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

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Part 2: Observations following the 4 Sept 2011 earthquake

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Background

- Arrived morning of Sunday Sept 5
- Was deployed on placarding operations for 3 days
- Did not do any specific data collection
- Photographic evidence plus interpretation of placard data

- Analysis is qualitative in nature

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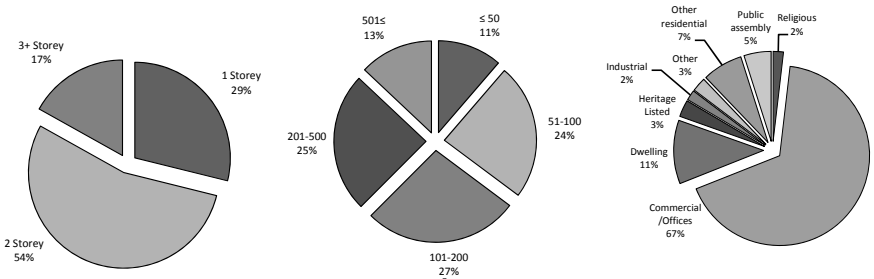
Figure 3.2 Building characteristics derived from interrogation of the inspection database (September 2010)



(a) Storey height (595 entries) (b) Footprint area (m^2; 301 entries) (c) Occupancy type (595 entries)

- Data generally consistent with projections
- More 3+ storey buildings than expected as national average, consistent with history of Christchurch

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Figure 3.3 Masonry rubble from collapsed wall

(a) Masonry rubble showing 'clean' bricks

(b) Weak mortar crumbles between fingers

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Condition of bricks in 'new' URM in 1901 Cheviot earthquake

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

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Figure 3.4 Large sections of masonry intact after fall from buildings

(a) Solid section of masonry gable

(b) Solid section of parapet

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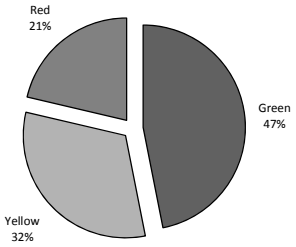
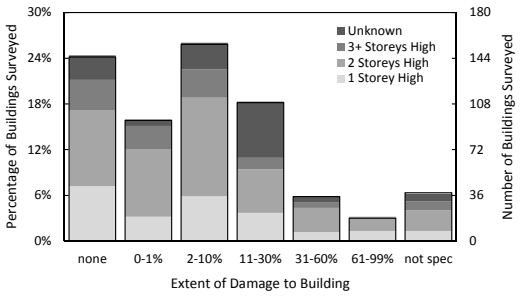
Figure 3.5 Damage statistics for the 4 September 2010 earthquake



(a) Distribution of placard assignments (595 entries)



(c) Extent of building damage

- 0.21 x 595 = 125 URM buildings with red placard

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Figure 3.6 Examples of chimney performance during the Darfield earthquake

(a) Two damaged chimneys and gable wall

(b) Unstable damaged chimney

- Reported to have been 14,000 insurance claims for chimneys

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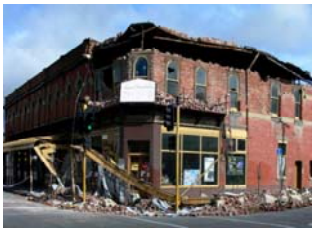
Figure 3.8 Examples of typical parapet failures

(a) Multiple front wall parapet failures



(b) Corner of Sandyford and Colombo Street

(c) Side wall parapet collapse onto roof.

(d) Corner Columbo and Tuam Street

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Figure 3.9 Anchorage failure of awning brace due to parapet collapse

(a) Anchorage failure

(b) Close-up of failed anchorage detail

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Figure 3.7 Examples of gable end wall failures

(a) 93 Manchester St

(b) 816 Colombo St

(c) Montreal-Armagh street corner

(d) Kilmore-Montreal street corner

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Figure 3.10 Examples of out-of-plane failures in solid masonry walls

(a) Corner Worcester and Manchester streets

(b) 118 Manchester Street

(c) 179 Victoria Street

(d) Failure of long wall

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Figure 3.11 Failure mechanism comparisons – observed earthquake damage versus experimental simulation

(a) Wall damage at 140 Linchfield Street

(a) High speed photograph of a dry-stacked masonry wall failing during a tilt test

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Figure 3.12 Examples of out-of-plane failures in cavity walls

(a) Cavity wall failure in a residential building

(b) 832 Columbo Street

(c) Butterfly wall ties still intact

(d) Metal wall ties badly deformed.

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Figure 3.13 Wall-to-diaphragm anchor details

(a) Gable end wall failure despite anchor (see also Figure 13a).

(b) Wall anchor still intact (see also Figure 6a).

