NATIONAL EARTHQUAKE CONFERENCE

2012 EERI Annual Meeting

Performance of Masonry Structures in Christchurch, New Zealand during the 2010/2011 Earthquakes

Arturo E. Schultz

Department of Civil Engineering

UNIVERSITY OF MINNESOTA

Contributors

THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

Jason Ingham

Mike Griffith

THE UNIVERSITY of ADELAIDE

Dmytro Dizhur
Auckland, NZ

Charlotte Knox
Auckland, NZ

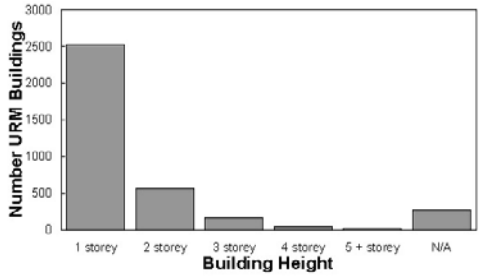
Hossein Derekhshan
Aurecon, NZ

Najif Ismail
Auckland, NZ

Lisa Moon
Adelaide, Australia

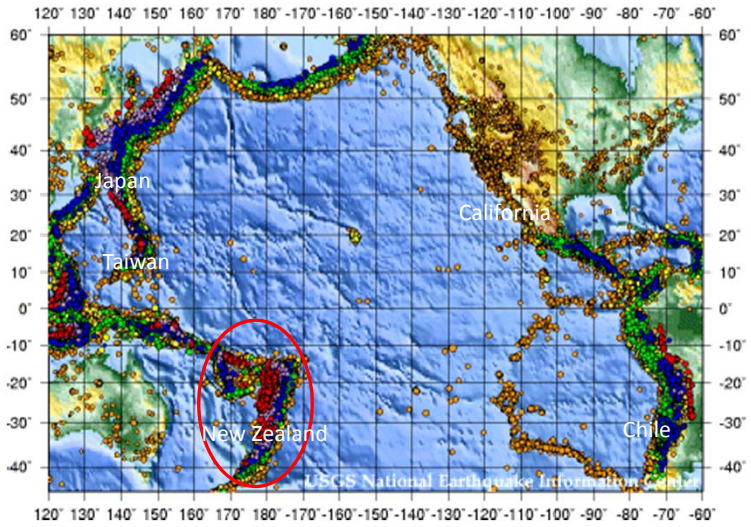
NZ URM Building Stock

Type	Description
A	One storey, isolated
B	One storey, row
C	Two storey, isolated
D	Two storey, row
E	Three+ storey, isolated
F	Three+ storey, row
G	Institutional, Religious, Industrial

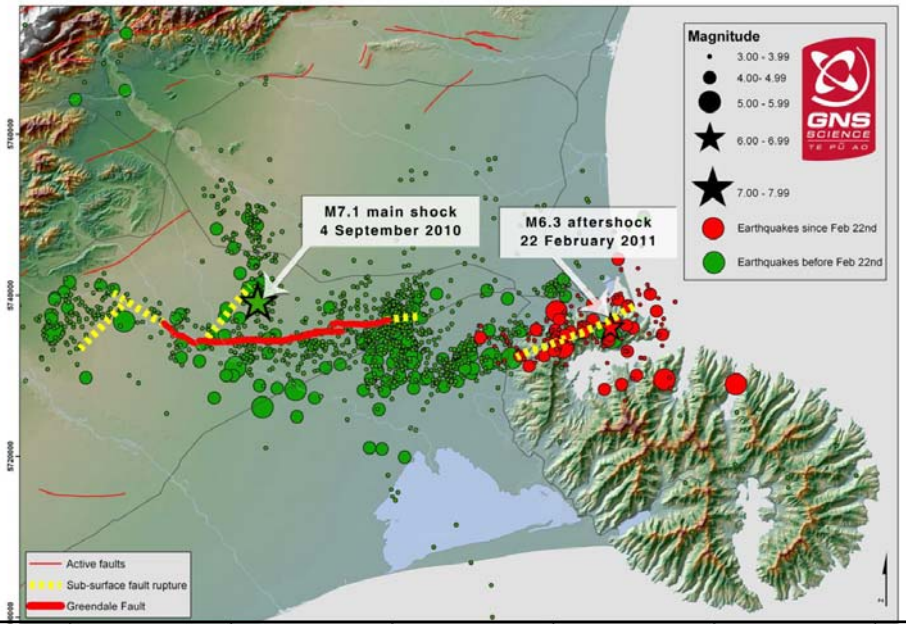


Province	Pre-1900	1901-1910	1911-1920	1921-1930	1931-1940	Total
Total URM Building population by decade	68	584	676	1781	758	3867

