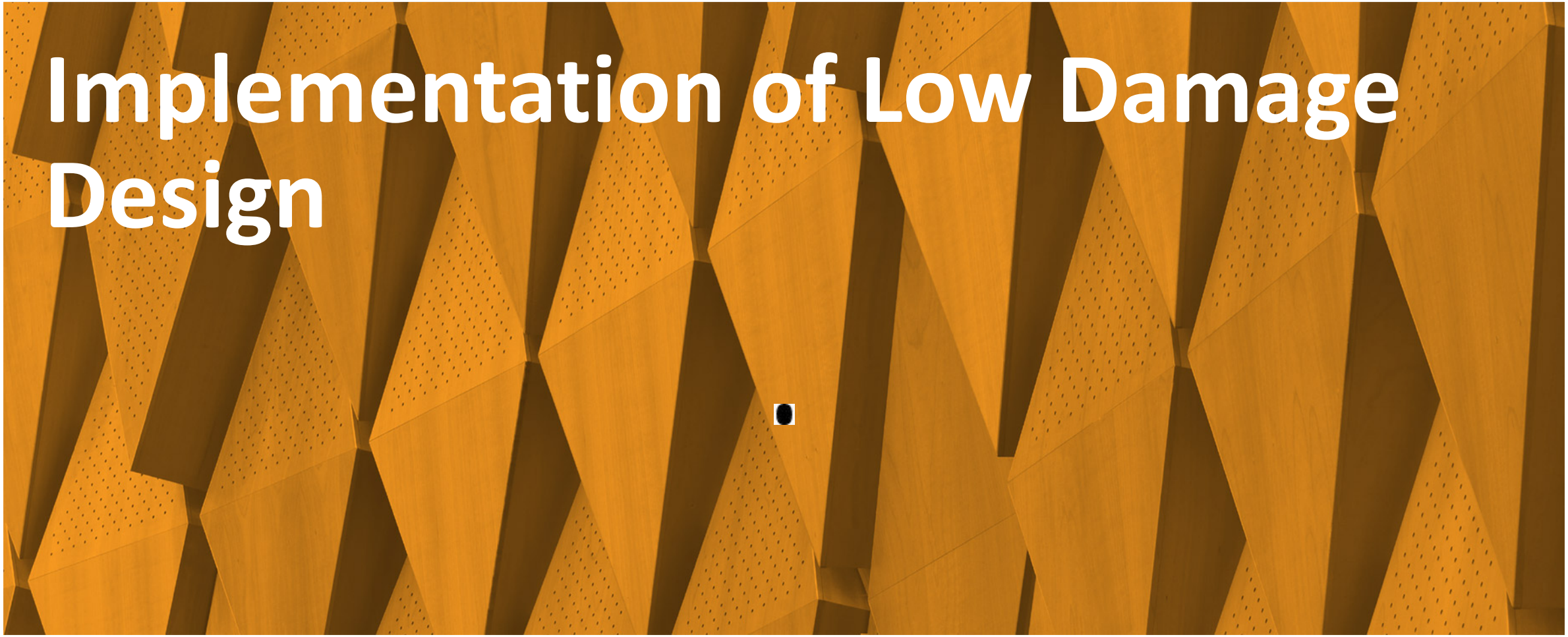
Implementation of Low Damage Design

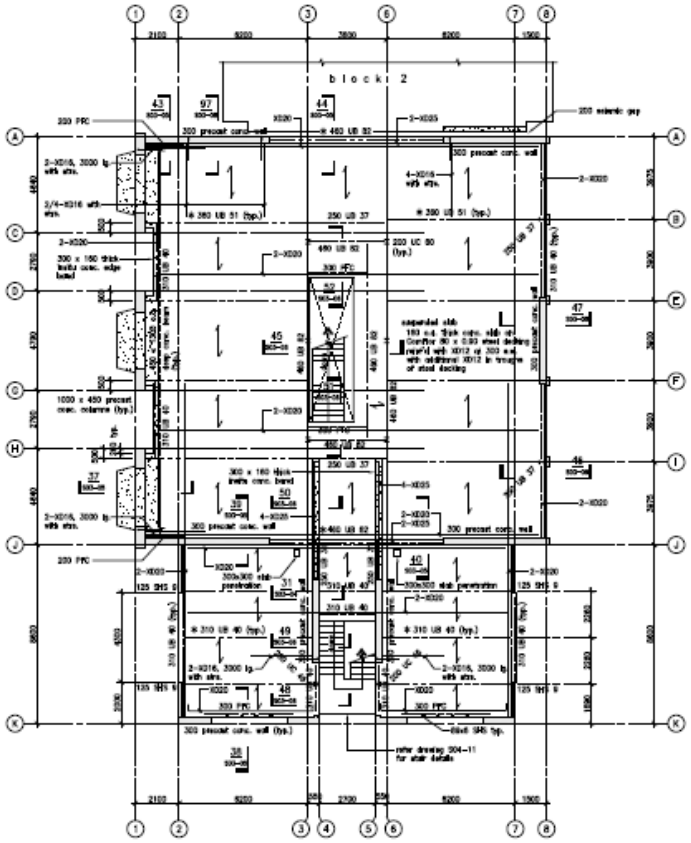


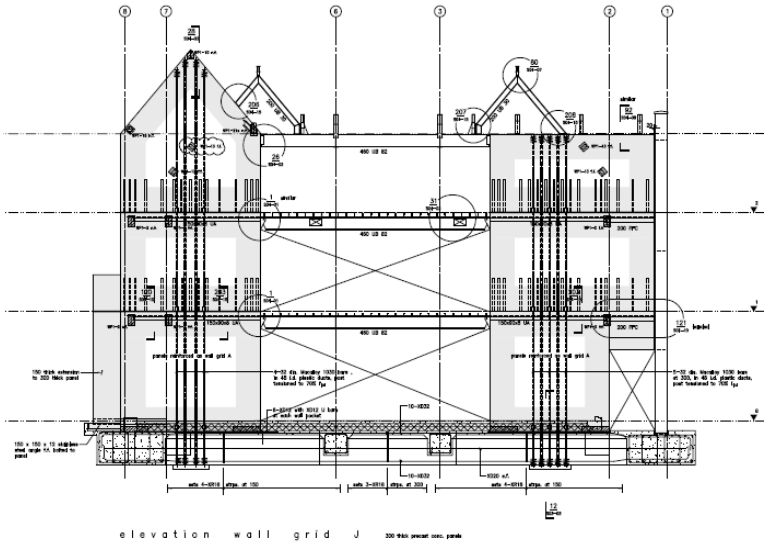
Three IL3 buildings – rocking walls, slotted beams & conventional wall/frames

