Hardening Building and Infrastructure Cluster

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

Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

bnhcrc.com.au

Project Participants

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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

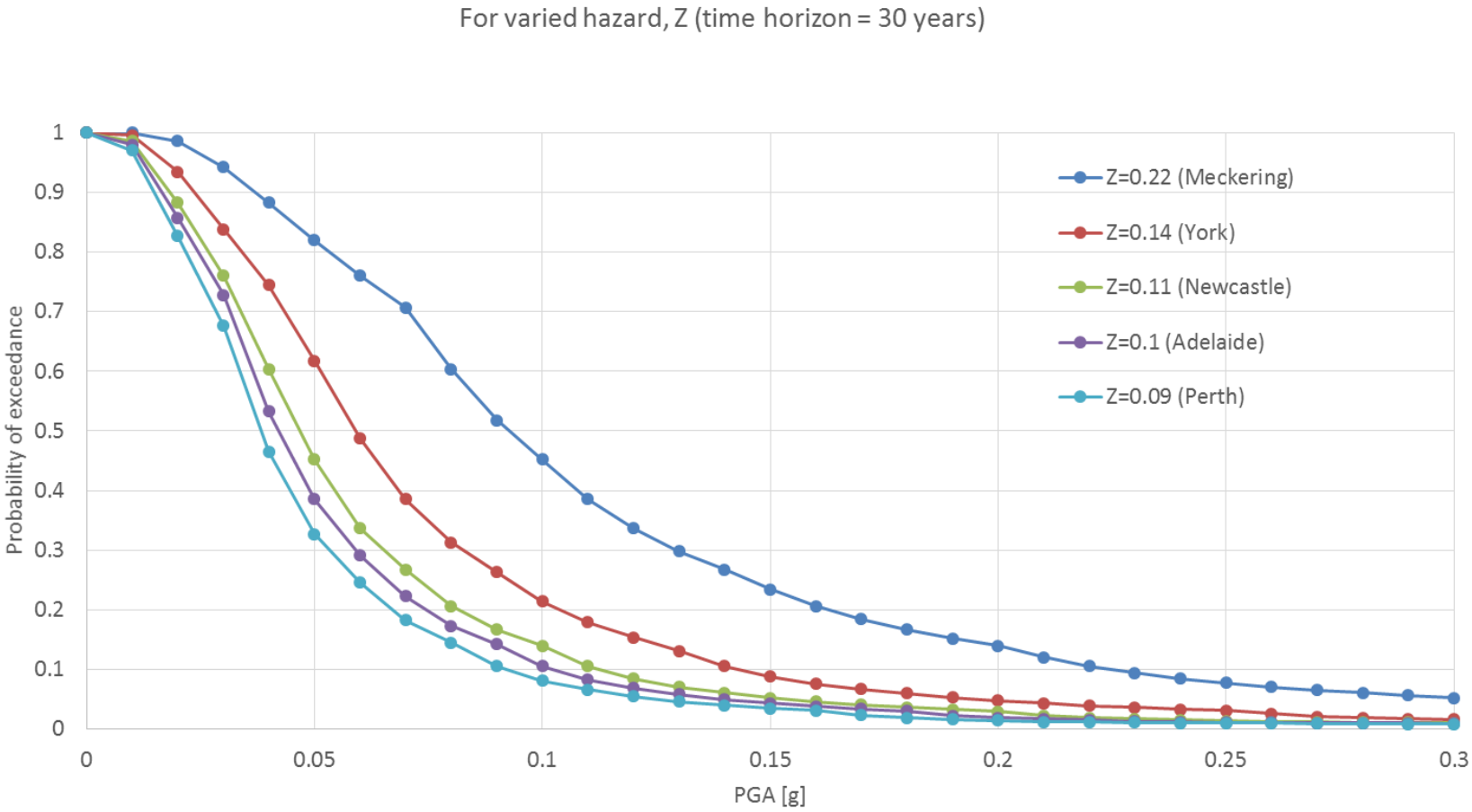
YORK PROJECT – GENERIC BUILDING TYPOLOGIES

