NZ Loadings Standard (NZS1170.5) 2016 and 2018 Modifications to Structural Clauses for Increased Seismic Resilience

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17th U.S. – Japan – New Zealand Workshop on the Improvement of Structural Engineering and Resilience

Outline

- NZS 1170.5
  - Amendment 1 - September 2016 but as yet uncited in Building Code
  - Amendment 2 – under preparation – due early 2019

The Impetus

- Christchurch Earthquake, 22 Feb 2011, M_w 6.2 (Canterbury Earthquake Sequence 2010 - 2016)
- Seddon Earthquake, 21 Jul 2013, M_w 6.5
- Lake Grassmere Earthquake, 16 Aug 2013, M_w 6.5
- Kaikoura Earthquake, 14 Nov 2016, M_w 7.8

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  - Amendment 1 - September 2016 but as yet uncited in Building Code
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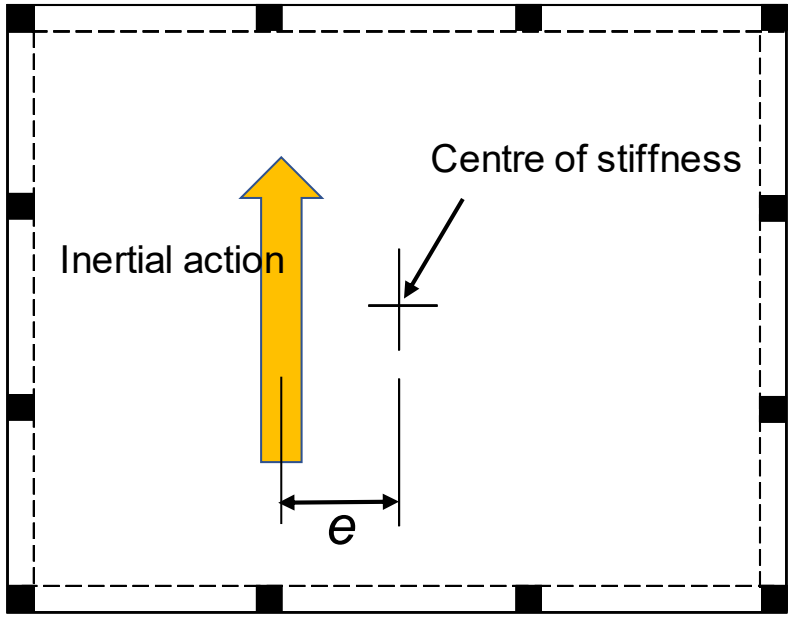
- Amendments Address
  - Changes to Design Loadings
  - Torsional Stability of Ductile Buildings
  - Ratcheting
  - Diaphragms
  - Parts and Components
  - Parts Supported on Ledges
  - ULS Definition
  - Requirements for Shaking Beyond ULS

