IMPROVEMENTS AND DIFFICULTIES ASSOCIATED WITH THE SEISMIC ASSESSMENT OF INFRASTRUCTURE IN AUSTRALIA

Ryan Hoult
Department of Infrastructure Engineering, The University of Melbourne, Victoria

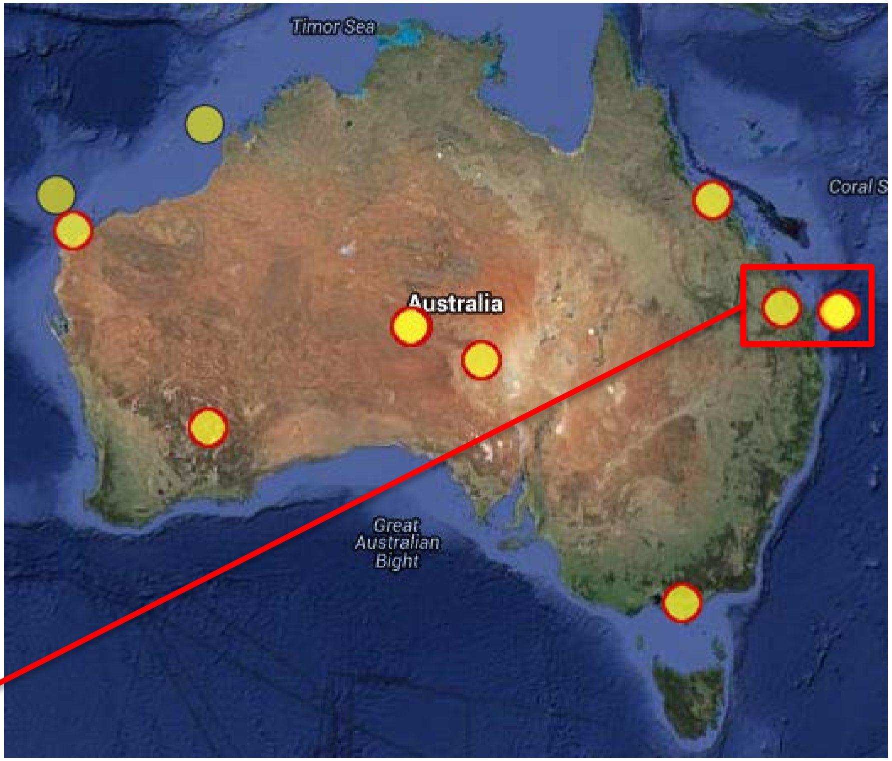
An Australian Government Initiative

CONTENTS

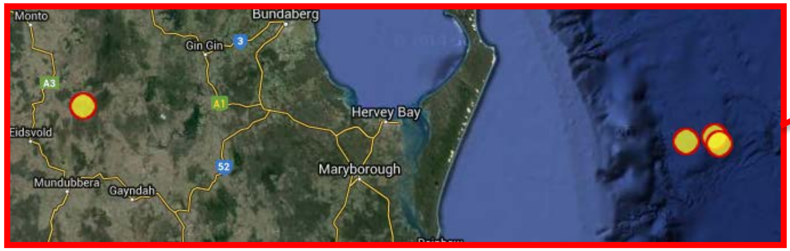
- History of Australian Earthquakes
- Motivation of research
- Seismic Assessment of RC Buildings
  - Demand
  - Capacity

AUSTRALIA – A LOW-TO-MODERATE SEISMIC REGION

- 2 x M>5 per year
- Higher level of seismic activity than other intraplate areas

