Shaping Future Practice for Non-Structural Seismic Performance

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ABSTRACT

Non-structural elements (NSEs) are essential for building functionality, yet their seismic performance is often poorly understood. Beyond posing a risk to life safety, damage to NSEs affects functionality, is costly to repair, and results in business disruption and downtime. This compromises the resilience that designers and owners expect of their buildings. The lack of minimum seismic performance standards for NSEs creates challenges in specification, construction, and procurement, which leads to uncertainty, increased costs and risks for industry professionals.

In response to these challenges, a BRANZ-supported collaborative initiative was launched to develop solutions that address shortcomings. In 2024, BRANZ published the Code of Practice for the Seismic Performance of Non-Structural Elements (NSE CoP). The NSE CoP provides guidance on the minimum acceptable standards for the design, coordination, selection, and construction of NSEs, aiming to enhance industry confidence that all aspects of a building will meet expected seismic performance levels. The NSE CoP also offers insights into designing systems that surpass minimum code requirements.

The next phase is underway to expand the current scope of the Code of Practice. This will incorporate technical design and coordination guidance for additional NSEs, offer more detailed guidance for construction installations, and develop dynamic testing protocols in-line with New Zealand Standards for seismic qualification of plant and equipment, amongst other initiatives.

This paper presents key developments from the latest phase of the NSE CoP and seeks collaboration from industry professionals and researchers for further input, with the authors eager to engage with partners in advancing this.

1 INTRODUCTION

Several recent earthquakes in New Zealand – including the 2010–2011 Canterbury earthquakes, the 2013 Seddon earthquake, and the 2016 Kaikōura earthquake – resulted in a significant number of buildings being rendered unsuitable for re-occupation due to failures and damage to non-structural elements (NSEs) (Dhakal, 2010; Baird, 2017). Damage to NSEs severely impacted building functionality, leading to major disruptions for businesses and communities. These events highlighted the critical need to enhance the seismic performance and resilience of our building stock.

2 PURPOSE AND MOTIVATION FOR NSE CODE OF PRACTICE

The primary purpose of the NSE CoP is to:
"*Provide guidance on the seismic design, coordination, and construction of non-structural elements to improve practices, and establish consistency in approach across the industry.*"

Over the past decade, the New Zealand building industry has increasingly recognised the need for a guidance document to address issues related to NSEs, such as inconsistencies in design practices and allocation of roles and responsibilities (BIP White Paper, 2020; Rashid, 2022). Problems also exist around the lack of clarity on the transfer of responsibilities and risk to contracting teams. More than this, there are significant challenges in satisfying the extensive and varied requirements for the functionality and seismic performance of NSEs. For example, ensuring services that penetrate fire walls are both fire-rated and capable of accommodating seismic movements can prove difficult. This often results in complications during the review and sign-off stages of construction. The recently published Code of Practice for the Seismic Performance of Non-Structural Elements (NSE CoP) offers guidance for industry professionals, addressing the seismic performance and functionality of NSEs.

In addressing the seismic performance of NSEs, the NSE CoP could have focused on numerous potential issues. After gathering industry feedback, key issues were identified as primary areas for focus, which align with the document's purpose above. These are explored further in the context of the NSE CoP's first version to industry, with future stages anticipated to broaden its scope. The main areas of focus are:

1. Roles, responsibilities and scope gap
2. Early coordination and design integration
3. Clarifying seismic performance objectives
4. Provide a baseline for seismic performance of NSEs & fostering innovation and research

3 KEY ASPECTS OF NSE CODE OF PRACTICE

3.1 Roles, Responsibilities and Scope Gap

A crucial challenge within the industry has been the lack of clarity in roles, responsibilities, and effective management of scope between stakeholders. The NSE CoP seeks to address this by providing a framework that outlines recommendations on the 'what', 'who', 'how' and 'when': making clear the process of multidisciplinary collaboration that should be undertaken. It emphasises the importance of early-stage engagement and coordination between disciplines—including structural engineers, architects, building services, fire protection, and others—which is crucial for improving seismic performance outcomes. This proactive engagement is essential for achieving and maintaining consistent seismic performance standards across a variety of projects.

3.2 Early Coordination and Design Integration

One of the key objectives of the NSE CoP is to optimise seismic performance by promoting early discussions and decisions between clients and design team, as well as between disciplines in the design team, during the planning and early phases of construction projects. The NSE CoP has intentionally aligned roles with the New Zealand Construction Industry Council Guidelines (NZCIC, 2023), which define and communicate responsibilities and outputs to all parties involved in a project through all project stages.

