External Research Report ER95 [2024]

Code of Practice for the Seismic Performance of Non-Structural Elements

Jan Stanway, Andrew Baird, Muhammad Rashid, Sara Hinz and Greg Preston

Project LR16324

Building Innovation Partnership, University of Canterbury funded by the Building Research Levy

BRANZ
1222 Moonshine Road
RD1, Porirua 5381
Private Bag 50 908
Porirua 5240
New Zealand
branz.nz

This report was prepared by the Building Innovation Partnership (BIP).

Funded from the Building Research Levy

BUILDING INNOVATION PARTNERSHIP

ISSN: 2423-0839

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Code of Practice for the Seismic Performance of Non-Structural Elements

BRANZ
Funded from the
Building Research Levy

September 2024

Version 2.1

Version Control

Version	Date	Details
2.1	27 September 2024	First issue to industry

Acknowledgements

This project is funded by the Building Research Levy administered by BRANZ.

BRANZ Funded from the Building Research Levy

Co-funding has been provided by the Building Innovation Partnership (BIP) which is supported by the Science Partnership Scheme from the Ministry of Building, Innovation and Innovation (MBIE).

This document has been prepared by:

- Jan Stanway – WSP (co-lead)
- Andrew Baird – Beca (co-lead)
- Muhammad Rashid, Silvester Clark Ltd
- Sara Hinz – WSP
- Greg Preston – BIP

The reference group comprised:

- Prof Tim Sullivan – UC
- Rajesh Dhakal – UC
- Corde Rhodes – WSP
- Ignatius Black – Silvester Clarke Ltd
- Brad Sara – Warren & Mahoney
- Jonathon Hill – Kaizon
- Mayank Tripathi – GIB
- Richard Arkinstall – AWCI
- Stephen Ridder – AON
- Andrew Reid – Pedersen Reid
- Andrew Marshall – HRS
- Amanda Bachelor – Naylor Love
- Harvey Duncan – WSP
- Martin Wemyss - Beca

Coordination with other related activities has been provided by

- Prof Ken Elwood, Chief Engineer, Resilience, MBIE
- Dave Brunsdon, Kestrel Group, HEAG
- Mark Willard, MoE
- Jared Keen, Beca, HEAG
- Paul Campbell, WSP, Low Damage Design

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Part A: Background, Project Briefing and Design Process

A.1. Introduction

Many buildings suffered minor structural damage as a result of the 2010-2011 Canterbury earthquakes, the 2013 Seddon earthquake, and the 2016 Kaikoura earthquake, however many of those buildings were unable to be used and re-occupied due to damage and failure of non-structural elements. In these instances, the damage to non-structural elements caused major disruptions to businesses and our communities (BIP White Paper, 2020).

Over the last decade the industry has highlighted (BIP White Paper, 2020; BIP White Paper, 2022) the need for guidance documentation to address inconsistencies in design practice, roles and responsibilities, design and coordination of non-structural elements and inconsistencies in construction practices including seismic qualification of plant and equipment.

It is proposed that this Code of Practice for the Seismic Performance of Non-Structural Elements (NSE CoP) will provide guidance on the minimum acceptable standards for non-structural seismic design, coordination, selection, and construction and provides the clarification and guidance needed to improve the industry's confidence that non-structural elements will achieve the expected seismic performance in the future. It also provides guidance on how to design and construct systems that perform better than code minimum.

> *The seismic restraint of Non-Structural Elements (NSE) constitutes a distinct design discipline focused predominantly (but not solely) on life-safety. However, the* ***seismic performance*** *of NSE is inherently integrated into the overall building design, necessitating deliberate design considerations and actions throughout the various stages of NSE and structural design. This Code of Practice provides guidance on how to achieve the seismic performance of the building.*

All disciplines associated with NSE, including Architecture, Building Services, Fire Protection, and others, actively contribute to the seismic performance of the building. The design, positioning within the building, and their interfaces with seismic forces collectively exert a critical influence on the overall building performance in seismic events and post event speed of re-occupancy/business continuity.

A.1.1. Purpose of this Code of Practice

The purpose of the Code of Practice for the Seismic Performance of Non-Structural Elements (NSE CoP) is to provide guidance on the seismic design, coordination, and construction of non-structural elements to improve practices, and establish consistency across the industry while meeting the performance requirements of the building code.

The NSE CoP is intended to be the means to achieve consistency in the seismic design and selection of non-structural elements (NSEs) as well as the coordination process between disciplines and through consensus-based solutions. The NSE CoP supports the translation of building functional requirements into design, construction methodologies and quality assurance processes for NSEs.

The NSE CoP:

- Offers guidance on how design teams should communicate seismic performance of NSEs to enable Clients to communicate the expected functionality and performance of the building/facility following seismic events.
- Clarifies the impact of NSE components and systems selection on overall building performance in non-technical terms.
- Assists designers/consultants to specify NSEs in line with facility/building performance requirements.
- Assists designers/consultants to understand and coordinate seismic design interfaces between NSE.
- Creates a common language, akin to an STC acoustic rating (which provides a single number method to rate how well wall partitions reduce sound transmission), for designers and contractors to communicate the selection requirements and required seismic performance of NSEs that are damaged when the building moves during earthquake shaking.
- Allows suppliers to categorise their products for apples-for-apples comparisons.
- Provides recommended Quality Assurance requirements.

The focus of this guideline is to provide guidance on how to design and construct NSEs to achieve the seismic performance and ultimately the overall building performance expectations of the client. It is shown graphically in Figure A-1.

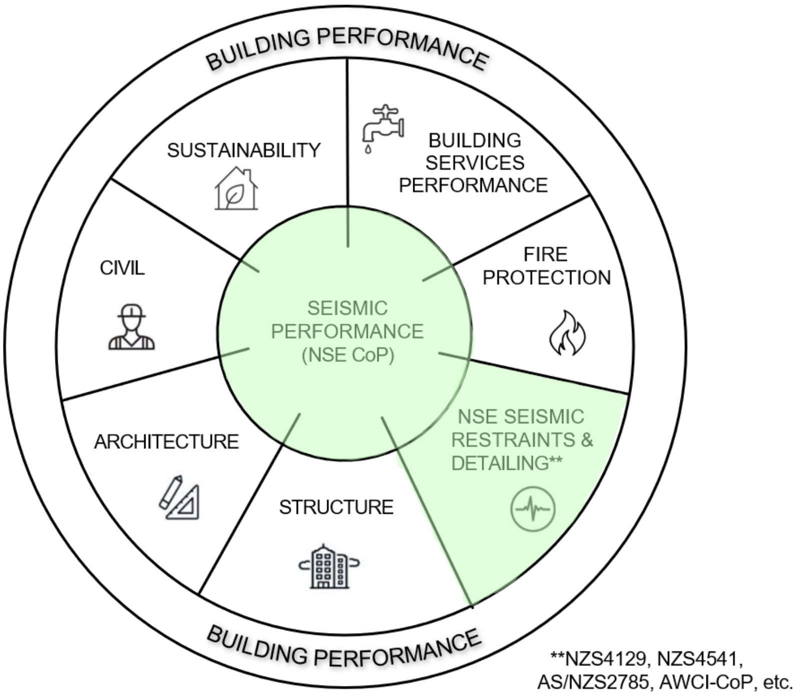


Figure A-1: Use of NSE CoP to achieve overall building performance

A.1.2. Who will use the Guidelines?

The NSE CoP is structured to provide guidance to clients, project managers, quantity surveyors, designers, contractors and sub-contractors.

Ways in which various users may use these guidelines are noted below:

1. Clients and their representatives: to help them understand what good seismic performance of NSEs means in relation to their building/facilities such that they can develop the Project Brief Requirements to align their business goals and their business continuity plans with the performance of the building/facility.

2. Clients and their representatives: to help them set projects up for success in terms of design methodology and process and procurement processes to ultimately achieve their functional and performance requirements both on a day-to-day basis and following earthquake events of varying magnitudes.

3. Insurance companies and Insurance Council NZ: to assist them in understanding seismic risk of buildings.

4. Project managers and quantity surveyors: to assist them with a common language for NSE components and detailing, such that appropriate costing for the building/facility to achieve the Project Brief Requirements can be estimated early in the project.

5. Architects, structural engineers, building services engineers, fire engineers, façade engineers, specialist NSE technical designers, quantity surveyors and project managers: to assist in the design, coordination, selection of appropriate components and component detailing, and integration and installation of NSEs during construction of NSEs.

6. Contractors and subcontractors: to assist in the design, coordination and selection of appropriate components and component detailing when components are designed during the construction phase.

7. NSE suppliers: to understand expectations from clients and design teams regarding the components and equipment they supply to the market and potential need for testing to a common standard.

8. Contractors and subcontractors, architects, structural engineers, building services engineers, fire engineers, façade engineers, specialist NSE technical designers: to assist quality assurance inspections.