Type	Example photo	Typical vulnerabilities
House – 1 storey isolated building		Chimney; out-of-plane (OOP) failure gable walls
Pub – 2 storey corner building		Parapets; chimneys; outward OOP failure of external leaf of cavity wall; collapse of these elements through awning and balcony

Single storey commercial – 1 storey row building		Parapet, possible failure through awning
Two storey commercial – row building		Parapet; OOP failure of upper storey wall

Two storey institutional – isolated building		Chimneys; OOP failure of upper storey wall
Two storey Bank – isolated building		Parapets; chimneys; OOP wall failure

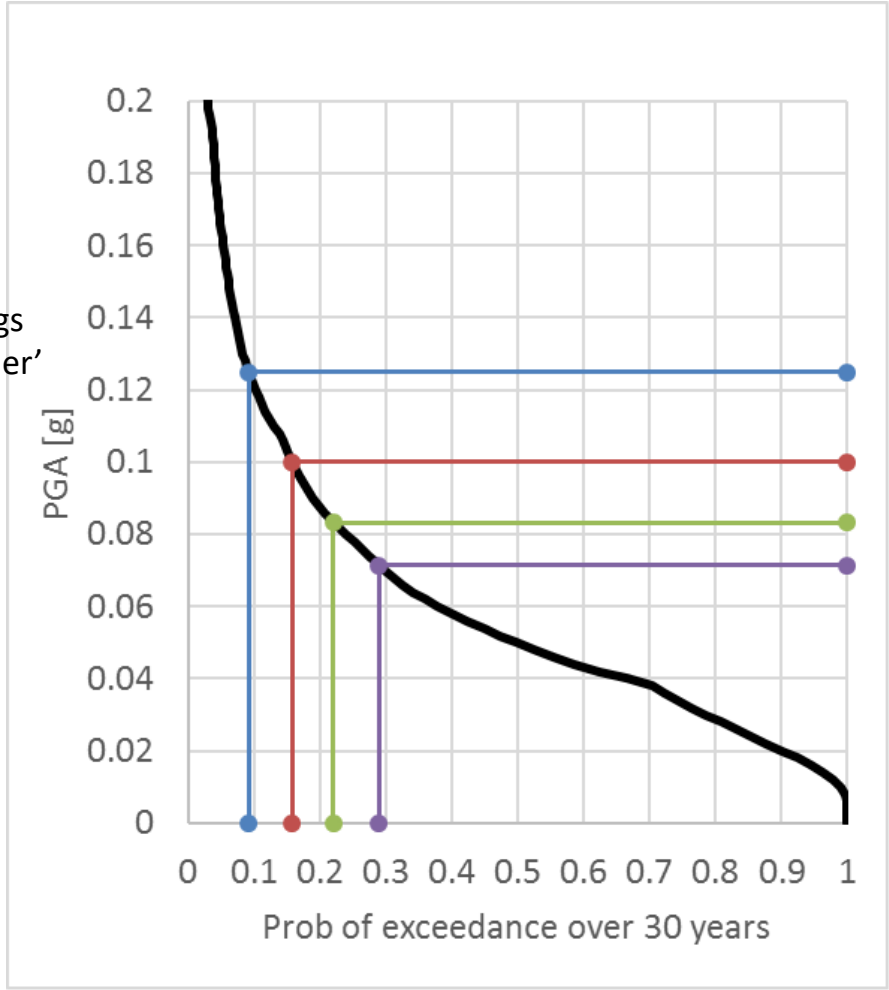
FRAGILITY CURVES FOR URM BUILDINGS

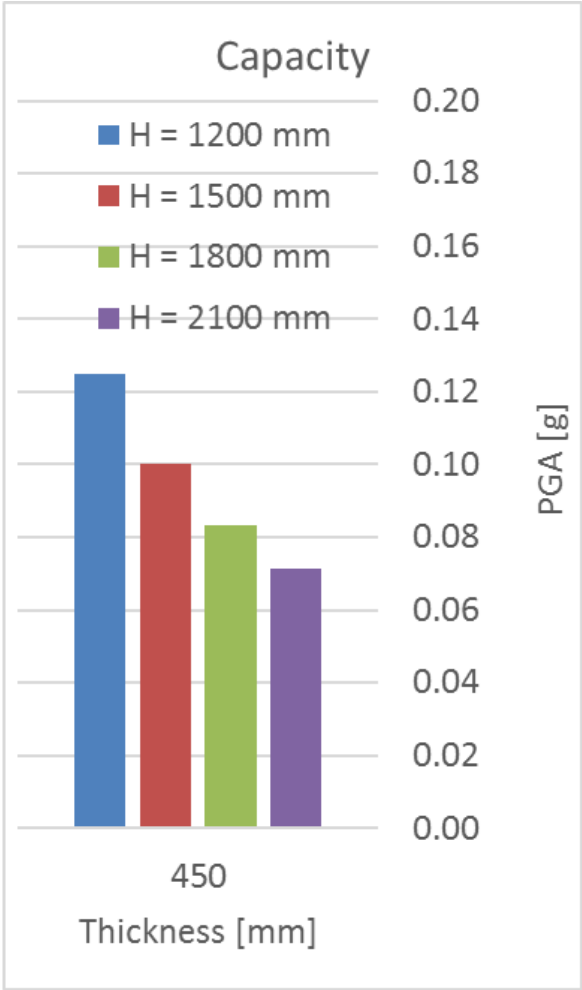


PGA CAPACITIES AND PROBABILITY OF EXCEEDANCE OVER 30 YEAR TIME HORIZON (YORK)

Chimneys

609 chimneys on
307 URM buildings
60 of them 'slender'