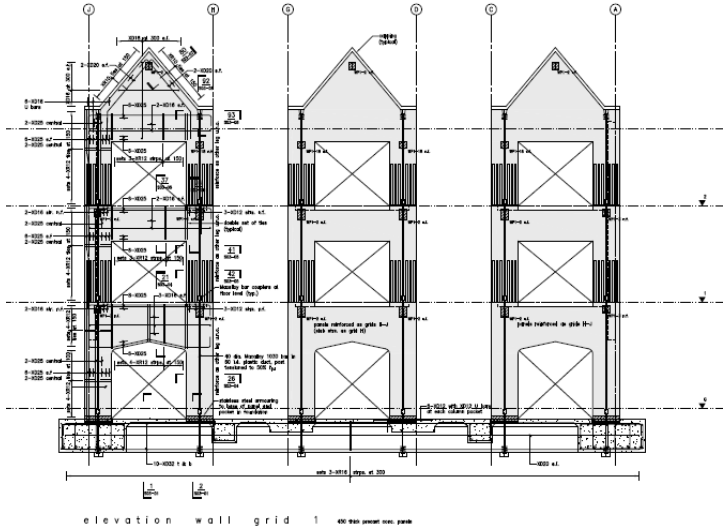
Holmes Consulting

Didier Pettinga
April 2017

Rocking Walls

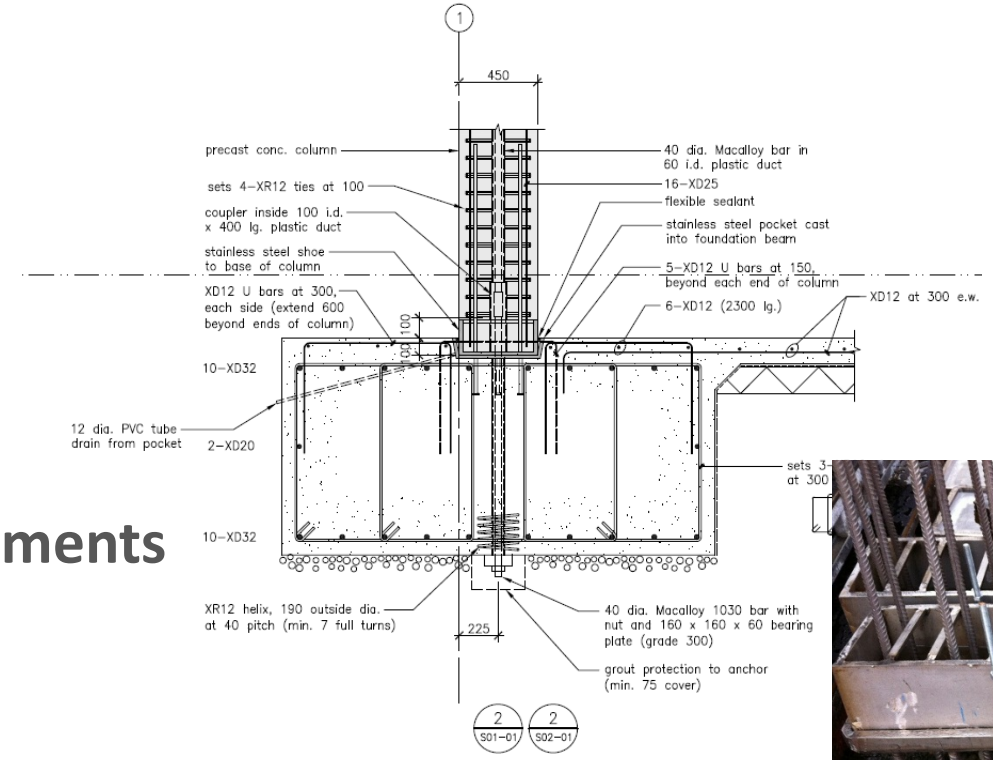