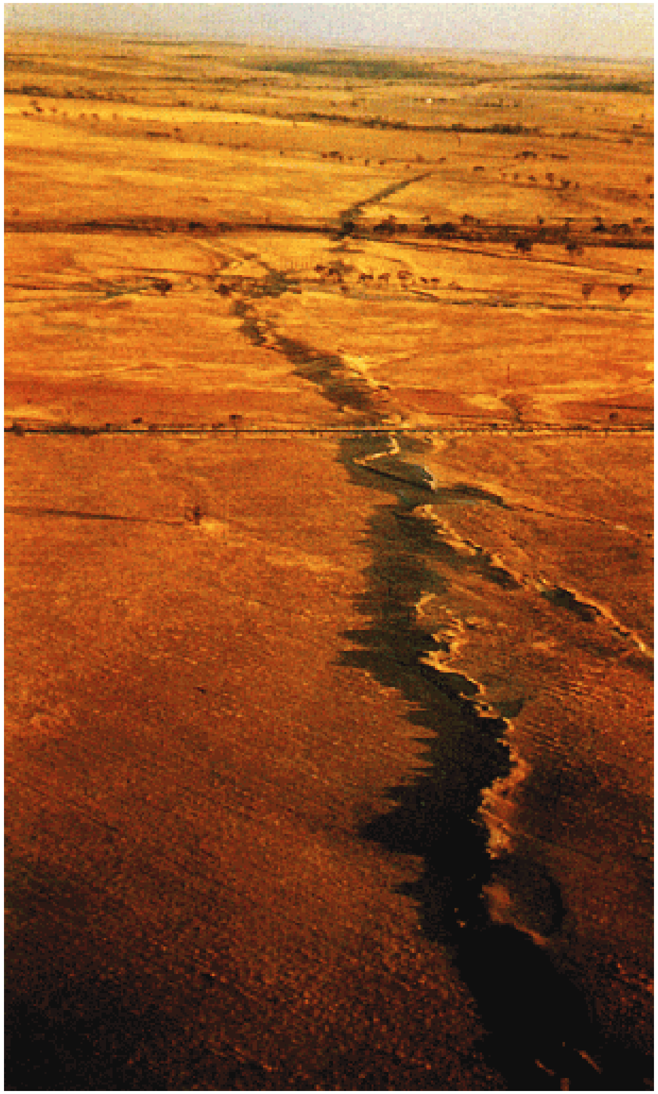


M>5 from 2005-present – GeoScience Australia



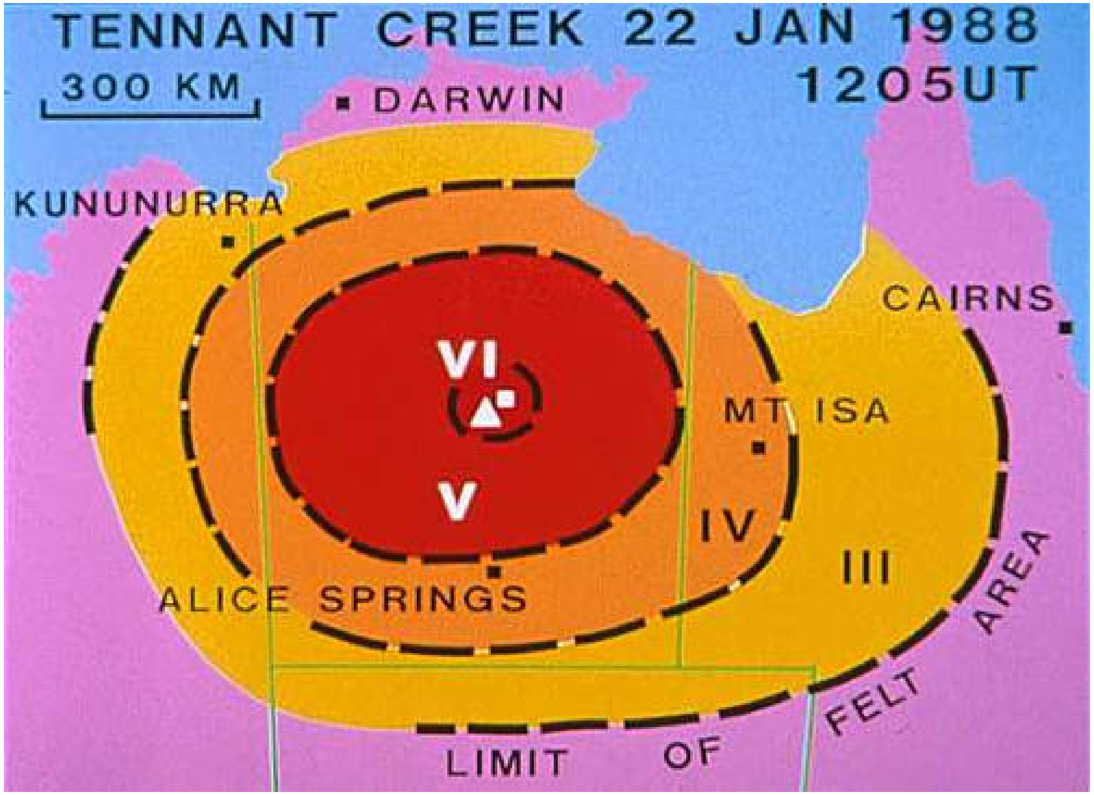
MECKERING (WA) 1968

- M 6.8
- Ruptured the surface for 35km



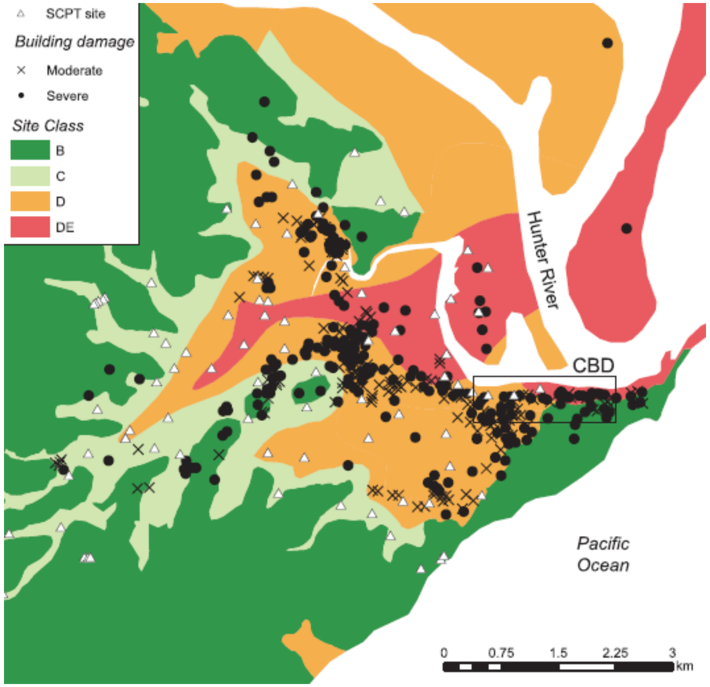
TENNANT CREEK (NT) 1988

- M 6.3
- M 6.4
- M 6.7



NEWCASTLE (NSW) 1989

- M 5.6
- 13 people killed
- AUD $3.2 billion
- AS 1170.4 (1993)



(McPherson and Hall, 2013)

MOTIVATION

(Photo by Jo Johnson)

I want to improve the performance of reinforced concrete wall and core buildings in Australia…

…by recommending cost effective detailing requirements…

…because the current detailing requirements have created a non-ductile building stock in Australia that is potentially vulnerable to a rare earthquake event.

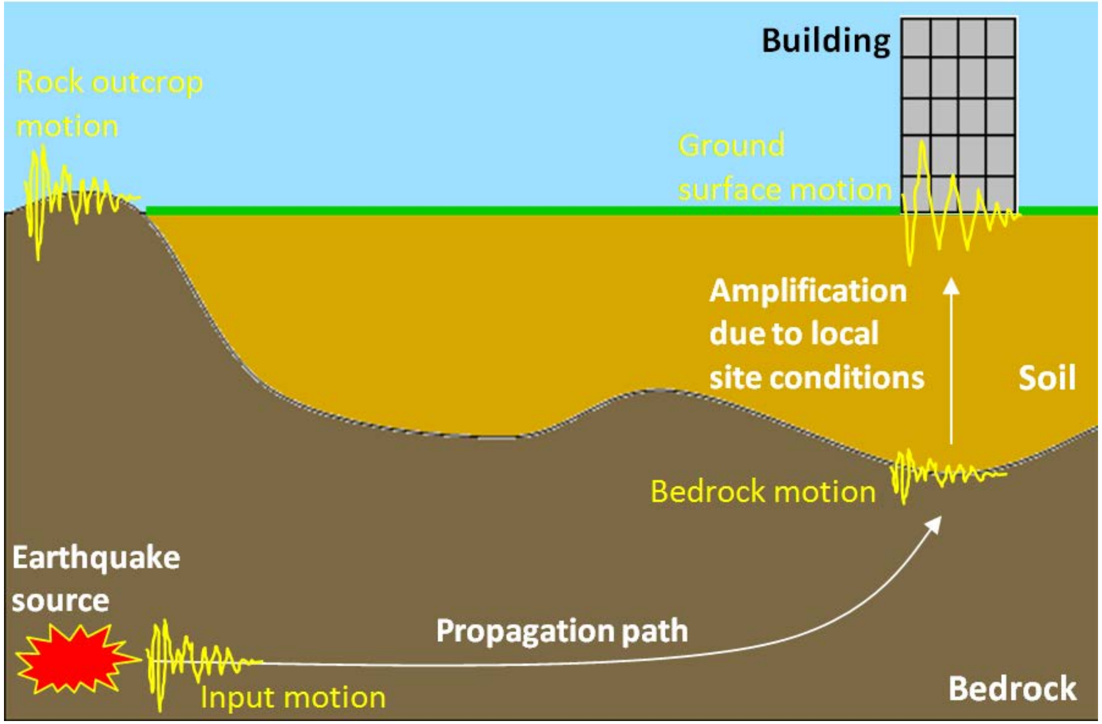
SEISMIC PERFORMANCE OF RC WALL AND CORE BUILDINGS

- A need for the understanding of the seismic performance of the Australian building stock

- Reinforced Concrete (RC) structures represent a great majority of that building stock

SEISMIC ASSESSMENT OF RC BUILDINGS

- DEMAND
  - Earthquake Recurrence Model
  - Seismic Attenuation
  - Site Amplification
- CAPACITY
  - Performance Objectives
  - Strain Limits
  - Plastic Hinge Length



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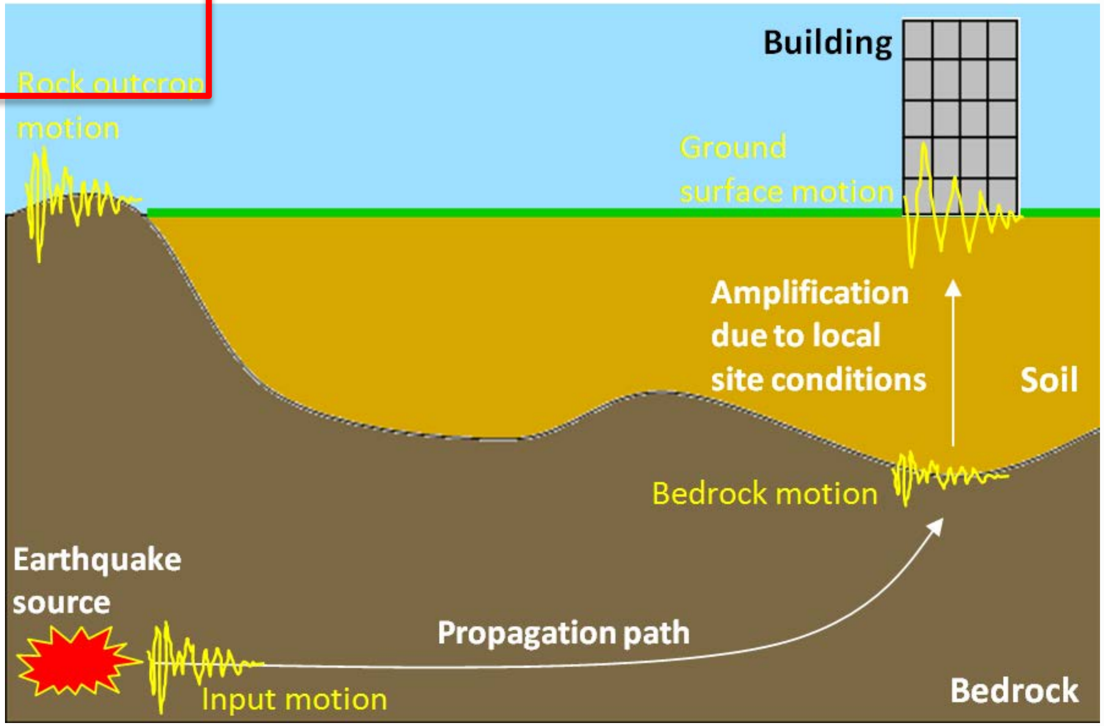
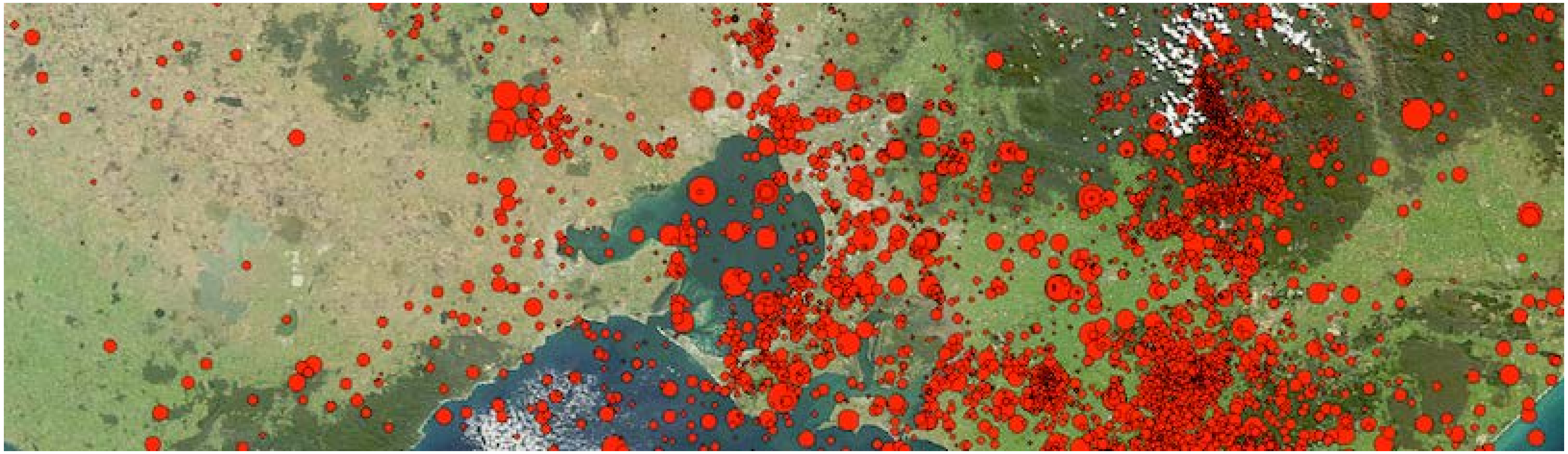