9. Consenting officials: to support confirmation that NSEs installed in buildings have achieved compliance with NZ Building Code

A.1.3. Disclaimer on use of NSE CoP

Information contained in this NSE CoP has been obtained from sources believed to be reliable. However, neither the Building Innovation Partnership, its supporting partner organisations nor the authors guarantee the accuracy or completeness of information published herein and neither the organisations nor the authors shall be held responsible for any errors, omissions or damages arising out of use of this information. This NSE CoP is published on the understanding that the authors are supplying information but are not attempting to render engineering or other professional services. If such services are required, the assistance of an appropriate professional should be sought.

A.1.4. Format of this guide

In general, the content within this guideline is intended to be informative as well as represent best practice recommendations.

Language within the body of this guideline that uses the word *should* (rather than shall) implies clear intent and a strong recommendation on how the requirements of these guidelines ought to be met.

This guideline is structured into three Parts as follows.

Part A is directed towards clients, their representatives, project managers, multi-disciplinary project teams, contractors and subcontractors. It includes important information on how to develop the Project Brief to align with Business Goals and Business Continuity Plans. This part also provides clarity on the project design methodology and processes through the project phases and into construction.

Part B defines the performance requirements for non-structural elements and will be used by project managers and multi-disciplinary project teams, suppliers, contractors and subcontractors. It also provides guidance on the requirements for seismic qualification of NSEs and testing protocols where testing is required to confirm the seismic performance of NSEs.

Part C provides technical guidance on the seismic design of NSEs and is directed primarily towards structural engineers and NSE technical designers. It gives the means by which the performance requirements set out in Part B can be met.

A.1.5. Glossary of terms, definitions, and acronyms

Table A-1: Glossary of terms

Term	Definition
Acceleration-Sensitive Components	Are those components most adversely affected by inertial forces resulting from the horizontal and vertical floor accelerations of the building in an earthquake. An example is a piece of mechanical plant that during an earthquake, by virtue of the momentum of its own weight, may cause damage to itself or items to which it is attached.
Code Compliance	Meets the minimum requirements of the New Zealand Building Code.
Damage	Damage to a component/brace that requires repair.
Drift-Sensitive NSE	Are those components that are most adversely affected by the change of shape of a building when it moves out of plumb in an earthquake. An example is a partition wall which is built plumb and level and uses large sheet materials that suffer damage when pushed out of square.
Functionality	Where the building and infrastructure systems are in a state that allows continued function of the building.
Limit States	States beyond which the structure or component no longer satisfies the design criteria.
Low Damage Seismic Design (LDSD)	Design completed in accordance with the Low Damage Seismic Design (LDSD) Guidelines to achieve better than code minimum design.
NSE Seismic Designer	Non-structural element seismic designer. Note that seismic restraint is only one part of the seismic design of non-structural elements.
Non-Structural Element (NSE)	All parts of a building that are essential to its functioning, but are not part there to hold the building up; such as ceilings, partitions, HVAC systems, electrical systems, plumbing and drainage etc.
Operational State	The Operational State is a description of the operational state of a building at a given point in time. Typical operational states are listed below.

	Normal operations: The building's pre-earthquake physical and operational state (pre-earthquake safety and functionality). "Full Recovery" is a term defined in FEMA P-2090 (FEMA, NIST, 2021) which describes the return to Normal Operations (the restoration of the building's pre-earthquake safety and functionality). Full functionality: A building for which post-earthquake structural and non-structural capacity is essentially maintained – initially to fulfil a specific post-disaster response function in the immediate aftermath of an event and then eventually to continue the intended functions of the building's pre-earthquake use. It does not mean there is no damage. A level of compromise in conditions, safety or risk tolerance relative to Normal Operations may be present. Partial (basic) functionality: A building for which post-earthquake structural and non-structural capacity may be reduced but is sufficiently maintained (or can be restored) to support the basic intended functions of the building's pre-earthquake use – or a significant enough portion thereof to be useful. It is similar to the term "Functional Recovery" defined in FEMA-P2090 (FEMA, NIST, 2021) which describes the re-establishment of basic functionality and gives additional examples. Shelter in Place: A building for which post-earthquake non-structural capacity may be significantly reduced-but supports the SPUR definition of "shelter in place" (SPUR, 2012). It is similar to the term "Re-occupancy" defined in FEMA P-2090 (FEMA, NIST, 2021). Building services such as HVAC, electrical systems, sewer and water supply may be damaged and unavailable until necessary repairs are completed-necessitating neighbourhood support within walking distance. The shelter structure may be damaged but is still considered safe to occupy and can provide basic shelter. This definition is normally only applied to places of residence. Not occupiable: A building which is either not safe to occupy or has non-structural damage to the point that it cannot fulfil even basic function and thus has no purpose to occupy.
Performance State	Performance-based design defines various performance states and defines the performance goal for each performance state. Each performance state has objectives and performance-based criteria that when met result in achieving the goal for the given performance state.

Primary Structure	The use of the term Primary Structure in this guideline refers to the structure required for the vertical and lateral support of a building's floors and enclosure. It includes the floor structure, columns, walls and roof framing such as posts, rafters and bracing which provide support for the gravity loads and loads on the building from wind and earthquake. It excludes the enclosure itself.
Project Brief	Description of the key elements of the project including project goals, project drivers and performance requirements. It is used to communicate project requirements to the Design and Construction Team.
Quality Assurance	Systematic process of determining whether a product or service meets specified requirements. Often undertaken in the construction phase to confirm that the building and components have been constructed and installed to meet the Performance Requirements of the building.
Resiliency	Capacity to withstand and recover following earthquake events.
Supplier	A company that supplies products, components and equipment needed to construct the building.
Secondary Structure	Structural components that are not part of the gravity and lateral load structural system of the building. For example, secondary columns provided to support façade components that are connected to, and supported by, the primary beams of the main structure.
Seismic Restraint	A structural assemblage of elements designed and installed to transfer earthquake-induced forces from a component to the supporting structure.
Seismic Performance	The way the building or component responds during and following earthquakes of varying hazard.
Specification	A written document that describes in detail the scope of work, materials to be used, methods of installation, and quality of workmanship for a parcel of work to be undertaken under contract.

A.2. Phased Release to Industry

This NSE CoP is a live guideline and will be regularly updated. The NSE CoP has focused development of guidance for the highest priority processes and technical design advice for the highest priority NSEs first. In this way the NSE CoP is intended to provide valuable information to industry in the fastest possible timeframe.

A.2.1. Scope of this version of NSE CoP

Version 2.1 – September 2024

This Version of the NSE CoP focuses on setting and understanding the required performance for the building. This includes definition of the project brief, the overall project design methodology and process, the performance states for non-structural elements, seismic qualification pathways for plant and equipment and the seismic design methodology for specific NSEs to achieve the key performance states:

a) no damage (SLS1),
b) damage control/repairability (DCLS),
c) functional continuity (SLS2), and
d) life safety (ULS).

These guidelines are appropriate for use in IL2, IL3, and IL4 buildings to demonstrate legal minimum building code requirements and where clients want to achieve above minimum requirements.

This version of the Code of Practice provides seismic design guidance for the following NSEs which are considered to be high priority for industry. These include:

- Lightweight partition walls,
- Suspended ceilings,
- Linear suspended services,
- Suspended equipment,
- Floor mounted equipment,
- Automatic fire sprinkler systems,
- Exterior glazing systems.

The technical seismic design guidance for other NSEs will be provided in future versions of the NSE CoP.

The design process recommended in this version of the guidelines is intended for use in any building project ranging from the simplest single storey office building to a complex multi-storey hospital. Similarly, the technical design information for the NSEs included in Part C of this version of the guidelines are intended to be applicable to all building types. Whilst the current design considerations have a bias towards commercial buildings, it is intended that these will be expanded upon in future versions to include more considerations and guidance regarding residential and industrial buildings.

The content of this version of the NSE CoP is written predominantly for application to new buildings. However, designers may be able to adapt the information within it to use on existing buildings and is expected to be able to be used to support the assessment of NSEs' seismic performance in existing buildings in accordance with The Seismic Assessment of Existing Buildings[1] (the Guidelines).

[1] The Seismic Assessment of Existing Buildings www.eq-assess.org.nz

A.2.2. Technical Guidance for Non-Structural Elements in this Guideline

There are many ways to list, group and categorise NSEs. One notable list of NSEs in buildings is included in the Kestrel Report titled 'Understanding and Improving the Seismic Resilience of Hospital Buildings' (Kestrel, 2022). The basis of prioritisation for specific design guidance of NSEs for this version of the NSE CoP was based on common usage in buildings, industry opinion, and the availability of relevant research data to support the design methodology guidance. Table A.2 lists the NSE categories where design guidance has been included in this version of the NSE CoP, along with examples of the different components covered by the NSE category. Table A.2 also highlights those NSEs where technical design guidance is not addressed in this version but will be covered in future versions of these guidelines.

