National Seismic Qualification Framework for Non-Structural Elements

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ABSTRACT

Recent studies on non-structural elements (NSEs) in New Zealand have found that there is insufficient knowledge about the seismic performance of NSEs and particularly how this performance impacts their primary function in the building. The repair cost of these elements is also typically the main contributor to the total repair cost of buildings for both minor and major earthquakes. Observations from recent earthquakes have shown that the performance expectations of NSEs are often not being met or there is misalignment between structural and non-structural performance. A recent study identified the urgent need for a National Seismic Qualification Framework for NSEs. The study highlighted the need for greater consistency in the knowledge of how various non-structural systems meet performance requirements (e.g., serviceability and ultimate limit states), as well as greater consistency in the outputs from consultants to contractors. This paper proposes a National Seismic Qualification Framework to provide guidance on the performance characterization, component specification and classification, and quality assurance protocols for NSEs.

1. BACKGROUND

Non-structural elements (NSEs) transform the structural skeleton of a building into a functional facility, under a variety of environmental situations. Many NSEs are proprietary products, that are manufactured (e.g., the functional design of a generator), proportioned (e.g., the sizing of a brace element and its attachments), and detailed (e.g., the connections between a gypsum board and the tracks in a partition wall) by individual manufacturers. Unlike structural elements, these are not always custom-designed for a particular project. In New Zealand, there has been greater awareness of the importance of seismic design of NSEs in buildings because of the experience of 2010-2011 Canterbury earthquakes, the 2013 Seddon earthquake, and the 2016 Kaikoura earthquake (Dhakal 2010, Dhakal et al. 2011, Baird et al. 2017). Despite the stark lessons in financial loss and business disruption due to non-structural damage and recent advancements in low-damage NSEs (Jitendra et al. 2022 & 2023), the state-of-knowledge about the likely performance of NSEs in different levels of earthquakes, and their roles in post-earthquake building occupancy and functionality, is largely unclear.

Recent studies, such as Stanway et al. (2020) and Rashid and Preston (2022), showed that there are no consistent procedures in the NZ industry regarding performance characterization, specification, and quality assurance of NSEs for seismic performance. It has been reported that there is considerable ambiguity as to how the capacities of a component at different damage states relate to the relevant NZ standards with respect to loads and performance requirements. It has also been identified that there is considerable variability in the metrics and sources of information being used to choose different components even in the same building facility; for example, one piece of equipment can be chosen based on its certified capacity to maintain operation determined using shake table testing, while another piece of equipment is installed based on consideration from another dynamic environment, e.g., vibrations from a ship or a truck. This implies that different building components have considerably different levels of confidence that they will be functional after a future earthquake due to the lack of consistent procedures for design and selection.

With increasing realisation of the need for better post-earthquake recovery, the seismic qualification of NSEs is becoming a necessity for buildings, particularly as more projects, especially those classified as IL3 or IL4, are required to be designed with higher confidence in their post-earthquake functionality. To enable such confidence in the performance of NSEs in future earthquakes, many aspects of non-structural design defined in standards like NZS 1170.5 (SNZ 2004) and NZS 4219 (SNZ 2009) need clarification and guidance for implementation.

It is proposed that a Framework will streamline processes for characterization, specification, and quality assurance of NSEs and generate minimum acceptable standards for non-structural design, selection, and installation. The overarching Framework will provide the clarification and guidance needed to improve the industry's confidence in the design of NSEs including developing pathways to resolve the contradictions between standards.

The Framework will also be a valuable resource for consultants undertaking low-damage design in accordance with the proposed MBIE Low-Damage Design Guidelines. Additionally, the Commerce Commission in its draft report on building material supply, has identified the need for alternative compliance pathways for building components (CC 2022).

The Building Innovation Partnership (BIP) has setup a BRANZ funded project to develop a Framework to provide guidance on these aspects. The Framework will include a guidance document and an online toolbox of design, evaluation, and inspection tools. This project will also link with an approved EQC proposal which aims to address one of the targets under Objective 2 in EQC's Resilient Homes and Buildings Action Plan on seismic retrofit of buildings using a whole-of-building and whole-of-life approach (EQC 2022).

