Seismic assessment and restraint of non-structural elements - practical solutions and implementation challenges

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ABSTRACT

Almost 10 years have passed since the 2010 - 2011 Canterbury Earthquake Sequence (CES). These major events, and more recently the 2016 Kaikoura Earthquake have confirmed the poor performance of non-structural elements (NSEs) such as non-loadbearing partition walls, suspended ceilings and suspended building services installed in existing buildings. Since 2010, there has been a concentrated effort to raise awareness and to improve the design and assessment standards and guidelines in New Zealand. Even though the industry is maturing, the design, documentation, coordination and construction monitoring responsibilities related to NSEs remain somewhat ambiguous. These responsibilities, often driven by procurement, are split between the various designers (architects, structural and building services engineers), proprietary manufacturers, contractors, trades sub-contractors, and increasingly a new group of seismic restraint specialists. Unsurprisingly, this leads to various issues when it comes to the procurement, cost estimate, execution of design, coordination and installation.

This paper looks back at the progress in the past 10 years in terms of key research findings and the updates of the design and assessment standards in New Zealand. The paper presents a project example of a practical implementation of the NZSEE / MBIE Technical Assessment Guidelines Part A and Section C10 in mitigating life safety hazards from NSEs. Following this, the paper presents some of the design challenges in the current procurement and delivery model for the seismic restraint of NSEs, and the solutions adopted in some of our recent projects. Proposed areas of further improvement in terms of detailing and design are also identified with examples.

1 INTRODUCTION

Major seismic events such as the 2010 - 2011 Canterbury Earthquake Sequence (CES), and more recently the 2016 Kaikoura Earthquake, identified poor performance with non-structural elements (NSEs) such as non-loadbearing partition walls, suspended ceilings and suspended building services installed in existing buildings (Darfield Earthquake Special Issue 2010; Christchurch Earthquake Special Issue 2011, Baird & Ferner 2017). These observations have raised concerns as to how the seismic performance of NSEs is being considered as part of design and installation across New Zealand and whether significant savings could be achieved by improving the current practice (Schouten 2013, Pennington 2017, Stanway et al. 2018).

Since 2010, there has been a concentrated effort to raise awareness and to improve the design and assessment standards and guidelines in New Zealand:

- Significant research on performance, evaluation and improvement of various NSEs (Baird et al. 2014, Tasligedik et al. 2015, Pourali et al. 2015, Dhakal et al. 2016a & Dhakal et al. 2016b),
- Informed amendments to standards and guidelines related to design and assessment of NSEs in New Zealand,
- A concentrated effort to raise awareness related to NSEs in the construction industry, including seminars, Practice Advisories and factsheets focused on design and installation of NSEs subject to seismic actions.

One of the recommendations from the CES Royal Commission was that “to prevent or limit the amount of secondary damage, engineers and architects should collaborate to minimise the potential distortion applied to non-structural elements” (CERC 2012). The recommendation initiated a number of efforts from MBIE to both better understand and quantify the risk posed by NSEs, and also provide more information to engineers on how to identify and assess risk posed by NSEs. This led to updates to the NZSEE Technical Assessment Guidelines as well as the issuing of two Practice Advisories (MBIE 2016).

The aforementioned efforts have resulted in increased awareness in stakeholders (such as building owners, property managers, tenants, professional engineers, contractors and building materials suppliers) to make informed decisions regarding the seismic performance of NSEs in new and existing buildings. Notwithstanding the above and while the construction industry is maturing, the design, documentation, coordination and construction monitoring responsibilities of NSEs remain somewhat ambiguous. These responsibilities, often driven by procurement, are split among the various designers (architects, structural and building services engineers), proprietary manufacturers, contractors, trades sub-contractors, and increasingly a new group of seismic restraint specialists. Unsurprisingly, this leads to various issues when it comes to the procurement, cost estimate, execution of design, coordination and installation. These issues have been identified and explicitly discussed in various papers in recent years (Ferner et al. 2016, MacRae et al. 2012).