Table A-2: Prioritization of NSEs in terms of need of guidance

Non-structural elements	Included in this version of Guideline	Examples
Lightweight partition walls	Y	Timber partitions Cold-form steel partitions
Suspended ceilings	Y	Exposed grid suspended ceilings Concealed grid suspended ceilings
Linear suspended services	Y	Suspended ductwork, electrical cable trays, mechanical heating/cooling pipework, plumbing and drainage pipework
Suspended equipment	Y	Fans, VAV boxes, heat exchangers, cassette units, grilles, diffusers, chilled beams
Floor mounted equipment	Y	Emergency generators, chillers, boilers, furnaces, pumps, air handling units (AHUs), transformers, outdoor condenser units, heat exchangers, control panels, motor controls, switchgear, distribution panels, fans/blowers/filters, air compressors
Automatic fire sprinkler systems	Y	Suspended fire protection piping, sprinklers & risers
Exterior glazing systems	Y	Curtain wall, spider glazing
Wall mounted equipment	N	Distribution panels, high wall units
Roof mounted equipment	N	Vents, flues, antennae, solar panels
Tanks and Vessels	N	Water tanks, hot water cylinders, buffer tanks, fuel tanks hazardous storage tanks
Lifts, Escalators	N	Lifts, escalators, conveyors, motor, controls
Exterior Cladding	N	Precast cladding, light-framed cladding, seismic impacts on Rigid Air Barriers
Racking	N	Storage racks, battery racks
Lighting	N	Pendant lighting, exterior lighting, ceiling-mounted lighting
Specialised medical equipment	N	Pendants, Specialist medical gas equipment
Masonry	N	Wall, parapets, chimney,

Hazardous storage	N	Compressed gas cylinders (O2, CO2, NH3, etc), batteries,
Computer access floors	N	Raised access floor
Contents	N	Large computer and comms equip (speakers, monitors), artwork (e.g. museum pieces),

A.3. Project Planning and Project Brief

Understanding the project specific requirements with regards to seismic performance of the building is a fundamental aspect of the design brief which requires early consideration by the client and the project team.

All projects are required to comply with the New Zealand Building Code as a minimum requirement, however specific additional performance requirements and clarifications may be identified for the project in addition to the minimum Building Code requirements. To ensure the building performance meets the post-earthquake functionality and operational needs, the requirements need to be outlined at the beginning of the project, preferably before the start of the design.

Examples of client requirements and possible response by the design team are provided below:

- An IL3 building with a specific requirement to protect valuable artwork. This might lead to above building code requirements for design of particular partitions or pedestals or consideration of locating valuable artwork on the ground floor rather than on upper floors, or consideration of structural system that minimises accelerations, along with consideration of above code ventilation in a dedicated room(s).
- An IL3 building which will store laboratory samples in a room located near the seismic movement joint of the building. To appropriately protect the laboratory samples, the water pipe movement joints may need to be designed to SLS2 or ULS building movement as an above code requirement (as opposed to SLS1 building movement).
- An IL2 building is to be used to manufacture food. Relocation of plant and equipment to enable continuation of the business would not be immediately feasible following an earthquake event that damages plant, impacts operation, hygiene or prevents occupation of the building. This may cause significant Business Interruption and potential long-term loss of business that is unacceptable to the Client. In this instance the Client brief may require continued operation performance requirements (SLS2) even though the building is an IL2 building – however it would likely require the design team to highlight in the first instance the likelihood of business interruption if the building was designed to minimum building code. If the client decides continued operation is necessary following an earthquake event, the design team will need to work with the client to determine the appropriate SLS2 hazard to meet the client's business plan and risk expectations. Note the LDSD guideline is a potential method to determine what is appropriate for SLS2 and provides good guidance on how to discuss this with your client (*LDSD will be issued in the future*).

A well-considered Project Brief, with client input, is considered fundamental to achieve the outcome expected by the client, both for day-to-day function and the functionality requirements post-earthquake. It is recommended that the Project Brief is completed as part of the Project Establishment, or as early as possible, for the project. Refer to the next section for more information.

A.4. Design Methodology & Design Phases

A.4.1. Overall Design Methodology

The required seismic performance of a building requires early definition and project wide coordination at all stages of the design.

Whilst historically the NSE seismic design, was undertaken during the construction phase with minimal design phase coordination it resulted in construction and seismic performance issues. The ability to achieve the required seismic performance of all non-structural elements was often compromised due to issues relating to disconnected timing of design work by various disciplines, poor or limited coordination between disciplines, inconsistency in design approach and confusion in scope between disciplines.

The NSE CoP provides guidance on how to work through the design process from project briefing through to design undertaken during the construction phase.

The following sections sets out the recommended approach to integrate the design and coordination of NSEs into the design methodology and design phases and is to be read in conjunction with Section A.5 where the roles and responsibilities for the different design disciplines are defined and the key design interfaces between disciplines highlighted so that they can be addressed through the design process.

A.4.1.1. Holistic / Integrated Design Methodology

Historically, the design of individual services, ceilings, and partitions has been undertaken by different designers, often operating in contractual silos. This rarely leads to best-for-project outcomes as it requires individual restraints to every individual element, with less opportunity for consolidation. Consolidation and coordination during design can significantly reduce site clashes and improve efficiency and costs.

The seismic design process should consider the operational requirements for NSEs, where the NSEs are to be located, how the restraints for different NSE interact, and expectations for components carrying loads from other NSEs. This should also consider the future needs of the building and provide appropriate (reasonable) allowances for future modifications that may rely on the fixing of new non-structural elements. An example of this is partitions designed to resist tributary ceiling loads from adjacent small rooms as well as to allow for face fixing of light finishes.

There is no one-size-fits-all design methodology for all projects. Every project is unique and for some projects certain areas or components will need more attention and integration/ coordination compared to other, even similar sized, projects that have a different focus.

> *It is recommended each project makes use of the design processes outlined in this guideline and scale the effort to suit the specific requirements of the project. Key activities should be undertaken, but they can be customised to suit the project's complexity and scope. If done so, better outcomes can be achieved in terms of design, construction efficiencies and costs, and seismic performance of the building.*

A.4.1.2. Building Movement Strategy

The Building Movement Strategy is an important aspect required for every design project. Every building has movements that occur during the day-to-day functions of the building, as well as movements that will occur to the building and components during seismic shaking.

There are often conflicting building/component movement requirements at various locations within buildings e.g. requirements for gaps for acoustic/vibration vs no gaps for passive fire vs seismic movement joints vs wall openings for air passes, or thermal movements of components required for day-to-day function of the building vs seismic restraint of components. These opposing requirements need to be discussed and agreed with the project team and documented into a multi-discipline report format similar to a Design Features Report and updated through the design and project lifecycle.

Work on the Building Movement Strategy should commence at concept design with discussion and coordination between disciplines regarding expectations for building and component movements. During concept design phase the initial Building Movement Strategy is developed and this should be continued to be revised and developed throughout the design process.

In development of the Building Movement Strategy the design team should consider all aspects of building movement and document requirements for movement and gaps versus locations/zones where movement needs to be restricted/restrained. Compromises may be required where thermal/acoustic/vibration/passive fire/structural drift requirements cannot all be met at a certain location/zone. In those locations the design team should **discuss and agree** what aspects are to take precedence and which can be compromised and why the decision was made. It is essential this process is well considered and **documented**.

The list below provides guidance on a starting point for discussion with the project team, but it is noted that the design team needs to be cognisant that each project is different and agree the scope for the building movement strategy for each individual building:

- List day-to-day functionality of the building and its components,
- Identify components that have operational thermal movements,
- Identify components that are vulnerable to being damaged during deformation of the building during seismic shaking, e.g. partitions, membraned wet areas (e.g. bathroom and wet areas), glazing, facade, risers (pipework and ducting in risers),
- Identify fire resisting elements of the building,
- Identify passive fire components and those that need to break away during fire events,

- Identify potential seismic gaps,
- Identify locations for acoustic walls and ceilings,
- Consider partition wall construction options (e.g. seismic joint above ceiling vs full height partitions),
- Consider different structural system options and identify options that best achieve the building movement strategy and the seismic performance requirements for the building.

A.4.1.3. Base Isolated Buildings

The principals of holistic design, development of the Building Movement Strategy and project team coordination are the same for Base Isolated Buildings, however over the seismic isolation plane, additional consideration is required for the significantly larger inter-storey displacements that occur at the seismic isolation plane. The solutions required for accommodating the building movements for NSEs over the seismic isolation plane can be complex and costly and require thorough coordination and appropriate costing.

A.4.2. Design Phases

A.4.2.1. NSE CoP link with 2023 NZCIC Guidelines

The NSE CoP provides additional information to supplement the use of the NZCIC guidelines. In the 2023 version of the NZCIC guidelines a new NSE Seismic Designer role has been included. Tasks are listed under the various design phases, but the NZCIC guidelines don't provide detail as to what is required for each task. The NSE CoP guidelines use the NZCIC guidelines and provide additional detail on what tasks, coordination and outputs are required to achieve the outcomes.