The NSE CoP provides a structured approach to design and coordination in a scalable framework that accommodates versatile applicability across a variety of building types and project sizes. This approach not only improves the integrity and quality of construction documentation, but also enhances the consistency of seismic design practices, which ultimately leads to better overall outcomes for building resilience and safety.

The NSE CoP is based on holistic design of all disciplines from the start of the project.

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Seismic performance is a complex aspect of building design that requires input and collaboration from multiple disciplines. This makes siloed approaches ineffective. The achievement of the required seismic performance of all NSEs has often been compromised by siloed approaches, resulting from disconnected timing of design work by various disciplines, poor or limited coordination between disciplines during the main building design, inconsistency in design approach and lack of clarity in scope between disciplines.

The NSE CoP provides guidance on how to work through the holistic design process, from project briefing through to design that is undertaken during the construction phase. The design process described in the NSE CoP is scalable and can be used for large complex buildings to smaller simpler buildings.

The design process includes development of a Building Movement Strategy, where the design team consider all aspects of building movement from early in the project. The Building Movement Strategy considers requirements for seismic movement and gaps versus locations where movement needs to be restricted and restrained, e.g. thermal movements of components required for day-to-day function of the building versus seismic restraint of components. It is acknowledged that there are often competing goals, with potential cost and performance implications, and compromises are likely to be needed. Nevertheless, the NSE CoP is clear that what is important is that the design team should agree what aspects are to take precedence and which can be compromised, and the agreement is to be clearly documented including why the decision was made.

The NSE CoP defines responsibilities for design tasks and coordination between disciplines for typical project phases, noting that, even if final design is to be undertaken during the construction phase, the design and coordination during the design phase is needed and the philosophy and coordination is to be handed over to the contracting team.

The NSE CoP identifies and acknowledges the challenges that occur at the interfaces between the work of multiple disciplines and that these interfaces are typically poorly coordinated. To address this, the NSE CoP provides guidance on various design elements and discipline responsibilities for six specific interfaces. This includes inter-storey drift interfaces, vibration isolation interfaces, thermal expansion interfaces, ceiling and partition interfaces, equipment/system section interfaces and passive fire interfaces.

The design process provided in the NSE CoP includes an iterative process for disciplines to coordinate design philosophies, consider the implications of the proposed building form and layout, structural system options, locations of heavy plant, fire engineering, building services reticulation strategy and the overall strategy for how building movements will be accommodated. Figure 1 provides an example of the conceptual design process from the NSE CoP.

