
Improving the Seismic Resilience of Buildings through Improved Seismic Performance of NSEs – Comparison of NZ and US Approaches

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ABSTRACT

Many recent earthquakes have shown that while seismic design codes provide the required life safety, they often fall short in supporting community resilience. This realization has led to a recent shift from a focus in both New Zealand and the US from life safety targets to targets that also include functional recovery and low damage with a focus on enabling buildings and organizations to recover quickly after seismic events. With the inclusion of functional recovery and low damage seismic design targets, the engineering community has also recognized the importance of the seismic performance of non-structural elements on the overall seismic performance of the building. In this paper, we summarize the approaches being taken in both New Zealand and US to ensure that the seismic performance of the non-structural elements not only meets minimum Building Code requirements but also meets client defined post-earthquake functional performance requirements and how the New Zealand and US approaches, in this regard, complement each other. While the design and detailing of the non-structural elements is critical to their performance, this paper also focuses on often forgotten construction coordination and quality assurance and control which is also critical to achieving the seismic performance of the building.

1 INTRODUCTION

Modern seismic design codes and standards both the United States and New Zealand primarily target life-safety objectives. They achieve this by providing a margin against collapse through the dissipation of earthquake energy via structural system ductility. This results in controlled damage imposed on selected structural components, resulting in safe, but non resilient systems. Observations from past earthquakes

(Loma Prieta, 1989; Northridge, 1994; Napa, 2014; New Zealand, 2010/2011; Türkiye, 2023), have demonstrated that this narrow design focus can result in damage to structural and non-structural elements such as ceilings, partitions and HVAC systems, causing significant downtimes and high repair costs, potentially leading to rebuilds, even following moderate levels of earthquake shaking (Steneker, 2023).

As a response, the structural engineering community has recently proposed enhanced performance targets (called “functional recovery” in US and “low damage seismic design” in NZ) in addition to life-safety goals. As non-structural elements support the building function and contribute most of the costs of buildings (Taghavi and Miranda, 2003), their seismic performance is now considered of equivalent importance to the performance of the structural system. The NEHP Provisions explicitly recognise that achieving functional recovery requires non-structural systems to perform at a level comparable to the structural system (NEHRP App A, 2026) and research has shown that non-structural element damage often governs post-earthquake building functionality and recovery time, even when structural damage is limited (Cook, 2022).

The seismic performance of non-structural elements is dependent on the proper design, coordination, detailing and construction quality. However, many non-structural elements in both New Zealand and the United States are often contractor designed items with performance specifications and/or specimen design provided by the main design team (Phipps, 2019; BIP, 2020). This means that engineer(s), other than the structural engineer for the primary structure, design and detail the non-structural components, often during construction process (deferred design). This process can lead to inadequate consideration of the structural response on the performance of non-structural elements, and inadequate coordination of components during design and review.

2 COMPARISON BETWEEN NZ AND US APPROACHES TO ACHIEVE IMPROVED SEISMIC PERFORMANCE OF NON-STRUCTURAL ELEMENTS

This paper provides an overview of suggested approaches to design, coordination and installation of non-structural elements in NZ and US to achieve enhanced seismic performance of the building. The NZ approach is based on the Low Damage Seismic Design guidelines [LDSD, 2025] along with the Code of Practice for the Seismic Performance of Non-Structural Elements [NSE CoP, 2026]. The US approach relies on provisions of Appendix A of 2026 NEHRP Recommended Seismic Design Provisions for New Buildings and Other Structures (NEHRP App A, 2026).

While both countries address the same topic – enhanced seismic performance of non-structural elements, the purpose and scope of the documents are somewhat different. The LDSD and NSE CoP guidelines are not part of the New Zealand Building Code and instead serve as a guidance only. On the other hand, NEHRP Provisions inform ASCE 7, which is ultimately adopted by US *code*. As such, the LDSD and NSE CoP can provide guidelines for design coordination and the level of non-structural element design completeness in each stage of design, whereas Appendix A of NEHRP Provisions cannot address these topics as they are not enforceable. Appendix A of NEHRP Provisions primarily focuses on construction quality, while that topic is not fully covered and enforceable in the current version of the LDSD and NSE CoP guidelines.

The sections below outline the respective approaches in New Zealand and the United States to achieve improved seismic performance of buildings, with a specific emphasis on the approach to improving the seismic performance of non-structural elements.

2.1 New Zealand Approach

New Zealand focuses on the seismic design and the holistic coordination of non-structural elements during both design and construction phases. The LDSD guideline requires the holistic design process, discipline coordination, development of a building movement strategy and non-structural element seismic design, as documented in the NSE CoP, to be followed to achieve one of the LDSD Categories (there are three Categories, LDSD Level 1, 2 or 3).