Torsional Stability



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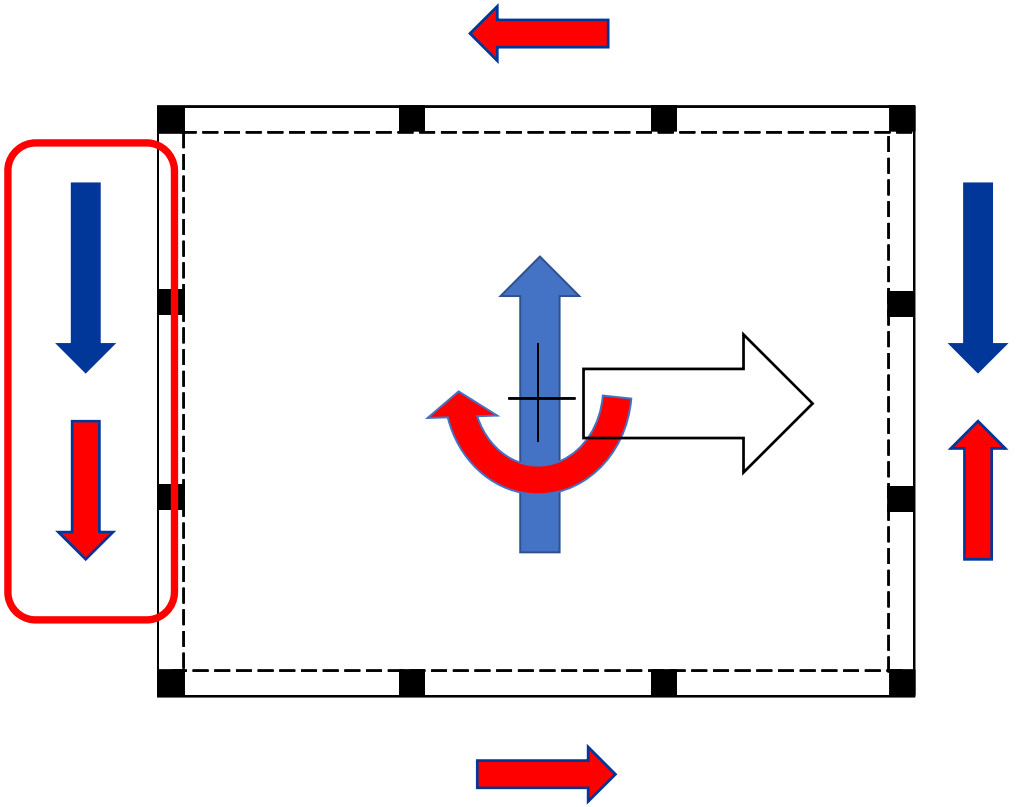

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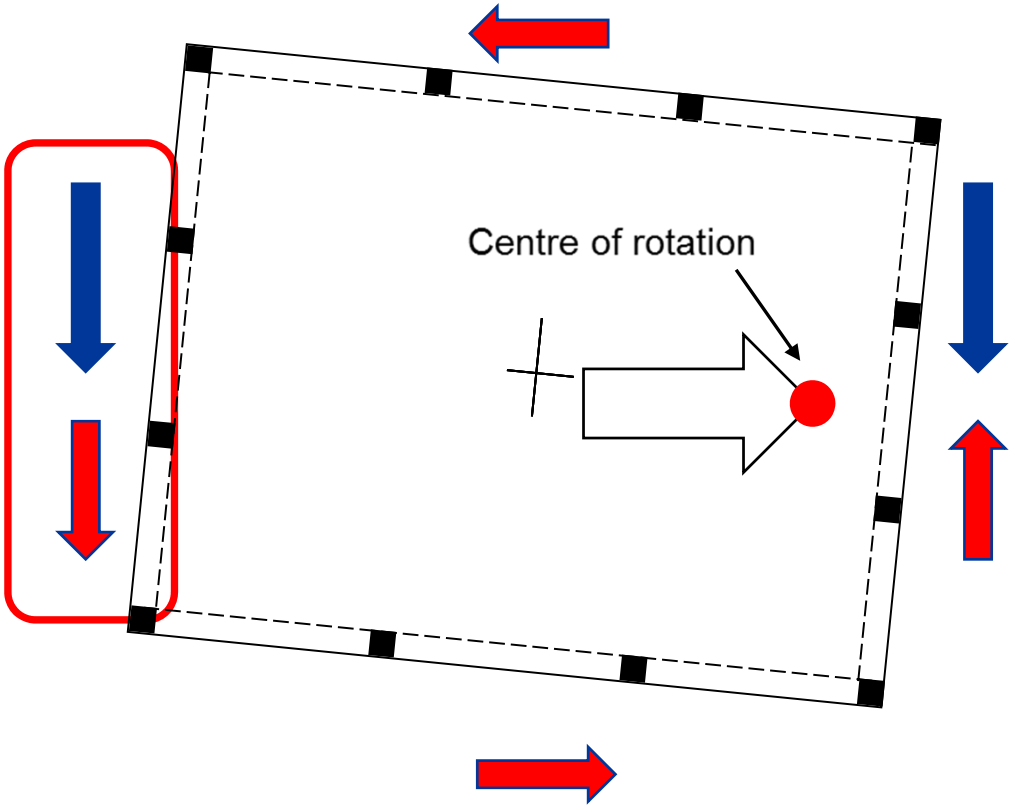
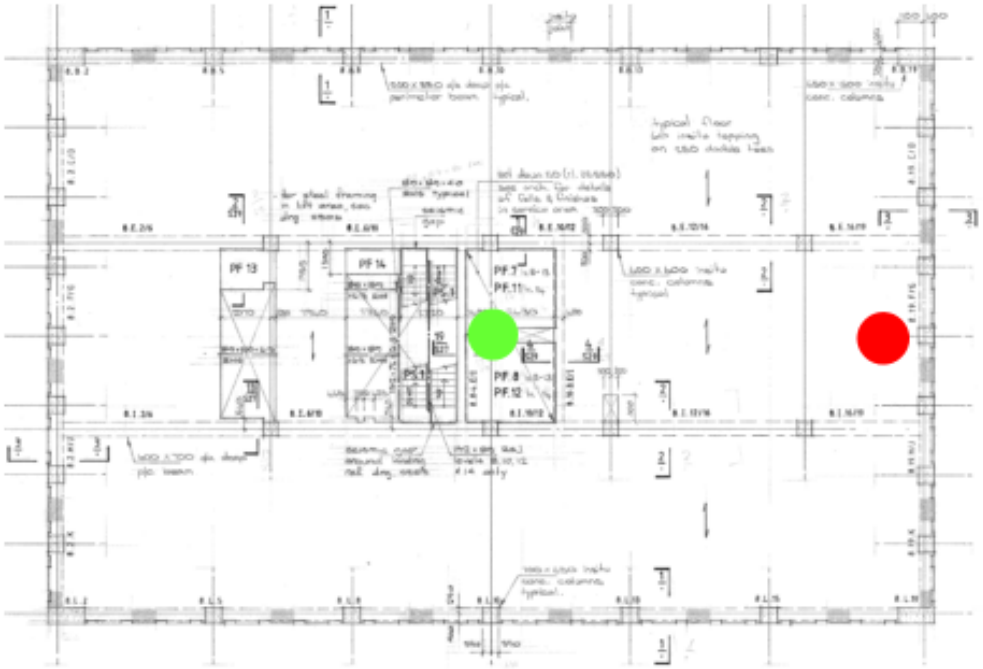


