of URM construction in NZ
 - Past impact of NZ earthquakes on URM buildings
 - Architectural features of NZ URM building stock
 - Comparing NZ's URM building stock with California and Australia
 - The role of URM buildings in the community
 - Estimates of number and distribution of URM building stock

History of URM construction in NZ

Purpose:

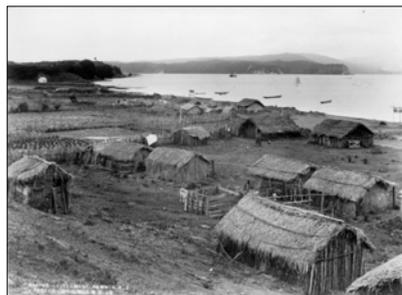
To briefly place in context the role of URM buildings in the formation of New Zealand cities and towns

To demonstrate that in general, construction of NZ's URM building stock spans the period 1880-1935

Typical Maori construction



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- No pre-European examples of masonry construction

1833 Stone store, Kerikeri

(http://en.wikipedia.org/wiki/File:Stone_store,_Kerikeri,_New_Zealand.jpg)



Early construction 1840-1860 Primarily in timber



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Queen Street Auckland, 1859



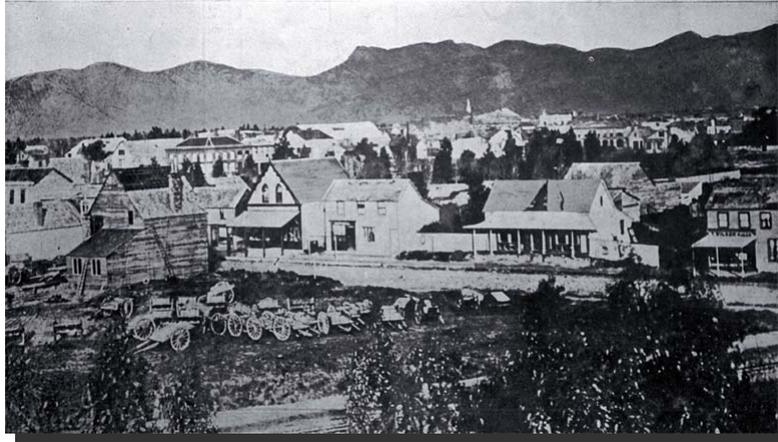
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Goldfield stone cottage, 1860

- Timber construction common
- Susceptible to fire

Christchurch shown nineteen years after its foundation [1869]

(<http://christchurchcitylibraries.com/Heritage/Photos/Disc5/IMG0036.asp>)



Canterbury Provincial Council & Supreme Court Buildings (constructed 1857-1865)

(<http://canterburyheritage.blogspot.com/2009/07/christchurch-1880-canterbury-provincial.html>)



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The spire, north transept & choir of Christ Church Cathedral under construction, [ca. 1880]

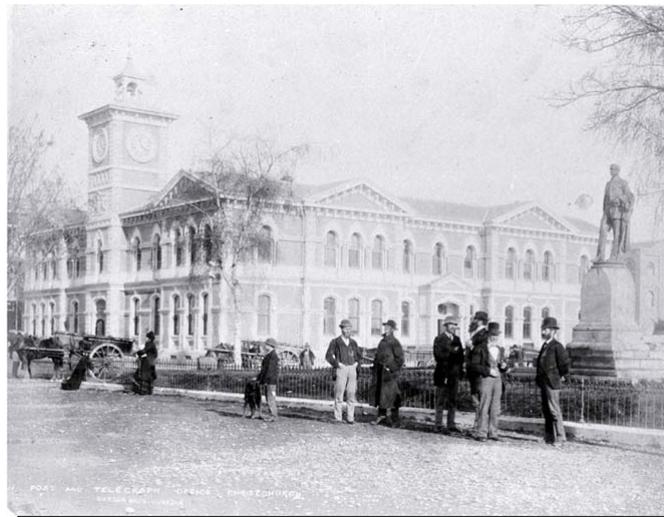
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Cathedral Square, showing the Post Office and Godley statue, with delivery carts and pedestrians [ca. 1882]