The LDSD guideline also encourages the option to do structural interventions to enhance the seismic performance of non-structural elements. Different low damage structural strategies can include limiting drift to limit damage to drift-sensitive non-structural elements or in a very high seismic area, potentially using more flexible structural systems to limit peak floor accelerations to defined limits for critical acceleration sensitive components alongside more innovative detailing/systems to meet the performance requirements for drift-sensitive non-structural elements at higher drifts.

As well as referring to the design process and coordination requirements recommended in the NSE CoP, the LDSD guideline includes additional design and coordination considerations for low damage seismic design of specific non-structural elements (building envelope, building services, stairs and ramps, lifts, ceilings, partitions, passive fire and contents).

2.1.1 Design and coordination requirements during each phase (including construction)

Early coordination among key disciplines (architect, structural engineer, building services engineer, passive fire engineer, and NSE Seismic Designer) is crucial in the New Zealand approach. The early coordination and consideration of seismic performance of the building will reduce the number of locations with competing movement requirements, reduce design complexity and improve seismic performance of the building.

2.1.2 Defined Roles & Responsibilities

The NSE CoP defines the roles and responsibilities for all disciplines through each phase of the project. It recognizes that the design interfaces between disciplines often impact or define the seismic performance of the building. The following describes some key roles and responsibilities defined in the NSE CoP, noting that the LDSD guideline requires these roles and responsibilities to be implemented for buildings to achieve a LDSD category:

- Roles & Responsibilities matrix
 - The NSE CoP provides a matrix for concept and preliminary design phases which confirms the required inputs, outputs and coordination requirements for each task in the holistic design process during these critical early phases of the project. The roles and responsibilities matrix defines what discipline is responsible for each task and what disciplines have a secondary role for coordination or input into that task.
- NSE Seismic Designer
 - A NSE Seismic Designer is required for each project. The role can be combined with another discipline role, but importantly the role has specific requirements that must be met. The role commences in the concept design phase and focusses on coordination of non-structural elements, seismic response of the structural system, seismic design of non-structural elements and the overall seismic performance of the building.
 - NSE Seismic Designer is to provide a briefing to the contractor to discuss the overall building and non-structural element seismic design strategy, key sub-trade interfaces and agreed procedures for areas where standard details may not apply.

- Seismic Restraint Installation Coordinator
 - This role is engaged by the main contractor to support the main contractor's critical role in implementing the seismic design, including the coordination and management across the various trades during construction. The Seismic Restraint Coordinator, is responsible for implementing the design including the non-structural elements, coordinating the final locations of the seismic restraints for non-structural elements and ensuring collaboration occurs between sub-trades at all interfaces to achieve the agreed seismic, thermal, acoustic and fire performance as required.

2.1.3 Building Movement Strategy

Design teams are required to document all expected building movements (thermal, acoustic, vibration, passive fire, and seismic) throughout the life of the building and confirm zones/locations where movement is necessary or restricted. Multi-discipline meetings (commencing during the concept design) are essential to discuss locations where there are competing movement requirements. Compromises may be required where thermal, acoustic, vibration, passive fire and seismic requirements cannot all be met at certain locations. Where this occurs the team needs to agree and document what can be compromised and why the decision was made. A Building Movement Strategy is required for all LDSO projects (the requirements for this document are described in the NSE CoP), from small simple projects to large complex projects and needs to be communicated to the contractor.

2.1.4 Seismic Hazard considerations for enhanced performance of NSEs

In New Zealand, minimum Building Code compliance includes life safety performance requirements for all building types (known as ULS limit state) and serviceability performance states, SLS1 and SLS2. To achieve enhanced seismic performance of low damage buildings the Low Damage Seismic Design Guidelines (LDSO, 2025) introduced a new limit state known as the Damage Control Limit State (DCLS). LDSO Category Level 2 and 3 buildings are considered to have a significantly higher likelihood of achieving partial functionality following a significant earthquake compared to an equivalent minimum Building Code compliant building.

Table 1 provides a comparison between minimum New Zealand Building Code requirements and the recommendations of the LDSO Guideline (LDSO, 2025) for the various design criteria and summarises the associated seismic performance objectives and seismic hazard for each.

Table 1: Comparison between minimum NZBC and enhanced LDSO Design Criteria and Seismic Hazard.

