Cost-Effective Retrofitting Strategy for Limited Ductile Reinforced Concrete Buildings in Australia

Bin Xing[1,4], Raneem Alazem[1,4], Elisa Lumantarna [1,4], Nelson Lam[1,4], Scott Menegon[2,4], Hing-Ho Tsang[2,4], John Wilson [3,4], Emad Gad[2,4]

[1]Department of Infrastructure Engineering, The University of Melbourne, VIC, [2] Faculty of Science, Engineering and Technology, Swinburne University of Technology, VIC, [3] Swinburne University of Technology, Sarawak Campus, Kuching, Sarawak, Malaysia,
[4] Bushfire and Natural Hazards Cooperative Research Centre

Reinforced concrete buildings are common in Australia and have been commonly designed with little to no ductility. This poster presents a methodology to assess the potential vulnerability of buildings in seismic conditions and the need of retrofitting.

Research Aims
To develop a methodology, specifically suited for Australian buildings, **for the evaluation and prioritization of existing vulnerable RC buildings**, in order to propose suitable cost-effective retrofitting strategies.

Three-Tiered Methodology
The **methodology** will provide significant **time-savings in the vulnerability assessment of RC buildings.**
Retrofitting Strategies will be proposed for the different vulnerable buildings identified

Research Significance
The **development of simple framework** to **assess the potential risk and identify the need of retrofitting** for the **existing RC** buildings in Australia.

Research Significance
Rapid seismic evaluation of existing Australian RC buildings, as performing **detailed nonlinear** analysis is computationally expensive when a large amounts of buildings need to be assessed.

Possible Application
In addition, it can be used as a **preliminary study for the development of Australian seismic evaluation and retrofit standards** of the existing buildings.

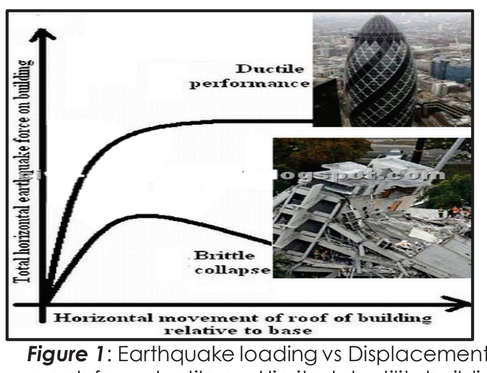


Figure 1: Earthquake loading vs Displacement graph for a ductile and limited ductility building

Proposed flowchart for Assessment Framework

Prior evaluation and site inspection

Check for vulnerable feature of category A

Vulnerable features : Category A
soft or weak-storey
Fragile structural wall
Unsecured or unfilled floor support
Inadequate foundation
Hollow-core floors

Figure 2: Soft storey building[1] . Menegon et al. (2019)

