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Seismic Restraint of Non-Structural Elements – A New Zealand Consultant's Perspective

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Abstract

Seismic restraint of Non-Structural Elements (NSEs) in New Zealand has developed significantly in the past decade. One of the primary drivers of this was the extensive damage to NSEs observed following the Christchurch, Seddon, and Kaikoura earthquakes. This damage resulted in significant economic losses and business disruption which prompted the need for a greater importance to be placed on NSEs.

In comparison, while Australia has regular earthquakes, most of these have been in rural settings so have not generated significant damage. However, there is growing awareness of the importance of the seismic performance of NSEs within Australia. NSEs can be greatly affected by small to moderate earthquakes, such as the earthquakes in Australia. The structure itself can often perform well but the vulnerability of NSEs can result in significant damage and disruption to the building.

Historically, seismic design was done during the construction phase in New Zealand which often resulted in poor project outcomes, including non-compliant installations and poor performance in earthquakes. However, over the past decade, seismic restraint design for NSEs in New Zealand has undergone substantial development, with the emergence of the seismic restraint engineering discipline. It has become more common for a seismic restraint engineer to be engaged earlier in a project to carry out seismic design for NSEs. It is our understanding that Australia is on a similar path with mandatory seismic design requirements and Territorial Authorities now checking for compliance, albeit much of the seismic restraint design in Australia occurs during construction.

This paper will present some of the benefits and challenges of early design engagement and coordination. Through our experience of delivering design and undertaking construction monitoring of seismic design for NSEs within New Zealand, the challenges and future steps will be highlighted.

Keywords: Seismic Restraint, Non-Structural Elements, NSEs, Earthquake

1 Introduction

Non-structural elements (NSEs) are defined as elements within a building that are not considered part of the primary or secondary structure. These components are generally classified into three distinct categories, building service systems, architectural systems, and building contents.

Damage to NSEs can contribute to economic and building functionality loss as well as pose a significant life safety risk. Past earthquakes in New Zealand and around the world have caused substantial damage to NSEs and subsequently, we have learned how important NSEs are in terms of building functionality and keeping people safe. (MBIE, 2017). One of the primary drivers of this was the extensive damage to NSEs observed following the Christchurch and Kaikoura earthquakes. This damage resulted in significant economic losses and business disruption which prompted the need for a greater importance to be placed on NSEs. (Yeow, et al, 2020). An example of damage to NSEs from the Canterbury earthquakes is shown below in Figure 1.

Figure 1: Damage to non-structural elements observed in the Canterbury earthquakes. (Dhakal, 2010).

In the past within New Zealand, seismic restraint design for NSEs was usually undertaken during the construction phase by each sub-trade. Unfortunately, this often led to installations that did not meet safety standards and poor performance during earthquakes. Due to the poor performance of NSEs during earthquakes in New Zealand and around the world, seismic restraint of NSEs in New Zealand has developed significantly in the past decade.

In New Zealand, it is increasingly common to undertake seismic restraint design earlier in a project, often at the same time as other design disciplines. This early involvement in the design process helps improve the overall project because it allows for better coordination, cost management, and addresses construction challenges. Seismic restraint engineers are now engaged at various stages of the project, ranging from the initial concept design to the detailed design phase. Note that there is still seismic restraint work being undertaken in the construction phase as this is a work-in-progress as the industry evolves.

In recent decades, Australia has not had large earthquakes in urban centres to generate significant damage, however, there is a growing awareness of the importance of NSEs' seismic performance. NSEs can be significantly affected by minor to moderate earthquakes, the earthquakes that are most common in Australia. The structure may perform well, but the vulnerability of NSEs can result in significant damage and disruption to the building.

It is our understanding that most of the seismic restraint design in Australia occurs during construction. This is in line with our Australian buildings approach at Beca, where a performance specification for seismic restraint is issued as part of the design documentation. This outlines the specification for seismic restraint design which is undertaken by the contractors and subcontractors during the construction phase.