In an attempt to follow on these changes and efforts, this paper provides:

1. A brief overview of key updates to standards and guidelines related to design and assessment of NSEs in New Zealand;
2. A practical example of a project that utilises the NZSEE / MBIE Technical Assessment Guidelines Part A and Section C10 in mitigating life safety hazards from NSEs;
3. An outline of the existing challenges related to the commonly used procurement and delivery model in the construction industry for seismic restraints of NSEs;
4. Proposed practical solutions and approaches for improved seismic performance of NSEs.

2 KEY UPDATES TO DESIGN AND ASSESSMENT OF NON-STRUCTURAL ELEMENTS

2.1 MBIE/NZSEE Technical Guidelines for the Assessment of Existing Buildings

In a joint effort funded by MBIE and the Earthquake Commission (EQC), a series of technical guidelines were developed and published in 2016 & 2017 concerning the seismic assessment of existing buildings (NZSEE 2017). These documents provide a framework for engineers who engage in undertaking and communicating initial and detailed seismic assessments in existing buildings. Part A & Part C10 which set out the criteria for identification of a significant life safety hazard and provide guidance in assessing different types of NSEs were used as the framework for the case study presented in Section 3 of this paper.

2.2 NZS 1170.5:2004, Amendment to Section 8

An amendment to the NZS 1170.5 New Zealand standard for structural design actions – Earthquake actions was published in 2016 (NZS 1170.5 2004). This amendment included revisions to Section 8 in particular the determination of the part category and part response factors for various types of building components. Most significantly, many building parts that were previously considered P.7 (designed for serviceability limit state 1 only), are now required to be designed to ultimate limit state and / or serviceability limit state 2.

2.3 AS/NZS 2785:2000 Draft for review

A draft of the standard for design and installation of suspended ceilings (AS/NZS 2785 2000) was released for review and comments in June 2019. Major changes applied in this draft included the introduction of the concepts of Seismic Grade (SG) of the ceiling, Design Producer's Certification (PS), Construction Monitoring (CM) and Specific Engineering Design (SED). Revisions were also proposed to design requirements, including earthquake and wind design, design of fasteners into concrete and acoustic requirements. Other additions included restraint of luminaires and detailing, ceiling restraints and services interaction.

2.4 NZS 3101.A3 (2017) Concrete Standard Amendment 3

NZS 3101 Amendment 3 (NZS 3101.A3 2017) introduces additional clauses for post-installed anchors into concrete substrate, which have substantial impact on the anchorage requirements for seismic restraint systems. For instance, post-installed anchors are required to meet the testing requirement as per ETAG 001 for type C1 and C2 crack categories:

- Cat C1 (0.5 mm static crack width, equivalent to ACI 355.2)
- Cat C2 (cycling crack width up to 0.8 mm max., more onerous than ACI 355.2).

Moreover, European Organisation for Technical Approvals EOTA TR-045 requires C2 rated anchors in seismic zones where ground acceleration > 0.1g, i.e. all New Zealand. As C2 rated anchors can cost twice as much as C1 rated anchors, this new requirement can add substantial cost to NSEs' seismic restraint solutions.

2.5 MBIE Practice Advisory 19 and 20

In 2016 MBIE released two practice advisories to the building sector on NSEs and secondary structural elements (MBIE 2016a, MBIE 2016b). The Practice Advisories provide guidance to the building industry on restraining ceilings, ducting and other NSEs in commercial buildings.

As well as technical advice to architects, engineers and contractors on how to design and coordinate, the Practice Advisories also include guidance for building owners, recommending them to "engage the building's structural design engineer, or consider engaging specialists with similar expertise, for the seismic design of non-structural elements". It also instructs building consent authorities to "check that the design documentation adequately covers non-structural elements". The latter has had a significant impact on the design of NSEs. This will be discussed in more detail in a later section.

2.6 Changes to consenting requirement

Most building consent authorities now require a PS1 to be submitted for NSE design as part of building consent lodgement. This requirement means the design of NSEs must progress earlier in the project. This provides an opportunity to coordinate the restraint requirements of different trades that may not otherwise be achieved if a "just-in-time" design was undertaken. This leads to the early identification of issues and provides better overall outcomes by addressing these issues during the design phase.