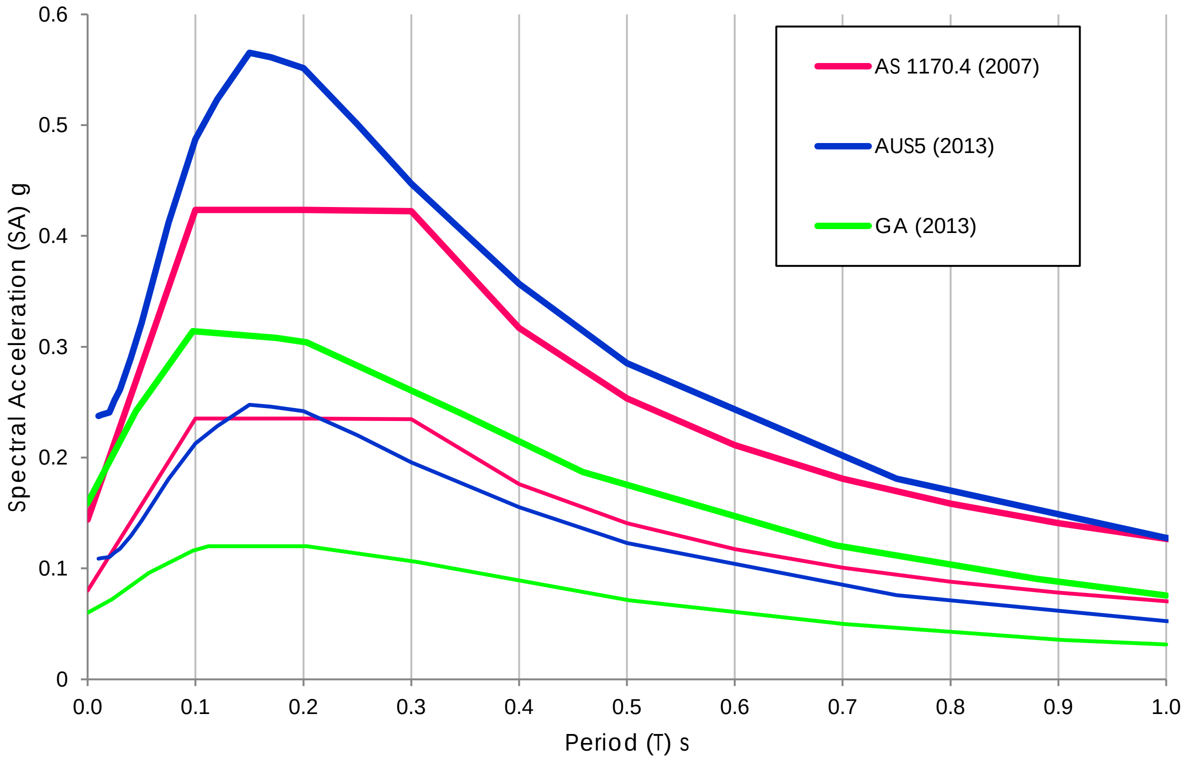
EARTHQUAKE RECURRENCE MODELS

- GA
- AUS5 (Brown & Gibson, 2004)



EARTHQUAKE RECURRENCE MODELS

- 500 and 2500 year return period spectra for Melbourne



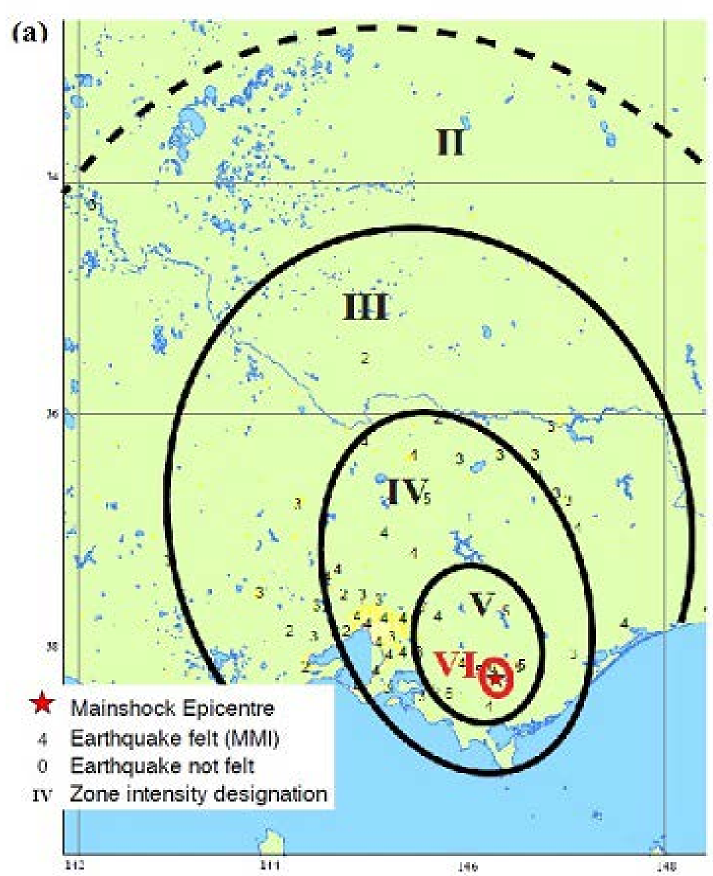
EARTHQUAKE RECURRENCE MODELS

Probability Factor (k_p)

	Probability Factor (k_p)		
Location	AS 1170.4 (Standards Australia, 2007)	GA (Leonard *et al.*, 2013a)	AUS5 (Hoult, 2014)
Adelaide	1.80	2.69	2.18
Brisbane	1.80	3.05	3.31
Melbourne	1.80	2.62	2.36
Perth	1.80	2.67	2.09
Sydney	1.80	2.83	2.08
Canberra	1.80	2.77	2.14
Hobart	1.80	3.01	3.09