Clarendon Building - Canterbury Earthquake Sequence

Clarendon swung about South frame:
Regular ?

North

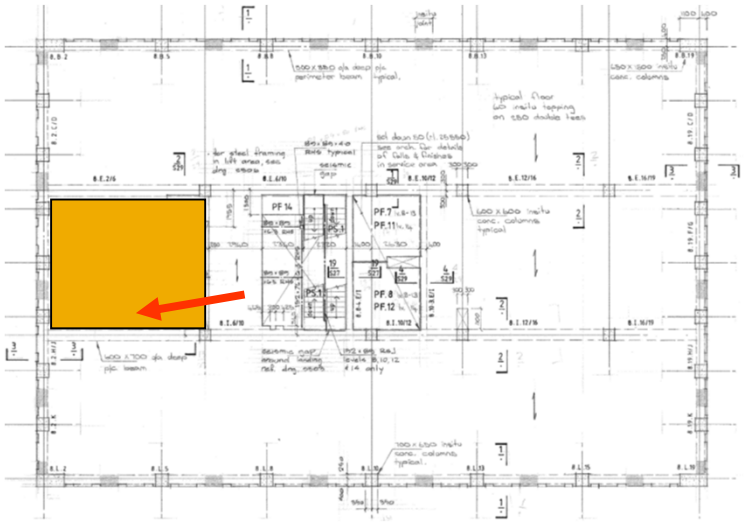


South

Clarendon Building - Observed Damage

- Unexpected non uniform nonlinear behaviour in “regular” lateral system
- Unexpected diaphragm damage
  - Cracking to slab due to frame elongation
  - Cracks/deformations = Loss of Seating = Potential Local Collapse!