However, earlier design of NSEs has presented challenges since the information available at consent stage is not always sufficient to undertake a complete design, e.g. building services equipment will often be determined by performance specification, and will not be selected until during the tender process, making it difficult to design the seismic restraints.

Earlier design for building consent has gone hand-in-hand with earlier design for tender. This enables a higher level of cost certainty to the project, as well as ensuring that the seismic restraint is included in the tender submission. Tendering has similar issues to consenting, in that the level of detail available from other consultants at tender may not be adequate for tender of seismic restraints.

2.7 BIM / Modelling / Design Automation

Modelling of NSEs seismic restraints during design phase is not commonplace but is beginning to emerge, particularly on large projects with high levels of service reticulation. The cost associated with the seismic restraints on such projects can be considerable and can drive the need for a higher level of coordination to ensure the achievement of an efficient design and execution.

With the advances made in BIM (Building Information Modelling) and VIM (Virtual Information Modelling), design automation is now a plausible option and is seen as a major disruptor to the construction industry. NSEs may be at the forefront of that disruption: The design of seismic restraint solutions for NSEs is often very repetitive and utilises a limited number of solutions. This makes the task of design well suited for design automation. This is particularly useful for building services, which are often subject to numerous changes during the design process. This has traditionally meant that design of seismic restraints can only proceed once all other consultants have finalised their design, potentially nullifying the benefits of early design involvement. However, automated design provides the ability to update seismic restraint solutions quickly to match changing layouts.

2.8 NSE Coordinator

The role of a 'non-structural seismic coordinator' has not been adopted as a formal project role in New Zealand like it has been in the US. However, it is becoming more common on large projects for there to be 'seismic restraint specialists' included. This role is often split, with a 'seismic restraint specialist' providing input during the design phase to the various consultants on the project, as well as the contractor having their own 'seismic restraint specialist' during construction phase.

The ultimate responsibility for coordination of building services and their seismic restraint remains with the main contractor as they are responsible for selecting equipment and finalising layouts during the construction phase.

3 QUALITATIVE ASSESSMENT CASE STUDY

The case study presented here is a qualitative assessment project for a client with a large portfolio (200+) of commercial properties across New Zealand. The properties serve various purposes and were located in towns and cities across New Zealand, hence subject to various levels of seismic hazard.

3.1 Assessment objective

The Client intended to obtain a minimum level of life safety assurance on their premises in line with the MBIE/NZSEE Seismic Assessment Guidelines herein referred to as NZSEE Guidelines. This meant identifying all NSEs that presented a potential significant life safety hazard. As per the NZSEE Guidelines, a significant life safety hazard is defined as that which can result from the loss of gravity load support that would reasonably affect a number of people (NZSEE 2017). The assessments were to be carried out in operating buildings and within a reasonable timeframe and budget.

3.2 Proposed Assessment model

The purpose, in line with the NZSEE Guidelines, was to "enable building owners to understand and be able to improve the seismic safety of their buildings and, where necessary, prioritise any mitigation works." (NZSEE 2017).

The traditional model of assessment involving a structural engineer on site, inspecting all NSEs was found inefficient for the project. Instead, a guided qualitative risk-based approach was proposed. Figure 1 shows a schematic flowchart showing the main steps in this method. The primary step, prioritization took into account the following factors:

- Regional seismicity (Classified into High, Medium & Low),
- Latest significant retrofit or renovations (An indication of potential agreement with the changes to parts seismic actions),
- Element type (Categories defined based on NZSEE Guidelines, Part A).

Prioritization was followed by a sample-based assessment by the contractor using assessment tools and checklists provided in the method. Finally, the assessment process concluded with reviews and recommendations by the structural engineer or the seismic specialist.

One of the merits of the approach is the adoption of a sample-based assessment method. This provides a feasible option for large portfolios with limited time and budget. For example, the prioritization identifies the partitions in a building likely to be a significant life safety hazard (installed pre-2011 and near egress routes). The assessor then reviews the available building plans and narrows down the total number of partitions in this building installed at the same time, to a reasonable sample size. This sample is assessed, and the results are assumed applicable to the whole.