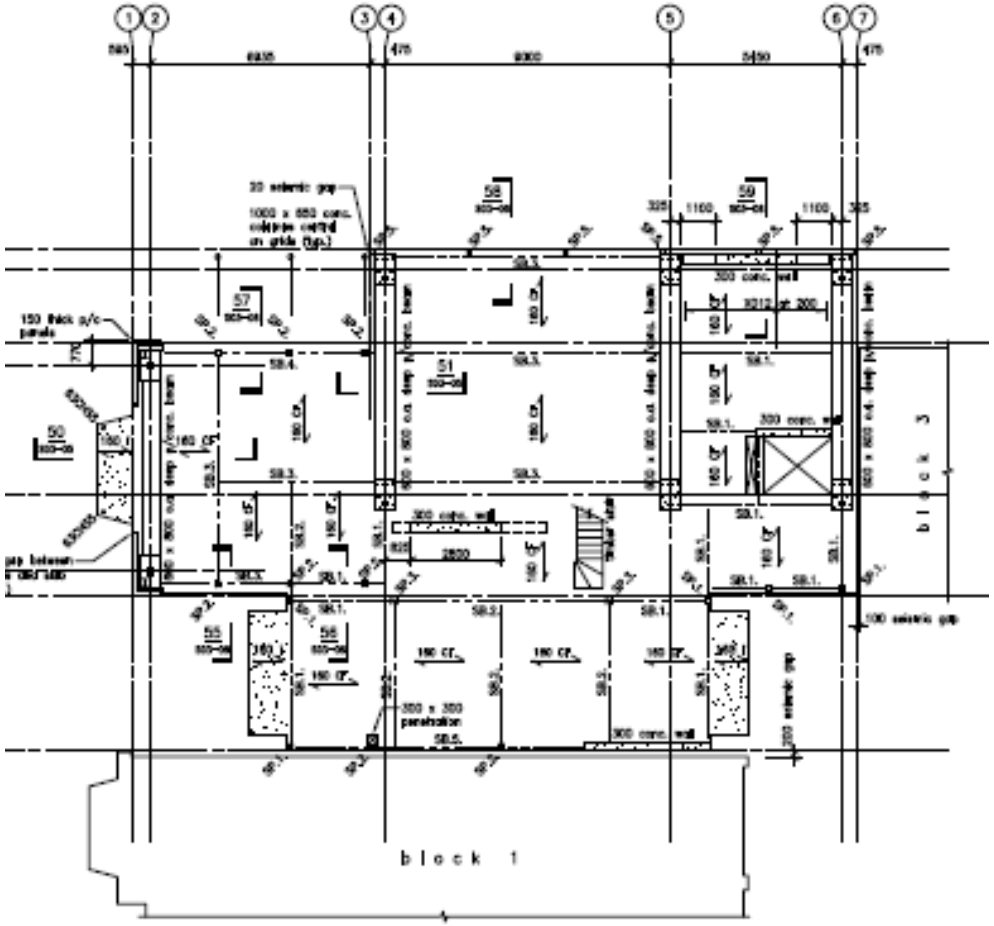


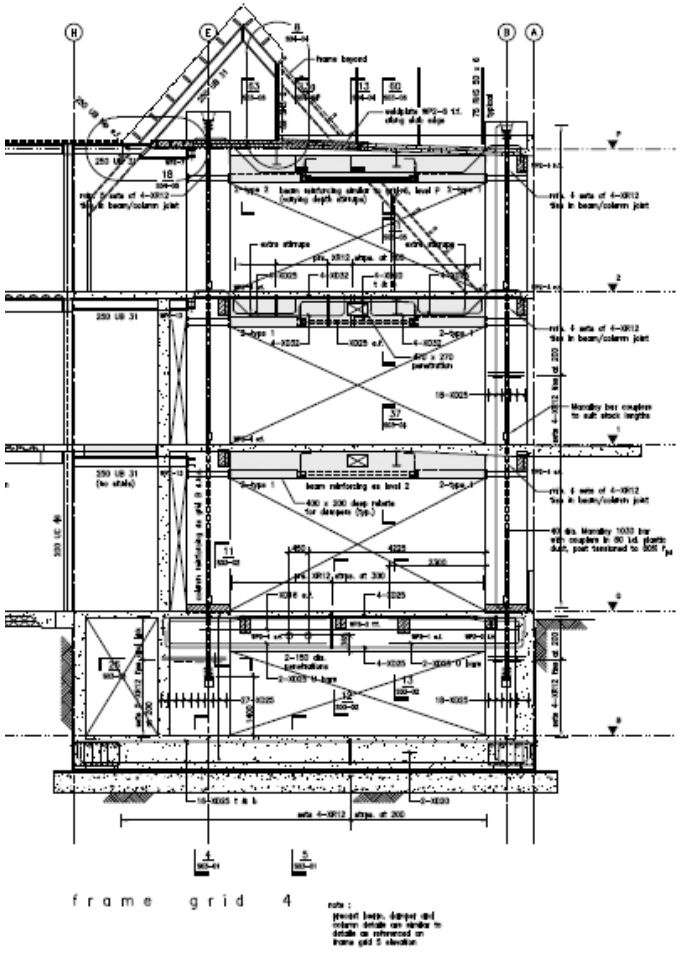
A Snag…Testing of Supplemental Damping Devices