Design Criteria	NZ Bldg Code Minimum Requirement	LDSO Guideline Recommendation ¹
SLS1 Performance objective	Avoid damage that would prevent the building from being used as intended without repair.	Performance objective is the same as NZBC minimum requirement
SLS1 Seismic hazard	APoE = 1/25	APoE = 1/50
DCLS Performance objective	N/A	Damage Control and Improved Functionality performance goals as defined in Section 7 of LDSO Vol2 Guideline

DCLS Seismic hazard	N/A	Varies by LDSD Category: LDSD Level 1 APoE = N/A LDSD Level 2 APoE = 1/250 LDSD Level 3 APoE = 1/500
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Notes to Table 1:

1. The seismic performance objectives and seismic hazard for SLS2 and ULS limit states is as per NZBC B1/VM1 (NZS 1170.5)

2.1.5 Construction Phase Activities

Effective construction monitoring by the design team is required for project quality and to ensure the design and coordination undertaken during the design phase is implemented. The role of the NSE Seismic Designer continues through into the construction phase, for construction monitoring to ensure compliance with the seismic design, while the Contractor's NSE Seismic Coordinator is to facilitate communication between the construction team and the design team regarding any deviations or amendments to the design or seismic design strategy for the building.

Contractor designed elements will occur in every project and may include precast floors, seismic devices, facades, lifts, ceilings and fire protection systems. It is important that the design team include contractor designed items in the design phase coordination and to ensure design interfaces and coordination considered during the design is explained to the contractor, with the final design by the contractor checking and confirmed the earlier design and coordination assumptions during the construction phase. Any implications due to product substitutions or coordination amendments are to be addressed in consultation with the NSE Seismic Designer and wider design team.

Operations and Maintenance manuals are to be provided for LDSD buildings. The O & M manuals should include relevant design parameters, the building movement strategy, movement zones such that the building can be properly maintained and should any future alterations occur, they can be done such that they do not inadvertently compromise the seismic performance of the building.

2.1.6 Business Continuity Plans

Whilst the LDSD guideline requires tenants and building owners to implement their own Business Continuity Plans, it acknowledges that the consultant and contracting team are best placed to support the development of the Business Continuity Plans to ensure efficient and timely inspections and repairs to meet the LDSD goals.

2.2 United States Approach

The US approach recognizes that the proper detailing and quality of construction will impact the seismic performance of non-structural elements and the resilience of the building as a whole. As such, the US focus is on the quality assurance (QA) of design, and quality assurance (QA) and quality control (QC) of construction.

The following sections summarise the key aspects of the US approach to improve the seismic performance of non-structural elements.

2.2.1 Seismic hazard for design of non-structural elements

When designing according to the Appendix A NEHRP Provisions, the designer needs to perform a two hazard-level design. The design at the Design Earthquake level (DE) ensures life-safety performance is

satisfied (this level is prescribed by the code). In addition, the functional recovery performance is checked at the Functional Recovery Earthquake (FRE_R).

US moved away from Uniform Hazard Spectra to a Risk-targeted approach during the ASCE 7-10 cycle. The DE earthquake is defined as 2/3 of Risk-Targeted Maximum Considered Earthquake (MCE_R), which has assigned risk of collapse of 1% (1.5% in the upcoming ASCE 7 standard) in 50 years, and conditional probability of collapse of 10% at MCE_R. Similarly, the FRE_R is assigned a risk of exceeding the target functional recovery time of 10% in 50 years, and conditional probability of exceeding the target functional recovery time of 25% at FRE_R. FRE_R is further capped by DE.

As such, the return period for both DE and FRE_R vary with location, site class and even with a period of vibration for a single location. However, internal comparison studies have shown that for high seismic regions along the West Coast of US, the DE based on the upcoming definition of MCE_R approximately corresponds to 400 to 600 year return period for California and 500 to 800 year return period for Pacific Northwest. For FRE_R the approximate return periods are 350 to 550 years for California and 350 to 450 years for Pacific Northwest. The seismic hazard in California is primarily governed by crustal earthquakes, while in Pacific Northwest, it is a combination of crustal and subduction zone.

2.2.2 Functional Recovery Coordinator

The functional recovery coordinator is a designated role in the design team. The functional recovery coordinator is responsible for review, acceptance, and coordination of the documentation, observation, quality assurance, and development of the post-earthquake recovery plan for the non-structural elements that are required for the basic intended function of the building.

The key purpose of this role is to have one individual/entity who has a holistic perspective of the entirety of the functional recovery aspects of the project and can prevent items necessary for functional recovery from “slipping through the cracks”. The functional recovery coordinator should be involved throughout the design and construction process and can be one of the design professionals already on the design team.

2.2.3 Contractor Responsibility

The general contractor plays a major role in the delivery of the project and its final seismic performance. Both the design and construction requirements are elevated in projects targeting functional recovery. As such there is a need for “buy-in” from the construction team to follow the elevated requirements.