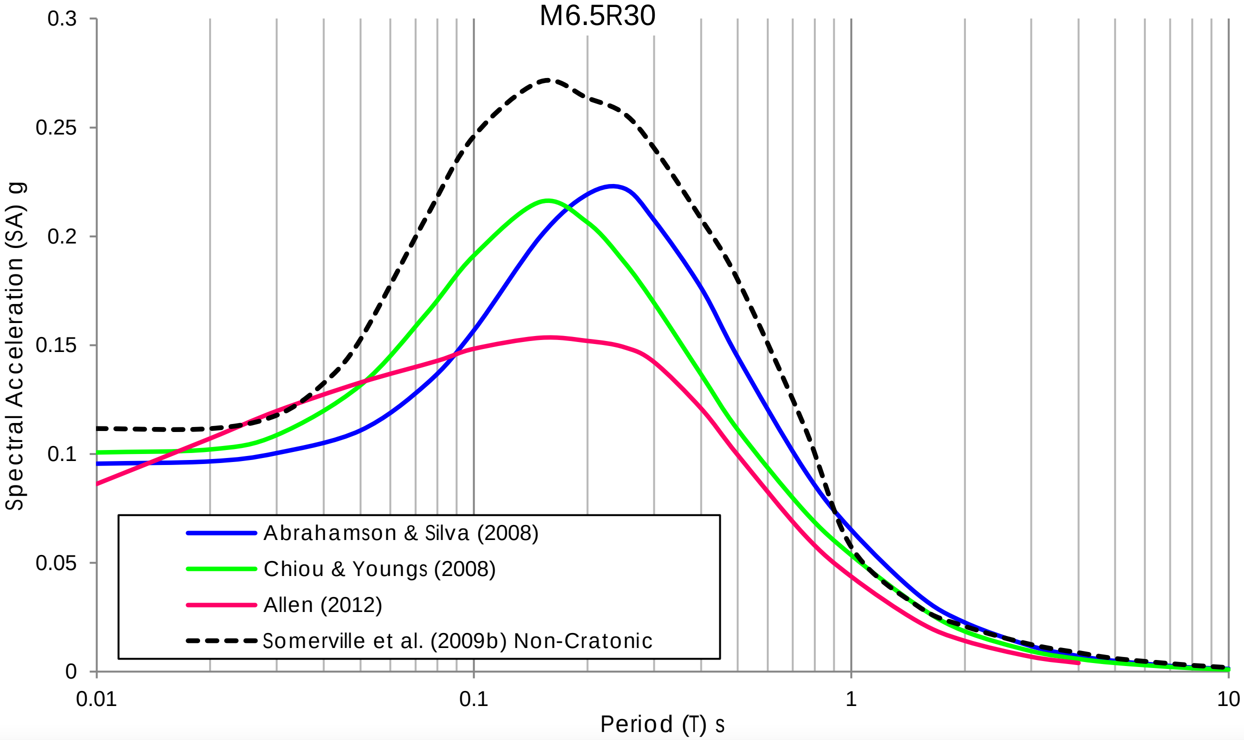
SEISMIC ATTENUATION IN AUSTRALIA

- Ground Motion Prediction Equations (GMPEs)
- Predict ground motions response
- No validated model for Australia