Specifically for the conceptual and preliminary design phases these guidelines provide more coordination between the disciplines than identified in the 2023 NZCIC guidelines. Experience shows early coordination reduces design and construction risk and makes it easier to achieve the required seismic performance.

Table B-B1 in Appendix B summarises the design tasks, project team considerations, and multi-discipline coordination for each phase of the project. Whilst each task/step is important for all projects, the scale of each task is expected to be different for each project. For example, for one project the design task/step may be completed in a one-hour multi-discipline discussion compared to the requirement for multiple workshops completed over a series of weeks for another project. The table includes references to the various sections of this document as recommended to be undertaken for each NZCIC design phase.

A.4.2.2. Project Establishment

A key aspect of the Project Establishment phase is to understand the project specific requirements with regards to seismic performance of the building. Many clients are often not aware of the limitations of the code minimum performance objectives and may have performance expectations which are out of the step from a design that seeks to achieve minimum compliance with the New Zealand Building Code. Code minimum performance focuses on life safety of building occupants during seismic events. Recent seismic events highlighted that code minimum building performance can lead to lengthy downtimes and high repair costs, where a large contributor to the disruption and repair costs was damage to non-structural elements.

The key aspect of this phase of the project is to **communicate with and understand the client and/or tenant operational needs for the building** and if any functionality is required/expected post a significant earthquake. It requires discussion with the client, **in lay terms**, to understand their goals for the building and interpretation of their requirements into engineering design parameters. The following questions (taken from Steneker, 2023) can be used to aid the discussions with the client/tenant and the answers used to help interpret the client's business resilience plan to develop the engineering design parameters for the Project Brief:

- What is the building's intended occupancy function?
- What is the anticipated time to re-occupy the building following a defined earthquake hazard?
- How sensitive is the business to downtime and interruptions?
- What alternatives are available to de-risk the client's exposure?
- What is the client's current and projected opportunity or borrowing costs?

Refer also to Section A.3 for high level comments on project planning and examples of seismic performance requirements for various types of buildings.

Confirm NSE Design Scope for different phases of the project

It is recommended that during the Project Establishment phase, the design responsibilities of the design engineer and the contractor are defined. It is recommended that a design responsibility matrix is used to clarify the design scope for each non-structural element. An example responsibility matrix is shown in Figure A-2 for linear services supported from above and from below. These design responsibilities should consider items that benefit from being included in the design phase versus those that require collaboration between the engineer and contractor.

NSE Group	Designer (pre-tender)	Contractor (post-tender)	Designer (post-tender)
Linear services, e.g. pipes, ducts, cable trays supported from **above**	Seismic brace and fixing details. Seismic brace layouts & maximum brace spacings. Spatial planning for seismic restraints, flexibility & clearances. Coordination of seismic loads with structural designer.	Gravity support design or selection. Selection of flexible elements and vibration isolators for combined thermal, gravity & seismic displacements. Construction phase set-out & coordination.	Review Contractor's layout, support & detail submissions & if/where appropriate, update/ complete design
Linear services, e.g. pipes, ducts, cable trays supported from **below**	Coordination of significant seismic point loads with structural designer.	Design of supports for gravity & seismic actions. Selection of flexible elements and vibration isolators for combined thermal, gravity & seismic displacements. Construction phase set-out & coordination.	Review Contractor's support structure design (calcs & details) w.r.t. seismic actions.

Figure A-2: Example of scope delineation between designer and contractor (Baird, 2022)

A.4.2.3. Concept Design

This section provides the recommended process to be undertaken during the concept design phase. The design process is described in the flowchart with descriptions of each task in the table below. The task numbers in the flowchart correspond with the task numbers in the table below and the task numbers in the concept design roles and responsibility matrix included in Section 5.

During the concept design stage, it is recommended to simultaneously investigate building services reticulation options (5), Fire engineering strategies (6) and locations of heavy plant (8) whilst considering the overall building movement strategy (7). The building movement strategy options should build the foundation for the development of the gravity and lateral structural system options (9).

Concept Design Process Flow Chart Legend

	Design, coordination, and documentation tasks		Coordination only task

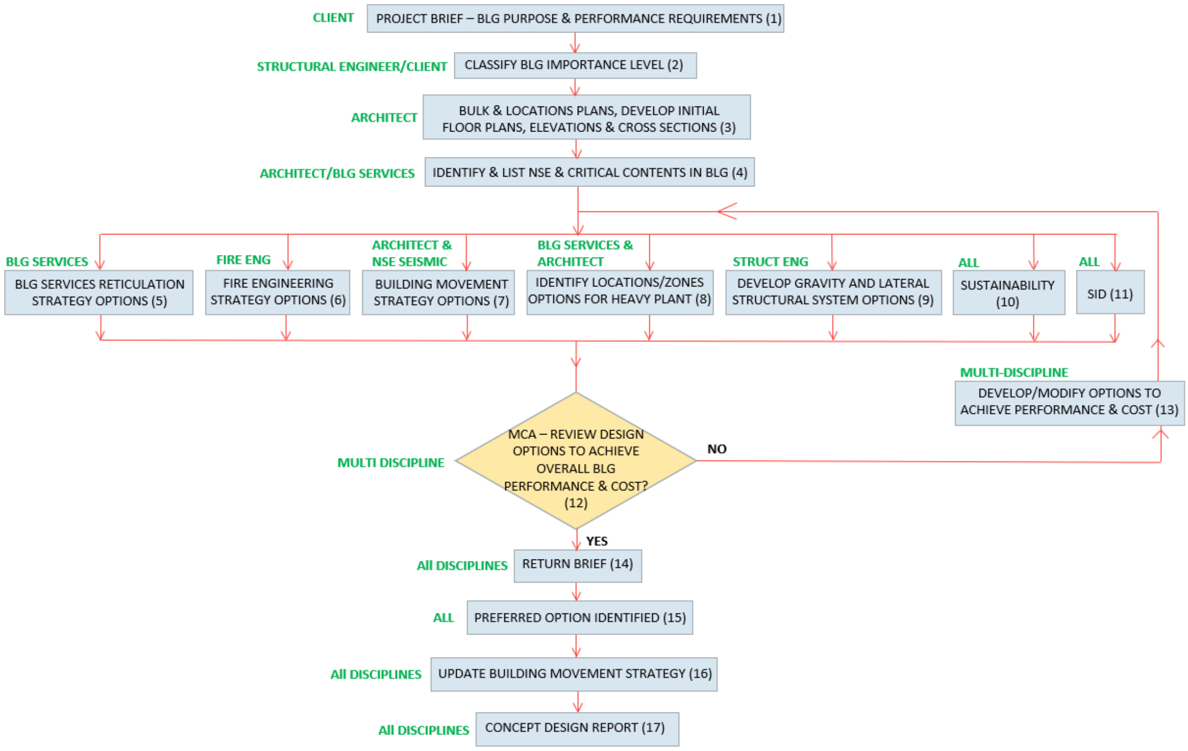


Figure A-3: Concept Design Process Flowchart

Table A-3: Design tasks included in Concept Design Phase

No.	Task	Scope
1	Project Brief	Client to define the building purpose and performance requirements, refer Section A.3. This will require confirmation on any post-earthquake functionality requirements for the building. This could be if the building is required for post-disaster in its entirety or if there is a requirement for certain systems, areas, rooms, to function post-earthquake for buildings that are not IL4.
2	Classify Building Importance level	Structural Engineer to confirm the interpretation of Building Importance Level and this is to be confirmed by the Client/Design Manager. Once confirmed Importance Level for building to be communicated to all disciplines.
3	Bulk & location plans	Develop initial floor plans, elevations and cross sections.
4	Identify & list non-structural elements and critical contents in building	At concept design phase design team to identify the key non-structural elements that will be included in the building. Note this is intended to be high level identification of components, not design or confirmation of components. The Pro-forma NSE and Content list provided in Appendix B Table B-B2 can be used for this purpose. Run through this list and tick components expected to be in the building and identify critical components for operation and any functional recovery requirements. Communicate to all disciplines.
5	Building Services Reticulation Strategy	High level description on options for how building services can be reticulated through the building. Riser(s), plantroom(s), main reticulation run locations in the field (e.g. down corridor), identify potential heavy