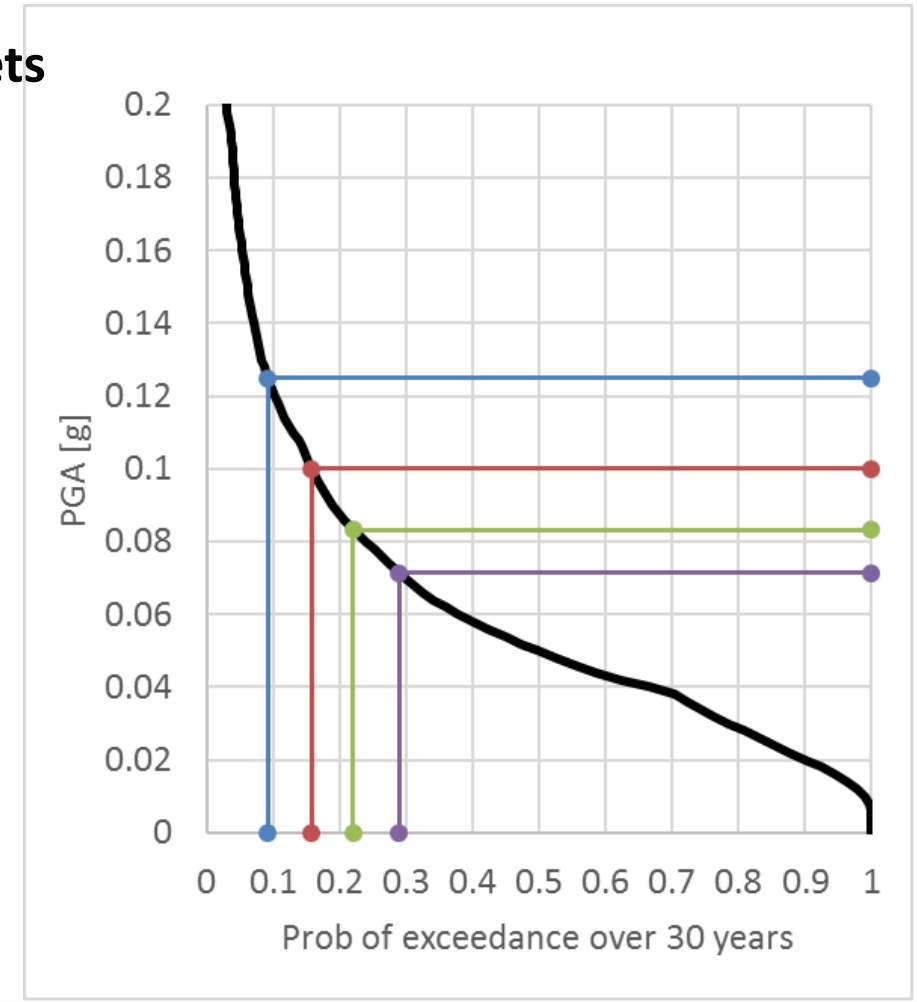


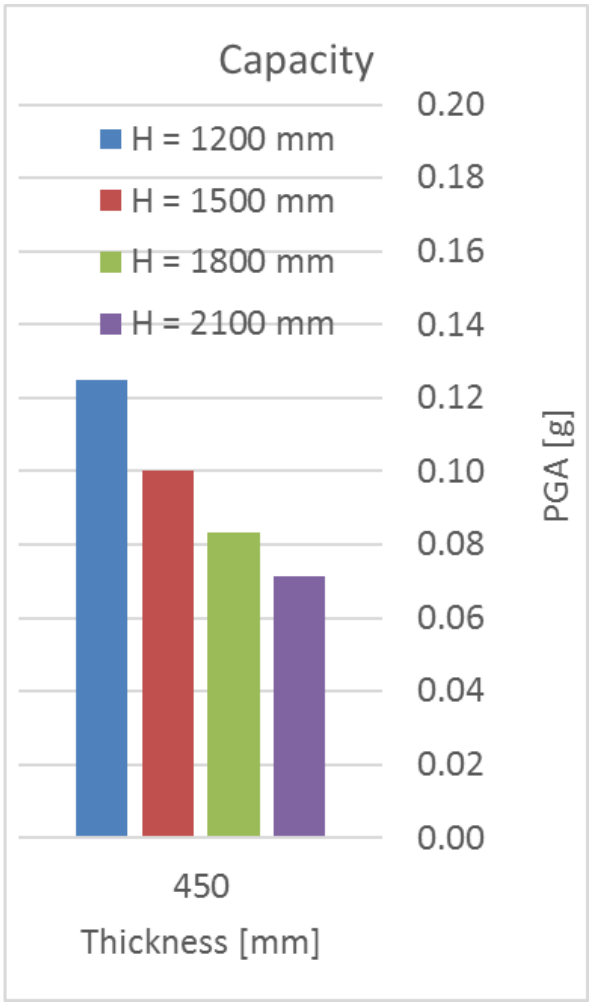
TYPICAL CHIMNEY FAILURES

A SUCCESSFUL CHIMNEY RETROFIT THAT SURVIVED THE M_W7.1 SEPTEMBER 2010 EARTHQUAKE IN CHRISTCHURCH.