- Exterior Walls
  - **Durability issues**
  - **Unable to add damping elements**
- Construction tolerances



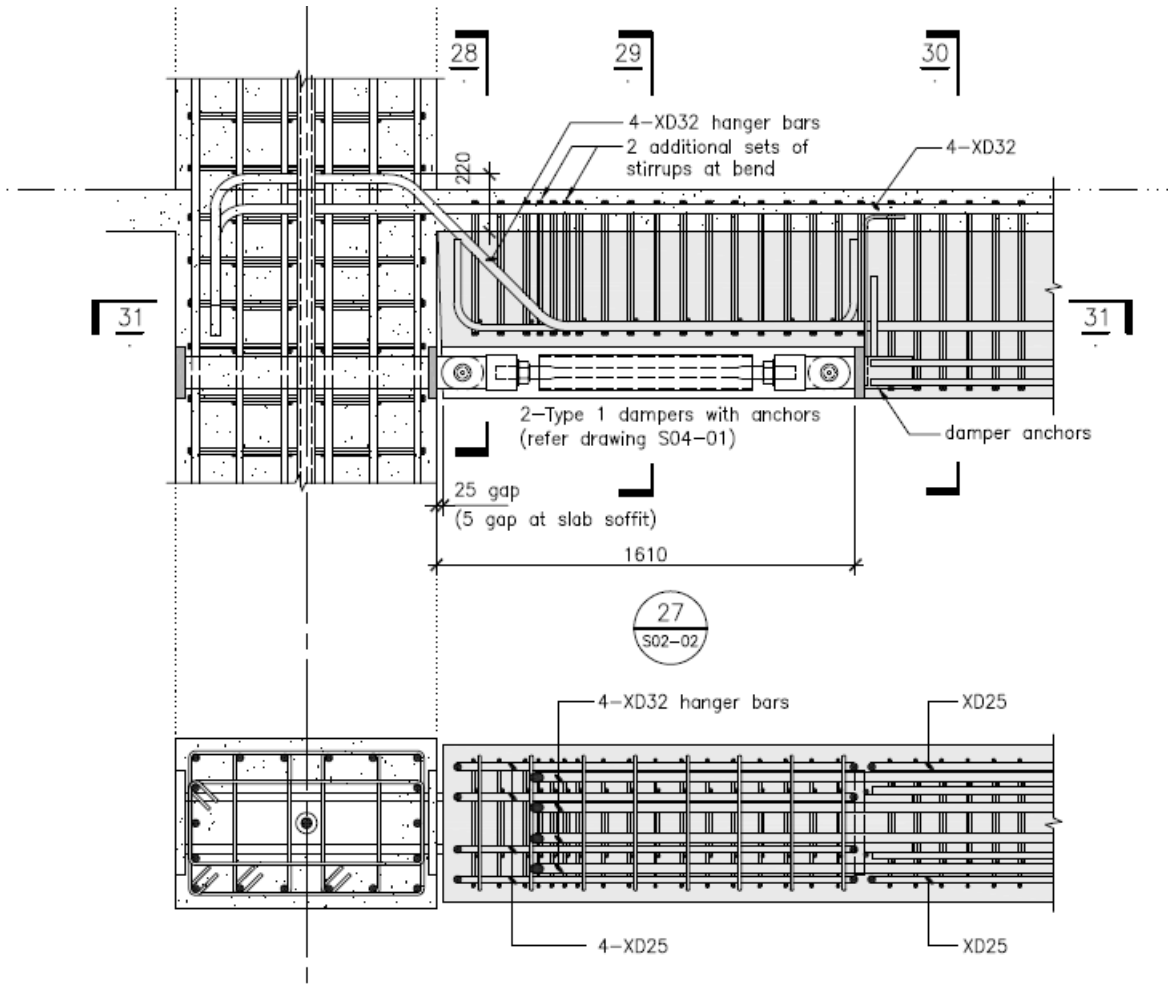
Non-tearing Floors





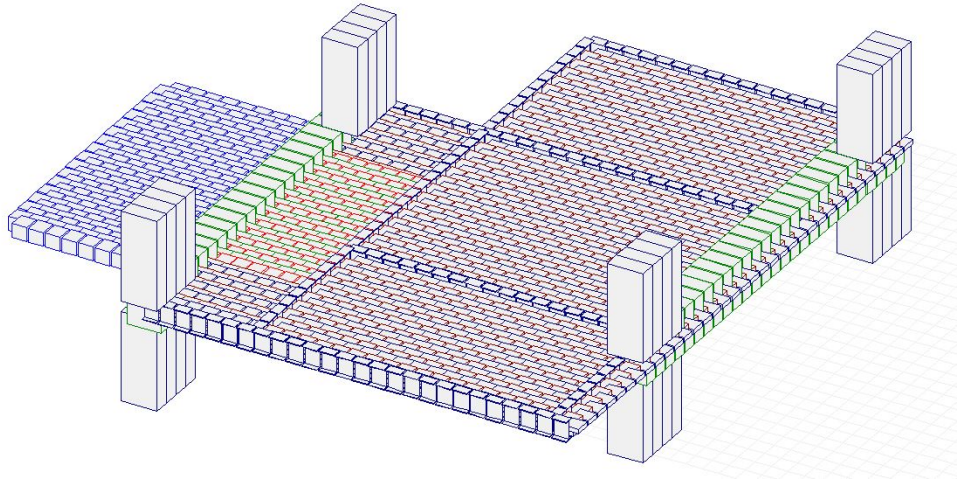
Reinforcing Detailing

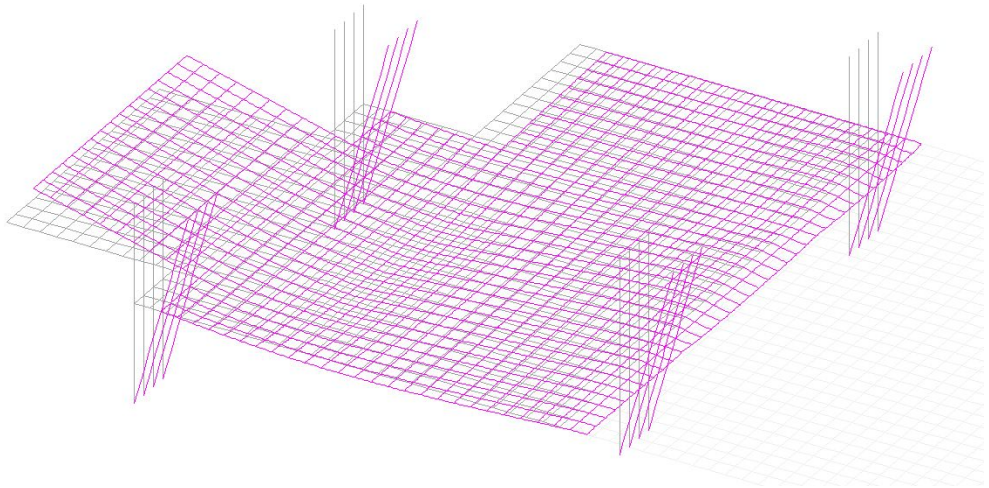
- Congestion in joints
  - **very little tolerance**
  - **governed member sizes**
- Location of bends
  - **Within column to prevent bursting**
- Casting of slot



