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The Serviceability of Resilient NZ Seismic Design

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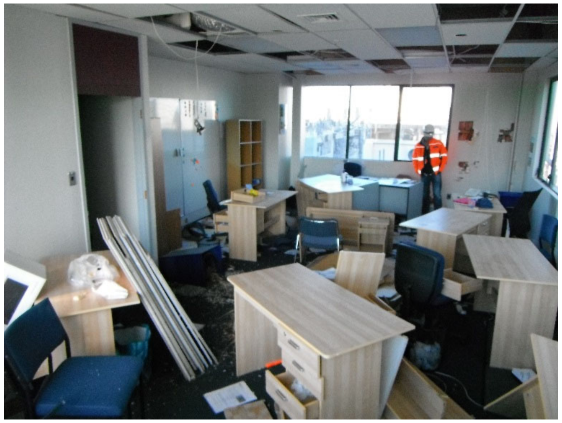
Introduction

- Recent NZ earthquakes have driven a lot of thought on acceptable building seismic performance – generally focused on building systems and details of design philosophy rather than methodology
- Are we satisfactorily meeting Serviceability performance expectations?
- Are we reaching far enough into the structural design industry to have real effects?
- In review of the Japan Building Standard Law (BSL)

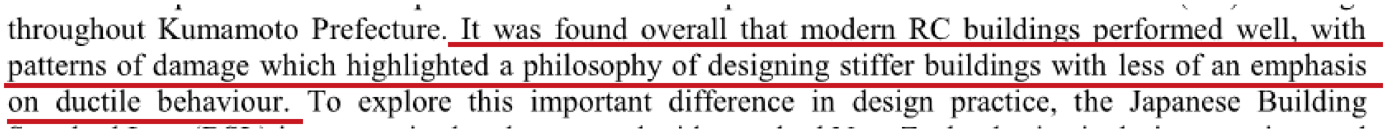
and

- US Performance-Based Design

We find a complete reversal in the order of design to standard NZ practice



Kumamoto 2016 – a driver for reconsidering things



throughout Kumamoto Prefecture. It was found overall that modern RC buildings performed well, with patterns of damage which highlighted a philosophy of designing stiffer buildings with less of an emphasis on ductile behaviour. To explore this important difference in design practice, the Japanese Building

- The NZSEE reconnaissance team visit to Kumamoto in June 2016 gained a strong impression of what resilient seismic performance looks like in a major city
- The subsequent NZSEE Bulletin paper explored the key differences in RC seismic design philosophy
- …and found some big differences in strength and stiffness outcomes
- Notably the limited spectrum reduction that is allowed using the D_s factor compared to μ or R
- **Highlighted that reliable performance across a wide-range of buildings is upheld by limiting deformations**

Methodology Comparisons

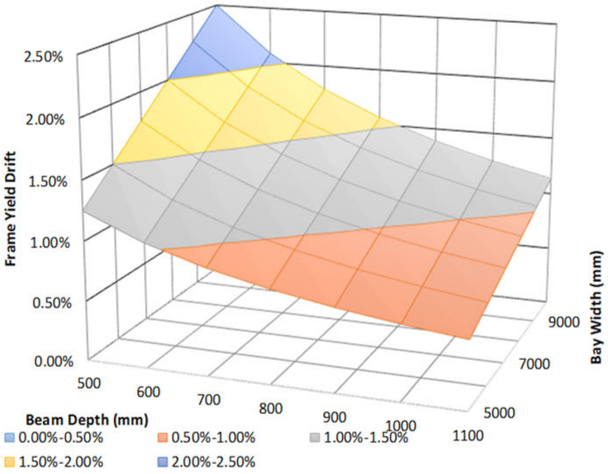
- Noted that that the Japan BSL sets out Level 1 Damage Limit (SLS) design as governing the initial design decisions on strength and stiffness to ensure elastic response for $\theta \leq 0.5\%$
- With a design "check" of inelastic base shear capacity for Level 2 Ultimate Limit State performance
- This bears a remarkable similarity to the Performance-Based Design approach that has been adopted from the Tall Buildings Initiative on the US West Coast.

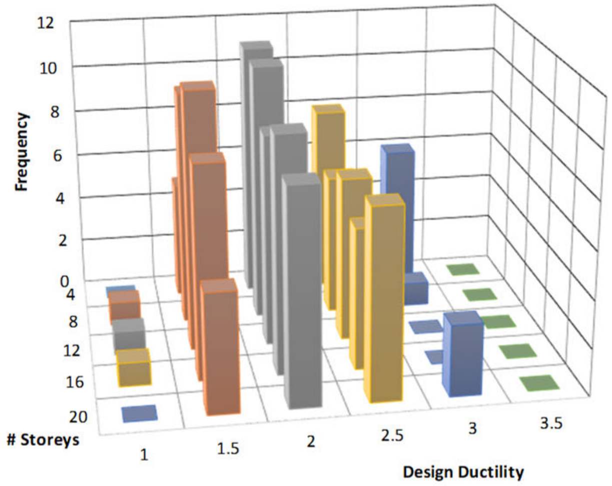
	Serviceability	**Ultimate Limit State/Life-Safety**
New Zealand NZS1170.5	No drift limit $\mu \leq 1.25$ Design check **25 yr RP with 5%**	$\theta \leq 2.5\%$ $\mu \leq 6$ **Primary design** 500 yr RP with 5%
Japan BSL	$\theta \leq 0.5\%$ $\mu = 1$ Elastic **Primary Design** **≈ 50 yr RP with 5%**	$\theta = 1.0\%$ (develop design base-shear) $D_s \geq 0.3$ Design check ≈ 500 yr RP with 5%
US PBD LATB Guidelines	$\theta \leq 0.5\%$ $\mu \approx 1$ Elastic **Primary Design** **43 yr RP with 2.5%**	$\theta \leq 3.0\%$ Design check MCE_R = 2500 year RP

What is the outcome of SLS 50 year RP?