PGA CAPACITIES AND PROBABILITY OF EXCEEDANCE OVER 30 YEAR TIME HORIZON

Parapets





2010 Kalgoorlie Earthquake

Parapet/awning damage in URM buildings in M5.0 earthquake

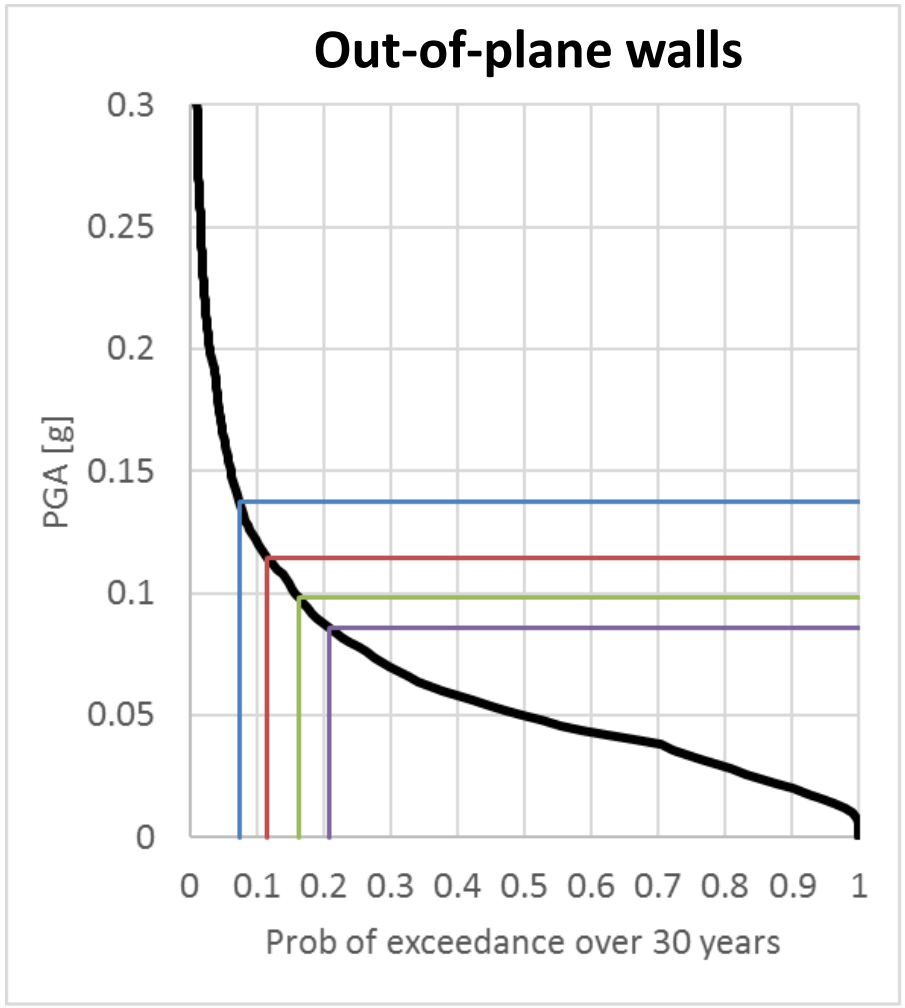
BOULDER, WA E/Q DAMAGE – SUCCESSFUL PARAPET RETROFIT

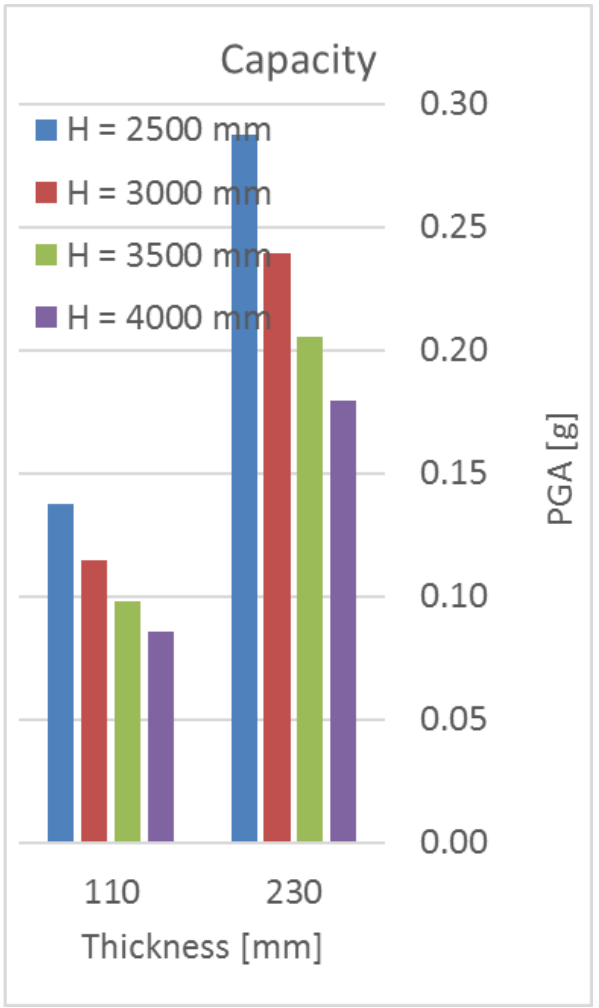
(a) Parapet front view

(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





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”