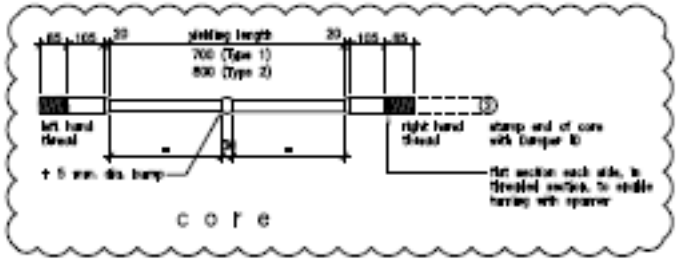
Torsion Induced by Floor Rotation

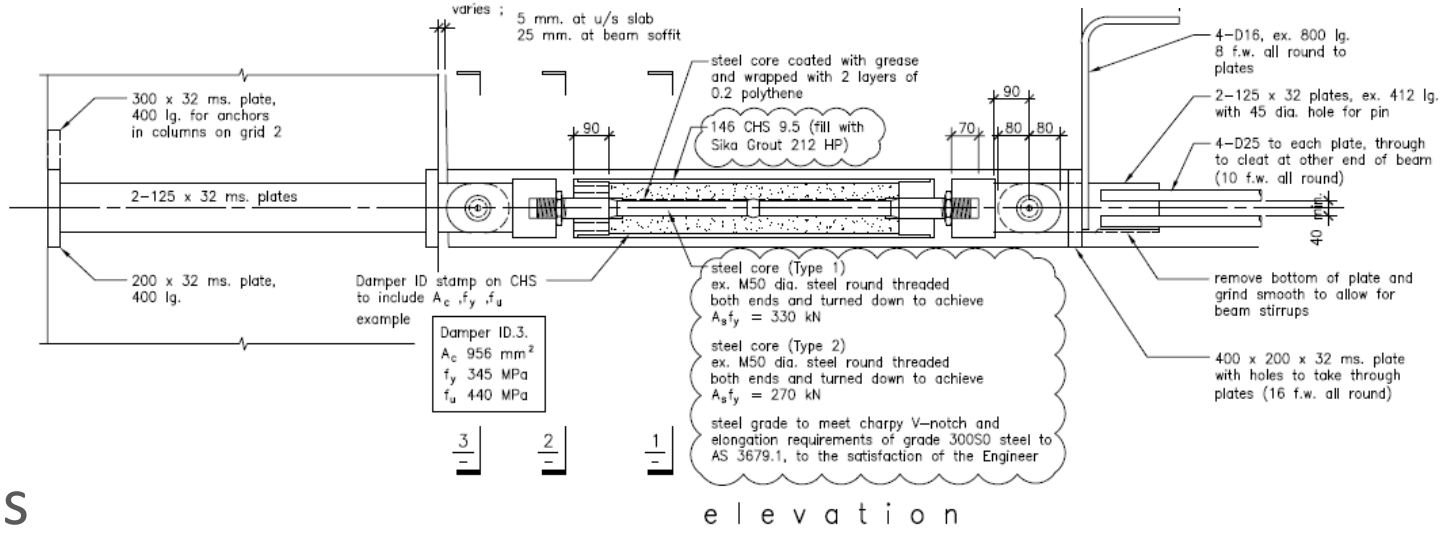
- Asymmetric floor loading of beams
- Slotted beams have different mechanism to resist torsion
- Looked at torsion induced by orthogonal drift
- Pure pin gravity connection





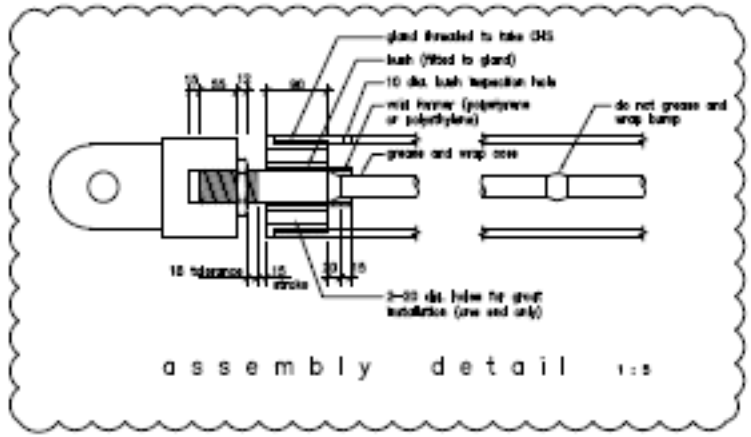