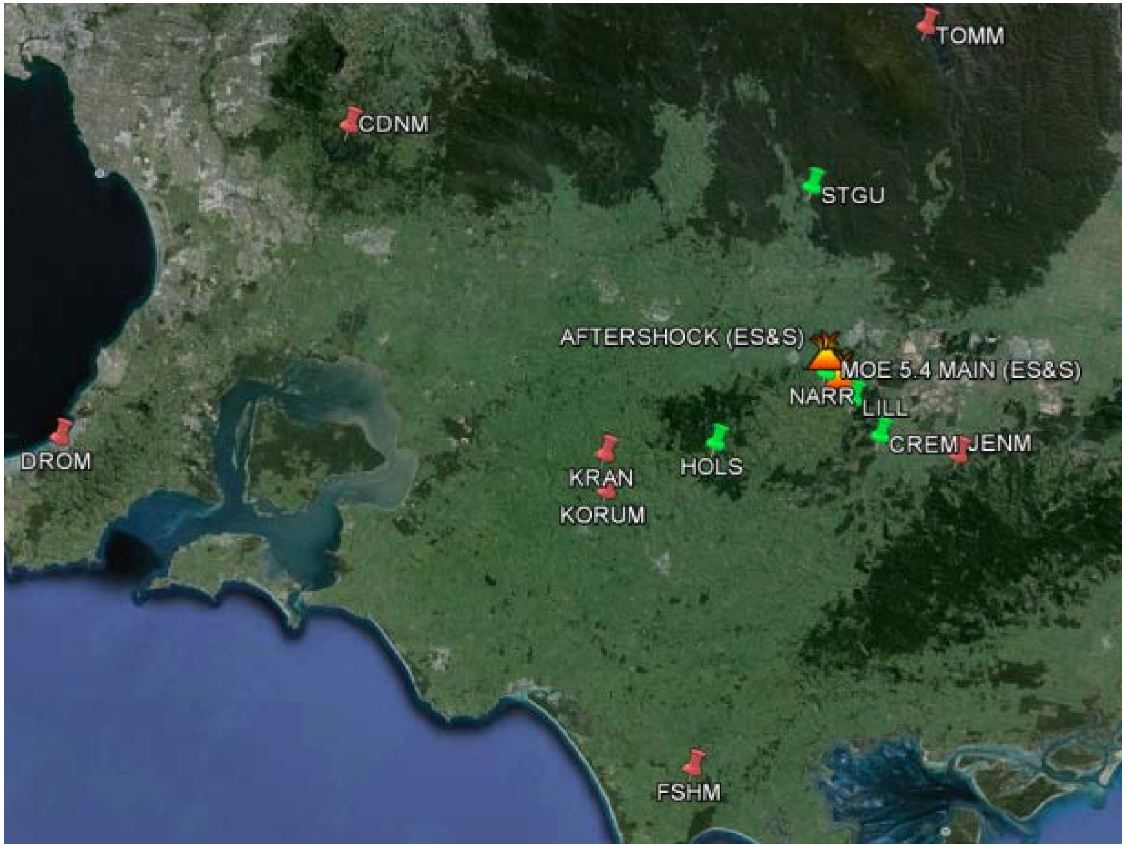
CHOICE OF GMPES

- Important for hazard studies
- Variability in prediction



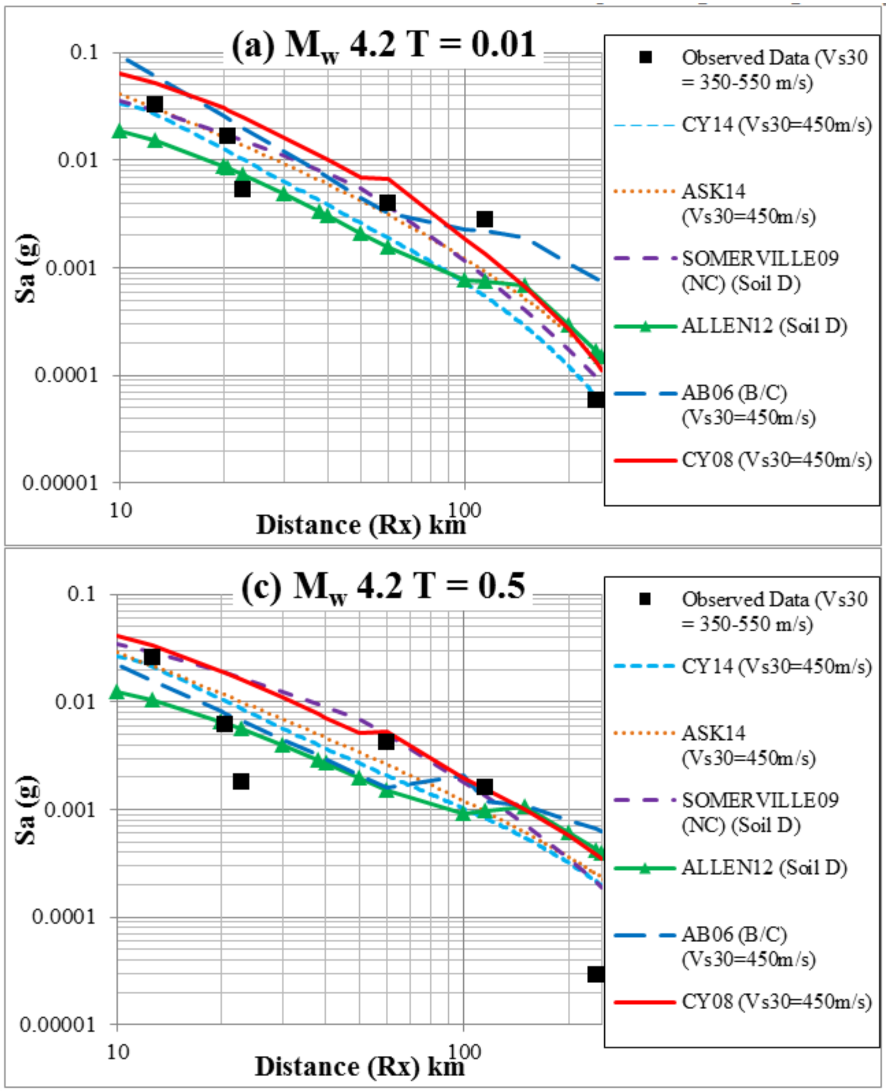
MOE (VIC) 2012

- M 5.4 (Main event)
- 8 Recordings
- M 4.4 (Aftershock)
- 13 recordings



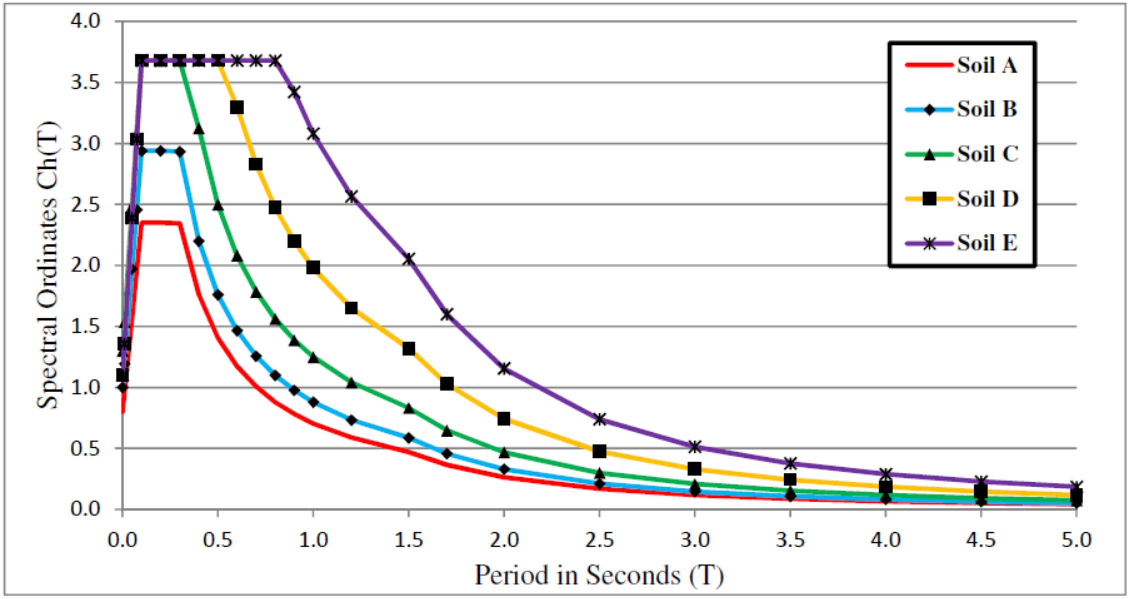
MOE (VIC) 2012

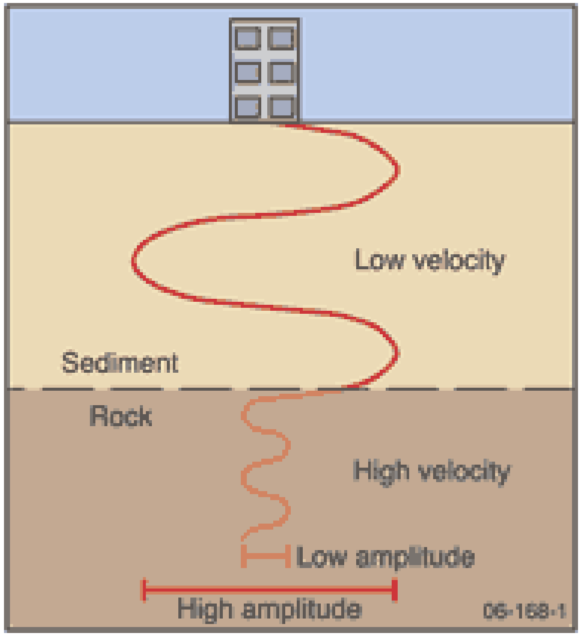
- Recommended GMPEs
- Further research needed
- Increase number of recorders



SITE RESPONSE

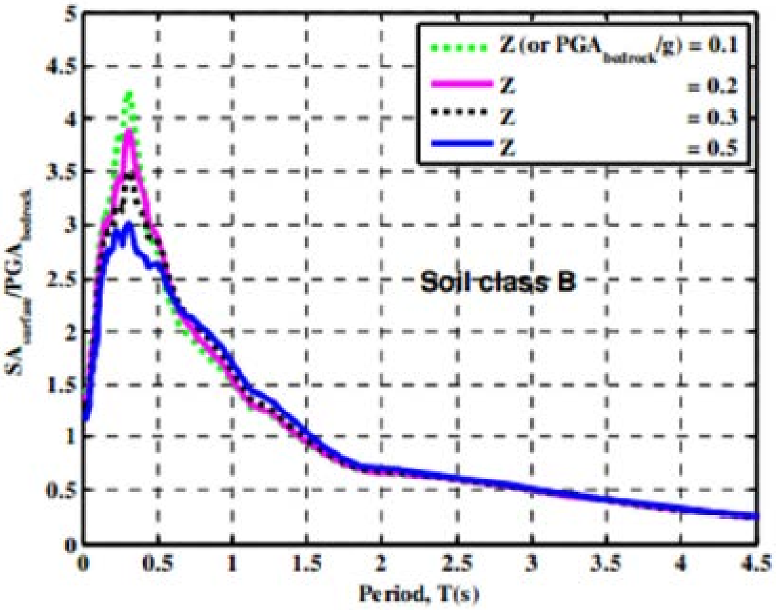
- Hard rock = less amplification
- Softer soil = greater amplification

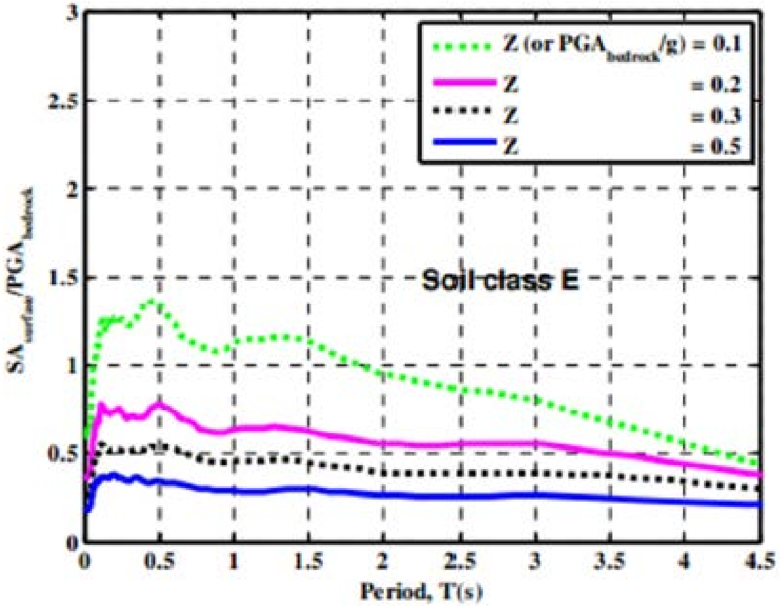




SITE RESPONSE

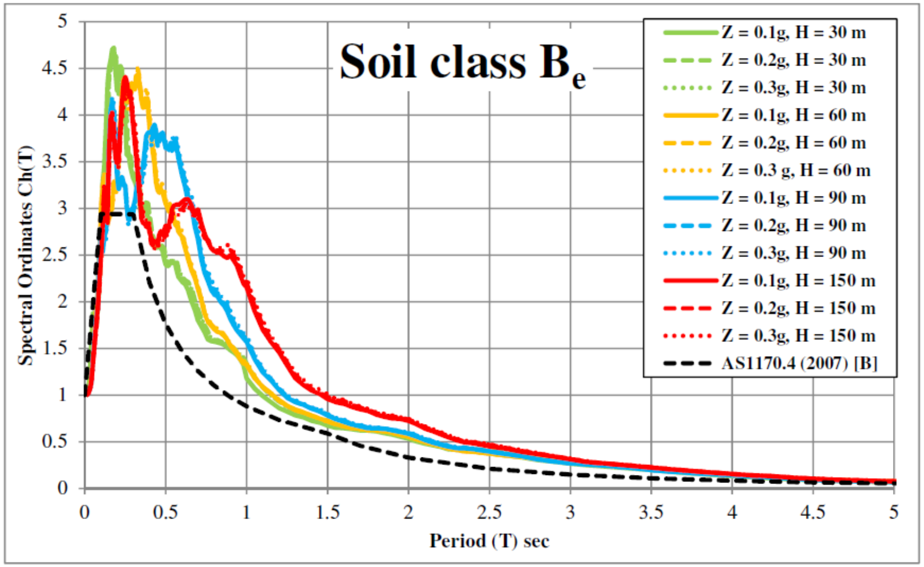
- Amplification dependent on:
  - V_s (shear wave velocity)
  - Z (intensity)

