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 $\mu$ or $R$
• Highlighted that reliable performance across a wide-range of buildings is upheld by limiting deformations
Methodology Comparisons

- Noted 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.

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<tr>
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<th>Serviceability</th>
<th>Ultimate Limit State/Life-Safety</th>
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<tbody>
<tr>
<td>New Zealand NZS1170.5</td>
<td>No drift limit $\mu \leq 1.25$ Design check 25 yr RP with 5%</td>
<td>$\theta \leq 2.5%$ $\mu \leq 6$ Primary design 500 yr RP with 5%</td>
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<tr>
<td>Japan BSL</td>
<td>$\theta \leq 0.5%$ $\mu = 1$ Elastic Primary Design $\approx 50$ yr RP with 5%</td>
<td>$\theta = 1.0%$ (develop design base-shear) $D_s \geq 0.3$ Design check $\approx 500$ yr RP with 5%</td>
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<tr>
<td>US PBD LATB Guidelines</td>
<td>$\theta \leq 0.5%$ $\mu = 1$ Elastic Primary Design 43 yr RP with 2.5%</td>
<td>$\theta \leq 3.0%$ Design check $MCE_r = 2500$ year RP</td>
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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 $\mu = 4$
- Building 2: ULS 500 yr RP Capacity Design $\mu = 2$ (from DDBD)
- Building 3: SLS 50 year RP Capacity Design $\mu = 1$
- NLTH average of seven pairs

The Serviceability of Resilient Design
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