NT MOVE
NTHING

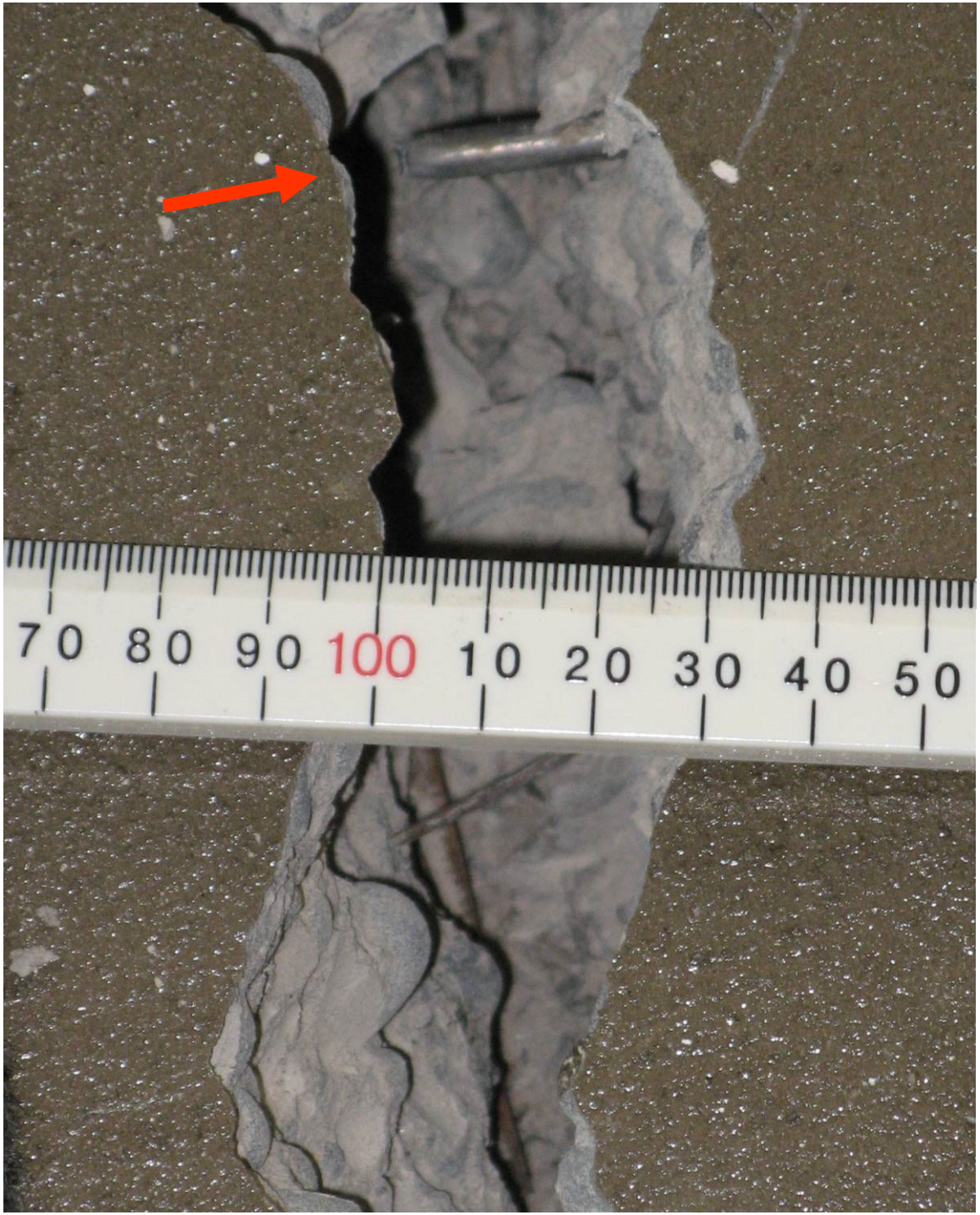



L8
2
40 50 60 70 80 90 100 10 20 30 40 50 60 70 80 90 200 10 20 30

N-W corner column

Corner pushed out

- Cold-drawn wire mesh fractures



Torsional Stability – How to Address?