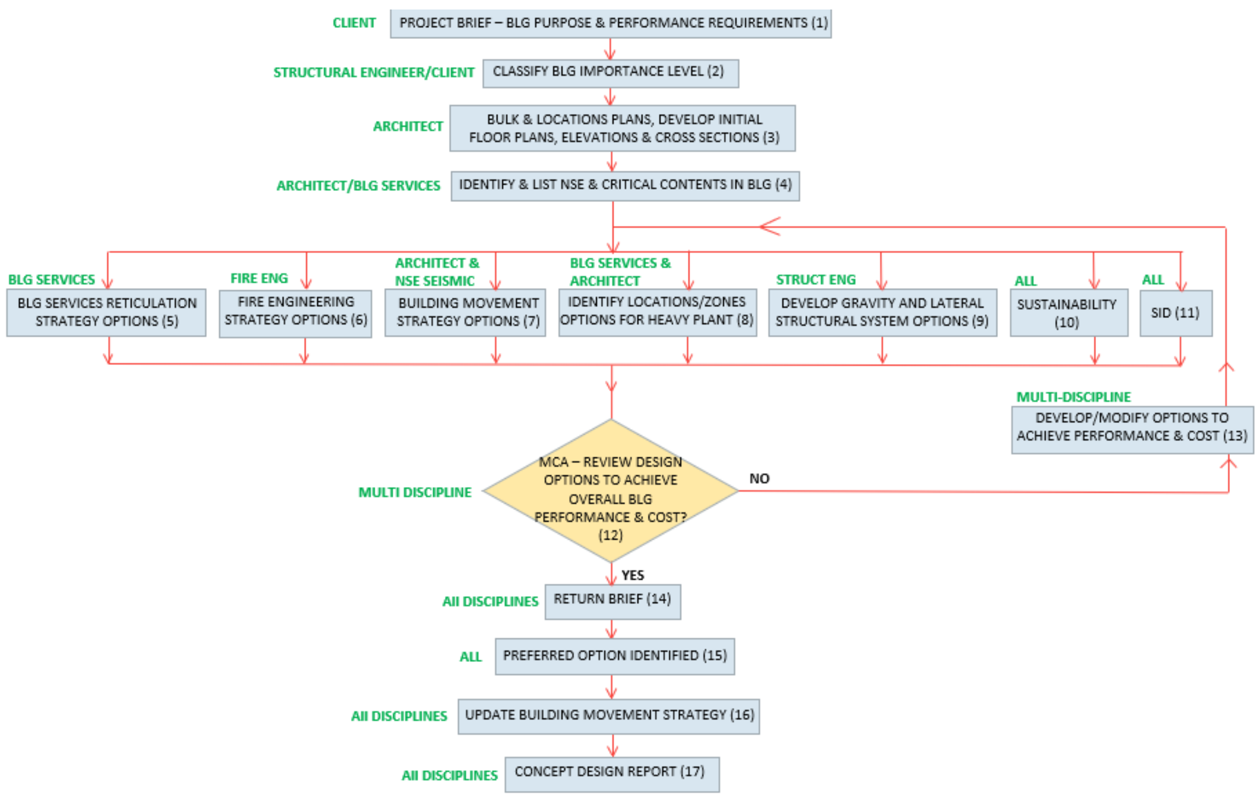

Figure 1. Concept design process flowchart.

3.3 Clarifying Seismic Performance Objectives

A central focus of the NSE CoP is the establishment of performance objectives for several NSEs, accompanied by detailed guidance on how to meet these. A notable example is the seismic performance of concrete anchors for the seismic restraint of services, partitions, and ceilings. Significant attention and research have gone into aspects like seismic rating, testing protocols, and potential prying actions, despite failures in the application of these anchors are rare. This suggests a potential mismatch between the areas where resources are concentrated and the actual issues that need addressing.

3.4 Baseline for Seismic Performance to Fostering Innovation and Research

The NSE CoP serves not only as a guideline, but also as a baseline reference for other forthcoming guidance documents that are currently being developed. These include the structural, geotechnical and building services design guidance for hospitals, and the low damage seismic design of buildings guidance document. The NSE CoP serves as a foundational baseline upon which these guidelines can build to address the specific requirements for hospitals and low-damage buildings.

The NSE CoP also serves as a catalyst for innovation and research by identifying and addressing existing knowledge gaps within the industry. By clearly highlighting these gaps, the NSE CoP can prioritise future research. The NSE CoP establishes a baseline level of performance that allows for meaningful advancements to be made.

3.5 Using Holistic Design to Improve Seismic Performance and Resilience

The NSE CoP supports the design team to consider various options to improve seismic performance and resilience of buildings. There are different means of providing a building with improved seismic performance and resilience. One option, being developed as a deemed-to-comply approach for low-damage seismic design (LDSD) (Sullivan et al. 2024), is to stiffen the building and thereby limit the storey drift demands. By limiting the storey drift demand, damage to structural elements and drift-sensitive non-structural elements can be reduced, but this approach may increase demands on acceleration-sensitive NSEs. A recent study by Sullivan et al. (2024) found that damage to acceleration sensitive NSEs could not be completely mitigated by bracing because some damage states depend only on the level of acceleration demand and not the amount of bracing. This finding is partly due to a lack of mechanical and electrical equipment that has undergone seismic qualification in New Zealand.

The NSE CoP supports the design team to work through the aforementioned considerations. As part of the holistic design process, the structural design team could aim to design the structural system to limit the acceleration demands on the NSEs. Relocation of acceleration sensitive equipment to lower levels offers one relatively simple and low-tech means of limiting acceleration demands to sensitive equipment in regions with high seismicity. A second general strategy for improved seismic performance and resilience is to design and detail structural and NSEs for larger storey drift capacities. While the benefits of detailing NSEs to accommodate larger drift demands may be appreciated by industry, there is currently no strong incentive for practitioners or suppliers to do so. To this extent, it is expected that the NSE Drift Classification System in the NSE CoP can play an important role in facilitating the development of incentives. Once this role is established, it will provide a simple way to communicate required performance and incentivise suppliers to provide products that can achieve performance at higher drifts.