To achieve simplicity, effectiveness and consistency, the assessors where provided with checklists and guides enabling them to identify the significant life safety hazards. The checklists required no calculations and sophisticated measurements on site. The questions directed the assessor to observe the NSE with considerations for the space (e.g. egress route, frequently used open space etc.) and check for the presence of acceptable supports. For example, the checklist designed for the assessment of suspended ceilings would guide the assessor to identifying the gravity and seismic load bearing supports with illustrations and check if the spacing of fixtures were less or more that the limits provided in the guide suitable for their scenario.

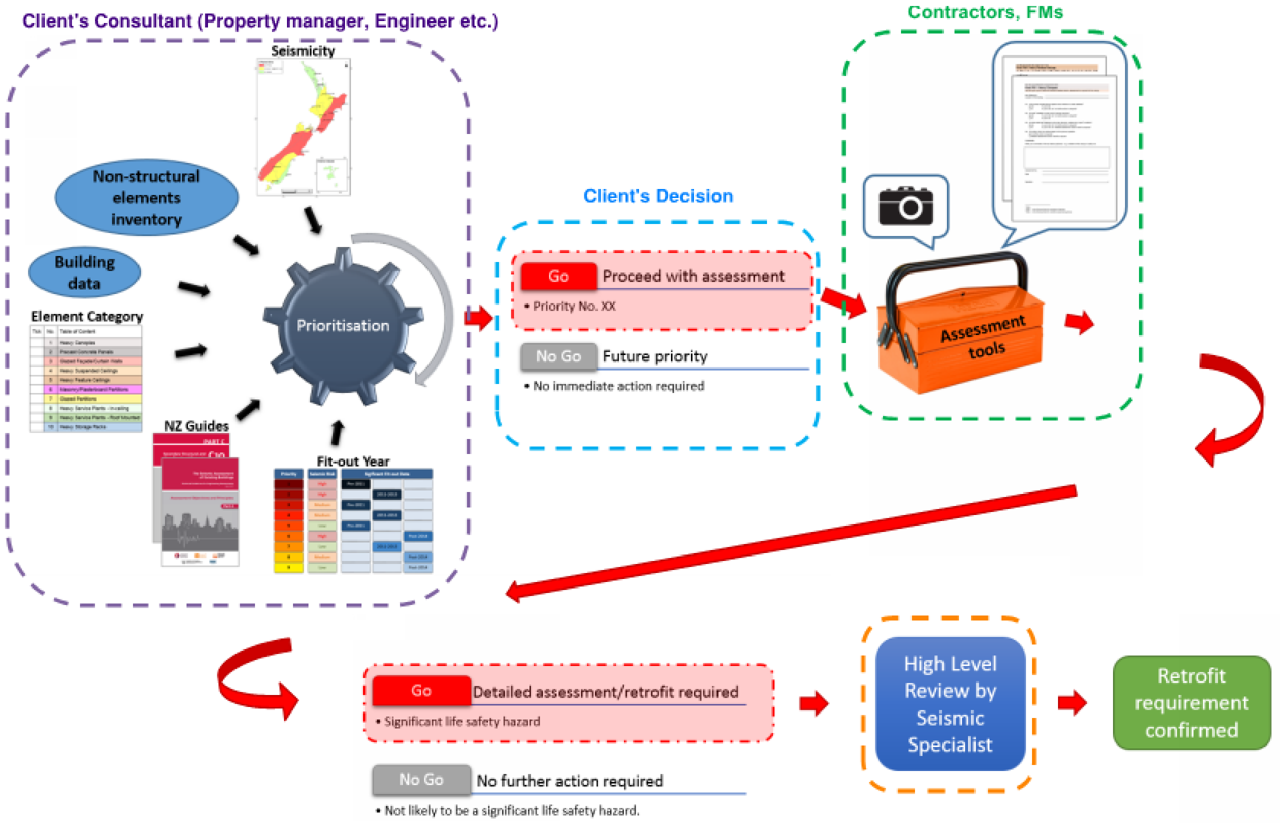

Figure 1: Schematic view of the assessment steps

3.3 Verification

Like every other prescribed and guided process, the success of the method relied on a rigorous verification scheme. The verification aimed at identifying the ambiguous areas, common mistakes and increasing the robustness of the proposed method and tools. The structural and mechanical engineers assigned to the project provided review and verification at the following stages:

- Prioritization of sites, choice of NSEs and sample sizes,
- Assessment reports i.e. checklists and photos captured by the assessors,
- Assessors' recommendations for No further action, Detailed assessment or Remediations

In addition to this ongoing dynamic review process, the engineers accompanied the assessors in the first 3 pilot sites (varying in size and application) and provided on site guidance. At the end of the pilot exercise the assessment reports of the two assessing teams and the project engineers were compared to check if the guided assessment method was yielding consistent results.