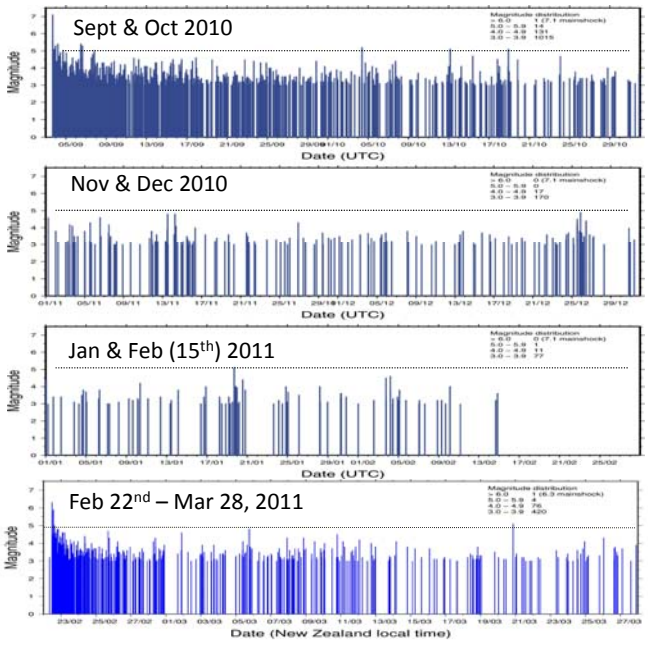
Tectonic Activity in New Zealand



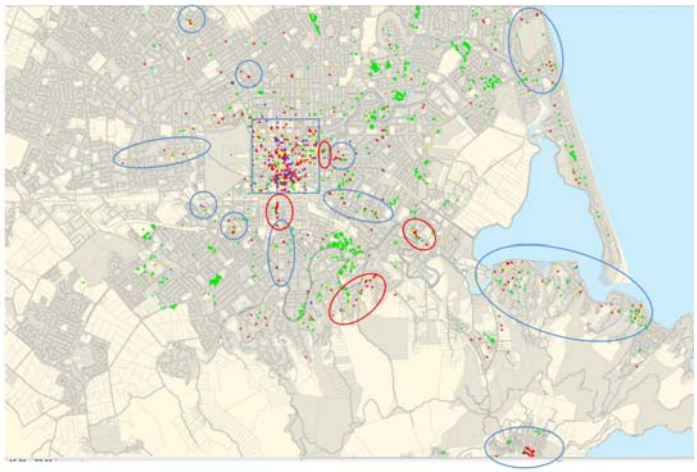
2010/2011 Earthquakes



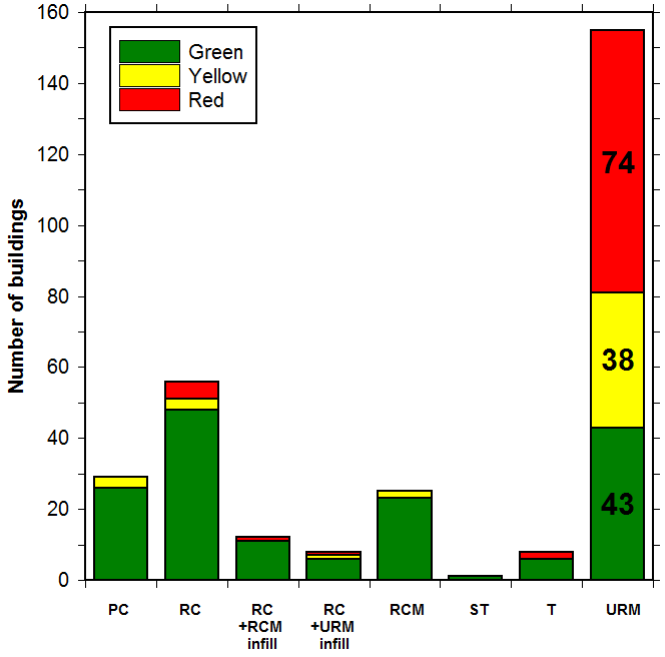
Earthquake Swarm



Areas surveyed



CBD Building Damage Survey after 22 Feb. 2011



URM = 52%

Of URM, 48% red

Red URM = 24.8%

Some buildings worse than appear from street front

Say about 1 in 3 red overall

Out-of-plane failures

Diaphragm flexibility responsible for failure
Note the anchorages into roof diaphragm