This paper aims to summarise the development of the seismic restraint of NSEs in New Zealand and Australia. It presents some of the benefits and challenges of early design engagement and coordination of NSEs. Through a consultant's experience in delivering design and construction monitoring (CM) of seismic design for NSEs within New Zealand, this paper will highlight challenges as well as future steps. This paper endeavours to open the channels between New Zealand and Australia for seismic restraint design and CM of NSEs to be able to share learnings from both sides and grow our knowledge.

2 Our understanding of Seismic Restraint for NSEs in Australia

While Australia has regular earthquakes, historically most of these have been in rural settings so have not generated significant damage. However, occasionally there are small to moderate earthquakes in Australia that impact urban areas, such as the M5.9 2021 Melbourne Earthquake (example of damage shown in Figure 2 below) and the M4.0 2023 Melbourne Earthquake (CNN, 2023), and these earthquakes can greatly affect NSEs. As such, there is growing awareness of the importance of the seismic performance of NSEs within Australia.

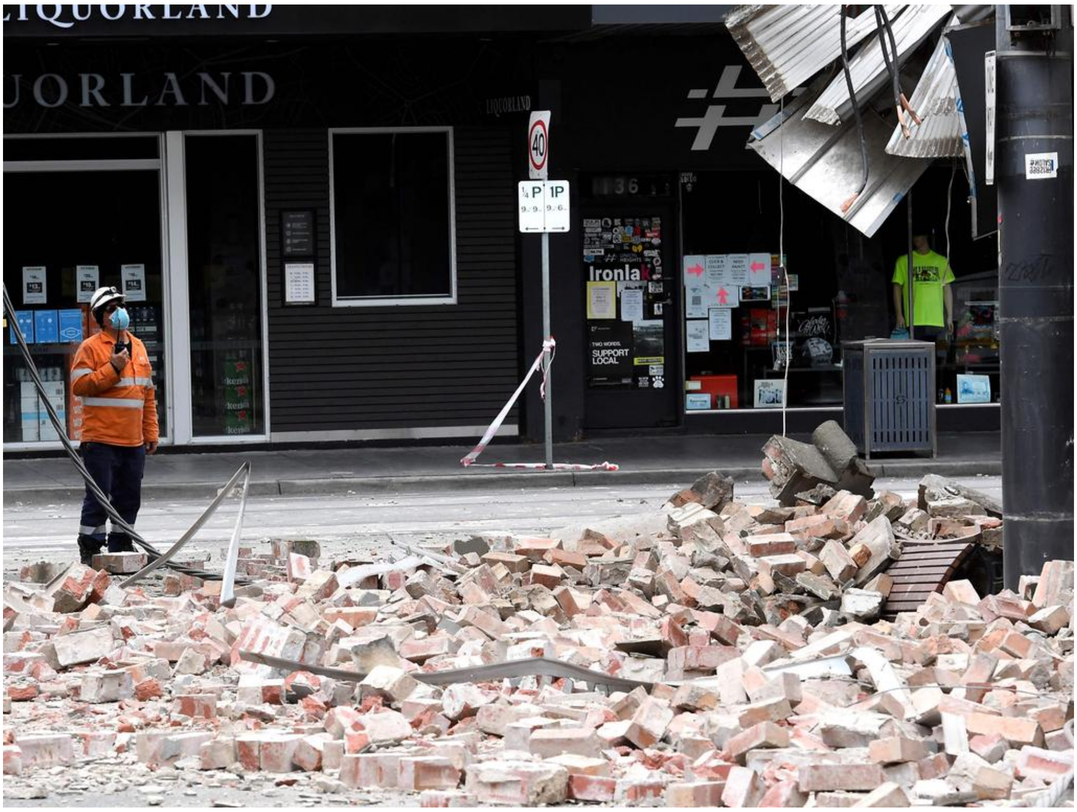

Figure 2: Damage from the M5.9 2021 Melbourne Earthquake. (ABC News, 2021).

For many years, Australia did not have seismic provisions in codes. After the 1989 Newcastle earthquake, seismic design began getting more attention. (Woodside, McCue, 2017). In 1993, AS 1170.4:2007 was introduced to provide seismic design loads for Australia, however it was not often applied to NSEs even though AS 1170.4:2007 Section 8 requires non-structural parts and components to be considered. (Con-form Group, 2023).