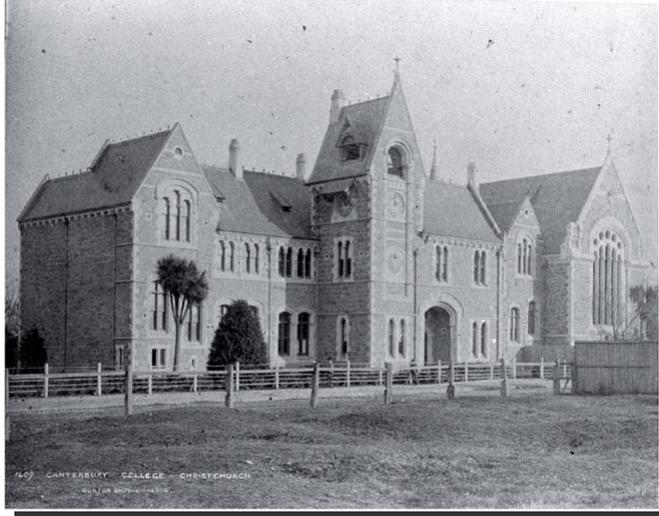
(<http://christchurchcitylibraries.com/Heritage/Photos/Disc1/img0054.asp>)



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Canterbury College, Christchurch, showing clock tower (1877-1879) and Great Hall (1882)

(<http://christchurchcitylibraries.com/Heritage/Photos/Disc1/IMG0012.asp>)



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Queen Street Auckland, 1882



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Wellington 1888 Lambton Quay; 1907 Fire

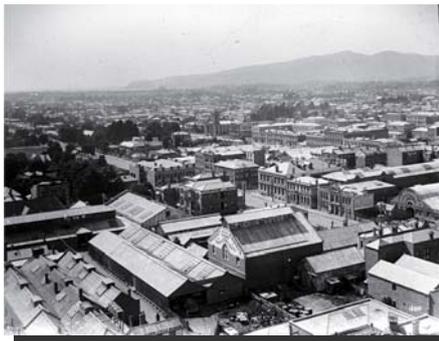


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Christchurch and Auckland, 1910



<http://christchurchcitylibraries.com/Heritage/Photos/Disc2/IMG0003.asp>



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1930 Christchurch; 1912-1918 Auckland



<http://christchurchcitylibraries.com/Heritage/Photos/Disc4/IMG0052.asp>



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Construction date of URM buildings

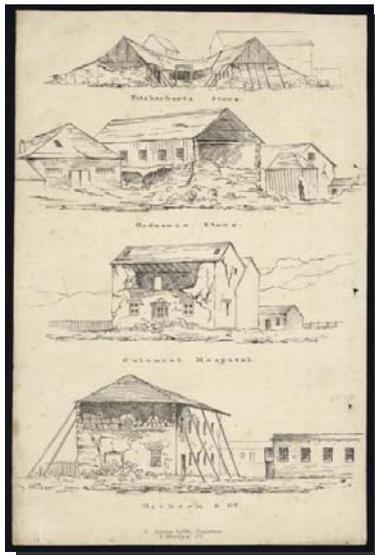


Past impact of NZ earthquakes on URM buildings

Purpose:

To demonstrate that much of what has been observed recently in Christchurch is a repeat of earlier observations

1848 Marlborough earthquake



- In Wellington, almost all buildings of brick or stone construction were damaged, including homes, churches, the jail, and the colonial hospital.
- Most wooden buildings were undamaged, although many lost their brick chimneys.
- In the Marlborough region itself, a number of homesteads were badly damaged.
- Several buildings damaged in the main shock were destroyed during strong aftershocks over the next few days.
- The only fatalities from the earthquake occurred when a damaged building collapsed during one of the aftershocks.
- http://en.wikipedia.org/wiki/1848_Marlborough_earthquake

<http://www.geonet.org.nz/earthquake/historic-earthquakes/top-nz/quake-01.html>



AFTER THE CHEVIOT EARTHQUAKE, 1901. *2072 photo.*

<http://www.nzetc.org/etmscholarly/Cyc66Cyc1ng/Cyc66Cyc106666.html>

1901 Cheviot earthquake

- “There was not a brick building or chimney left standing”

Earthquake in New Zealand.

