TOWARDS A NEW DELIVERY APPROACH TO IMPROVE THE PERFORMANCE OF NON-STRUCTURAL ELEMENTS IN NEW ZEALAND

How design, coordination and construction of non-structural elements has a significant effect on the resilience of buildings and the wider New Zealand Economy

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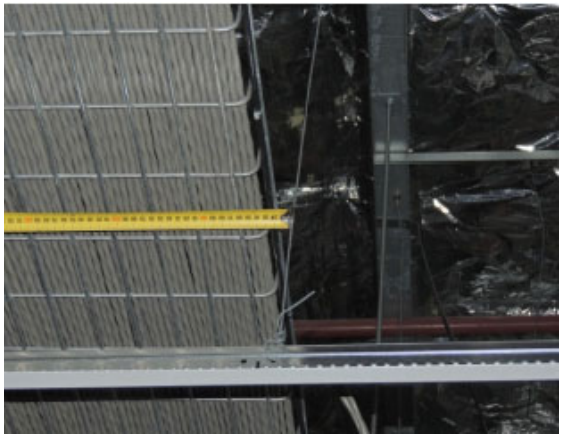
What are Non-Structural Elements?

- Architectural features such as exterior cladding and glazing, ornamentations, ceilings, interior partitions and stairs,
- Building contents, such as moveable furniture, bookshelves, computers and entertainment equipment.

What are Non-Structural Elements?

- Mechanical and plumbing elements and systems including air conditioning equipment, ducts, pipework, lifts, escalators, pumps and emergency generators,
- Electrical elements including transformers, switchgear, master control centres, lighting and cable trays,
- Fire protection systems including piping and tanks,



Observations & Consequences of damage to NSE

- Non-structural elements suffered extensive damage in the Canterbury (2010, 2011), Cook Strait (2013) and Kaikōura (2016) earthquakes.
- Observations following these earthquakes indicated that recently completed buildings with code compliance certificates did not in many cases meet the NZBC requirements – resulting in considerably more damage to non-structural elements than would be expected for compliant installations.

- The damage highlighted the complexity and duration of repairs to non-structural elements significantly impacts business interruption.
- Costs of damage to non-structural elements included:
  a) Repair of non-structural elements
  b) Business interruption

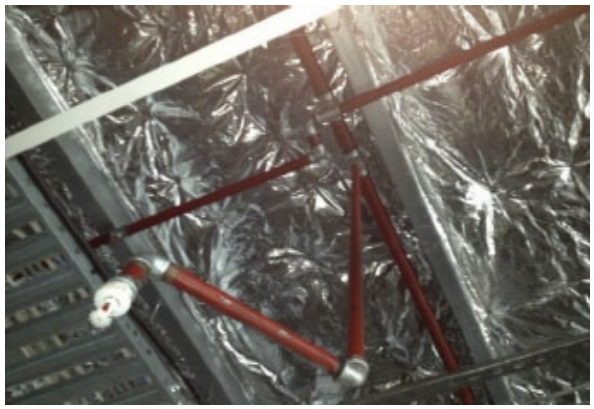
Reasons for Poor Performance of NSE

Based on observations from recent NZ earthquakes the main reasons that non-structural elements are not performing as desired appear to stem from:

- Issues with the existing procurement process in NZ.
- Issues with current NZ installation practices.
- Issues with compliance checks of completed installations.
- Issues with current code provisions for non-structural elements.
- Limitations of our understanding of the seismic behaviour of non-structural elements.

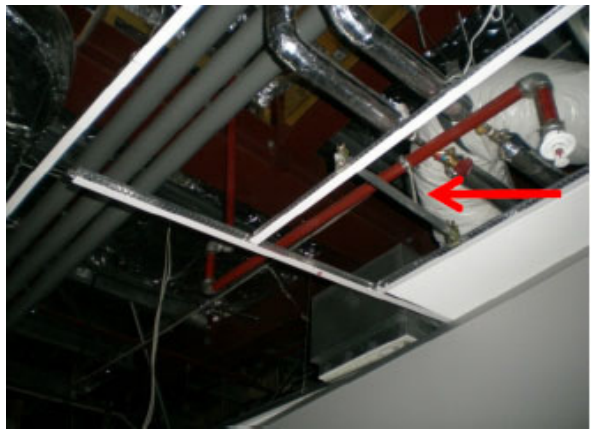
Issues with the existing procurement, installation and approval process

- Current practice does not include fully coordinated design documentation prior to procurement (this applies to both traditional (design then tender) and in Design-Build contracts).
- Current procurement process puts all risk onto the main contractor that the design, coordination and installation of non-structural elements will meet the New Zealand Building Code requirements.
- Main Contractor carries significant risk they may not have fully understood the complexity of the installation (interaction of different NSE, sufficient room to install all components, provision of adequate clearances).