For significant remediations proposed by the contractor and approved by the verifier, a structural engineer will be involved/subcontracted for the design and construction monitoring which will provide a producer statement for the designed elements.

3.4 Advantages & Disadvantages

Implementation of a prioritisation scheme means allocation of effort to the most critical items. The scheme considered the application and function of the property (i.e. what it would mean to the client/community if there was damage in the event of an earthquake), the age of the building fitout and its seismicity (i.e. which properties to address first, second and last). This was found the most practical advice to clients with large portfolios and limited resources.

Defining roles enables all parties to focus on their allocated responsibility which allowed for a more efficient assessment process. For instance, focusing on significant life-safety hazards throughout the assessment means that only the items that could potentially pose a life risk to more than one person inside or outside the building must be assessed or mitigated. It will also require constant awareness of the function of the space (i.e. frequency of use) and presence of any measures for hazard mitigation (e.g. furniture as shelter).

On the downside, the project engineer will have to rely on the information provided by the contractor/ assessor (report and photos) for their final high-level review and verification. While the sample-based approach is beneficial in addressing more with reasonable practicality, it has its inherent risks and limitations. These limits should be clearly communicated with the client and the level of engagement of the engineers can be adjusted according to the significance of the risks and consequences.

Implementing a sample-based and risk-based assessment approach is inevitable in large projects and can help develop a planning discipline. However, to maximize efficiency the assessors need to familiarize themselves with the site (review floor plans and enquire about the type of NSEs and services on site) and discuss the assessment plan with the engineers prior to the site visit.

4 IMPLEMENTATION CHALLENGES AND PRACTICAL SOLUTIONS

The historical approach towards seismic resilience of NSE has many challenges due to a variety of limiting factors and implementation challenges across the construction industry (Ferner et al. 2014). This section briefly summarises these challenges and proposes practical solutions or approaches that we believe lead to both better project outcomes as well as improved seismic performance of NSEs. The various topics and associated commentary noted below are based on lessons from projects and for further consideration on future projects.

4.1 Procurement and Delivery Models

The historical procurement model for seismic restraint of NSEs consists of Architects and Building Services design consultants issuing performance specifications for the Contractor to meet. Contractors subsequently engage specialist sub-trades. This model results in solutions that often have minimal consideration of other disciplines, inefficient designs and numerous construction phase interruptions.

Although the historical approach reduces risk to the design team and shortens the design programme, the overall project risk remains. This means the quantum of seismic restraints, installation methodology and costs are unknown at the tender stage. Contractors may be forced to add in a high cost contingency, meaning the clients end up paying more than necessary. It is also sometimes not possible to ensure an adequate design or installation compliance with design standards, leading to poor outcomes for owners, occupants and the community.

The following are suggested approaches to procurement and delivery models that are aimed at addressing these challenges.

4.1.1 Engagement of seismic resilience specialist during design phase

Late design changes and construction phase design are a commercial reality in the current procurement model of building services and architectural elements. To suit the current procurement of building services, a possible solution is to develop a generic seismic resilience design during the design phase and allow for review and redesign to suit construction phase design/layout changes.

It is recommended a competent seismic resilience specialist is engaged during the design phase of a project to enable this to occur. Earlier engagement of a seismic resilience specialist has numerous advantages and benefits for a given project and are described in further detail in the sub-sections below.

4.1.2 Early contractor procurement

Earlier main contractor and sub-contractor input to finalize detailed design and layouts of building services and enable thorough coordination has significant potential to reduce cost of seismic restraints of NSEs (MBIE 2017). Early information about final services layouts enables coordination and informed NSE restraint design. Early layout information considerably reduces the ad-hoc management/design modifications required to address unforeseen clashes.

