Lateral load tests on earthquake damaged houses in Christchurch

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Nov 2012
Overview

• Previous survey work on house damage
• House Test objectives and selection
  – Test Setup & Measurement systems
  – Results & Conclusions
  – Future proposal

• COLLABORATORS
• Joshua Briscoe, Logan Holt
  Auckland Students with construction experience
• David Carradine, David Yeoh
  University of Canterbury
Christchurch earthquakes - house assessments

- 100,000 houses damaged, ~$10 billion
- 3 main Causes of damage:
  - Liquefaction
  - Rock fall
  - Shaking
- Operation suburb rapid assessments
- 2011 students and data from Christchurch city
  - Very crude data, 3000 of 70,000 houses
Morris - Christchurch Houses

Chimney Damage compared with Horizontal PGA
(Shown as Stars)

Andrew King, GNS
Bexley

Also
Interior walls
Exterior Walls
VPGA etc

Chimney Damage compared with Horizontal PGA (Shown as Stars)
BRANZ Survey

- **BRANZ**
  - 300 houses with rigorous sampling, detailed data

- **Damage**
  - Brick claddings - mostly cracking
  - Little damage to claddings such as weatherboard.
  - Gypsum plasterboard lining cracks
    - at sheet joints
    - and opening corners
  - Lath and plaster, fibrous plaster linings
    - diagonal cracking
  - Evaluation underway at Victoria (Geoff Thomas VUW)

*In houses with little physical damage, residents noted that they creaked more in the wind*
Objectives

• Measure the extent of reported stiffness degradation in moderately damaged houses
  – Good qualitative studies but nothing quantitative

• Determine likely residual strength in moderately damaged houses
  – typical of the less damaged houses in Christchurch
  – representative of the New Zealand building stock

• Validate the test methodology
House Selection for load assessment

- Moderate damage
  - Typical of what is being repaired
  - Likely to be typical of moderate event elsewhere
- Preferably flat site with access
- Single storey
- Light cladding
  - Stiffness not dominated by cladding
Methodology

- Wairoa St
  - Heavy tile, gable, fibreboard, wood piles, 1980
- Bexley Rd
  - Heavy tile, hip, weatherboard, concrete ring foundn & piles, 1947

House 1: Wairoa St, Bexley
House 2: Bexley Rd, Bexley
Methodology

- Loading concepts
  - Load beam
  - Tension
  - Anchoring
House 1

150 RHS Anchor beam

Load Cell

360 UB Load beam

Acrow prop towers

Reaction Chain & 7.5 Tonne Chain Pulley

Load Cell
Test Rig – House 2

Anchor plate

Sliding plate
Measurement System

- Deflection recording
  - Electronic
  - Manual

Gauge locations

Electronic Potentiometers

Manually recorded deflection gauges
Measurement System

- Tension measuring
  - Load cell

- Computer data logging

Load cell locations

Load cell in tension

Data recording
Loading Sequence

7.5 T Chain block pulley
Results – Damage observed

Cracking in plaster board – 100kN load – Wairoa Road
Results – Damage observed

60 kN load (1/2)

130 kN load (max)
Results – Damage observed

Load Direction

Load Direction
Results – Deflections

**Expected:** 30-50mm under 100kN load

**Observed:** 3-12mm local under 130kN load
(6mm average at ceiling level)

Deflected shape at 130kN load (max)
and 60kN load (1/2)

Wairoa Street – deflections exaggerated 1:100
Results – individual gauges

- Deflection variation along building Wairoa St
Results – Deflections

**Expected:** 30-50mm under 100kN load

**Observed:** 2-30mm local under 130kN load
(15mm average at ceiling level)

Deflected shape at 130kN load (max)
and 60kN load (1/2)

Anchor point

Bexley Road – deflections exaggerated 1:30
Results - Stiffness

Predicted: Variations in stiffness

Load [kN] vs. Deflection [mm] graph showing:
- Slack
- Increasing stiffness
- Failure
Results - Stiffness

**Observed:** consistent pattern, different to expected
Results
Stiffness

- Wairoa St
  - 1980, Pine
  - Gib-board
  - Steel brace?

- Bexley Rd
  - 1947, Rimu
  - Fibrous plaster
  - Wood brace?
Results - Stiffness

Difference in stiffness between buildings

Wairoa St

Bexley Rd

$k = 18 \text{ kN/mm}$

$k = 9 \text{ kN/mm}$

Slope = stiffness = $k$
Discussion – Actual Earthquake Loads

Wairoa St
Period: 0.16 seconds
(SDOF)
SA: 1.3g

Bexley Rd
Period: 0.26 seconds
SA: 1.0g
Discussion – Loading Comparison

Design Loads – Actual Earthquake Loads – Test Loads

- Max Test Load: \(\approx 130\) kN
- Calculated Load: \(\approx 117-119\) kN
- Design Load NZS 3604:2011
- Design Load NZS 1170:2004
- Design Load NZS 3604:2011

Load [kN] vs. Deflection [mm]
Conclusions

- No indication of earthquake softening

- Large amount of residual strength, rigidity and resilience in damaged houses

- Test rig performed well and applied loads comparable with design standards and 2011 earthquakes

Future:
Remove linings after initial test, try different repairs
Use higher stiffness load system
Pseudo static cyclic loads and dynamic snap back
Proposed Tests

Low loads - stiffness
Cyclic Quasi- static loads
Snapback

Single load beam, steel and timber to
Minimise additional mass

Assistance from Ivan Giongo (Italy) & Caleb Deverell (Summer Student)
Proposed Load System

Remove For snapback
Acknowledgments

Funding: Civil and Environmental Engineering - Timber Engineering
Technical support from staff at Universities of Auckland and Canterbury
The team at CERA for access to test houses
Nikau Contractors for the load beam