4 FUTURE VERSIONS OF NSE CODE OF PRACTICE

The first version of the NSE CoP summarises a significant amount of engineering practice and academic research, but it is far from addressing all issues faced by the industry. While the performance of some NSEs is relatively well understood, the performance of others, such as suspended ceilings, is largely unknown. In the first instance, the collation of performance data and ongoing testing is essential to fill in the gaps in the performance framework. Further iterations of the NSE CoP are also expected to include specific guidance for the residential sector. It is further recognised that this first release of the NSE CoP, and by necessity, is mainly focused on the design process. Later phases will have a greater emphasis on the roles of the contractors and subcontractors. This section outlines the key activities planned for the second phase of the NSE CoP and serves as a call-to-action for those eager to contribute their input or expertise to this next stage.

4.1 Workshop with Industry Professionals for Prioritisation of Work

As part of the ongoing development of the NSE CoP, the authors intend to host a workshop with industry professionals to gather valuable feedback on the first version of the document. This workshop will serve as a platform to reflect on the strengths and limitations of the initial release, while identifying critical areas that require focused attention in the next phase. By stepping back and actively seeking input from industry practitioners and researchers, the next phase aims to effectively address the most pressing priorities and deliver meaningful improvements.

The authors are committed to fostering a collaborative approach, recognising the expertise and insights that stakeholders across the industry can contribute. Through this engagement, the aim is to refine the CoP to better align with practical needs and advance the seismic performance and resilience of buildings. The authors welcome the opportunity to collaborate with partners and are eager to work together to achieve these shared goals.

4.2 Seismic Verification of Plant and Equipment

The next phase of the NSE CoP will include a focus on the requirements, testing protocols and considerations around equivalency of international testing to provide seismic verification of plant and equipment in New Zealand. New Zealand currently lacks a definitive seismic verification methodology and often relies on international testing standards, which might not align completely with New Zealand's specific performance requirements.

A significant gap in our knowledge lies in understanding the comparative performance of NSE and systems from different suppliers. While New Zealand relies heavily on imported building components due to its small market size, locally manufactured mechanical equipment often lacks standardised seismic performance testing. Currently, there is no consistent framework for verifying the seismic performance of non-structural elements (NSEs), whether sourced domestically or internationally. This equivalency problem is a focus of the next stage of the NSE CoP. A desktop exercise will be undertaken to compare codes, loading standards and testing protocols to develop seismic verification framework. This will draw on national and international performance data to define testing protocols for drift and acceleration sensitive systems. A review of overseas definitions of 'robust' products and 'experience' data will look to provide a consistent system to allow engineers and contractors to have a common language and confidence in component selection.

The current version of the NSE CoP provides recommended minimum seismic verification requirements for structural integrity and operational integrity. Structural integrity only confirms that the plant and equipment will not, in whole or part, create a falling hazard during ULS seismic shaking, whereas operational integrity verifies that the plant and equipment can continue to operate following a designated level of earthquake. This area remains under development, with further refined recommended requirements for seismic verification outlined in Table 1.

Table 1. Minimum Recommended Seismic Verification Requirements for Plant and Equipment

	Component Description	***Structural Integrity Seismic Verification[1] Required?***	***Operational Integrity Seismic Verification[1] Required?***
P1, P2, P3	Component that represents a hazard to life outside of the building or within the building and is not inherently rugged.	Yes (ULS)	Not required[2]
P4	Component necessary for the continuing function of the evacuation and life safety systems within the building and is not inherently rugged.	Yes (ULS)	Yes (operation following ULS event)
P5	Component of a system required for operational continuity of the building and/or designated space and is not inherently rugged.	-[3]	Yes (operation following SLS2)
P6	Component for which the consequential damage caused by its failure is disproportionally great and is not inherently rugged.	-[3]	-
All categories	Component is **inherently rugged**	Not required	Not required
P7	All other components	Not required	Not required

Table notes:

1. Seismic verification includes a) analysis, b) testing, or c) experience data as described in ASCE 7-22 Clause 13.2.1.

2. A client may choose operational continuity verification, or be a NZBC requirement for IL4 buildings
3. Refer to category P1, P2, P3 requirements for structural integrity verification if the component is a life safety hazard.

The NSE CoP also provides a list of inherently rugged plant and equipment that have been shown to consistently function after design earthquake level or greater seismic events when adequately anchored or supported which do not require seismic verification to meet the NZBC requirements. Under NSE CoP Phase 2, it is intended that the list of inherently rugged equipment will be expanded where possible. This is likely to consider a potential acceleration limit, below which seismic verification would not be required for compliance.