		weight items. Simple markup of floor plan(s) and cross sections with simple memo that includes high level discussion on building movement strategy in relation to Building Services (refer Section A.4.1.2). Advise at high-level what alternative options are available.
6	Fire Engineering Strategy	High level description of fire engineering strategy e.g. are fire walls needed within floors? Sprinklers? Passive fire. Advise at high level what alternative options are available.
7	Building Movement Strategy	The initial Building Movement Strategy is developed based on high level discussion between disciplines – refer Section A.4.1.2.
8	Identify locations/zones options for heavy plant	For heavy plant and equipment identified in Concept Design Task 3 identify options for locations of these components. Simple markup of floor plan.
9	Develop structural gravity & lateral load Strategy	Mark up conceptual structural options on floor plans and cross sections. Advise alternative options include estimate of drifts and top floor accelerations (noting only conceptual design level, may even be discussed in relative terms between options) for each option.
10	Sustainability	High level consideration of how the NSE design can accommodate changes in 20 – 25 years when services and fitout are replaced. Reuse of materials and focus on climate change when considering overall NSE strategy. Also undertake tasks for sustainable design as documented in NZCIC for concept design.
11	Safety in design	High level consideration of safety in design and how the building will be operated and maintained.
12	Multi-criteria analysis	A Multi-criteria analysis (MCA) should review the design options from each discipline and evaluate them based on various criteria such as cost, daily operation, constructability, seismic resilience, and overall building performance. Identify preferred option for each discipline. Include consideration of primary structural system options to achieve overall building seismic performance requirements (architectural objectives and holistic seismic performance of building). Expected to be undertaken as a multi-discipline workshop. Depending on scale of project the MCA may be completed in a 1hr combined discipline meeting through to multiple hour workshops. Output of key discussion points and agreement to be documented in memo/report with actions as needed. The outcomes are to be incorporated into the Conceptual Design Report prepared by each discipline.
13	Develop/modify options to achieve Building Performance & Cost	The multi-criteria analysis meeting/workshop may highlight alternative option(s). This process is to allow for the discipline(s) to update the conceptual options to align with the outcome of the MCA meeting/workshop.
14	Return Brief	Following confirmation of each discipline's concept design via the holistic integrated MCA assessment, each discipline should prepare a statement of the seismic performance that will be achieved. Turn engineering metrics (drift, accelerations, building movements) back into tangible outcomes for the client, e.g. at 1 in 100 yr seismic event, fire wall partitions will be damaged which can impact continued occupancy, but no damage is expected to the structure, following 1 in 500 yr extensive damage to structural and non-structural elements expected which may necessitate demolition of the building.

15	Preferred concept design identified	Following receipt and understanding of what performance will be achieved, client to confirm the client brief met and then the Preferred concept design for each of the disciplines can be identified. Note it may be necessary to identify more than one preferred option in concept design to develop further in preliminary design before the preferred option is confirmed.
16	Update Building Movement Strategy	Update the Building Movement Strategy following confirmation of the holistic integrated (i.e. all disciplines) concept design.
17	Complete concept drawings and concept design report	Completion of design deliverables as per NZCIC guidelines.

A.4.2.4. Preliminary Design

This section provides the recommended process to be undertaken during the preliminary design phase. The design process is described in the flowchart with descriptions of each task in the table below. The task numbers in the flowchart correspond with the task numbers in the table below and the task numbers in the preliminary design roles and responsibility matrix included in Section 5. Refer to the concept design flowchart for the flowchart legend.

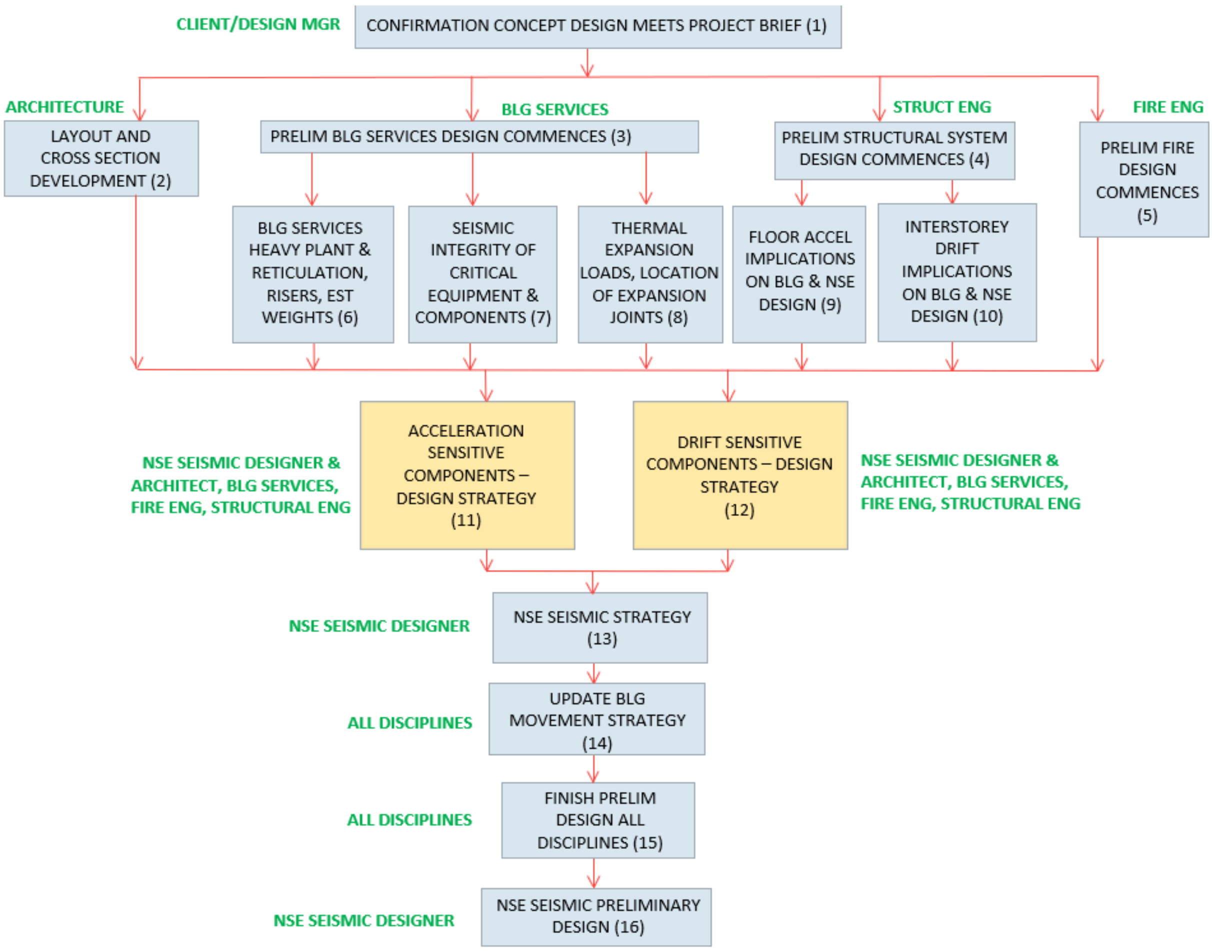


Figure A-4: Preliminary Design Process Flowchart

Table A-4: Design tasks included in Preliminary Design Phase

No.	Task	Scope
1	Concept design meets Project Brief	Client and/or design manager reviews concept design report with drawings and confirms that the concept design meets the performance requirements documented in the Project Brief.
2	Layout and cross sections	Development of the building plans, elevations and cross sections. Organise project team workshop to discuss and agree strategy for tasks 11 and 12.
3	Preliminary building services design	Commence preliminary building services design with consideration of tasks 6, 7 and 8. Before going too far meet and discuss tasks 11 and 12 with the wider design team to ensure full project team agreement on way forward.
4	Preliminary structural design of gravity and lateral system	Commence preliminary structural design with consideration of tasks 9 and 10. Before going too far meet and discuss tasks 11 and 12 with the wider design team to ensure full project team agreement on way forward.
5	Preliminary fire design	Commence preliminary fire design. Before going too far meet and discuss tasks 11 and 12 with the wider design team to ensure full project team agreement on way forward.
6	Building Services heavy plant & reticulation	Identify location of heavy plant and reticulation (such as Main Switchboards, Ring Mains, Chillers, Tanks) on plans and cross sections and provide estimated maximum weights for those components – coordinate with structural engineer to confirm load path.
7	Seismic integrity of critical building services equipment & components	Further development of building services components and equipment and identify critical equipment and components that are needed for post-earthquake functionality. Output = table that outlines the components, component category (NZS4219 3.3.2), identifies critical equipment, required operational & structural integrity of components.
8	Building Services components with thermal expansion – locations and loads	Identify components that will have thermal expansion in normal operation and identify their anticipated movement. Coordinate movement with the NSE Seismic Designer and Structural Engineer to ensure the thermal expansion load is considered as part of the load transmitted into the structure. Thermal expansion strategy and seismic restraint strategy to be aligned. Where are anchor points, where are expansion joints? Markup with anchors point by NSE seismic designer, markup with expansion locations by Building Services Engineer.
9	Floor acceleration implications on building and NSE design	Estimate floor accelerations and consider implications to acceleration sensitive NSEs (refer to the NSE list prepared during concept design and further developed in task 7).
10	Inter-story drift implications on building services, walls, ceilings and facades	Estimate building and inter-storey drifts and consider implications to drift sensitive NSEs (refer to the NSE list prepared during concept design and further developed in task 7).
11	Acceleration Sensitive Components – Design Strategy	NSE seismic designer, architect, building services engineers, fire engineer and structural engineer to coordinate the acceleration sensitive component design strategy. Acceleration sensitive components include building services pipework, ducts, equipment, ceilings etc. This task