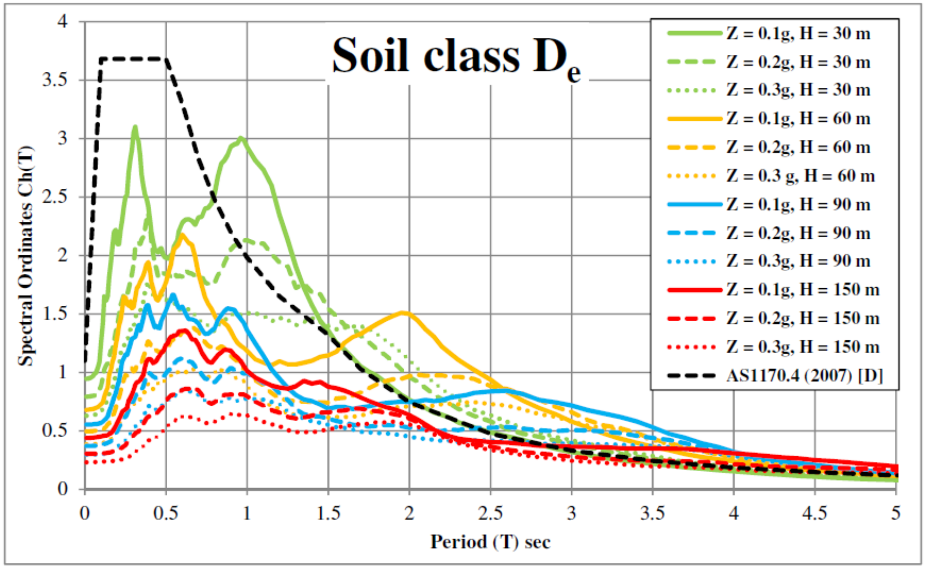




SITE RESPONSE

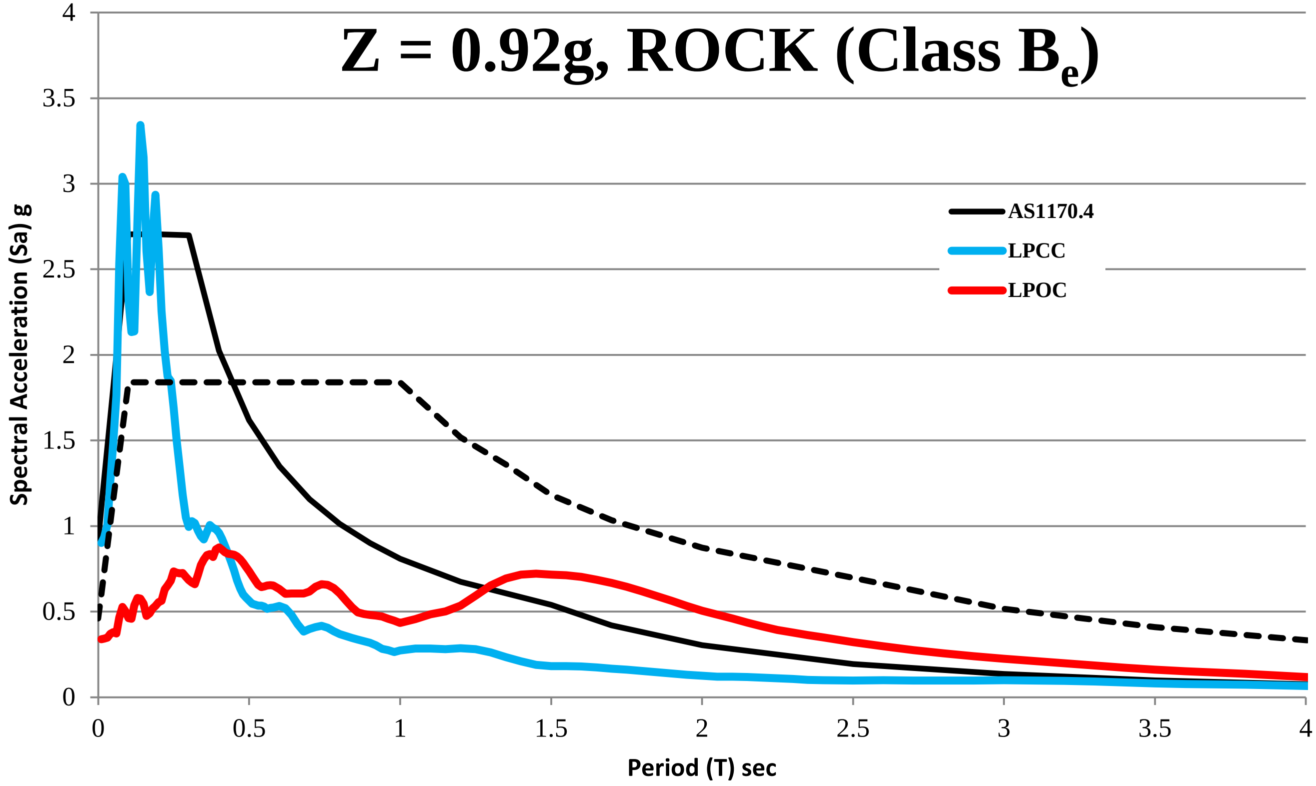
- UoM research revealed same intensity dependent parameter





SITE RESPONSE

- Observed in reality?



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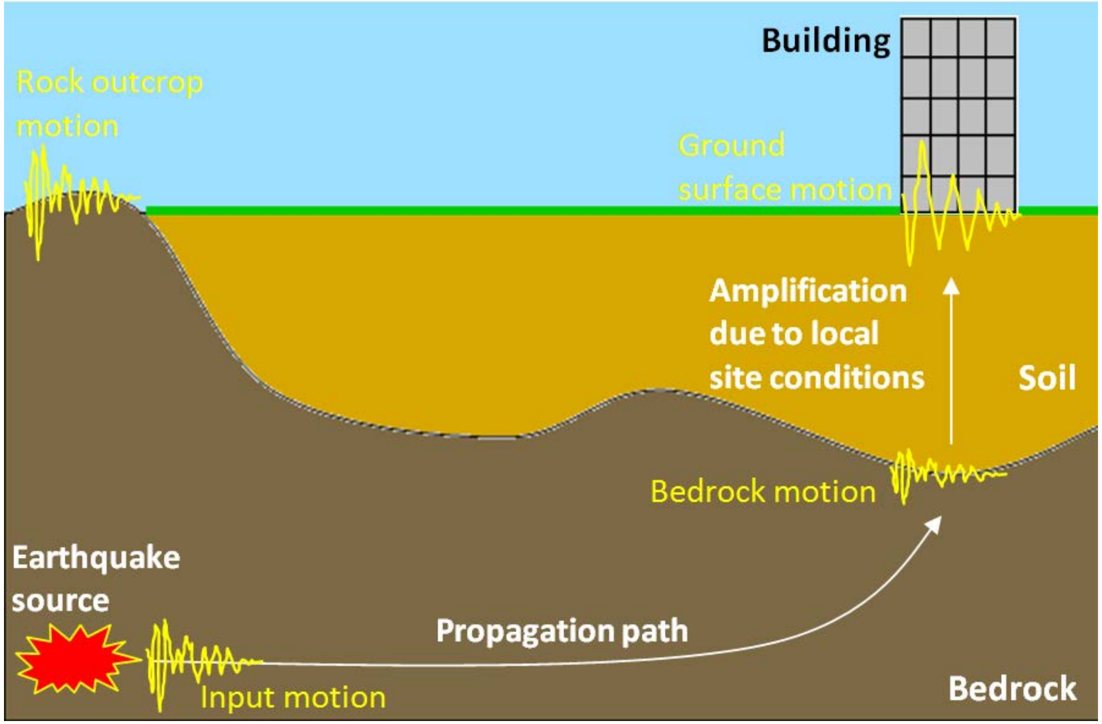
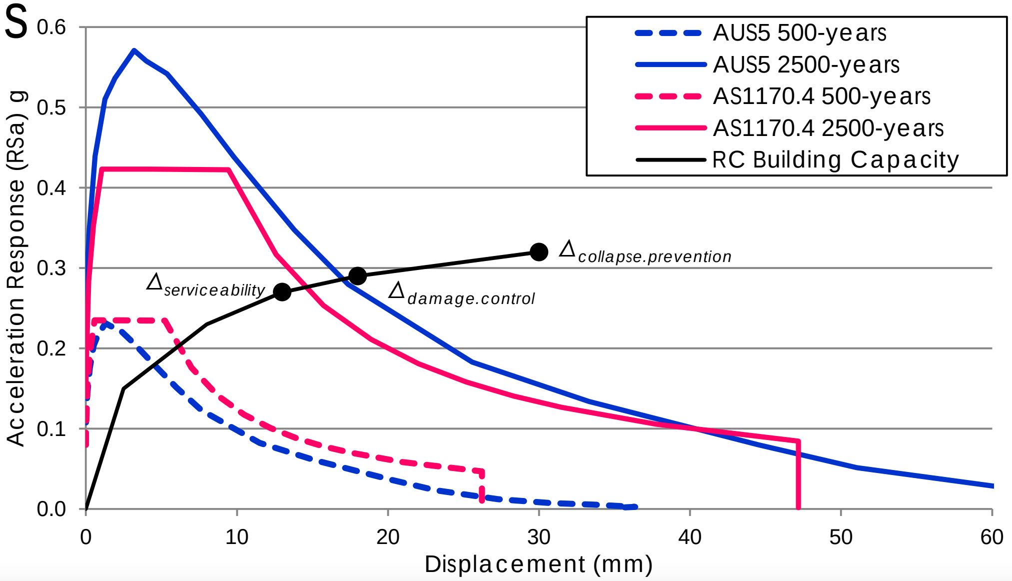