In the last few years, however, there has been significant change in Australia in terms of NSE compliance and seismic design is now very much established in Australia. It took a long time for building authorities to request it, but now it is standard practice and is mandatory under the National Construction Code (NCC). John Woodside notes that compliance is not as consistently achieved as it is in New Zealand, however building authorities now require compliant designs. Therefore, consultants and the general industry are typically documenting seismic design more frequently, which has progressed the evolution of the service offering in Australia. (Woodside, 2020).

It is our understanding that most of the seismic restraint design in Australia occurs during construction. Often seismic specialists are engaged, either by the building developer or the main contractor or sub-contractor. The seismic specialist will provide seismic restraint drawings and will certify the design. Construction monitoring of seismic restraints however can be varied. (Rad and Sharifi, 2020).

Our understanding is that Australia now uses the combined AS/NZS 2785:2020 for the design of ceilings, however, does not have a standard for the seismic design of building services or building contents such as those that exist in New Zealand. (NZS 4219:2009 & NZS 4104:1994). This lack of guidance can lead to mixed results for the seismic restraint design.

3 History of Seismic Restraint for NSEs in New Zealand

Historically, the seismic restraint design of non-structural elements in New Zealand was poorly executed and would often get overlooked. Although there were New Zealand Standards that covered the seismic restraint design and installation of NSEs, these were poorly followed. (Kevin O’Connor & Associates Ltd, 2016).

Generally, the design and installation of NSE restraints fell to the main contractor during the construction phase. The main contractor would rely on their subcontractors to design and coordinate the installation of the restraints as part of their trade. Often, however, the work was executed poorly or not at all. (Ferner, Lander, Douglas & Baird, 2015). This was often due to a lack of understanding on the part of the construction team. Engineers, architects, and territorial authorities often did not inspect or enforce the installation of restraints. Also, as coordination was typically done by each trade, there was often congestion and poor planning of service layouts, and it was often not practical to install bracing to NSEs.

During the Canterbury/Christchurch earthquakes (2010 and 2011) and the Cook Strait/Seddon Earthquakes (2013), a large amount of damage was caused by NSEs. (Schouten, 2013; Thomson & Bradley, 2014; Helm, 2014). Often this was due to non-compliant seismic restraint designs, including no bracing at all. Often clearances between services were not achieved which led to services moving around. It was not uncommon after these earthquakes to see the collapse of ceilings and services and significant water damage caused by impact on fire sprinkler heads which fractures the head and result in water leaking.

Even though the primary structures of the buildings were in many cases largely undamaged, swinging or fallen NSEs caused significant operational disruption. Tenants often had to find temporary premises elsewhere, for a significant period, while their damaged premises were repaired. At the same time, many of these damaged premises were found to contain non-compliant NSE restraint design, and this was often rectified and upgraded to the current code during the damage repair process.

Following the earthquakes, a general shakeup took place across New Zealand as awareness and understanding grew of the importance of properly restraining NSEs. Training courses were offered by IPENZ (now Engineering New Zealand) and other organisations to construction professionals and tradespeople, to discuss the basics of the seismic restraint of NSEs and how to apply the various standards. Fixings for components such as bracing and hangers, also had to comply with the standards and often these had to pass European or American tests including satisfactory performance in cracked concrete.

However, there was still significant discussion regarding when seismic restraint design should take place and who was best placed to undertake the design. Seismic restraint of NSEs was, for a while, still seen as best carried out during the construction phase, as it could be done based on shop drawings produced by the subcontractor and based on the specific product and equipment they selected. An issue with this approach was subcontractors often did not have the skills to design and apply the standards and they did not allow enough in their Tender price to do it. The other issue was that Councils did not get visibility of bracing solutions at the Building Consent stage (prior to construction) and there was no clarity on what contractors or subcontractors should price at the Tender Stage. Design during the construction stage, especially when done by individual subcontractors) also meant that coordination was left too late and smart solutions could not be implemented.