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Figure 3.14 Successful gable end wall and side wall anchorages

(a) Arts centre building

(b) Arts centre building

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Figure 3.15 Successful wall-floor and wall-roof diaphragm anchorages

(a) Front elevation

(b) Side elevation

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Cycle patrol raised to thwart the "horse fiend", Christchurch, 1896

http://mp.natlib.govt.nz/detail/?id=9416&recordNum=14&f=tapuhigroupref%24PAColl-3051&s=a&l=mi

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Figure 3.18 Partial bed joint shear failure surrounding anchorage detail

(a) Wall-roof anchorage failure **(b) Gable end anchorage failure**

- These 'partial failures' emphasise the effect of earthquake duration (being 10-15 sec). Greater duration would have led to far worse damage

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Figure 3.16 Examples of in-plane wall damage above window openings

(a) Extensive vertical cracking above window openings

(b) Vertical crack above window opening

(c) Vertical crack through spandrel

(d) Diagonal crack extending from window opening

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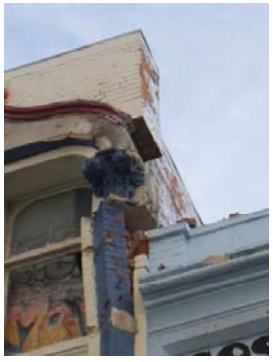
Figure 3.22 Example of building pounding damage

(a) Building overview

(b) Close-up of column



(c) Close-up of column

Figure 3.23 Manchester Courts building

(a) North wall piers, levels 3-4

- 21% of 595 URM buildings received red placard

  = 0.21 x 595 = 125 buildings

- XXXX URM building demolished

General interpretation

- URM failure modes of all types were readily explainable and had been routinely observed in past earthquakes
- There were many examples of securing of parapets and gables that appeared to have performed well
- Failures were almost entirely attributable to out-of-plane deformation mechanisms

- No loss of life led to a certain lack of deeper inspection
- It appeared that most earthquake strengthening schemes had performed well (as there was no particular attention to retrofits that had failed)

Postulated performance on 22 Feb 2011 if the Darfield earthquake had not occurred

Purpose:

To inspect if the damage and fatalities on 22 February 2011 would have been greatly different if buildings damaged in Sept 2010 had been occupied

Assumptions

- Different epicentral locations of 2 earthquakes means that they would have a different effect on any given building

  but

- 22 Feb 2011 earthquake clearly more damaging to entire building stock

- Assume:
  - Manchester Court to collapse
  - Assume 50% of demolished buildings to collapse
  - Account for parapet failures in non-demolished buildings

Fatalities – Manchester Court

- Manchester Court
  - Assume pier failure and progressive floor collapse
  - Some restraint provided by stair core
  - 30-40 occupants impacted
  - 10-15 people in street or cars
  - 10-15 in adjacent building

  - Assume midpoint 60 fatalities

  - Would be a 5th specifically identified building in the Royal Commission Terms of Reference

Fatalities due to collapse

- 33 buildings demolished post-Sept
- Assume 75% collapse
- Assume 5 occupants per building
- Deaths:
  0.75 x 33 x 5 = 124

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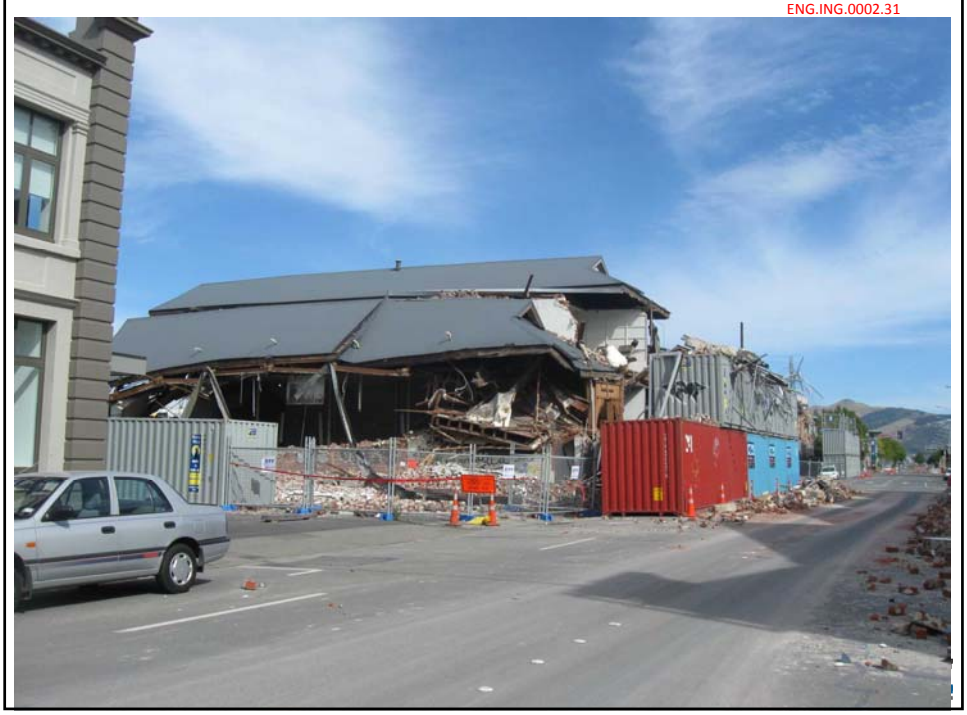

How many parapets/facades collapsed?

- We know that 21% of 595 URM buildings received red placard = 0.21 x 595 = 125 buildings
- Assume 50% of these had collapsed parapets = 0.5 x 125 = 62 collapsed parapets
- In 22 Feb 2011 there were 86 parapets that collapsed
- (86+62)/86 = 1.72
- Façade collapses killed 32 people.
- No restricted access results in 2.0 times density of those at risk = 32 x 1.72 x 2 = 110 people
- Total = 60 + 124 + 110 = 294

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