A CHILD KILLED.

CHEVIOT POST OFFICE WRECKED.

CHRISTCHURCH CATHEDRAL DAMAGED.

Wellington, Sunday.—An earthquake of a particularly severe character was experienced on Saturday morning in North Canterbury. The post office at Cheviot was completely wrecked. An infant was killed, and two other accidents are reported. The township of Cheviot is in a state of collapse, and business is suspended. Later reports show that an earthquake shock was felt throughout the colony this morning lasting about half a minute. Christchurch Cathedral spire was cracked in two places, and the part of the spire under the cross was shifted about a foot.

Later.—It is estimated that it will take £200 to repair the cathedral spire at Christchurch, about the same as when a piece was shaken off the top 18 years ago. The shock was felt on the West Coast gold field towns, and as far south as Invercargill. At Tamaru the tremors lasted fully a minute. Shocks of lesser violence were experienced in the North Island.



<http://christchurchcitylibraries.com/heritage/photos/disc5/img0067.asp>

The North Western Advocate and the Emu Bay Times
20th Nov 1901 <http://nla.gov.au/nla.news-article64551010>



1929 Murchison earthquake



<http://mp.natlib.govt.nz/detail/?id=9959&l=mi>

<http://mp.natlib.govt.nz/detail/?id=42847&recordNum=4&q=earthquake&=tapuhigroupref%24PAColl-3051&s=a&l=mi>



1931 Hawke's Bay earthquake



<http://www.teara.govt.nz/en/historic-earthquakes/6/1>

1931 Hawke's Bay earthquake



<http://familygalore.homestead.com/Napier.html>



<http://www.hastingsdc.govt.nz/imagegalleries/historic/displayimage.php?pid=271>

- 256 deaths, 525 aftershocks in 14 days, M7.8

1942 Wairarapa earthquake



<http://www.library.mstn.govt.nz/history/images/earthquake2.jpg>



<http://www.library.mstn.govt.nz/history/images/earthquake3.jpg>

Slow steady loss of URM buildings, post-1930 Photos from Wellington, 1950



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2007 Gisborne earthquake



1931 Hawke's Bay earthquake

- Following the observed poor performance in Napier, URM construction rapidly came to an end
- Hence URM construction period approximately 1880-1935

- **Conclusion:**

URM buildings have been damaged in most large NZ earthquakes, and can be expected to continue to fall down in future large earthquakes unless either earthquake strengthened or demolished

Architectural features of the New Zealand URM building stock

Purpose:

To demonstrate a classification of the building stock into types

To show that these types can be found throughout NZ

Acknowledgement



- Russell, A. (2010). 'Characterisation and Seismic Assessment of Unreinforced Masonry Buildings', Doctoral dissertation, University of Auckland, Auckland, New Zealand, October, 344p. <http://hdl.handle.net/2292/6038>