Eventually, the industry has generally moved towards a coordinated design being carried out by professional engineers during the main design stage of a project to ensure compliant installation on site is achieved. Figure 3 below shows an example of a project design in 3D on the left compared with the final on-site installation on the right.

Figure 31: Seismic Restraint 3D Model compared with the physical installation on site. (Beca).

4 Current Status of Seismic Restraint Design and Construction Monitoring in New Zealand

As outlined above, in recent years there have been significant changes in the way NSEs are seismically designed and restrained in New Zealand. The catalyst for this was the Canterbury earthquake sequence (2010-2011) but several drivers have contributed to the changes. Most notably, the lack of design resulting in large-scale failures increased public awareness of the issues. This led consenting authorities in several jurisdictions to require design Producer Statements (PS1) to be issued by a Chartered Professional Engineer (CPEng) before consent would be granted for new buildings.

In New Zealand, producer statements are used to support building consent applications and code complaint certification as a professional opinion based on sound judgment and specialist expertise. A PS1 is a designer producer statement typically required at the initial building consent lodgement stage. A PS4 is a construction review producer statement required on completion of the installation to confirm construction compliance. Both the PS1 and PS4 require review and sign off by a suitably qualified independent design professional (CPEng). (MBIE, 2022). In New Zealand, a PS1 and PS4 for seismic restraint is required.

To deal with this change, the industry has transformed significantly since 2010. There are now several ways procurement of seismic restraint design can vary significantly depending on the project complexity and client requirements, typically it is broken down into three categories as shown below in Table 1.

Table 1: Seismic restraint design procurement options

Performance Specification	Indicative Design	Coordinated Design
Performance specification by the design team (architect and services engineers).	Performance specification by the design team (architect and services engineers).	Performance specification by the design team (architect and services engineers).
All elements are designed and built by the contractor.	Indicative restraint layouts (for selected elements) and pre-consent phase PS1 by the restraint engineer.	Coordinated design and PS1 by the restraint engineer (to an agreed level of development).
	Coordination is carried out by the contractor along with the remaining design and build elements.	Construction phase design carried out by the contractor.

All three options noted above can be appropriate for a given project but, in some cases, delaying the design of NSEs to the construction phase can pose significant risks to the client including cost overruns, re-coordination after shop drawings are issued, and programme delays. As a result, it is now common in New Zealand particularly for large, complex projects to include the pre-consent phase design of NSEs.

While there have been numerous positive changes, the industry is still working through several issues that have resulted from the rapid progress that has been made. Design consistency is a concern as many of the relevant standards that have been revised (such as NZS 1170.5:2004 (incl. Amd 1) and AS/NZS 2785:2020) have not been directly incorporated into the New Zealand Building Code (NZBC). This has resulted in many engineers interpreting and applying seismic requirements differently causing confusion for clients and consent authorities and resulting in potentially under-designed or over-designed buildings. To clarify this, some larger clients, such as the Ministry of Education, have produced their own guidance to better define the performance requirements for NSEs. (MoE, 2020).

Along with these changes, the level of coordination required for seismic restraint is still poorly defined. It is only briefly mentioned in the New Zealand Construction Industry Council Guidelines (NZCIC) with most of the responsibility still left to the contractor. Client specific Building Information Modelling (BIM) execution plans are often used to fill this gap when seismic restraint design is included as part of a coordinated design approach.

The recent focus has been on new buildings, but the poor performance of NSEs in existing buildings drove the changes. Along with updates to building code requirements for new builds, the seismic assessment of existing buildings guidelines was also amended and now contains a section specific to NSEs. (NZSEE, 2017).

The New Zealand Earthquake-Prone Building Amendment Act 2016 (New Zealand Government, 2016) focuses only on those buildings that are considered earthquake prone (%NBS score of <34%), with higher importance buildings, and those located in higher seismic regions, requiring strengthening first, refer Figure 4 below. Along with the primary building structure, all elements that pose a significant life safety risk also require remediation such as unreinforced masonry, heavy ceilings, large plant with hazardous materials, and tall storage racks.