The client and project team should consider the effects of early contractor involvement as it may reduce the potential for competitive tendering, variety of available building services equipment options and premature commitment to equipment and technology that may be outdated by the end of construction.

4.1.3 Allocation of responsibility for seismic resilience of NSEs

The benefit of clear allocation of responsibility across various disciplines for seismic resilience of NSEs cannot be underestimated. There needs to be a clear definition of roles and responsibilities for the inputs, coordination, design, documentation and specifications for seismic resilience of NSEs.

A possible approach is to create project specific matrix/tables of roles and responsibilities for each discipline, with inspiration from NZCIC guidelines. The matrix can be created to capture the various NSE categories and their interfaces with other NSE elements, for example, suspended building services, suspended ceilings, partitions, etc. The responsibility matrix would need to extend across traditional design and construction phase activities.

For each NSE category, ultimate responsibility for design and documentation should be assigned to the discipline/party that is considered to have most control over the elements. The roles of other disciplines/ parties can include providing timely input, assistance and coordination.

Dispersing responsibilities across multiple parties for the design and documentation of seismic resilience of NSEs should be avoided. The lack of clarity can lead to conflicting documentation or gaps in scope altogether.

4.1.4 Construction phase Building Services Coordinator

It is recommended a dedicated Building Services Coordinator is appointed by the Contractor for a given project. The Building Services Coordinator would need to be responsible for coordinating the construction phase building services design and services layouts across various disciplines. The Building Services Coordinator would also ensure the seismic resilience design intent is adequately considered and captured, including documentation of restraint positions on construction phase building services shop drawings.

4.2 Technical Challenges

Effective seismic resilience design solutions (layouts and details) are not solely based on restraints/braces being designed to resist seismic loads. Solutions need to consider three key criteria (NZS4219 2009):

- Restraint – to resist seismic actions, with consideration of gravity and thermal effects.
- Flexibility – to minimize potential for damage/failure considering displacement of building
- Clearance – to minimize potential for damage/failure considering interaction between elements

It is also necessary to meet the requirements of the elements being restrained. A few items requiring consideration are noted below:

4.2.1 Vibration and acoustic isolation

Certain building services equipment (e.g. fans, attenuators, fan coil units etc.) may require external vibration and/or acoustic isolation from adjacent services. Isolation may be provided via a combination of rubber mounts, springs, flexible connectors etc.

The seismic restraint details and layout should be developed with consideration of these criteria such that the restraints do not ‘short-circuit’ the isolation measures. The solutions should be determined with liaison with the project acoustic & vibration and building services consultants.

4.2.2 Acoustic and fire separation penetrations

It is inevitable that building services will pass through acoustic and fire separation partitions or structural wall elements. Not all fire separation details include provision of large gaps or thick sealants around services passing through wall elements. This can result in displacement incompatibility between the wall and building services elements, diminishing their intended performance. Significant modification of fire separation details may not achieve the desired outcome as fire separation details are typically based on tested assemblies. The seismic restraint design team should liaise with the fire protection specifier regarding the use of fire products and sealants that have been certified via testing for seismic movements.

The position of restraints either side of fire and acoustic walls should be carefully considered to prevent damage/rupture of services under relative movement. The selection of solutions should be determined in consultation with the wider design team on the project. Solutions may include provision of flexible connectors in building services or analysis of the continuous service element subject to imposed movements.

4.2.3 Thermal expansion and contraction

Certain building services runs (e.g. chilled and heated water pipes) are subject to expansion and contraction due to temperature changes. Over-constraining these elements can result in premature failure or decrease their long-term durability. This is especially important on long, straight runs of pipes or where more than one longitudinal restraint may be required.

Solutions may include provision of expansion loops, pipe offsets, proprietary products or simply designing the longitudinal restraint as an anchor point for the service run. The selection of solution should be determined in consultation with the building services and structural engineers on the project.

4.2.4 Pipe clamps

Pipe clamps are typically selected by the Contractor as part of the construction phase design. These may commonly be selected to meet gravity, thermal or durability design criteria, but not often selected with consideration of adequacy under seismic loads.