2. WHAT IS THE FRAMEWORK?

The Framework is essentially a platform to identify problems related to NSEs and to build consensus on possible solutions to such problems. It will provide a series of guidelines and tools for performance characterization, specification, and quality assurance inspections that specifically relate to NSEs. The guidelines will be predominantly used by architects, contractors, subcontractors, engineers, quantity surveyors and project managers to assist in the design, coordination, and construction of NSEs.

It is envisaged that the Framework will be a path to achieving consistency in component design and selection within the building industry through consensus-based solutions. The Framework is also expected to be used by consenting officials to support compliance with NZ Building Code and could become, over time, the approved method of verifying NSE compliance with the Code.

The Framework will be developed over multiple phases. The plan for Phase 01 of the Framework is described below.

2.1 Phase 01: Gap Analysis & Development of the Framework

The core research team have agreed the following will be undertaken in Phase 01 of the Framework development:

A. Define the objectives for the Framework and its three key themes:
   i. NSE Performance Characterisation,
   ii. NSE Classification and Specification, and
   iii. NSE Quality Assurance.

B. Prioritize provision of information into the Framework.
C. Gap analysis to highlight areas where further work and research is required.

2.1.1 Define objectives for the Framework

The objectives of the Framework and each section of the Framework will be documented in Phase 01 such that they respond to the key high-level questions and issues raised by industry regarding performance characterization, classification specification, and quality assurance of NSEs.

<u>Objectives for the Framework</u>

The following is an initial list of the expectations for the Framework:

- To provide a common language that is used throughout the design and construction industry to categorise NSE performance (e.g., like an STC rating).
- The lowest performance criterion for each NSE in the Framework should meet minimum Building Code compliance.
- The Framework is flexible enough to cater for the ongoing and future innovations in low-damage NSEs and their impact on how NSEs will be designed and built in the future. Simply put, the Framework should be able to accommodate new technologies to ensure that it does not become outdated.
- The Framework is accepted by suppliers as a way for them to benchmark their own offerings. Suppliers see a benefit in stating the Framework classification category achieved in their product datasheets.
- The Framework is accepted by designers/consultants as a way for them to identify and/or specify NSEs according to the performance requirements of a facility/building.
- Explains in plain language ("non-technical speak") the impact that the selection of NSEs can have on achieving the whole-of-building performance for facilities.
- To provide guidance on which criteria are important for different types of NSEs (acceleration, drift, or both?).
- To clearly re-direct readers to other standards/guidelines/publications to develop solutions to ensure that the Framework does not reproduce, or conflict good work undertaken by others.
- The performance criteria provided reflects appropriate damage limits that are cognisant of when step changes in performance of NSEs occurs.

Objectives for NSE Performance Characterization

1. To provide guidance on damage states for different NSEs. For example, failure of a window at the serviceability limit state means leaking – not necessarily observable leaking as it can leak into the framing or cavity, whereas the failure of a window at the ultimate limit state could be glass breakage, especially if it could fall onto people below or injure people in a designated egress path.
2. To provide guidance on how to quantify, calculate, or test capacities of different NSEs at different damage states.

Objectives for NSE Classification and Specification

1. To provide a methodology where NSEs are classified according to their acceleration and drift capacities for selection/specification and installation according to the requirements of a facility/building. See, for example, Sullivan et al. (2020).
2. To consider if a methodology can be developed to assess if existing systems that have been classified may be able to be used to assess equivalency of similar products/components.

Objectives for NSE Quality Assurance

1. To provide guidance to support and inform procurement of NSEs.
2. To be used as a guidance tool to support QA inspections.
3. To be used as a guidance tool to confirm compliance with the New Zealand Building Code or any building performance requirements, such as when higher than code minimum performance is required.