		could be undertaken in meeting or workshop. The outcome is to agree the NSE seismic restraint strategy and identify which components/zones will be restrained using single service restraint, areas/components where combined services hangers or modular frames will be used, and how the ceiling design strategy will be incorporated. Combined coordination workshop for items 11 and 12 recommended.
12	Drift Sensitive Components – Design Strategy	NSE seismic designer, architect, building services engineers, fire engineer and structural engineer to coordinate the drift sensitive component design strategy. Drift sensitive components include partitions, façade, ceilings, and vertical reticulation of services in risers. This task could be undertaken in meeting or workshop. The outcome is to agree the partition design strategy (full height vs sliding joint above ceiling), agree façade design strategy, vertical reticulation strategy for services etc. and alongside task 11 agree ceiling design strategy including identification of zones where partitions will be used to restrain the ceilings. Combined coordination workshop for items 11 and 12 recommended.
13	NSE Seismic Strategy	Document the NSE seismic strategy for acceleration and drift sensitive NSEs. The NSE Seismic Strategy should include clarification of the design responsibilities for the design engineer and the contractor (refer Sections A.4.2.7 and A.4.2.8 for more information).
14	Update Building Movement Strategy	Update the Building Movement Strategy to align with the agreements from the coordination meetings, refer tasks 11 and 12, and the holistic integrated (i.e. all disciplines) preliminary design.
15	Finish preliminary design	Continue coordination between disciplines and complete preliminary design deliverables.
16	NSE Seismic preliminary design	Complete the preliminary design for NSE Seismic. In some projects a slight lag of a week or two between the delivery of architectural, building services, structural and fire engineering preliminary design and the completion of preliminary design for NSE Seismic may be warranted.

A.4.2.5. Developed Design

Follow 2023 CIC guidelines for developed design noting that there are always lates changes that occur in every design, and it is important that NSE seismic considerations and coordination are captured and included when changes occur. Depending on the size and complexity of the project it may be useful to have a lag for the developed design of NSE seismic following the core discipline delivery of NSE. This is to enable the changes that occur towards the end of developed design to be understood and implemented in the NSE design.

A.4.2.6. Detailed Design

Follow 2023 CIC guidelines for detailed design, noting there are always lates changes that occur in every design, this is particularly so in the detailed design phase. We recommend a lag is provided in the project programme between the completion and delivery of the detailed design for the design disciplines and the delivery of the NSE documentation. This is to enable the appropriate coordination of NSE seismic in their deliverables to align with the NSE seismic design scope of work for that project.

The following covers the **minimum** expected documentation to be delivered by the NSE seismic designer(s) at the end of detailed design:

- NSE Seismic Design Strategy
- 2D Drawings. In general, these are expected to be read in conjunction with those of the parent element (services, partitions, ceiling etc).
- Specifications. Material specifications should be provided and coordinated with those of the parent element (services, partitions, ceiling etc).
- Producer Statements for Design—PS1.
- Supporting calculations for Building Consent.

A.4.2.7. Construction Phase Design and Interface with Detailed Design

Outputs from detailed design seismic design of non-structural elements typically include plan layouts, project specific details, standard details, and performance specifications for undefined elements. Finalisation of seismic restraint layouts cannot take place until building services sub-contractor construction phase design and equipment selection takes place. There may also be changes in the design by one or more design disciplines. It is important that NSE seismic performance and detailing considerations are captured and included when changes occur. Note that these changes may have implications for the Building Consent that will need to be addressed.

It is expected that it will be necessary to integrate the sub-contractor design of non-structural elements and equipment selections with the seismic design of these components. The following approach is recommended to assist with this integration:

1. NSE Seismic designer to provide initial briefing meeting with the contractor, building services, ceiling and partition subcontractors to discuss general principles to be followed, shop drawings process (if any), standard details to be used and agreed procedures for areas where standard details may not apply.
2. Once seismic design layouts are issued for construction, the subcontractors will need to incorporate the seismic restraint design layouts into their layouts (and potentially shop drawings) to confirm final layouts are compatible with the subcontractor construction phase design layouts and selections.
3. The main contractor's non-structural elements seismic coordinator will work with all subtrades to coordinate the seismic bracing design with the finalized sub-contractor design.
4. The designer will review sub-contractor shop-drawing submissions to check seismic restraint design intent is considered and incorporated.

The main contractor plays a critical role in implementing the seismic design phases, including the coordination and management across the various trades. It is recommended that a 'Seismic Restraint Installation Coordinator' is identified during construction who is responsible for coordinating the final locations of all seismic restraints to non-structural elements. This coordinator can also consider other design factors that may not have been explicitly considered in the seismic restraint design, such as thermal expansion, pressure/thrust, vibration, acoustics, etc.

A.4.2.8. Construction Phase Design and Coordination Scope

While the aforementioned design activities are intended to resolve the bulk of seismic design for non-structural elements, there will be facets of NSE design that cannot occur until the construction phase. This is often due to it not being possible to progress the design until equipment is selected. It is important to note that design and coordination activities should still occur for these elements during design, but this final design will need to be checked or confirmed during construction phase.

For example, the number and size of fixings for floor mounted equipment will typically not be known until the unit is selected. However the approximate weight and size will be known, so the seismic over-turning demands from the equipment should be coordinated with the structural engineer during the design phase. During construction, the final design of hold-down fixings for the equipment should be checked/confirmed to confirm the earlier assumptions were appropriate.

There is often similar confusion over how to design NSE which include both gravity and seismic demands. Refer to Section A.5.6 for discussion on the roles and responsibilities for gravity design of NSEs.

A.5. Roles & Responsibilities

A.5.1. Background

Historically a Seismic Restraint Engineer designed and co-ordinated the seismic restraint of non-structural elements during the construction phase (SESOC, 2022). Often different Seismic Restraint Engineers were engaged for each sub-trade, commonly during the construction phase. This approach led to poor project outcomes including re-work, non-compliance and poor performance in earthquakes (BIP, 2020). **Historically the focus of design was solely on seismic restraints (life safety), rather than <u>seismic performance of the entire building</u>**. Design interfaces between disciplines that impact or define the seismic performance of the building were often not considered or only considered as an after-thought with set parameters. In contrast, the NSE CoP focuses on the overall seismic performance of the entire building.

A.5.2. Design Manager Role

The design manager's role is to coordinate all building design elements. The design manager as described in this guideline has responsibility to manage the coordination and interfaces between disciplines and identify and manage coordination and interfaces that will be finalised during construction. This requires a variety of skills and vast knowledge in multiple design disciplines. Seismic performance of buildings remains to date a specialist skillset. It is expected that the Design Manager will have the following qualities to ensure seismic performance is achieved through coordination:

1. Fundamental understanding of building services.
2. Understanding of seismic forces.
3. Understanding of building movements including drift and thermal expansion.

4. Understanding of the impact of NSE performance on overall seismic performance of the building.
5. Experienced in construction observation/construction coordination of NSE seismic restraints and detailing.

The entity best placed to undertake the role and responsibility of design manager (as described in these guidelines) should be decided on a best-for-project basis. What is important is that the responsibility for coordination and interface management is agreed and assigned at the start of each project.

The Design Manager's role is important to ensure the disciplines coordinate and discuss strategy throughout the design. Refer to conceptual design as described in Section A.4.2.3 and preliminary design as described in A.4.2.4 as well as enforcing coordination and delivery of the disciplines at later stages to enable the NSE Seismic Designer to complete their work in the designated lag period.

Part A of this guideline provides design process flow charts, design roles & responsibilities and how interfaces between disciplines should be coordinated. It is the Design Manager's role to coordinate those design interfaces, including the discipline interfaces identified in Section A.5.5 and Section A.5.9.

A.5.3. NSE Seismic Designer Role

The role of a specialist NSE Seismic Designer has emerged more recently. This role typically commences during the design phase of projects. Engagement of a specialist NSE Seismic Designer enables the design of non-structural elements to be co-ordinated during the design phase, minimising the need for design changes during the construction phase.

A.5.4. Structural Engineer Role

Typically, common structural flooring systems will be able to support direct fixing of well distributed, lighter-weight NSE's without undue constraint nor the need for much, if any, additional strengthening/bracing. However, lightweight systems, such as light gauge purlin roofs, may not be appropriate to carry and restrain rooftop plant or access structures and suspended NSEs. It is the Structural Engineer's role to understand these loads and provide structure as necessary. This can include mixtures of additional bracing, blocking and, additional plywood or panel products, a more robust roof structure and/or additional secondary steelwork.

The cost of any additional secondary structure should be accounted for in determining and costing the appropriate structural system, as it can be significant. The simplicity and improved future flexibility offered by heavier structural systems should be considered.

A.5.5. Design load interface - NSE Seismic Designer & Structural Engineer

A collaborative effort between the NSE Seismic Designer, building services engineers, architect and the Structural Engineer should be made to ensure drift or acceleration induced NSE force reactions acting on primary structure are compatible and practical.

NSE Seismic Designers determine specific reactions from NSE restraint systems on structure as part of the restraint and anchorage design and provide this to the Structural Engineer who has control over the capacity provided in the primary structure to resist these forces.