Selection and specification of pipe clamps that are considered adequate to transfer seismic loads, but not adversely diminish durability of pipes should be in consultation with the contractor and building services engineer on the project.

4.2.5 Riser displacement compatibility

Construction observations have identified that often inadequate consideration is given to thermal effects and lateral deformation of vertical services within risers. This leads to premature buckling and leaking of pipes, reduced durability and loss of amenity. Where transition of vertical services from risers into horizontal branches is not considered, this leads to congestion, and deformation incompatibility with the structure.

During the design phase, it is necessary to establish the concepts for gravity support, measures to accommodate thermal & pressure expansion/contraction, transition of services from risers into horizontal branches and possible locations of anchors and guides. The seismic solution should be developed in alignment with the requirements noted above.

4.3 Seismic Resilience Design and Coordination

The historical design approach has meant that often the design of seismic restraints gives minimal consideration to the overall building architecture and structure, and vice-versa. This is particularly evident when seismic restraint designers are engaged by various sub-trades during the construction phase and adopt a siloed approach. This invariably leads to design schemes that are not spatially coordinated, schemes that are not buildable or lack the consideration toward transfer of restraint loads into primary structure (especially lightweight roofs).

Suggested approaches to the design and coordination of NSEs aimed at addressing these challenges:

4.3.1 Seismic resilience specialist

A competent seismic resilience specialist should provide a project specific seismic resilience strategy suitable for use across the entire project. This strategy should be developed in close consultation with the wider design team. The strategy is to consider and meet (sometimes conflicting) requirements of multiple design disciplines such as architectural, acoustic, building services performance, fire and structural. The scheme and solutions need to be developed with simultaneous consideration of multiple trades, rather than a siloed approach. The seismic resilience specialist should assist in defining, documenting and capturing the project specific statutory and client requirements as the basis of design. Thus, a competent seismic resilience specialist is one that is knowledgeable across the various disciplines.

4.3.2 Holistic design approaches and solutions

Early involvement in the design process allows seismic resilience specialists to develop holistic and innovative solutions. Such solutions contribute to the overall better building performance. Holistic solutions also reduce the extent of seismic restraints, reducing congestion and construction cost.

An example of a holistic solution is restraining services passing through penetrations in floor beams. This reduces the overall number of braces required, saving space and cost (Figure 2). This scheme needs to be developed in consultation with the structural engineer responsible for the design of the primary structure.

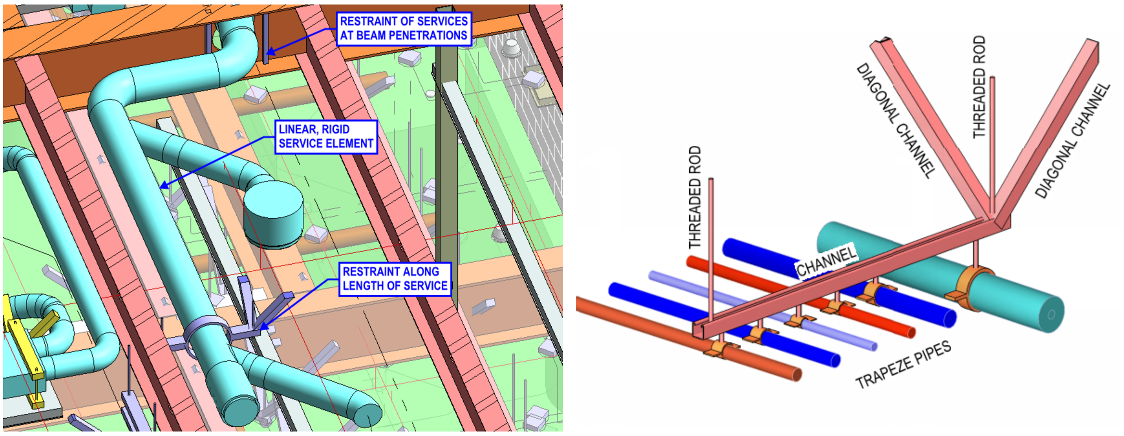

Figure 2: 3D modelling of seismic restraints and combined services hangers

Ceilings, partitions and building services invariably interact, so it is advantageous to establish a seismic restraint strategy that considers this (Figure 3). The strategy should give due consideration to both seismic restraint demands and the relative movement of building services, partitions and ceilings from gravity and earthquake deformations.