Hysteretic Dampers





elevation

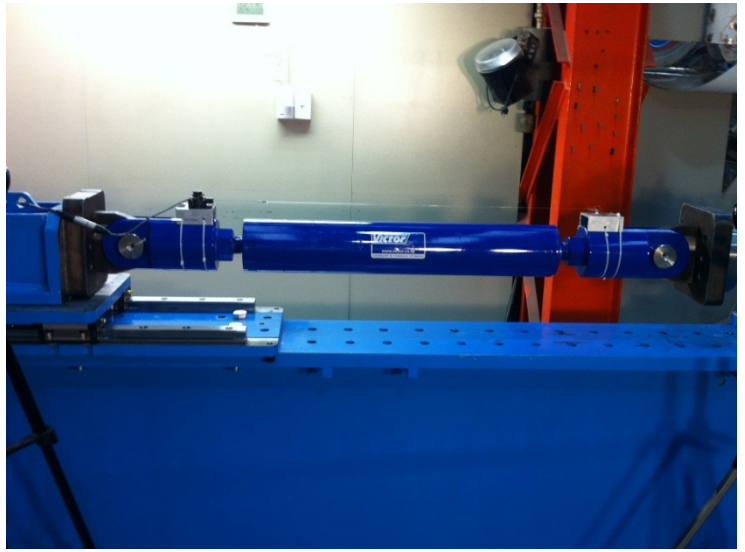
- Essentially short BRBs
- Low-cycle fatigue – calculation vs. scaled research vs. 1170.0 App B verification
- Adjustability on site

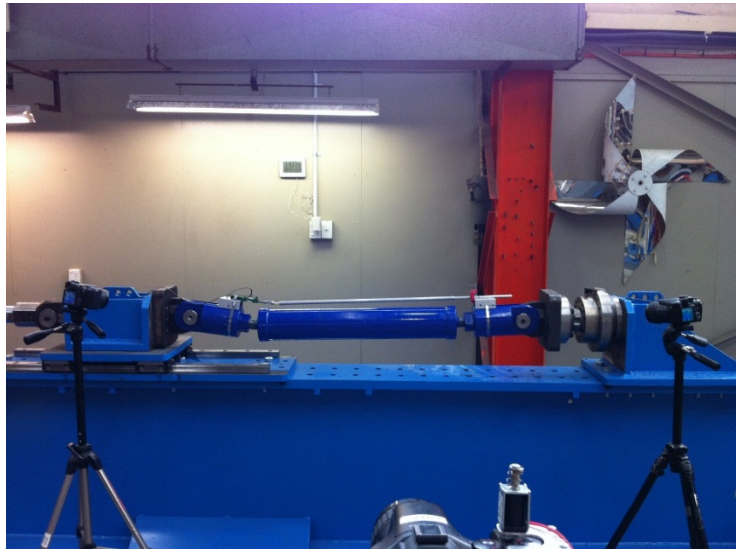


assembly detail 1:5

Damper Testing (HSL)