- In the NZ context it reduces the maximum design ductility that can be assumed in determining the design spectrum reduction for ULS
- Indicatively this is $\mu \leq 3$
- Which is interesting because that aligns with the likely maximum design ductility outcomes from Direct Displacement-Based Design

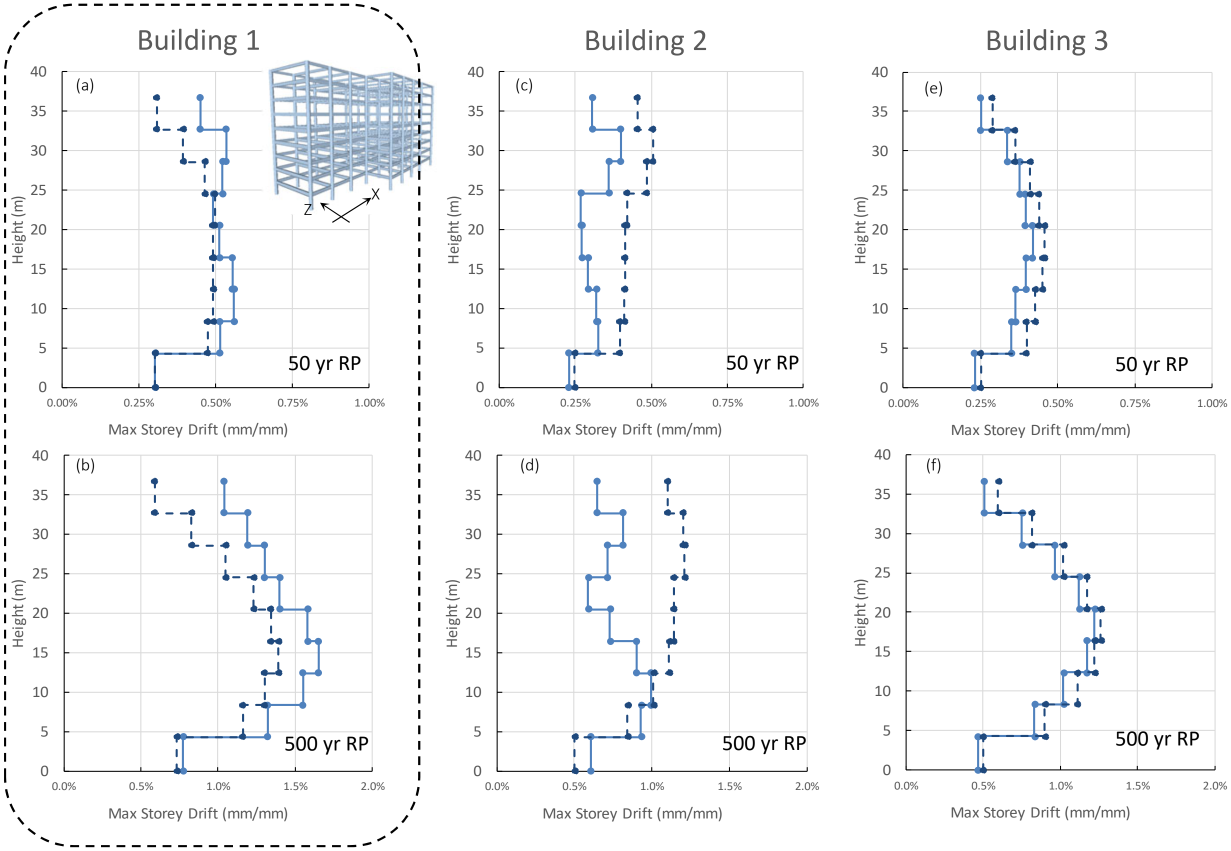
Example:
RC Moment-Frames
Steel Moment-Frames
are similar





A Quick Comparison of Performance

- Building 1: ULS 500 yr RP Capacity Design μ = 4
- Building 2: ULS 500 yr RP Capacity Design μ = 2 (from DDBD)
- Building 3: SLS 50 year RP Capacity Design μ = 1
- NLTH average of seven pairs



Looking for building stock improvements…

- A reversal of NZ typical design practice to emphasis SLS design - might well offer the best penetration of improved seismic design through out the industry
  - **The impact of the Kumomoto observations was the breadth of modern building typologies that had performed well – it wasn't just the showcase buildings**
- DDBD has brought positive outcomes where engineering firms have the capability to learn and apply the method
  - **It is a steep learning curve and not without its limitations/difficulties…unlikely to see industry-wide adoption**
- The outcomes from this simple study suggest that providing more emphasis on our SLS requirements, in what is otherwise a normal design approach, could achieve similar positive design outcomes as DDBD

The Implications?

- Real building-stock improvements will only come if average (and below-average) engineers can easily adapt their existing understanding to any changes in design codes
- Design to elastic SLS response with an appropriate drift (and check with ULS demands) will inherently contain the ULS ductility development to a level that is realistic for that seismic hazard
- International comparisons strongly indicate our SLS return period needs revision…to 50 years?
- A basic study indicates that the outcomes of SLS driven design are very similar to ULS designs based on DDBD evaluation of design ductility
- Is Serviceability-driven design a simpler change than expecting low damage design systems or DDBD to sufficiently permeate through our building-stock, such that we see overall improvement in seismic resilience?

Thank you

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