4.4 Industry Perception

The inclusion of seismic resilience design during the design phase has historically been perceived as an additional project cost which may increase the design programme. It is positive to note that recently, institutional clients, long term owners and occupiers are consistently recognising the importance of NSE seismic resilience design. However, the value of NSE seismic resilience design during the traditional design phase is not always well understood or widely recognised.

Continued education of the construction industry is necessary to improve the awareness and understanding of seismic resilience design. This needs to include the whole construction industry and stakeholders of assets. This includes building owners, tenants, insurance providers, practicing consultants, Contractors and product supply chain. The value and benefits of early engagement of seismic resilience specialists during the design phase also needs to be better conveyed to clients, project managers, quantity surveyors, design teams and contractors. Proposed updates to industry understanding include:

- Consideration of project life cycle costs, rather than focusing on initial design and capital costs;
- Not perceiving seismic resilience design as an additional service and cost.

The associated cost would be incurred as part of the construction phase of the contractor's fees regardless. Considering seismic resilience during traditional design phase can help reduce the overall project installation programme and cost.

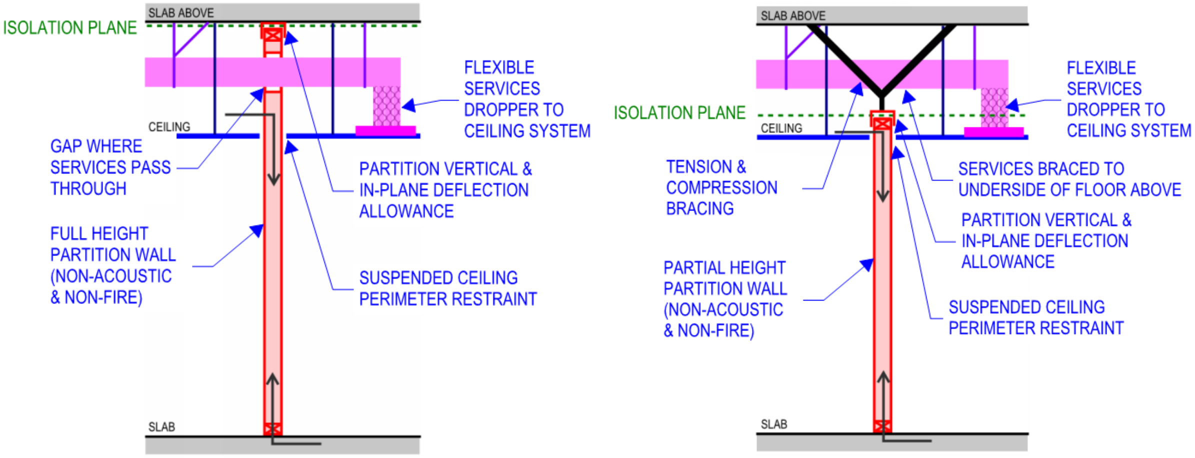

Figure 3: Possible seismic resilience schemes with consideration of suspended ceilings, partitions & services

5 CONCLUSIONS

Historically, consistent systemic shortcomings in the approach toward non-structural elements (NSEs) have resulted in their poor seismic performance in buildings in New Zealand, negatively affecting many communities across the country. This has led to growing awareness in the construction industry and associated stakeholders to address these shortcomings. While this is a good sign, a paradigm shift in thinking, approach and execution is required across the construction industry and stakeholders to realise the benefits of suitable seismic resilience design and installation of NSEs.

This paper i) looked back at the changes and updates in the design and installation of NSEs in New Zealand in the recent decade, ii) provided an example case study which implemented some of these updates in assessing NSEs in a portfolio of existing properties and finally iii) listed the proposed practical solutions and changes the authors believe would positively improve the current procurement and delivery model for NSEs seismic restraints in New Zealand.

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