- Followed ACI374 loading protocol scaled to peak drift
- Failure due to inadequate embedment of core in restraining tube
- Addition of a steel bush achieved approx. 15x required fatigue life



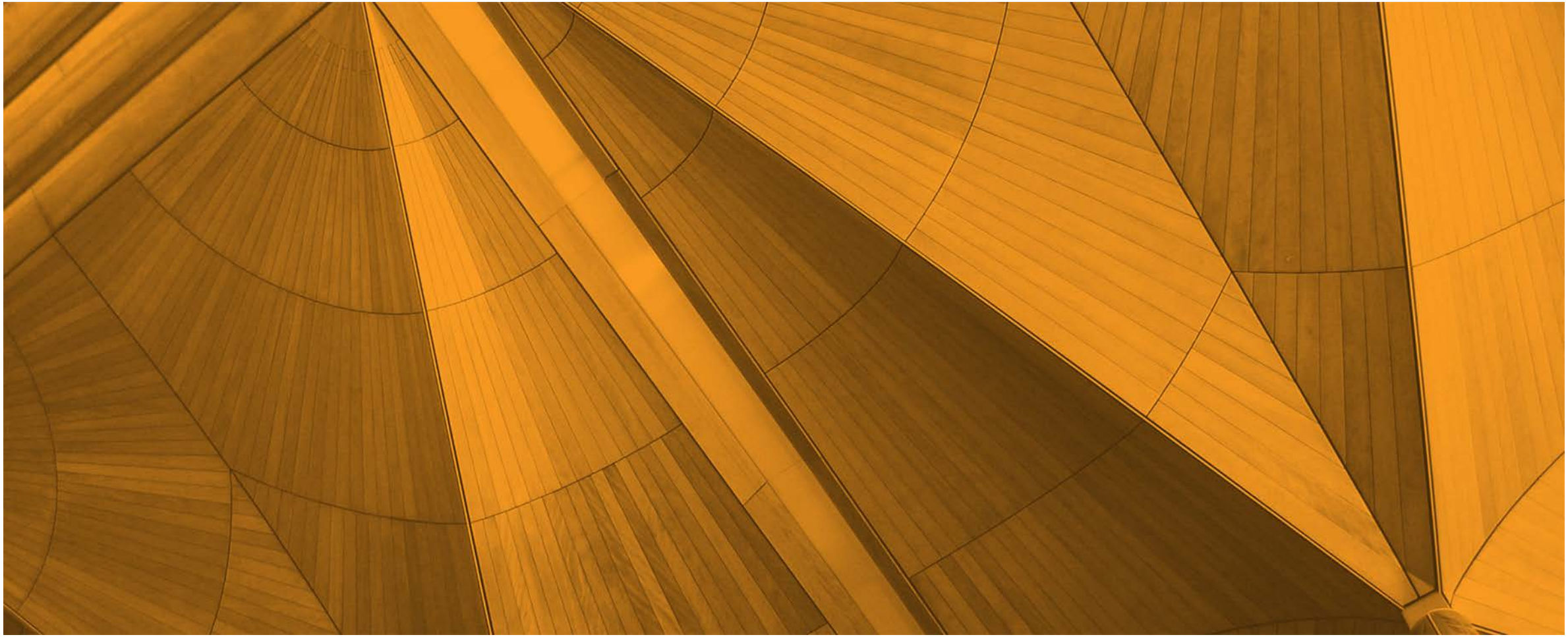


Testing of Supplemental Damping Devices

- Prototype testing of full-scale devices (or as close as practicable) is a must if similar units have not been rigorously tested previously
- EN15129:2009 Anti-Seismic Devices (and similarly ACI 374) provides a logical and comprehensive approach to demonstrating performance
- The articulation and kinematic behaviour often associated to LDD systems removes many of the secondary load-paths that have provided stability in ‘typical’ systems
- It is important because devices do not necessarily scale from the lab to practice, particularly relative to end fixings which can be comparatively oversize at lab-scale and provide partial fixity at the ends
- Trying to incorporate details to accommodate 3D deformation of a joint region can result in significantly worse behaviour!