Pier failures

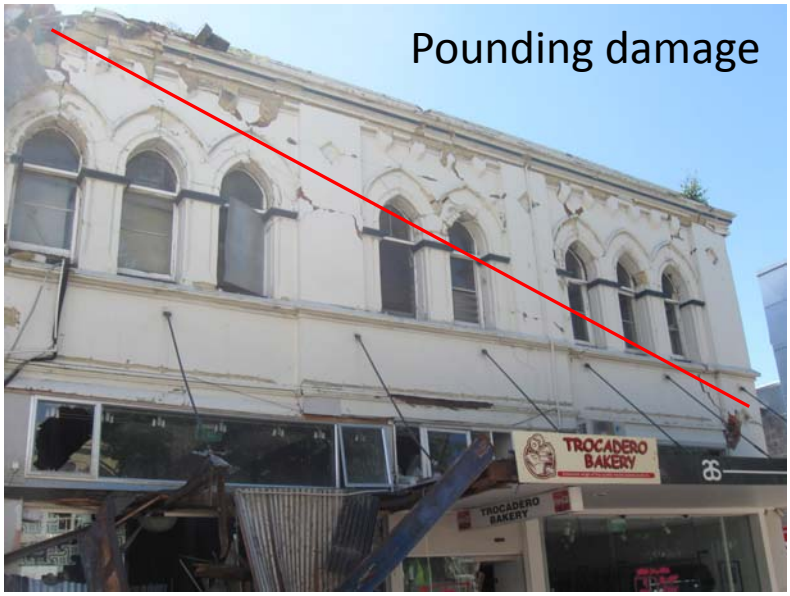
Diagonal pier failure reasonably well understood
Spandrel failure over arched windows requires more attention

Spandrel failures

Pounding damage

Widespread examples of pounding damage

Pounding damage



Mixed Mode failure
(In-plane, Out-of-plane, corner effects)

Awnings/canopies and anchorage failures

Failures observed at both ends of braces

Cavity construction often lacked header bricks to tie the wythes

Damage to rubble masonry construction in Holy Trinity church (1872), Avonside

Damage to brick masonry in St Luke's church (1859), Christchurch

Damage to a gable in St James church (1926), Riccarton

St James Church (1926), Riccarton; wall composition

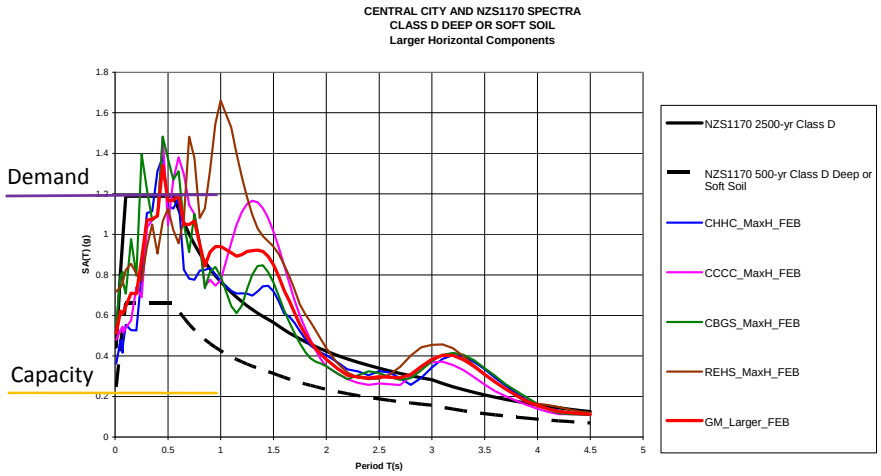
The Christchurch Cathedral

[1888]

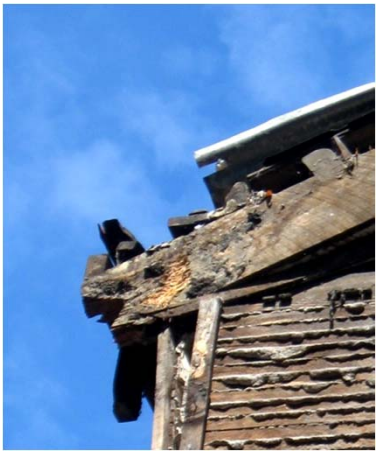
[February 2011]

The Cathedral was designed by the Englishman G.G. Scott and work began on it in 1863. The tower and spire, paid for by the Rhodes family, are complete in the photograph but were damaged multiple times by earthquakes in 1881, 1888 and 1901.