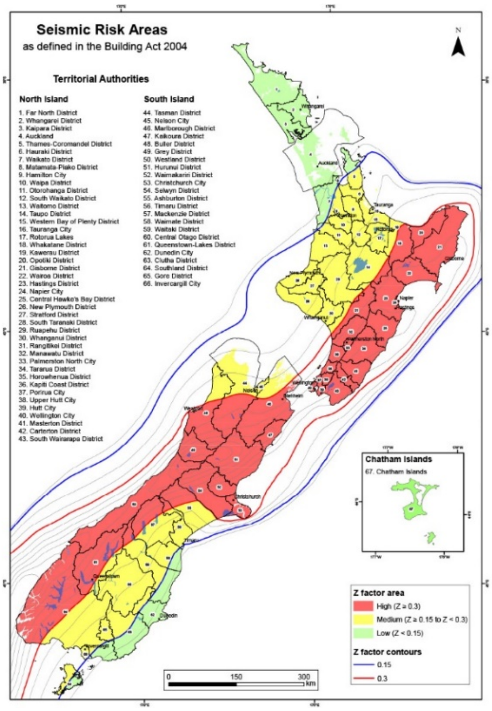

Figure 42: Seismic risk map of New Zealand (MBIE, 2018).

During the construction phase of a project in New Zealand, the seismic restraint engineer typically carries out inspections to CM2 (Construction Monitoring Level 2) or CM3 (Construction Monitoring Level 3), as defined by ACE NZ (Association of Consulting Engineers New Zealand). Site inspection reports are provided by the seismic restraint engineer to the contractor and any issues are rectified and closed out. Eventually, the seismic restraint engineer issues a PS4 Producer Statement to acknowledge they are satisfied that the works are complete and are generally in accordance with their design intent as shown on the Building Consent documentation. This process appears to be working well and is in line with the construction monitoring process of other disciplines such as structural and building services engineering.

5 Benefits of early engagement of a NSE Engineer

Early design involvement of a seismic restraint engineer gives rise to better overall project outcomes by allowing for a better ability to coordinate, cost, and address constructability issues. Seismic restraint design of NSEs is most effective when it is completed in phase with architectural, structural, and building services designs. This ensures holistic project coordination and reduces rework if a seismic restraint engineer is engaged at a later phase.

The latest SESOC (Structural Engineering Society New Zealand) Interim Design Guidance (SESOC, 2022) identifies the need for early engagement of non-structural seismic restraint specialists to enable the design and detailing of NSEs to be coordinated during the design phase, thereby minimising the need for design changes during the construction phase. Recommendation 11.2 states:

> *"Advice from non-structural seismic restraint specialists should be sought early during the design phase of projects. This is to enable the design and detailing of non-structural elements to be coordinated and minimising the need for disruptive design changes during the construction phase. – SESOC"*

Ideally, a seismic restraint engineer should be included right from the project's outset, during the concept or initial design phase. During these early project stages, the seismic restraint engineer can offer valuable insights and guidance to other design teams, including suggestions for the most suitable seismic restraint strategies. Attempting detailed design work at this early point is often not productive and may prove to be ineffective. Instead, the focus of the seismic restraint engineer should revolve around providing critical advice and coordinating efforts.

Early engagement of a seismic restraint specialist enables more efficient coordination of non-structural element (NSE) designs with architectural, structural, and building services disciplines. A simplified figure of typical coordination items between architects, building services engineers, and structural engineers with building seismic restraint (BSR) engineers is shown below in Figure 5. It allows for more strategic solutions to be designed to create a smoother construction phase when contractors are building and coordinating on-site. Design changes during later stages of the project including construction can be disruptive and incur costs. The opportunity for overall influence on design, and detection of design risk, is greatest at the early design stages.