Typology A: 1 storey stand-alone



Parnell



Newmarket



Wellington



Epsom

Typology B: 1 storey row



Newmarket



Parnell



Royal Oak



Epsom

Typology B



Typology C: 2 storey stand-alone



Bulls



Bulls



Tainape



Mt Eden

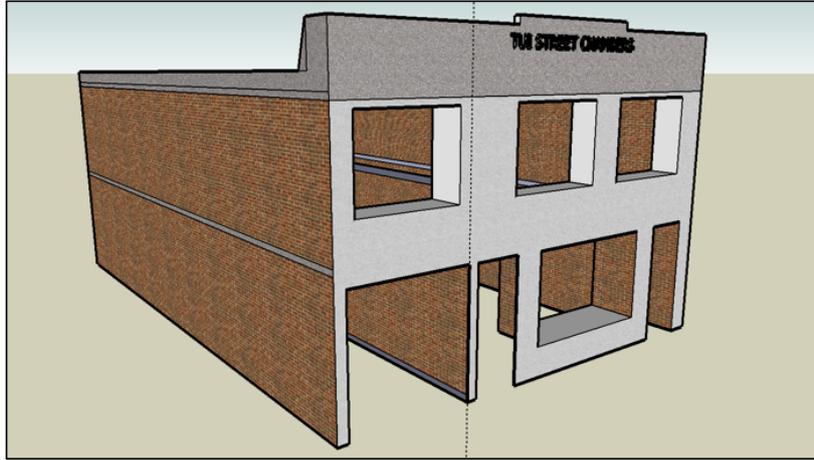


Mt Eden



Tainape

Typology C



Typology D: 2 storey row



Jervois Rd



Albert St



Palmerston North



Jervois Rd



Mt Eden





1914 Napier, 2007 Auckland,
2011 Christchurch



Typology E:
3+ storey stand-alone



Wellington



Wellington



Wellington



Wellington



Fort St, Auckland

Typology F: 3+ storey row



Customs St



Cuba St



Lambton Quay



Customs St

Typology G Monumental, religious and industrial



Palmerston North



Auckland CBD



Paeroa



Wellington CBD



Takapuna, Auckland

Building Typologies

Typology	Description	Prevalence (rank)
A	One storey stand-alone	4
B	One storey row	3
C	Two storey stand-alone	2
D	Two storey row	1
E	Three + storey stand-alone	7
F	Three + storey row	6
G	Religious and monumental	5

Comparing NZ's URM building stock with California and Australia

Purpose:

To demonstrate the value to NZ of learning from
others lessons, and what others can learn from NZ

Report 2, Figure 2.1:
Comparison of New Zealand and Californian URM building stock



(a) San Luis Obispo, Cal -Typology A



(b) Auckland, NZ - Typology A

Report 2, Figure 2.1:
Comparison of New Zealand and Californian URM building stock



(a) San Luis Obispo, Cal -Typology C



(b) Bulls, NZ - Typology C

Report 2, Figure 2.1:
Comparison of New Zealand and Californian URM building stock



(a) San Francisco –Typology E



(b) Auckland –Typology F

Christchurch and Adelaide



Christchurch corner shops



Adelaide corner shops



Christchurch theatre



Adelaide arcade

Christchurch and Adelaide



Christchurch mall



Adelaide mall



Christchurch Arts Centre



Simon's Town, Cape Town, South Africa



The role of URM buildings in the community

Purpose:

To demonstrate the role of URM buildings in defining a 'village feel' both in smaller towns and large cities throughout New Zealand

To demonstrate the impact if the majority of these building were to be demolished

Bulls



Temuka



Thames



Ashburton



Taipahē



Oamaru



Matamata



Timaru



Rotorua



Nelson



Palmerston North



Dunedin



Newtown, Wellington



Petone, Wellington



Wellington CBD



Devonport, Auckland



Epsom, Auckland



Grey Lynn, Auckland



Kingsland, Auckland



Cashell St Mall, Christchurch



Three options for earthquake prone URM buildings

- 1. Status quo
 - Accept the risk and expect deaths and fatalities in earthquakes
 - Note that this is the default ‘do nothing’ option
 - If no decision is made, then this is the decision
- 2. Demolition
 - Pragmatic, but the impact to the character of NZ towns and cities will be massive
- 3. Earthquake strengthening
 - Who pays?
 - Early evidence suggests that on average, the cost of earthquake strengthening the building may be greater than the current value of the building

Estimates of number and distribution of URM building stock

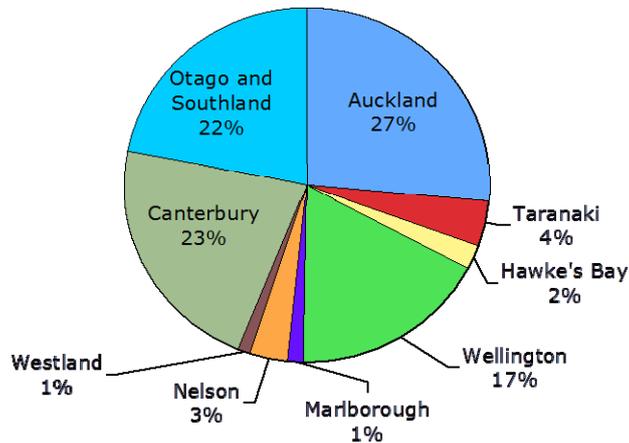
Purpose:

To understand the size of the hazard

Estimation Methods

- Contrary to expectations, actual data was not (and still is not) available on number and location of URM buildings
- Estimation technique No. 1:
 - Data set for URM buildings from Auckland City, Wellington City and Christchurch City
 - An assumption was made that buildings were built approximately in proportion to the population of people present at that location at that time, and that demolitions since have also been proportional
 - Census data was obtained for the appropriate era of construction

Pre-earthquake estimate of distribution



Estimate based upon census population

Province		Pre-1900	1901-1910	1911-1920	1921-1930	1931-1940	Total
Auckland	Population	175,938	193,581	278,357	393,639	516,886	
	URM	16	55	40	737	178	1026
Taranaki	Population	34,486	45,973	48,546	63,273	76,968	
	URM	3	11	7	118	25	164
Hawke's Bay	Population	37,139	46,906	51,569	65,037	77,652	
	URM	2	6	5	72	0	85
Wellington	Population	132,420	189,481	199,094	261,151	316,446	
	URM	27	127	169	243	111	677
Marlborough	Population	13,499	15,177	15,985	18,053	19,149	
	URM	1	3	2	27	6	39
Nelson	Population	33,142	45,493	48,463	49,153	59,481	
	URM	3	10	7	91	19	130
Westland	Population	15,042	15,194	15,714	14,655	18,676	
	URM	1	3	2	27	6	39
Canterbury	Population	145,058	166,257	173,443	206,462	234,399	
	URM	7	190	211	233	211	852
Otago and Southland	Population	174,664	156,668	191,130	206,835	224,069	
	URM	8	179	233	233	202	855
Total URM Building population by decade		68	584	676	1781	758	3867



Age distribution of URM buildings in Christchurch CBD:
Have undercounted pre-1900 buildings

Decade of construction	No. of buildings	% of total buildings	% of building for which date known
1860-1869	6	2%	4%
1870-1879	13	4%	8%
1880-1889	24	7%	15%
1890-1899	20	5%	13%
1900-1909	55	15%	36%
1910-1919	24	6%	16%
1920-1929	12	3%	8%
unknown	216	58%	-
Total	370	100%	100%

Annotations: A bracket groups the 1860-1899 decades, indicating a total of 18% of total buildings. Another bracket groups the 1860-1899 decades and the 1900-1909 decade, indicating a total of 40% of total buildings.

Calibration

- Wikipedia says June 2010 populations:
 - Christchurch = 390,300
 - Canterbury = 565,800
- Estimated that Canterbury has 852 buildings
- Projected that Christchurch has $852 \times 390.3/565.8 = 588$ URM buildings
- 380 URM building now known to have been in CBD at 22 Feb 2011
- Approx. 250 URM buildings known outside CBD at 22 Feb 2011
- Approx. 33 URM buildings demolished before 22 Feb 2011
- Sum = 663 URM buildings were in Christchurch

Calibration

- There were 595 (90% of 663) placard entries after 4 Sept 2010 earthquake
- Error $(663-588)/663 =$ Under counted by 11%
- Recalibrate for Canterbury:
 $852 \times (663/588) = 961$ (increase of 109)
 – demolitions of 320 (approx.) = 641 (decrease of 211)
- Recalibrate for Otago and Southland:
 $855 \times (663/588) = 964$ (increase of 109)
- “About 3,800 URM buildings in NZ”

High density URM locations

- Probably there are ‘pockets’ of URM buildings where the data undercounts, based on comparative wealth in 1860-1900:
- Wanganui and Timaru – port cities in 1900s
- Paeroa/Waihi and Dunedin/Otago – gold fields



Recommendation (Adopted as Recommendation #5 in Interim report)

- Maintain a national inventory of URM buildings, including:
 - Location
 - Building sizes,
 - Occupancy type
 - Rental rate
 - Property valuation
 - Retrofit status
 - Social and cultural conditions