Routine NSE Seismic Designer practice utilises simplifying assumptions for practical reasons and to simplify communication of requirements to installers. This can apply to design assumptions for weight, restraint spacing, potential resonance with primary structure (i.e., parts load derivation), concurrency of loading and ductility. The design impact on the restraint itself is usually minimal and offset by practical construction efficiencies. However, when these assumptions are compounded with similar simplifying assumptions made by interfacing engineers for primary structure, the outcomes can become materially conservative. This can lead to theoretical scenarios where primary structure has low calculated capacities relative to the assumed NSE seismic restraint loading which poorly reflects the true capacity available.

Structural Engineers and NSE Seismic Designers should work together to ensure careful and pragmatic management of simplifying assumptions—which achieves the performance requirements but gives enhanced recognition to structural capacities and is better reflective of real loading conditions and performance. Both parties are responsible for communicating and collaboratively reviewing this load interface and this collaboration needs to be done early to be appropriately implemented and included in the cost plan.

A.5.6. Gravity Support Design Role for NSEs

There is often similar confusion over how to design NSE which include both gravity and seismic demands. Gravity dominant elements such as plant room framing are traditionally designed or selected by sub-contractors to suit the building service gravity requirements and spatial constraints on site. Where seismic support requirements exceed gravity support requirements, this strategy should be reconsidered. Whilst it is often inefficient for the design engineer to design all elements of these frames (gravity and seismic) during the project design phase, the focus of the design activities during the design stage should be on identifying the load path strategy for all elements and coordination of the main support frames. Additional design and coordination work alongside the contractor during construction can then be completed using the detail of the final support solutions for both gravity and seismic demands.

The following approach is recommended:

- The seismic restraint design should consider gravity support design wherever possible, particularly when gravity design is inextricably linked.
- Generally, standalone gravity support can be undertaken by the Contractor as a Design and Build element.
- The consideration towards gravity support for NSE should be given by the NSE Seismic Designer, as part of their design.
- NSE Seismic Designer to document their assumptions (e.g. 2m of tributary gravity load has been allowed for in the design of the seismic brace solution).

A.5.7. Seismic Restraint Installation Coordinator

The main contractor should have a non-structural elements seismic coordinator. Ensuring the main contractor has a NSE Seismic Coordinator is critical to the success of good NSE installations. Coordination tasks for the seismic restraint coordinator are discussed in Section A.4.2.7.

A.5.8. Roles & Responsibilities Matrix

Tables A-5 and A-6 provide the Roles and Responsibilities for the Concept and Preliminary Design Phases as described in Sections A.4.2.3 and A.4.2.4. These tables use the NZCIC 2023 Guidelines as basis with additional detail provided to guide designers through good integrated design in these important design phases. Note that the first column provided in the R & R Matrix is the Task Number which aligns with the task numbers provided in the Concept and Preliminary Design Phase, refer sections A.4.2.3 and A.4.2.4.

<u>Roles and Responsibilities Matrix table legend</u>

	Primary Role, Responsible		Secondary Role, Coordination responsibility, Input required

Flowchart task	Design Stage	Design Step	Required Input	Client	Project Manager	Quantity Surveyor	Design Manager	Cultural Advisor	Sustainability Consult.	BIM Manager	Architect	Façade Engineer	Fire Engineering	Structural	Civil	NSE Seismic Design	Mechanical	Electrical	ICT Consultants	Plumbing & Drainage	Fire Protection	Main Contractor	Other	Scope of output
1	Concept Design	Project Brief																						Report
2	Concept Design	Classify Building Importance Level	Project Brief (1)																					Report
3	Concept Design	Location Plans, Develop Initial Floor Plans, Elevations & Cross Sections	Project Brief (1)																					Floor Plans and Sections
4	Concept Design	Identify and list NSE & critical contents in the building	Project Brief (1)																					Report
5	Concept Design	Building services reticulation strategy options	Architectural plans & cross sections (3), Project Brief (1), Critical Content (4)																					Options Memo with Markups (design strategy requirements as per NZCIC)
6	Concept Design	Fire engineering strategy options	Architectural plans & cross sections (3), Project Brief (1), Critical Content (4)																					Options Memo with Markups (design strategy requirements as per NZCIC)
7	Concept Design	Building movement strategy options	Architectural plans & cross sections (3), Project Brief (1), Critical Content (4)																					Options Memo with Markups (design strategy requirements as per NZCIC)
8	Concept Design	Identify locations/zone options for heavy plant and equipment	Architectural plans & cross sections (3), Project Brief (1), Critical Content (4)																					Options Memo with Markups (design strategy requirements as per NZCIC)
9	Concept Design	Develop structural gravity & lateral load systems	Architectural plans and cross sections, all information from (1),(2),(3),(4),(5),(6),(7),(8)																					Options Memo with Markups (design strategy requirements as per NZCIC)
10	Concept Design	Sustainable design	Architectural plans & cross sections (3), Project Brief (1), Critical Content (4)																					Report
11	Concept Design	Safety in Design	Architectural plans & cross sections (3), Project Brief (1), Critical Content (4)																					Report
10	Concept Design	Multi Criteria Assessment Workshop	all information from (1),(2),(3),(4),(5),(6),(7),(8),(9)																					Workshop, Workshop Notes
11	Concept Design	Develop/modify all design options to achieve performance & cost	output from Workshop (10)																					Options Memo with Markups
12	Concept Design	Return brief	output from Workshop (10), Project Brief (1)																					Memo; section in DFR (as per NZCIC)
13	Concept Design	Preferred option identified	Project Brief (1), output from Workshop (10), modified design (11)																					Update options memo and confirm design strategy for all elements across relevant disciplines (NZCIC)
14	Concept Design	Update building movement strategy	Project Brief (1), preferred option (13)																					Report
15	Concept Design	Concept design report	Project Brief (1), preferred option (13)																					Concept design deliverables as per NZCIC

Table A-5: Concept Design Roles & Responsbility Matrix

Flowchart task	Design Stage	Design Step	Required Input	Client	Project Manager	Quantity Surveyor	Design Manager	Cultural Advisor	Sustainability Consult.	BIM Manager	Architect	Façade Engineer	Fire Engineering	Structural	Civil	Non-Str. Seismic Design	Mechanical	Electrical	ICT Consultants	Plumbing & Drainage	Fire Protection	Main Contractor	Other	Scope of output
1	Preliminary Design	Confirmation of concept design																						
2	Preliminary Design	Layout & cross section development	Concept design confirmed (1)																					preliminary design as per NZCIC
3	Preliminary Design	Preliminary building services (tasks 6, 7 & 8)	Concept design confirmed (1)																					preliminary design as per NZCIC
4	Preliminary Design	Preliminary structural system design	Concept design confirmed (1)																					preliminary design as per NZCIC
5	Preliminary Design	Preliminary Fire Design	Concept design confirmed (1)																					preliminary design as per NZCIC
6	Preliminary Design	Building Services heavy plant & reticulation, risers, estimated weights	Concept design confirmed (1)																					markup plans & cross sections
7	Preliminary Design	Seismic integrity of critical building services equipment & components	Concept design confirmed (1)																					Table
8	Preliminary Design	Thermal expansion loads, locations of expansion joints and anchor points	Concept design confirmed (1)																					markup plans
9	Preliminary Design	Floor acceleration implications on building and NSE design	information from (6), architectural layout plans & cross sections																					Part of DFR or Memo
10	Preliminary Design	Inter-storey drift implications on building services, walls, ceilings and facades.																						Part of DFR or Memo
11	Preliminary Design	Workshop to strategy (NSE services restraint, combined services hangers, modular frames, ceilings design)																						Confirmed project strategy
12	Preliminary Design	Workshop to agree partition & facade and ceiling design strategy																						Confirmed project strategy
13	Preliminary Design	NSE seismic strategy	workshop outcomes from (11) and (12)																					Part of DFR or Memo/Report
14	Preliminary Design	Update building movement strategy																						Report
15	Preliminary Design	Completion of preliminary design																						preliminary design deliverables as per NZCIC
16	Preliminary Design	Completion of NSE seismic preliminary design	all information from (15)																					preliminary design deliverables as per NZCIC
17	Preliminary Design	Preliminary design report	all information from (6), (7), (8), (9), (10), (11), (12), (13), (14), (15), (16)																					design report, drawings/markups as per NZCIC

Table A-6: Preliminary Design Roles & Responsbility Matrix

A.5.9. Roles and Responsibilities for Design Interfaces

As stated earlier, the seismic performance of NSE is inherently integrated into the overall NSE design, necessitating deliberate design considerations and actions throughout the various stages of NSE design. All disciplines associated with NSE, including Architecture, Building Services, Fire Protection, and others, actively contribute to the seismic performance of the building. The design, positioning within the building, and their interfaces with seismic forces collectively exert a critical influence on the overall building performance in seismic events. This goes beyond just the seismic restraint of NSEs.