4.3 Construction Phase

Improving construction phase implementation of seismic design is crucial to improving the seismic performance of NSEs. While early design stages and a holistic approach can establish a strong foundation for improved seismic resilience, it is the individuals on-site who are directly responsible for installing NSEs. Deviations from the design intent—whether due to oversight, shortcuts, or lack of understanding—can negate the potential benefits intended by the design. For example, the finalisation of seismic restraint designs often depends on the subcontractor's equipment selection during the construction phase. This necessitates integration between subcontractor selections and seismic restraint designs to ensure consistency. Furthermore, the main contractor plays a pivotal role in managing and coordinating seismic restraints across various trades, ensuring that all parties align with the overall seismic performance objectives. Without clear communication, coordination, and accountability during construction, the risk of misalignment grows, which potentially compromises building functionality and safety during seismic events. Addressing these challenges requires an industry-wide focus on better collaboration and accountability throughout the construction phase, which the NSE CoP Phase 2 aims to address.

4.4 Technical Guidance

The next phase of the NSE CoP will involve a significant expansion of the technical guidelines section, broadening its scope to include additional non-structural elements (NSEs), updating guidance for existing NSEs, and introducing more detailed sections for critical components. This expansion will enable the NSE CoP to provide more comprehensive and practical recommendations which address a wider array of scenarios across different building types. Industry input will play a pivotal role in this process by helping to identify and prioritise efforts, especially given the breadth of potential areas to cover. While there is much that can be accomplished, a targeted approach will ensure resources are directed toward the most impactful issues.

The expanded guidelines will explore opportunities to incorporate residential, industrial, and light-commercial sectors, to expand the relevancy of the NSE CoP to a broader range of stakeholders. By collaborating with industry professionals, researchers, and practitioners, it is hoped that the NSE CoP will be able to better align with real-world needs and improve the seismic performance of NSEs across all types of buildings.

Research will also play a major role in the future development of the NSE CoP. The NSE CoP, in effect, sets out a research agenda. Questions in need of urgent answers exist within the interactions between systems, the balancing conflicting performance requirements, on safe-to-fail components, how the performance of systems is defined when they are both drift and acceleration sensitive, amongst many more. Beyond this, there is a need to understand and improve how Building Information Modelling (BIM) can be used to enhance coordination and reduce risk.

4.5 Implementation and Community of Practice

Implementation of the NSE CoP is also a major piece of future work. The development of guidance is only the beginning of this process. Initially, promotion be done through conferences, publications in industry journals, and through other communications. For the NSE CoP to have real impact, however, there are additional approaches that need to be undertaken. Firstly, a community of practice around holistic design must be built. This will leverage other guidelines which reference the NSE CoP, such as the Low Damage Design Guidelines that are currently being developed (Sullivan, 2024). These guidelines are likely to have real-world as they are being developed by the New Zealand building regulator (the Ministry of Building, Innovation and Employment, MBIE) and the organisation responsible for administering the chartership of professional engineers (Engineering New Zealand). A first step will include the formation of special interest groups within the Structural Engineers Society New Zealand and the New Zealand Society of Earthquake Engineering.

The challenge of creating new industry roles, such as the NSE Seismic Designer, are likely to be longer-term. While it is likely that forward-thinking designers and contractors will create these roles, it is reliant upon the clients and their procurement teams to stipulate the importance and fund them. The best levers for this are within central government procurement. Current changes in the way the New Zealand Government supports the procurement of major projects, through the creation of the National Infrastructure Agency, may provide a pathway to making these changes.

5 CONCLUSION

The NSE CoP sets out to provide practical guidance to all parties involved in the planning, procurement, design, and construction of buildings. By encouraging a holistic view of building design, the NSE CoP is a critical step toward elevating New Zealand's building practices. Its role in fostering a collaborative and integrated approach ensures that all stakeholders, from architects to engineers and contractors, contribute to the seismic resilience of structures. The NSE CoP has applicability across our building stock, including design and construction of new buildings and work within existing buildings. By applying these principles, the industry can accelerate improvements in the seismic performance and resilience of both.

The NSE CoP not only addresses the immediate needs posed by known vulnerabilities but also paves the way for future developments tailored to the specific demands of New Zealand's unique seismic landscape.

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