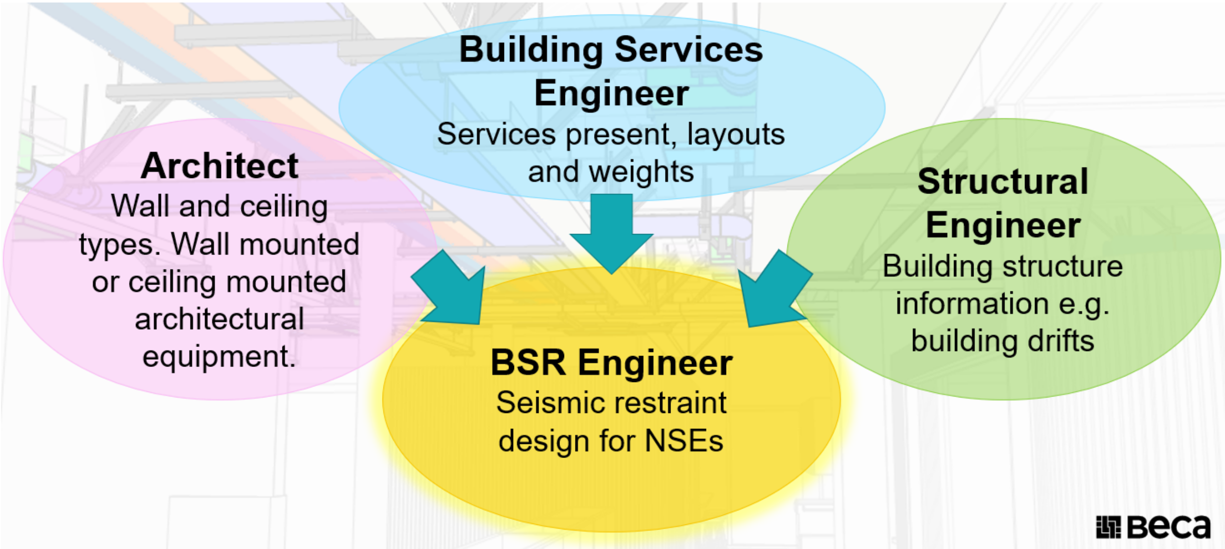

Figure 53: Seismic Restraint Design Roles and Responsibilities

It should be noted that not all NSEs benefit from early engagement and the seismic restraint engineer should focus on the items that will have the most impact on the overall project at the early stage. Some items are still better to be left with the contractor in the construction phase to detail. It should also be noted that the level of early engagement depends on the complexity of the project with the end goal of optimising value added and remaining cost effective in terms of design fees.

Early engagement is beneficial for consenting purposes. Most councils in New Zealand are now requiring a PS1 (designer producer statement) for the seismic design of NSEs at the initial Building Consent lodgement phase. Therefore, to gain building consent, seismic restraint design is required to be undertaken in the project design phase. This shift gives councils greater visibility of the seismic design.

In our experience, it is common for a seismic restraint engineer to be brought in during the developed or even the detailed design phase, often just before the project is submitted for Building Consent. While this might work for simpler projects, it frequently means that the design phase is occurring too late in the overall process to effectively influence other disciplines and make substantial improvements in the project's outcome. For instance, during the detailed design phase, making significant changes such as relocating plant rooms or reinforcing the structure becomes impractical. These types of alterations can have a major impact on the seismic performance of NSEs. Additionally, discovering errors in design assumptions at a later design stage can lead to significant disruptions in terms of costs and programme delays.

Early engagement of seismic restraint engineers increases tendering accuracy due to design documentation being available at the time of tender rather than being accounted for during the construction phase. If seismic restraint design is left until construction phase, pricing by the contractor is typically an estimated lump sum value. Therefore, if the seismic design completed earlier, more accurate pricing can be obtained at the tender phase.

6 Current Challenges and Future Steps for New Zealand

There are still challenges and areas of development relating to the design and construction monitoring of NSEs within New Zealand.

From a recent paper on a similar topic, it is noted that the lack of industry standards for seismic restraint design of NSEs contributes to differing outputs of design, difficulties with design timing, and confusion in scope. (Clarke, Baird & Kam, 2023). The inconsistency in seismic restraint design outputs poses challenges for contractors, other design consultants, and clients. Because there are no standard guidelines, there is no expectation on what documentation should be delivered. Contractors in particular face difficulties in accurately pricing designs due to differences in the quality and appearance of drawings received from seismic restraint engineers, which reduces tendering accuracy.