2.1.2 Prioritize Information

This work will involve listing the various NSEs typically included in buildings and then prioritizing the list such that the Framework develops guidance for the highest priority NSEs first. In this way the Framework can provide valuable information to industry in the fastest possible timeframe. The research team will:

i. Prioritize non-structural elements in terms of the need for guidance and the relative importance of NSEs to the post-earthquake functionality, downtime and costs.
ii. Identify acceleration and displacement sensitivity of different NSEs at serviceability and ultimate limit states (SLS1, SLS2 and ULS).
iii. Relate possible damage states of different NSEs to performance requirements, i.e., serviceability, functionality, and life-safety.

2.1.3 Gap analysis to highlight areas where further work and research is required

The third action item in Phase 01 will serve as a gap analysis exercise to highlight areas where further research or industry expertise is needed to provide guidance on possible damage states, classification of NSEs, how to quantify the relevant engineering parameters and construction inspections and quality assurance. For instance, there is a dearth of information on the seismic performance of ground or floor-attached equipment in NZ.

2.2 Timeline for Phase 01

The Framework project is being funded by BRANZ. The Framework will be developed in multiple phases with the development pathway illustrated in Figure 1. The research team will use an agile approach, developing a minimal viable product at each development stage so that the Framework can quickly and easily provide benefits to industry at every stage of its development.

The development process began with a workshop in February 2023 that included participants from the core research team and the review panel. By August 2023, the project team will have confirmed the objectives of the Framework and its constituent sections – performance characterization, specification, and quality assurance – such that the project team can confirm that the Framework adequately responds to the key high-level questions and issues raised by industry in relation to the seismic performance of NSEs.

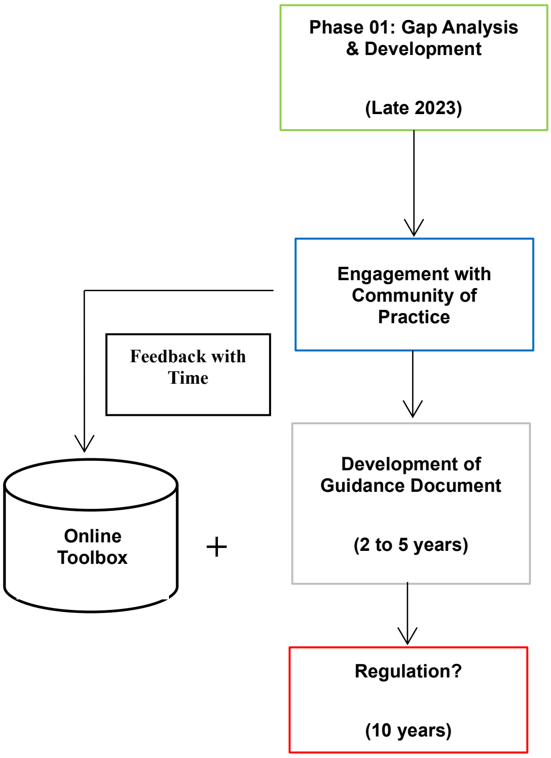

Figure 1: Development pathway for the Framework

3. CONCLUSIONS

Recent studies of non-structural elements (NSEs) in New Zealand have found that there is insufficient knowledge about the seismic performance of NSEs and particularly how this performance impacts their primary function in the building. The studies have also highlighted the need for greater consistency in the knowledge of how various non-structural systems meet performance requirements, as well as greater consistency in the outputs from consultants to contractors.

This paper introduced the objectives and action plan for developing a national seismic qualification Framework for NSEs in NZ. The Framework will provide a series of guidelines and tools to characterize NSE performance, and enable consistent classification, specification, and quality assurance inspections for NSEs. The intention is that the Framework will be predominantly used by architects, contractors, subcontractors, engineers, quantity surveyors, consenting officials and project managers to assist in the design, coordination, procurement, and construction of NSEs.

It is envisaged that the Framework will be a path to achieving consistency in NSE design, selection and installation to achieve the expected performance requirements through consensus-based solutions.

For further information, and if you want to get involved, please contact Greg Preston at the Building Innovation Partnership (BIP) based at the University of Canterbury at greg.preston@canterbury.ac.nz.

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