Spectra for 22 Feb. 2011 Ground Motions



Poor quality of diaphragm timber



Poor quality of mortar

- $\tau = c_o + \mu \cdot \sigma_v$
- σ_v is low
- Vertical acc's high

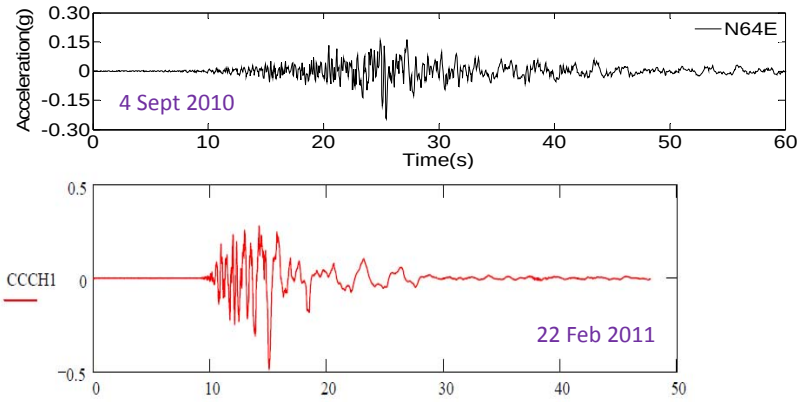
Many samples tested
Compression strengths were 1.0 – 1.5 MPa (150 – 200 psi)

Is this what we should expect?

- Yes. URM buildings consistently collapse in large earthquakes
- The NZ URM building stock is analogous to that of other European colonies. Past failures elsewhere have relevance to NZ.
- Unretrofitted URM buildings were loaded to about 6 times their calculated capacity.
- **Why did not ALL URM buildings collapse completely?**

Short duration of ground shaking

(Less than 10 seconds of string ground shaking on both occasions)



Progressive Damage from Repeated Events

[1906]

[2010]

[Sept. 2010]

[Feb. 2011]

Progressive Damage from Repeated Events

(a) Post-September 2010 – minor visible damage

(b) Post-February 2011 – section of masonry on verge of collapse

(c) Post-June 2011 – collapse of the wall

Implications for NZ and elsewhere?

- The URM building stock in NZ is remarkably homogeneous & similar to that in central US
- Similar outcomes can be expected anywhere in NZ and central US after a large earthquake

OPTIONS:

1. Do nothing
2. Seismic improvement
3. Demolition

Steel strong backs generally performed well



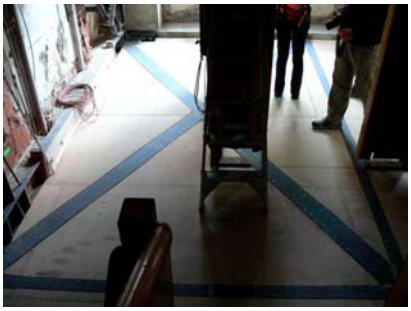


Steel Frames


Shotcrete

Textile Reinforced Mortar

Floor Diaphragm Retrofits



Unsuccessful Parapet Strengthening

Wall has detached from struts

Unsuccessful Retrofit Diaphragm Connections

Through Plate Anchor Failures

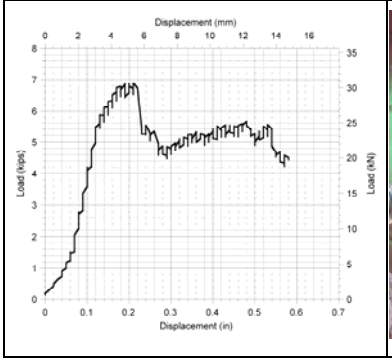


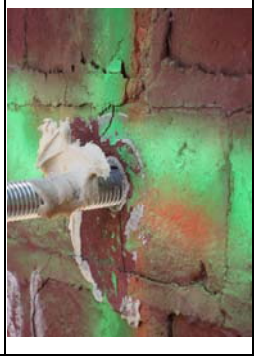

Failure of epoxy bonded connections



Field Study of Adhesive Anchor Performance

Anchor Test 054 / Building A / Adhesive 1 / Sleeved / Straight / 16mm ϕ / 400mm depth





Conclusions & Recommendations

- Massive loss of architectural heritage: "Christchurch now has no earthquake-prone buildings". *What about the central US?*
- Clear lesson for NZ and *central US* regarding earthquake prone buildings": Improve or remove!
- Negative impacts from the Christchurch experience:
  - Futility is spreading: public lacks of confidence in URM
  - Insurance companies claim that they will not insure strengthened URM buildings
  - Buildings are being demolished that would previously not have been 'red-carded'
- Better knowledge of URM buildings and materials needed.
- Success of a number of retrofit technologies was shown.
- Retrofit diaphragm connections require further study.