CAPACITY OF A STRUCTURE

- Acceleration-Displacement Response Spectrum (ADRS)
- Displacement-Based Assessment (DBA)
- Performance Objectives



STRAIN LIMITS

- Steel and concrete strain limits determined for unconfined concrete

- Drift limits are also determined for the performance objectives considered

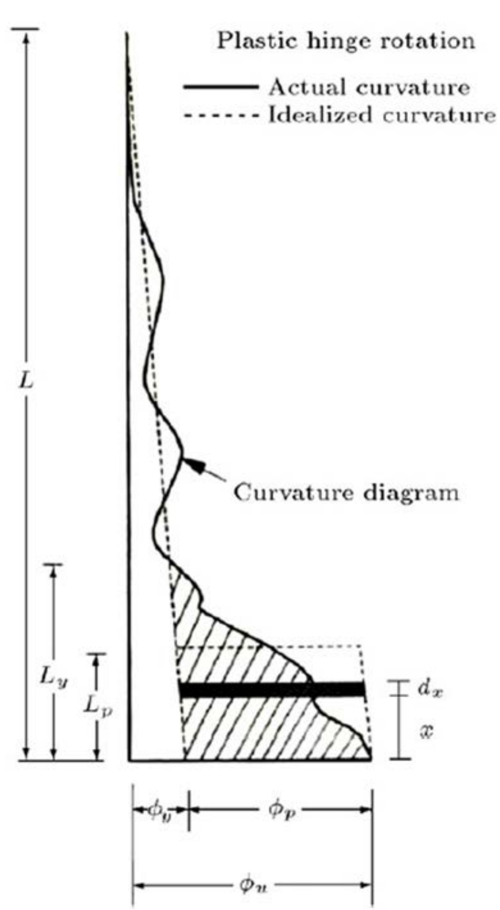
Structure Performance Limit State (Unconfined Concrete)	Concrete Strain (ε_c)	Steel Strain (ε_s)	Drift Limits (%)
Serviceability: The concrete stress-strain curve is close to linear and steel strains limited to twice the nominal yield value so that residual crack widths are small.	0.0010	0.005	0.5
Damage Control: Concrete is now in non-linear range but there is a low expectation of spalling. Steel strains are sufficiently low so that repair is inexpensive; Also, there is low likelihood of low cycle fatigue or out-of-plane buckling on load reversal.	0.0015	0.010	1.5
Collapse Prevention: Ultimate limit state of concrete at spalling due to the very brittle nature of the potential failure (crushing and longitudinal bar buckling). Steel strains are limited to prevent collapse due to low cycle fatigue (due to inelastic cycles in main event plus aftershocks) and out-of-plane buckling on reversal of load.	0.0030	0.015	-

PLASTIC HINGE LENGTH

- $\Delta_i = \Delta_y + \Delta_p = \frac{\varnothing_y H_i^2}{2}\left(1 - \frac{H_i}{H_n}\right) + (\varnothing_{ls} - \varnothing_y) L_p H_i$

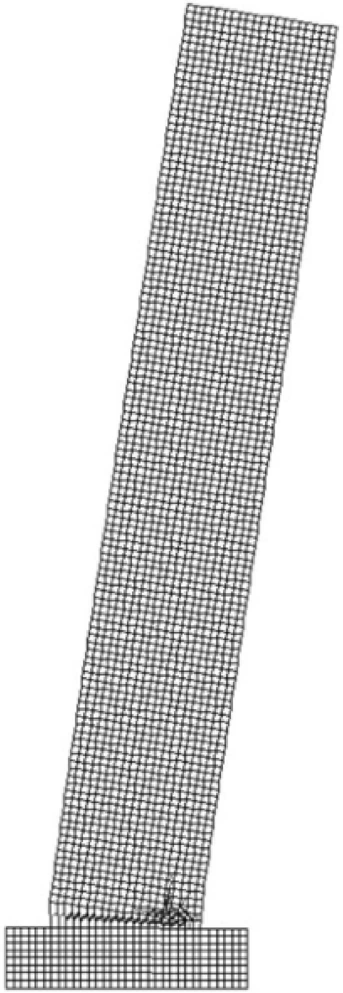
- Plastic Hinge Length (L_p) equations exist for heavily reinforced walls ($\approx \rho_{wv} > 1.0\%$)

- RC walls with light reinforcement have performed poorly



GALLERY APARTMENTS BUILDING

- Christchurch Earthquake
- "Lightly" reinforced wall (ρ_{wv}=0.16%)
- Insufficient amount of reinforcement to initiate "secondary cracking"

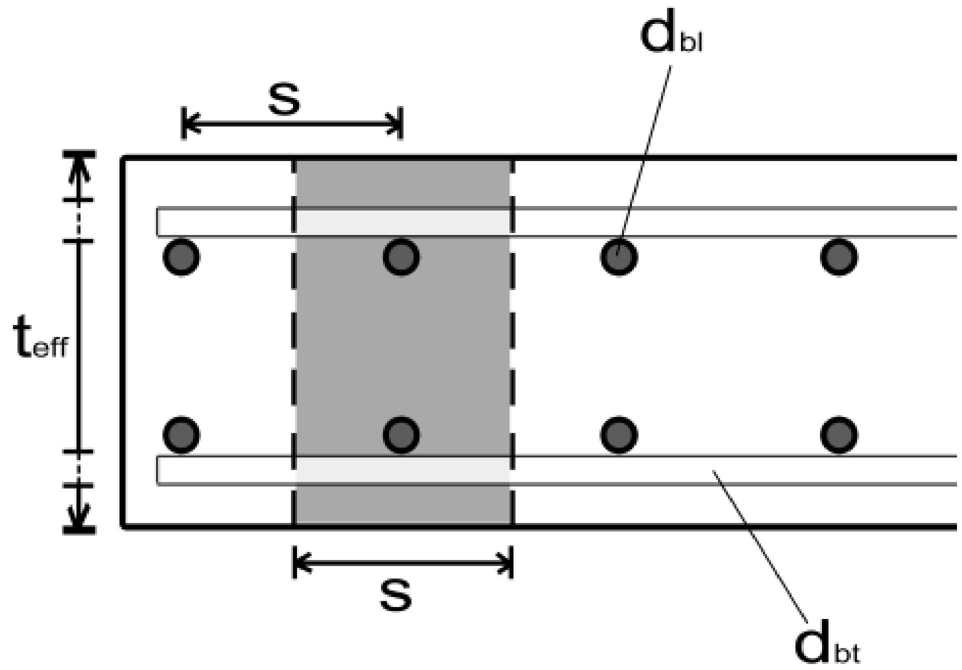


PYNE GOULD CORPORATION BUILDING

…'it was unlikely that sufficient tension could have been transmitted to initiate a secondary crack in the concrete'…