It is recommended that seismic restraint design is included in the NZCIC Industry guidelines and should include things such as the purpose and key activities at each standard design stage. Proposed seismic restraint design tasks and responsibilities at each project stage have been suggested within the paper titled 'Early engagement of non-structural seismic restraint specialists' by G. Clarke, A. Baird, and W.Y. Kam. Industry guidelines would be beneficial to standardise the seismic restraint approach and clarify design responsibilities. These guidelines would standardise what scope items need to be completed early in the project and those which make more sense to be completed by the contractor in the construction phase.

For existing buildings, the challenge is obtaining as-built records of the NSEs that have been installed, as it is often difficult and time-consuming to survey elements enclosed within a ceiling. Trying to upgrade existing NSEs to current code requirements is challenging because there is often too much congestion to install bracing or to provide the clearances required between elements. Coming up with more efficient ways to upgrade existing NSEs is currently under development, by consultants and contractors in the New Zealand construction industry. Common approaches often include trying to obtain "best value for money" and addressing higher risk items in terms of life safety, business continuity and protection of contents. (Ferner, Lander, Douglas & Baird, 2015). These approaches generally involve significant consultation with the landlord or tenant.

7 Conclusions

The seismic restraint design for non-structural elements (NSEs) holds critical importance due to the risks it addresses in terms of both life safety and building functionality during earthquakes.

Historically, seismic restraint of NSEs has been poorly executed. However, over the past decade, seismic restraint design for NSEs in New Zealand has undergone substantial development, with the emergence of the seismic restraint engineering discipline. The advantages of involving seismic restraint engineers early in the process are now widely acknowledged. Australia is on a similar path with mandatory seismic design requirements and Territorial Authorities now checking for compliance.

Early engagement with a seismic restraint engineer facilitates the creation of comprehensive strategies and solutions. This proactive approach helps mitigate the risk of design revisions and additional construction expenses. When NSE seismic design aligns with architectural, structural, and building services plans, it enhances project outcomes by improving coordination, cost-effectiveness, and constructability considerations.

Current developments include advocating to incorporate a separate seismic restraint discipline in the NZCIC Guidelines, to standardise the scope, inputs, timings, and deliverables of the seismic restraint discipline. Also in progress is the development of more effective methods to upgrade existing installations.

8 References

ABC News. 2021, September. Mansfield magnitude-5.9 earthquake shakes Melbourne, regional Victoria, southern NSW, Sydney, Canberra, Adelaide and Launceston. Retrieved from: https://www.abc.net.au/news/2021-09-22/earthquake-victoria-melbourne-nsw-sydney-canberra-act/100481732

ACE NZ Construction Monitoring Guidelines - https://assets.nationbuilder.com/acenz/pages/1431/attachments/original/1593472578/Guideline_on_the_Briefing_and_Engagement_for_Consulting_Engineering_Services-1st_Edition_2004.pdf?1593472578

AS 1170.4:2007. Structural Design Actions – Part 4: Earthquake Actions – Australia. Standard Australia.

AS/NZS 2785:2020. Suspended Ceilings – Design and Installation. Standards Australia and Standards New Zealand.

Clarke, G., Baird, A., and Kam, W.Y. 2023. Early engagement of non-structural seismic restraint specialists. Structural Engineering Society New Zealand (SESOC), June 2023.

CNN. 2023, May. Largest earthquake in 120 years rattles Melbourne but causes little damage. Retrieved from: https://www.cnn.com/2023/05/29/australia/melbourne-largest-earthquake-intl-hnk/index.html.

Con-form Group. 2023. Looking at Seismic Compliance of Non-Structural Components in Australia. Retrieved from: https://con-formgroup.com.au/looking-at-seismic-compliance-of-non-structural-components-in-australia/.

Dhakal, R.P. 2010. Damage to Non- Structural Components and Contents in 2010 Darfield Earthquake, Bulletin of the New Zealand Society of Earthquake Engineering, Vol. 43, No.4, pp. 404-411.

