Hardening Building and Infrastructure Cluster

PROJECT A9: Cost-effective mitigation strategy development for building related earthquake risk
Project Participants

Univ of Adelaide:
MC Griffith, M Jaksa, P Visintin, J Vaculik

Univ of Melbourne:
NTK Lam, H Goldsworthy, E Lumantarna

Swinburne University:
JL Wilson, E Gad, HH Tsang

Geoscience Australia:
M Edwards, H Ryu, M Wehner

End Users:
WA DFES, York Shire Council, ABCB, Standards Australia, EMA, State/Local Governments
AERIAL VIEW OF CHRISTCHURCH SECONDS AFTER THE 22 FEBRUARY 2011 EARTHQUAKE (only M6.3 but ~ 10km from CBD)
Aim: to develop evidence base to inform decision making for earthquake risk mitigation

- Establish seismic vulnerability classes for representative building types in Australia
- Survey existing retrofit techniques for known performance in recent earthquakes
  - Develop cost-effective Australia-specific retrofit solutions
  - Develop decision-support and earthquake risk forecasting tools to support infrastructure managers
  - Develop economic loss models that include business interruption and casualty costs
The main project milestones are as listed here with more detailed milestones being in the Project Schedule table:

Dec 2017: • Completion of Fragility Curves for LDRC Buildings
  • Report of Business Resilience Models

June 2018: • Completion of Fragility Curves for URM Buildings
  • Completion of Retrofit Methods for LDRC Buildings
  • Reporting on Economic Framework and Precinct Cordon Model

Dec 2018: • Development of Retrofit Tests for LDRC Buildings
  • Final Report on Fragility Curves for As-Built and Retrofitted URM Buildings

June 2019: • Final Report on Fragility Curves for Retrofitted LDRC Buildings
  • Reporting on Economic Evaluation of Mitigation Strategies at Building Level

Dec 2019: • Completion of Case Study CBD Precinct Cost-Benefit Analysis

June 2020: • Completion of the final stage of Economic loss model
End User Engagement

- WA Dept Fire & Emergency Services
- York Shire Council
- Standards Australia - AS 3826
- Other indirect
  - EMA
  - State & local governments
  - Bldg Code of Australia
<table>
<thead>
<tr>
<th>Type</th>
<th>Example photo</th>
<th>Typical vulnerabilities</th>
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<tbody>
<tr>
<td>House – 1 storey isolated building</td>
<td><img src="image1.jpg" alt="Example photo" /></td>
<td>Chimney; out-of-plane (OOP) failure gable walls</td>
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<tr>
<td>Pub – 2 storey corner building</td>
<td><img src="image2.jpg" alt="Example photo" /></td>
<td>Parapets; chimneys; outward OOP failure of external leaf of cavity wall; collapse of these elements through awning and balcony</td>
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<td>Single storey commercial – 1 storey row building</td>
<td>Parapet, possible failure through awning</td>
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<tr>
<td>Two storey commercial – row building</td>
<td>Parapet; OOP failure of upper storey wall</td>
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<tr>
<td>Two storey institutional – isolated building</td>
<td>Chimneys; OOP failure of upper storey wall</td>
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<td>Two storey Bank – isolated building</td>
<td>Parapets; chimneys; OOP wall failure</td>
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FRAGILITY CURVES FOR URM BUILDINGS

For varied hazard, Z (time horizon = 30 years)
PGA CAPACITIES AND PROBABILITY OF EXCEEDANCE OVER 30 YEAR TIME HORIZON (YORK)

Chimneys

609 chimneys on 307 URM buildings
60 of them ‘slender’

Graph showing the probability of exceedance over 30 years for different capacities and thicknesses.
TYPICAL CHIMNEY FAILURES
A SUCCESSFUL CHIMNEY RETROFIT THAT SURVIVED THE Mw 7.1 SEPTEMBER 2010 EARTHQUAKE IN CHRISTCHURCH.
PGA CAPACITIES AND PROBABILITY OF EXCEEDANCE OVER 30 YEAR TIME HORIZON

Parapets

- Graph showing PGA capacities and probability of exceedance over 30 years.
- Two plots: one for probability of exceedance over 30 years, and another for PGA capacities.
- Bar chart for capacities at different thicknesses:
  - H = 1200 mm: Capacity = 0.20
  - H = 1500 mm: Capacity = 0.18
  - H = 1800 mm: Capacity = 0.16
  - H = 2100 mm: Capacity = 0.14

Thickness [mm]: 450
2010 Kalgoorlie Earthquake

Parapet/awning damage in URM buildings in M5.0 earthquake
(a) Parapet front view

(b) Rear view, note point connection for parapet restraint

Figure 4: Collins Building, Avon Terrace, York.
PGA CAPACITIES AND PROBABILITY OF EXCEEDANCE OVER 30 YEAR TIME HORIZON

Out-of-plane walls

Capacity

- H = 2500 mm
- H = 3000 mm
- H = 3500 mm
- H = 4000 mm

Prob of exceedance over 30 years

Thickness [mm]
Parapet and out-of-plane wall failures

Typical building damage in M5.6 Newcastle Earthquake
Damage & Economic Loss Modelling

1. Rank Vulnerability of Common Construction Types
2. Estimate Structural Drift for Various Magnitude Events
3. Develop Damage-Drift Relationships to Estimate Building Damage for unstrengthened and strengthened buildings
4. Develop Cost-Damage Relationships to Estimate Economic Impact* of Natural Hazard

❖ costs to include fatalities & injuries, business interruption at a precinct level

1, 2 ‘done’; 3 & 4 in progress
ECONOMIC EVALUATION

Annualised Long Term Loss for Hazard Exposure:-

- Integrate total unmitigated losses for all likelihoods to determine annualised loss without action.
- Integrate total mitigated losses for all likelihoods to determine annualised loss with mitigation action.

Annual Benefit of Mitigation:-

- Subtract annualised unmitigated loss from mitigated case to determine benefit

Benefit Versus Investment Cost of Mitigation:-

- Discount the annual savings realised through mitigation to PV
- Divide PV of savings by retrofit cost to obtain B/C
Expected Outputs (as stated in proposal):

- A cost-benefit analysis methodology for key retrofit options at both the building and regional levels

- Information and models to enable planning authorities to develop policies and legislation, backed up by substantiated economic benefits
Closing Remarks

• WA DFES and York Shire Council end user engagement has been fantastic:
  ➢ Community engagement has been good;
  ➢ Seismically vulnerable buildings have been identified;
  ➢ Seismic strengthening options now being developed for typical York buildings;
  ➢ DFES and York Shire application for a NDRP 2018-19 grant in preparation to support earthquake mitigation in York;

• Much of the assessment and retrofit solutions being developed for York will have national application

• Professor Griffith leading update of AS 3826 “Earthquake strengthening of existing buildings”