Issues with the existing procurement, installation and approval process

- Main Contractor sub-contracts installation of NSE to individual sub-contractors working in the various sub-trades. Limited coordination between the sub-trades and location of services can be dependent on which sub-trade arrives on site first.
- Difficulties for Building Consent Authorities to confirm compliance with NZ Building Code when the seismic restraints of NSE was consented by reference to performance specifications with the possibility of basic standard details.
- For traditional design followed by tender, the design team is not contractually responsible for undertaking inspections to confirm the installations are installed in accordance with the relevant Standards and NZ Building Code.



Issues with current code provisions

The desired performance requirements for non-structural elements are currently defined in NZS 1170.5 and various Standards including building services (NZS 4219), sprinkler systems (NZS 4541) and suspended ceilings (AS/NZS 2785).

The various Standards have varying performance standards, and on top of this there are inconsistencies in the interpretation of the NZ earthquake loadings standard (NZS 1170.5).

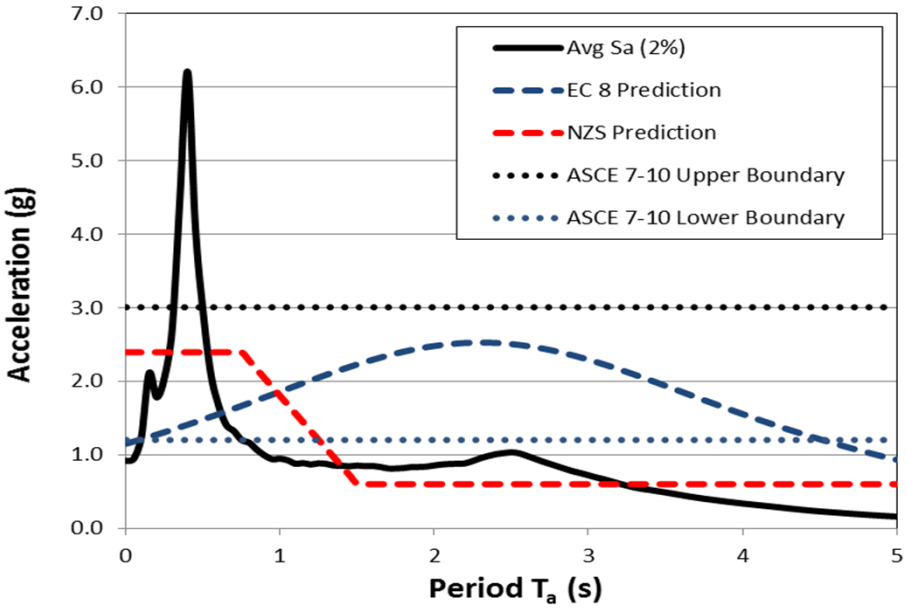
The current fragmented nature of the performance requirements and interaction between ceilings, sprinkler systems and building services does not support the coordination of these important elements of buildings.

Issues with current code provisions

In addition to the issues with the current performance requirements, research has also demonstrated that current code provisions for non-structural elements may be inadequate.

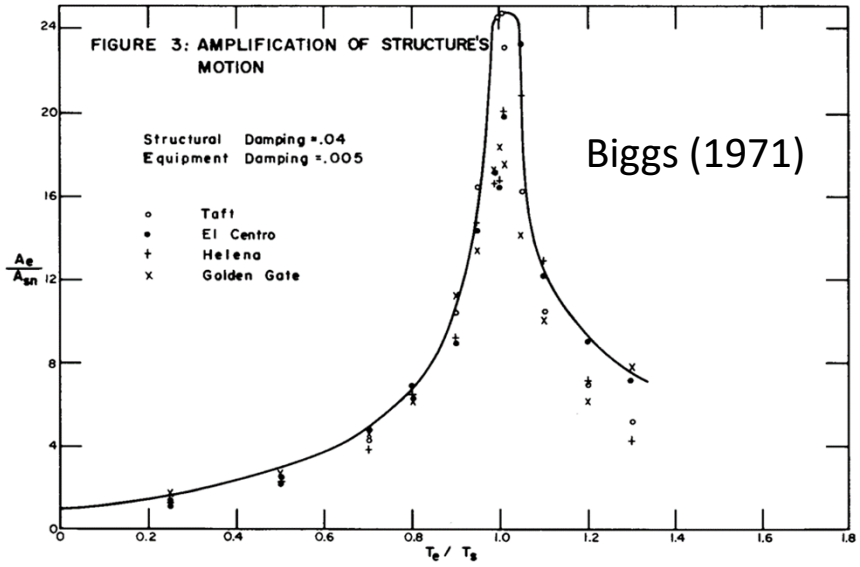
Examples of where code provisions appear to require revision include:

1. Estimation of acceleration demands on non-structural elements



Comparison of predicted floor acceleration response spectra at top level of an 8-storey RC wall building.

Sullivan et al. (2013)



Dynamic amplification factors
(ratio of acceleration demand on a component to peak floor acceleration demand)

Issues with current code provisions

Further examples of where code provisions may require revision include:

2. Design provisions to account for non-linear deformation of non-structural elements

PART RESPONSE FACTOR, C_{ph} and C_{pv}

Ductility of the part μ_p	C_{ph} and C_{pv}
1.0	1.0
1.25	0.85
2.0	0.55
3.0 or greater	0.45

3. The NZ standard for earthquake actions (NZS 1170.5) provides guidelines to calculate the seismic demands for acceleration sensitive NSE, but further guidance should be provided for the verification of drift sensitive non-structural components.

4. Proprietary guidelines for the design of braced non-structural elements should better account for component mass, size and inclination of braces, and types of connections between braces and components.

Limitations of our understanding of the seismic behaviour of non-structural elements

There are also limitations with our current understanding and knowledge:

- Nonlinear behaviour of NSEs is not well understood, difficult to estimate inelastic forces and deformation/displacement demands.
- Damping of acceleration sensitive NSEs affects design demands. Damping is not well documented.
- Interaction between different NSEs and NSEs and the supporting/surrounding structure is not well understood.
- Fragility functions are required to assess the likely impacts impact, but fragility functions for all NSEs are not known. Compounding this issue is that for many NSEs the fragility functions depend heavily on the connection details to the supporting structure.

Towards a New Design and Delivery Approach

Review of the performance of non-structural elements in past earthquakes has shown that the current delivery approach is a significant contributor to the poor performance of non-structural elements in recent NZ earthquakes.

Damage and insurance losses sustained during recent earthquakes shows there is value proposition for both business and the wider macro-economic resilience for the improvement in the seismic performance of NSEs.

Towards a New Design and Delivery Approach

Review of the issues points towards the need for a new delivery approach. Indications are that implementing the following delivery model will significantly improve the seismic performance of non-structural elements and consequently reduce economic costs and downtime, therefore improving the resilience of buildings and our communities:

1. Updates to Codes and Standards to clarify performance requirements, estimation of acceleration demands, confirm appropriate ductility reduction factors, guidance for drift sensitive NSEs and guidance on the interaction between different NSEs and NSEs and the supporting/surrounding structure.
2. Full design and coordination of NSEs including their seismic restraint in the main design documentation that is submitted for Building Consent.
3. Independent inspections and certification/sign off that the installation of NSEs is consistent with the agreed final coordinated BIM model, which in turn ensures that the installation meets the requirements of the NZ Building Code and relevant Standards.

Conclusions

- Majority of damage to non-structural elements in past earthquakes has been caused through a lack of appropriate seismic restraints and clearances for seismic actions.
- Further research into the response of various non-structural elements in buildings is expected to inform updates to NZ Standards and improve the seismic design, restraint detailing and determination of appropriate clearances.
- Updates to Standards can also address the current issues with consistency in performance standards and interpretation of NZS 1170.5 in the design of non-structural elements.
- Feedback from consultants and the construction industry indicates that the New Zealand construction industry needs to introduce design and coordination of NSEs, including seismic restraints, during the design and consenting phase, followed up with independent inspections to confirm that the final installation meets the requirements of the relevant Standards.
- The expected outcome of this approach would be to significantly improve the resilience of buildings through reduced business interruption time and costs, reduced repair costs, less replacement of building materials and therefore reduced environmental impacts.