- Limit nonlinear behaviour in lateral system as a whole (μ < 1.25)
- Limit nonlinear deformation in lateral system making conservative assumptions on centre of rotation and effect of perpendicular lateral resistance
- Redundancy in lateral resistance (three or more lines of resistance reasonably well distributed with similar stiffness and strength (within 20%))
- Require perpendicular lateral system to carry torsion alone while remaining nominally ductile (μ < 1.25)
- Relevance of the centre of strength vs centre of stiffness in a ductile system
- Torsion calculated assuming lateral system at overstrength

Ratcheting

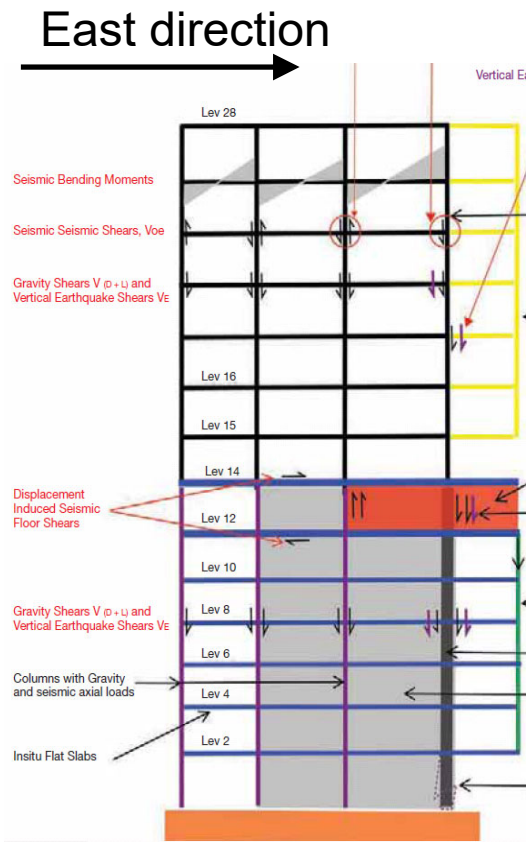
Ratcheting

- Observed in ductile structures with greater lateral strength in one direction compared with the reverse direction
- Results in progressive increase in inelastic deformations in strong and/or long duration shaking
- Greater lateral displacements than expected occur in the reverse (weaker) direction
- Implications:
  - In severe cases can affect structural stability (higher ductility demands)
  - Significant effect on aspects sensitive to lateral deformations

Ratcheting - Structures Affected

- Eccentric gravity load resulting in lower provided strength in one direction compared with the other
- Non-symmetrical structural elements – particularly L, U or T shaped shearwalls resulting in lower provided strength in one direction compared with the other
- Structures braced against side sway using tension braces or restrained buckling braces
- Moment resisting frames with lower strength in one direction compared with the other

Hotel Grand Chancellor – Observed Behaviour



"***…gives the building a tendency to sway to the east by reducing lateral force resistance in this direction and increasing the lateral force resistance for displacement towards the west…***". (Royal Commission Report Volume 2)

Ratcheting– How to Address?

- Feedback from Amendment 1 indicates that those provisions were not easy to understand and simplification proposed
- Definition of a Ratcheting Index, r_i :

$$r_i = \frac{\text{lateral resistance in stronger direction}}{\text{lateral resistance in reverse (weaker) direction}}$$

- Applied above the lowest level of expected inelastic behaviour
- Lateral resistance includes effect from eccentric gravity actions
- Offsets in plan to allow for building torsion may be ignored
- Designer can control

Ratcheting– How to Address?

- Still discussion around;
  - limiting values of r_i before NLTHA required (NLTHA definitely if r_i > 1.5)
  - relationship between r_i and the increase in lateral defections that should be designed for

Acknowledgements

Thank you