(CERC, 2012)

SECONDARY CRACKING MODEL



$$t_{eff} = t - (n_t . d_{bt})$$

$$A_{eff} = t_{eff} s$$

$$T = n_l A_b f_u$$

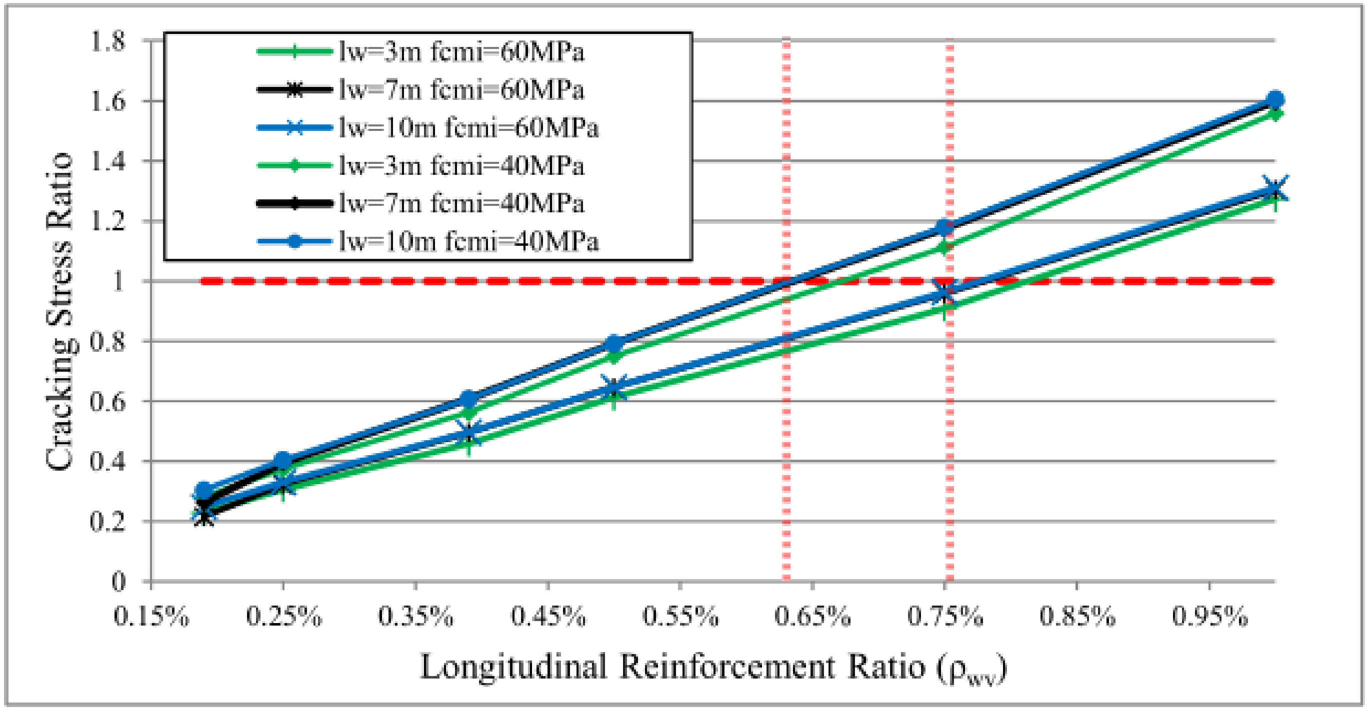
$$\sigma_{crack} = \frac{T}{A_{eff}}$$

$$\text{Cracking stress ratio} = \frac{\sigma_{crack}}{f'_{ct.f}}$$

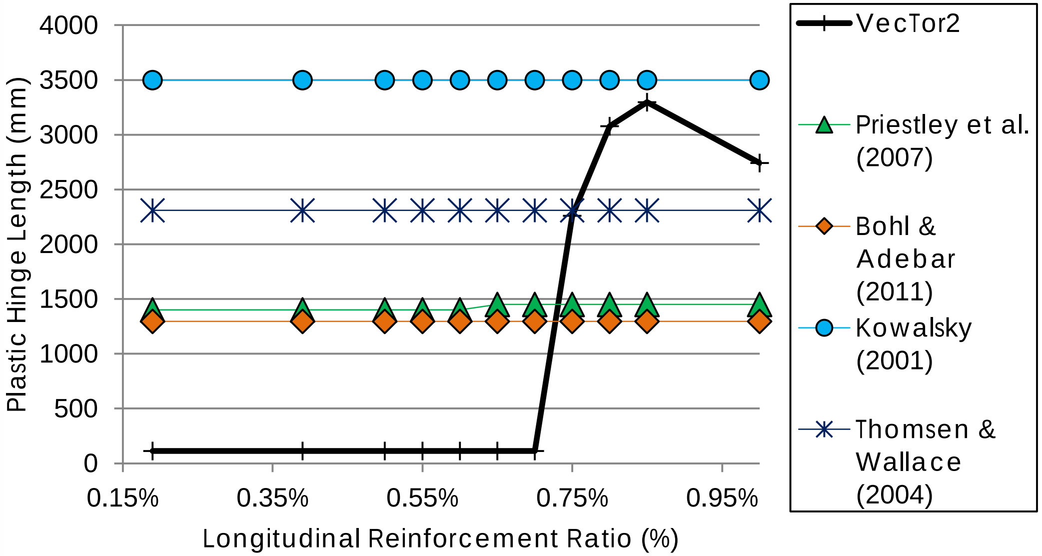
SECONDARY CRACKING MODEL

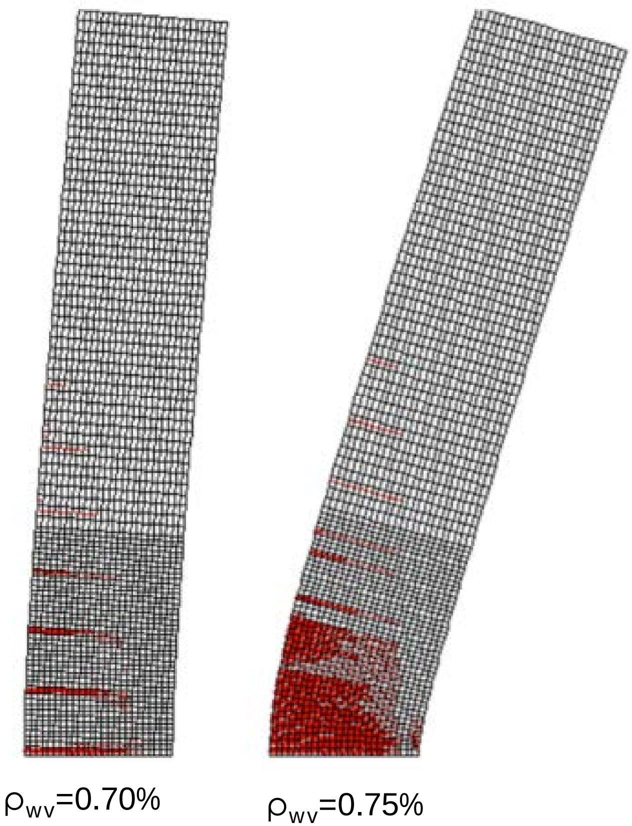
- $\rho_{wv.min} = 0.15\%$

- Is $\rho_{wv.min}$ sufficient?



FINITE ELEMENT MODELING – VECTOR2





MINIMUM REINFORCEMENT

- Minimum longitudinal reinforcement in RC walls to initiate "secondary cracking"

e.g. f_{cm}=32MPa, f_y=500MPa, f_u=540MPa

$$\rho_{wv.min} = \frac{0.54\sqrt{\kappa f_c'}}{f_u}$$

→ 0.0057 = 0.57%

$$\rho_{wv.min} = \frac{0.4\sqrt{f_c'}}{f_y}$$

→ 0.0055 = 0.45%

(SESOC, 2011)

Still much higher than 0.15%!!!

CONCLUSION

- Uncertainties still exist
- Improvements to the hazard (demand) and capacity models
- Minimum reinforcement too low?
- Further research at UoM

ACKNOWLEDGEMENTS

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