- Pre-construction functional recovery conference
 - The contractor is briefed by the functional recovery coordinator on the elevated requirements (review of delegated/contractor design items, seismic certification requirements, engineering observations and special inspection, and overall documentation).
- Functional recovery statement of responsibility
 - General contractor acknowledges that they are aware of and understand the elevated requirements and will communicate these requirements to all subcontractors.
- QAQC schedule and log
 - The general contractor maintains a schedule of work and required special inspections to ensure all special inspection and tests are performed. The specialty/component engineers often work as subcontractors to either the general contractor or the design team and need to be kept up to date on the schedule to help facilitate both engineering observations, and special inspections and tests.

2.2.4 Delegated/Construction Phase Design Considerations

Many of the non-structural elements are procured as delegated design items (design during the construction phase). This can pose issues when communicating the performance requirements, coordinating the design with other components, and ensuring the proper installation. Delegated design considerations include:

- Communication of functional recovery criteria
 - The functional recovery criteria are specified clearly on the drawings or as part of the specification. The information needs to be concise and complete and includes information to determine the non-structural inertial forces, structure movements, functional recovery category and related importance factors, seismic qualification requirements, and other information.
- Review of the delegated design
 - Historically the delegated design items may have lacked the review scrutiny from the Structural Engineer of Record (SEOR) and/or the Authority Having Jurisdiction. However, since these items are critical for the functional recovery, the design review to confirm the seismic performance of non-structural elements is now required to be undertaken by the functional recovery coordinator. The review ensures that the design meets the performance criteria and that the required detailing is implemented.
- Engineering observations during construction
 - The engineer for each non-structural element performs engineering observations in the field to confirm that the component has been installed properly according to their design. The engineering observations are in addition to any special inspection requirements.

2.2.5 Special Inspection and Testing

In the US, special inspection and testing is performed by an agency hired by the owner and completely independent from the contractor. The current life-safety requirements require special inspection of the main lateral and gravity structural system, and limited inspection of non-structural elements.

To support the functional recovery, the special inspection of non-structural elements is expanded and brought on the same level of importance as the special inspection of structural system. The provisions clearly describe the components that need to be inspected and prescribe the tasks, i.e. how to inspect the component, that the special inspector needs to perform during the inspection. The tasks are prescribed in a way to keep the added costs as low as possible while ensuring the proper installation. As such, they primarily involve verification of already installed components (rather than verification during the installation process). Hence the special inspector does not need to be present at the construction site at all times, but only at certain intervals.

2.2.6 Post-Earthquake Functional Recovery Plan

The requirements for a Post-Earthquake Functional Recovery Plan ensure that in the event of an earthquake, the building owner and operations team have a plan to allow for quick and proper post-earthquake evaluation, potentially undertake temporary repairs, and a means to provide back-up utilities. Specifically, the plan addresses following:

- Identification of functional critical structural and non-structural components, their potential damage mechanism, and how they should be inspected.
- Access to as-built drawings, including architectural, structural, MEP, and fire protection drawings.
- Instructions for rapid measures to address jammed egress doors, fire protection system, and elevators (where deemed function critical).

- How to operate onsite back-up services (electrical power, water and sewage) and/or providing temporary services.

2.2.7 Other Considerations

A large unknown after any earthquake is the performance of utilities. While the building can be undamaged, it cannot properly function without utilities. The NEHRP Provisions require onsite back-up power, potable water, and sewage storage for the Functional Recovery A structures (highest performance category) and at minimum electrical power external hookups for Functional Recovery B structures.

As mentioned, the NEHRP Provisions ultimately inform US building code, as such, many “good practices” (such as coordination of drawings, non-structural seismic restraint coordinator, etc.) which are needed for successful projects cannot be codified. However, to ensure that the engineers are still informed about them, these practices are included in the commentary of the NEHRP Provisions.

3 DISCUSSION AND CONCLUSIONS

From the description above, it may appear that NZ and US focus on different parts of the design and construction process to achieve enhanced seismic performance of buildings. While that may be true for the governing documents presented here, we must recognize that the documents are written with different scopes (as highlighted in the introduction). Even then, the NZ Low Damage Seismic Design Guideline and NSE CoP Guideline both recognize the importance of construction quality assurance and quality control, and similarly Appendix A NEHRP Provisions encourages early coordination in the commentary.

As we see, the two approaches complement each other. The early coordination itself cannot preclude potential errors in the installation process. On the other hand, without early coordination, the clashes or errors during construction process will be more prevalent and their remediation will result in increased construction costs and time. The two approaches and documents show a clear path forward that includes both early coordination and effective design and construction quality assurance and control. This combined approach will ensure we see an improvement in the seismic performance of our buildings in both New Zealand and USA.

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¹ The NEHRP Provisions are still under development at the time of writing of this paper. However, Appendix A has been approved by the Provisions Update Committee.

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