Ferner, H., Lander, M., Douglas, G., and Baird, A. 2015. Pragmatic Approaches to Improving the Seismic Resilience of Non-Structural Elements in Existing Building. Proceedings of the NZSEE Conference 10-12 April 2015.

Helm, N. 2014. The cost of earthquake resilience, BUILD (145). Building Research Association of New Zealand (BRANZ).

Keen, J. 2023. Recent Developments in Improving Seismic Resilience in Healthcare Facilities in New Zealand, IHEA Conference 2023.

Kevin O'Connor & Associates Ltd, 2016. Survey of Seismic Restraint of Non Structral Elements in Existing Commercial Buildings. Commissioned by Ministry of Business, Innovation and Employment (MBIE) and Earthquake Commission (EQC). Retrieved from: https://www.mbie.govt.nz/assets/178a7534c9/survey-of-non-structural-elements-in-20-commercial-buildings.pdf

Ministry of Business, Innovation and Employment (MBIE). 2017. "Economic Benefits of Code Compliant Non-structural elements in New Buildings", Opus. Ministry of Business Innovation & Employment.

Ministry of Business, Innovation and Employment (MBIE). 2018, August. Building Performance - How the system for managing earthquake-prone buildings works. Retrieved from:

https://www.building.govt.nz/managing-buildings/managing-earthquake-prone-buildings/how-the-system-works/

Ministry of Business, Innovation and Employment (MBIE). 2020, December. How to support your building consent application – Producer statements. Retrieved from: https://www.building.govt.nz/projects-and-consents/apply-for-building-consent/support-your-consent-application/producer-statements/

Ministry of Education (MoE) and MBIE. Designing Schools in New Zealand Structural and Geotechnical Requirements Version 3.0, October 2020.

New Zealand Government. New Zealand Earthquake-Prone Building Amendment Act 2016. Retrieved from: https://www.legislation.govt.nz/act/public/2016/0022/latest/DLM5616102.html

New Zealand Society for Earthquake Engineering. The Seismic Assessment of Existing Buildings: Technical Guidelines for Engineering Assessments, July 2017, Version 1, C10 – Secondary Structural and Non-Structural Elements.

NZS 1170.5:2004 (incl Amd 1). Structural Design Actions – Part 5: Earthquake Actions – New Zealand.

NZS 4104:1994. Seismic Restraint of Building Contents. Standards New Zealand.

NZS 4219:2009. Seismic Performance of Engineering Systems in Buildings. Standards New Zealand.

Rad, A.N. and Sharifi, P. 2020. Construction Monitoring Report for Seismic Bracing of Non-structural components. Australian Earthquake Engineering Society (AEES) Virtual Conference, November 2020. Available from AEES.

SESOC (Structural Engineering Society New Zealand). 2022. Interim Design Guidance - Design of Conventional Structural Systems. Version 11. Available from SESOC.Schouten, H. 2013. Call for more controls for ceilings, fittings, Stuff. https://www.stuff.co.nz/dominion-post/business/commercial-property/8800732/Call-for-more-controls-for-ceilings-fittings

SESOC (Structural Engineering Society New Zealand). 2022. Interim Design Guidance - Design of Conventional Structural Systems. Version 11. Available from SESOC.

Thomson, E.M. and& Bradley, B.A. 2014. Preliminary analysis of instrumented Wellington building responses in the July/August 2013 Seddon/Lake Grassmere earthquakes. Proceedings of the NZSEE Conference 21-23 March 2014.

Woodside, J. 2020. The Design of Suspended Ceilings in accordance with AS 1170.4 and AS/NZS 2785 for Australia. Retrieved from: https://awci.org.au/sa/files/2020/02/Ceiling-presentation-SA-Final.pdf

Woodside, J. and McCue, K. 2017. Early History of Seismic Design and Codes in Australia. Australian Earthquake Engineering Society (AEES), 2017. Available from AEES.

Yeow, T., Baird, A., Ferner, H., Ardagh, M., Deely, J., Johnston, D. 2020. Cause and level of treatment of injuries from earthquake damage to commercial buildings in New Zealand. Earthquake Spectra, Vol. 36, pp. 1254–1270.