A Snag…Testing of Supplemental Damping Devices

- The prototype testing represents:
  - **Potential time delays – solved by accelerating that part of the design so that a specification for Tender can be sent-out ahead of time**
  - **Direct costs associated to fabrication of the prototype units and the testing**
  - **An opportunity to assure the client that they are getting a reliable and proven component that is fundamental to the structure performing well**
- Also furnishes key information for verification of building performance through modelling such as NLTHA often needed to demonstrate BC compliance



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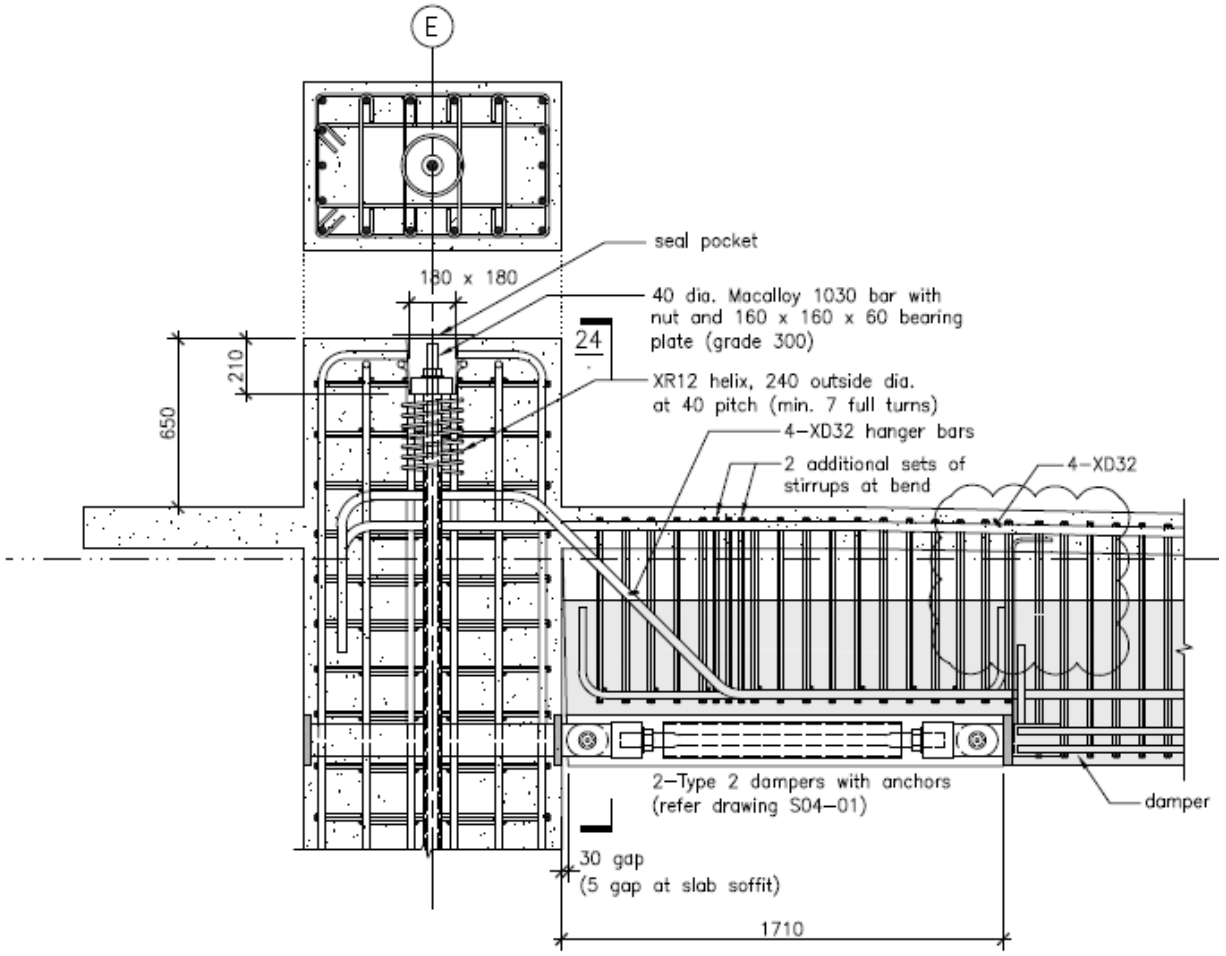
Reinforcing Detailing

- Note that an extension of the column is required above the slab level at top floor



Other points to check with Des
Things that make the design difficult

- Construction – getting the contractor to recognise the instability of the partially built structure (particularly before installation of dampers or stressing of PT)
- Secondary effects
    - beam torsion due to asymmetric floor loading
    - axial force in the beams due to diaphragm actions but limited/reduced connection to the column
    - Design for exterior exposure both architectural and durability of damping components such as BRF, friction interfaces (life-span and construction weathering)
- Supplemental Dampers
    - Designing for low-cycle fatigue vs. completing testing of a sufficient number of samples via Appendix B NZS1170.0 to demonstrate otherwise from calculation

Things that went well

- Contractor enthusiasm for a ‘special’ project generally overcomes perceived difficulties or unusual details/methodologies…just needs a lot of communication at kick-off
    - Presenting an example sequence of construction helps