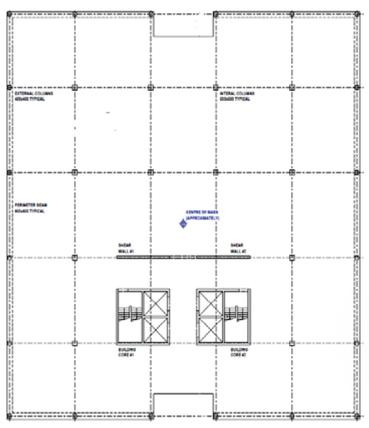
Level 1.1 scan check

Y → **Building is safe**

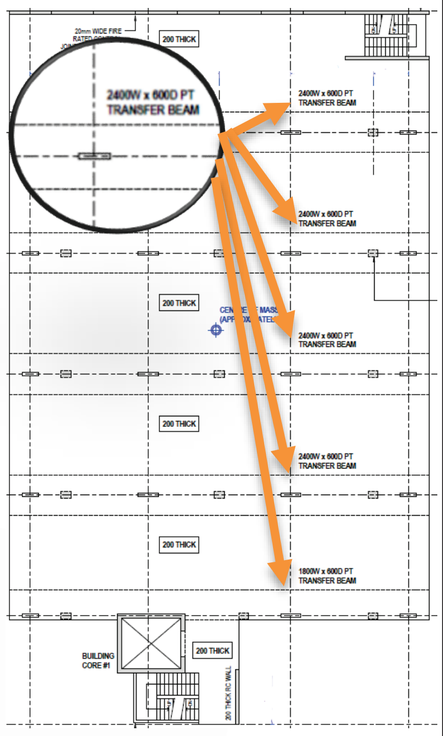
N → **Check for vulnerable feature of category B**

Building height range	Acceptance criteria
Building height up to 8m	No category A features
Building height up from 8m to 50m	Building with adequate bracings and no category A features. (symmetric building plan with minimum two major core walls)
Building height more than 50m	Buildings with adequate lateral bracings and no category A features

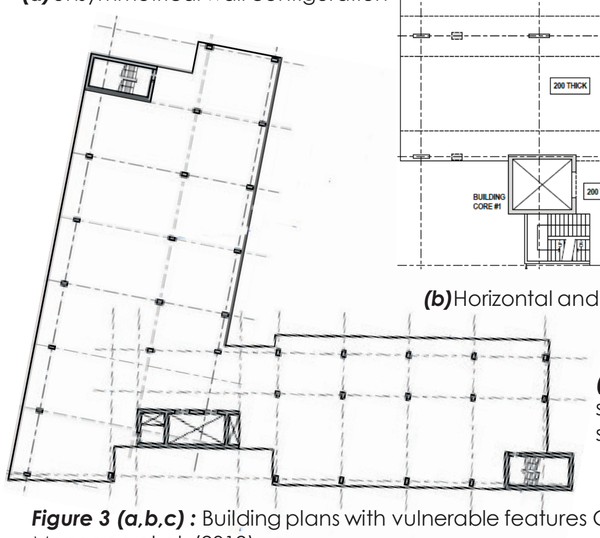
Vulnerable feature: Category B	
High axial load	Horizontal irregularities/ Unsymmetrical structural plan
Undersized column	
low column aspect ratio	Concrete spalling, cracking, disintegration.
Non-ductile detailing	
Vertical irregularities	Inadequate wall anchorage
Soil Class D/E	



(a)Unsymmetrical wall configuration



(b)Horizontal and vertical irregularities



(c)Highly stressed, high strength RC columns with small dimensions

Figure 3 (a,b,c) : Building plans with vulnerable features Category A & B[1]. Menegon et al. (2019)

Level 1.2 scan check

Y → **Building is safe**

Identify if there are **any category A features and more than one category B feature** . The check may require simple hand calculations.

N → **Level 2 scan check**

Y → **Building is safe**

Conservative check, including **calculations to identify deficiencies found in Level 1 scan**: torsional stiffness, eccentricity, and earthquake demand by applying linear elastic analyses such as generalized force method (GFM) or linear elastic dynamic analysis in accordance with AS1170.4.

N → **Level 3 scan check**

Y → **Building is safe**

If the building does not pass level 2 check, **rigorous analysis are required such as pushover or dynamic time-history analysis based on the non-linear behaviour of the RC building.**

N → **Work out if retrofit for torsion or translational of critical column is required**

→ **Non-structural component checklist**

→ **Decision making of retrofitting strategies for the building**

Retrofitting strategies depend on

- Nonlinear analysis of typical Australian limited ductile RC buildings
- Governing failure modes and local location of failure
- Finding suitable retrofitting method for each governing failure mode
- Comparison of structural behaviour before/after retrofitting
- Cost benefit analysis to obtain the most cost effective solution

[1] Menegon, S.J., Tsang, H.H., Lumantarna, E., Lam, N…K., Wilson, J.L. and Gad, E.F., 2019, "Framework for seismic vulnerability assessment of reinforced concrete buildings in Australia", Australian *Journal of Structural Engineering*, in press (April 2019),