A fundamental principle in engineering is to determine the most qualified individual to provide specific information. Seismic performance, being intricately connected to various design disciplines, relies on the expertise of professionals in those fields who can contribute significant design data into the seismic design. This guideline delineates the roles and responsibilities of each discipline, specifying the necessary inputs, coordination efforts, and deliverables expected from each discipline at different stages of the design process.

A.5.9.1. Key Interfaces and coordination with Project Team

The following provides key areas/items required by each discipline for interfacing with other members of the project team.

Architect (typically also design lead)

- Spatial coordination (holistically ensuring all inputs are interlinked)
- Partitions and deflection head strategy
- Ceiling systems and details
- Setout and coordination strategy for ceiling systems with building services
- Coordinate with all disciplines and coordinate and show movement locations (as provided/confirmed by individual disciplines)

Structural Engineer

- Provision of accelerations and deformations/drift.
- Compatibility of detailing
- Compatibility of loading

Building Services Engineer

- Spatial coordination
- How services and trades might be grouped in their support
- Operational continuity/continued function
- Seismic movements
- Thermal movements
- Repairability

NSE Seismic Designer

- Overall building movement and NSE seismic design strategy (in coordination with all disciplines)
- Refer to Section A.5.3

Seismic Restraint Installation Coordinator

- Refer to Section A.4.2.7 and Section A.5.7.

Contractor

- Construction and procurement strategy
- ECI and buildability

- Possible novation

A.5.9.2. Specific Interfaces for Building Design

The tables in this section list specialised design elements that interface with the NSE seismic performance discipline. It is imperative to recognize that no single designer can independently address these design elements. Coordinated efforts are indispensable for optimizing the seismic performance of the building.

The purpose of this section is to outline the key interfaces and outline the specific responsibilities assigned to each discipline in the overall design process relating to that interface. These interfaces can be challenging as multiple disciplines involved.

Table A-7: Inter-story drift interfaces

Design element	Primary Responsibility
Amount of building movement during seismic events	Structural Designer
Confirmation on where movement occurs	NSE Seismic Designer
Identification of NSE that are impacted by the building movement	Building Services Designer, Architect, Fire Engineer
Amount of movement for movement joint selection	NSE Seismic Designer
Selection of movement joints (material, suitability for the relevant service, amount of movement)	Building Services Designer, Architect, Specialist Supplier
Illustration of movement & break away joints on drawings	Building Services Designer, Architect
Support/Restraint of movement & break away joints	NSE Seismic Designer – note timing of when this occurs should be agreed (design or construction phase)
Selection of suitable passive fire products that can accommodate movement	Passive Fire Designer, Specialist Supplier

Table A-8: Vibration isolation interfaces

Design element	Primary Responsibility
Requirement for vibration isolation	Acoustic Designer
Consideration of spatial requirements	Building Services Designer
Selection of suitable vibration isolator	Specialist Supplier
Acceptance of vibration isolator	Building Services Designer, Acoustic Designer, NSE Seismic Designer
Calculation of resulting loads and confirmation of load path into the structure	NSE Seismic Designer

Table A-9: Thermal expansion interfaces

Design element	Primary Responsibility
Amount of thermal expansion occurring in piping systems	Building Services Designer
Identification of piping systems that require thermal expansion compensation (such as expansion loops, expansion bellows, slider brackets)	Building Services Designer
Selection of thermal expansion compensator	Building Services Contractor, Specialist Supplier
Acceptance of thermal expansion compensator	Building Services Contractor, NSE Seismic Designer
Coordination of thermal anchor points with seismic anchor points and the load path into the primary structure	Building Services Designer, NSE Seismic Designer Structural Engineer *(coordinated output required due to opposing design interests – Movement vs. Restraint)*
Illustration of thermal expansion and thermal anchor points on design drawings	Building Services Designer
Illustration of seismic anchor points on design drawings	NSE Seismic Designer

Table A-10: Ceiling / partition selection interfaces

Design element	Primary Responsibility
Material, linings, build-up, and detailing including that required to achieve acoustic and fire rating requirements	Architect
Wall height and deflection head heights	Architect (input from NSE Seismic Designer)
Confirmation on where movement occurs	NSE Seismic Designer
Restraint requirements of ceiling or partition, including where movement is required	NSE Seismic Designer
Assessment of product availability and requirements for the project	Architect (input from NSE Seismic Designer)
Confirmation of load path into the structure	NSE Seismic Designer
Structural and operational integrity of proprietary systems, e.g. ceiling grids	Architect (input from NSE Seismic Designer) select products whose data sheets show required performance. NSE Seismic Design to ensure selections do not compromise seismic performance. Specialist supplier, Contractor *Contractor to allow for pricing of testing if suitable evidence not available*

Table A-11: Equipment/system selection interfaces

Design element	Primary Responsibility
Identification of structural integrity requirements for each equipment	Building Services Designer
Identification of operational integrity requirements for each equipment	Building Services Designer
Assessment of product/equipment/systems availability and requirements for testing for the project	Building Services Designer (input from NSE Seismic Designer) – purpose for Building Services Engineer to ensure that equipment is available that has seismic capacity – testing may be required but testing may not achieve requirements if accelerations are too high
Confirmation of structural and operational integrity of equipment	Specialist supplier, Contractor Contractor to allow for pricing of testing if suitable evidence not available
Confirmation of load path into the structure	NSE Seismic Designer
Approval of structural and operational integrity of equipment	Building Services Designer (input from NSE Seismic Designer)

Table A-12: Passive fire interfaces

Design element	Primary Responsibility
Placement of seismic restraint brackets next to duct breakaway joints associated with duct fire dampers	NSE Seismic Designer
Illustration of duct break away joints on drawings	Building Services Designer

Part B: Seismic Performance Framework for NSEs

B.1. Introduction

This part of the document provides a general framework for the seismic performance of NSEs. This is technical in nature but is not specific to any particular non-structural element. Instead, it is intended to provide seismic performance principles that are broadly applicable to all NSEs.

This includes establishing a consensus on the general descriptions of seismic performance states for NSEs. These performance states describe the physical performance using easily understandable terms that non-engineers can understand. While these performance states are linked to the design limit states commonly used in NZ, they should nonetheless be applicable for the design, assessment or testing of NSE.

Guidance is also provided on how to quantify, calculate, or test different NSEs to establish seismic performance based on the states described. This aims to highlight existing methods that are aligned with NZ regulations and promote ready-to-use solutions that can be immediately implemented.

B.1.1. Performance States

The NSE CoP considers the following Performance States. These descriptions provide definitions in the context of NSE, and are in alignment with definitions elsewhere, such as NZ loading standard and the low-damage seismic design guide.

Table B-1: Performance states for NSEs

Performance State	Key Focus	Description
Serviceability Limit State 1 (SLS1)	Serviceable	The element does not require repair.[1]
Serviceability Limit State 2 (SLS2)	Functional	The non-structural element is able to maintain operational continuity. [2]
Damage Control Limit State (DCLS)	Repairable	An amount of repairable damage is acceptable, but the cost of repair should be significantly less than the cost of replacement.[3]
Ultimate Limit State (ULS)	Life Safety	Damage to NSE's that cause a risk to life safety due to failure of a NSE, failure of the support of a NSE, or an inability to evacuate a building.

[1] - In accordance with NZBC a component/element can be damaged but if it does not require repair then it achieves SLS1 limit state.

[2] - Non-structural elements may be damaged and repair may be required. SLS2 for non-IL4 buildings is currently not required for Code Compliance as the NZS1170.5 Amendment 1 is not cited in the Building Code. It is also important to note that for IL2/IL3 buildings, it may be possible for an element to be damaged and repaired in a suitable timeframe, e.g. days to weeks, for the element/building to be deemed to remain operational.

[3] – Not a Building Code Requirement, but further information can be obtained from the LDSD guideline (to be published in the future).

For some non-structural elements there may be an appreciable difference between first damage and loss of function. An example of this is glazing where first damage results in loss of watertightness, leaks, and air seal, but you can continue to function until the damage has moved to the next damage state, i.e., glass breakage. Loss of watertightness and air seal still require replacement, so whilst function can continue restoration will be required at some point following the earthquake event.

B.1.2. Part Classification

It is expected that people using this guideline will determine the classification of parts and components as per Table 8.1 of NZS1170.5. It should be noted that components often fall into more than one Part Category. The following additional clarifications are offered:

- Components designated P1-P3 are required to retain structural integrity at ULS, but not necessarily remain functional.
- Components designated P4 are required to remain functionally operational at ULS.
- Components designated P5 are often a good guidance for those applicable for DCLS.

Refer to Section B.4.1 of this guideline for seismic qualification requirements for plant and equipment for different Part Categories to achieve the required system performance.

B.2. NSE Drift Classification System

The non-structural element drift classification system provides a common language between designers and quantity surveyors, contractors and suppliers. The purpose of the proposed drift classification system is to provide a simple naming convention to describe the amount of deformation a drift sensitive non-structural element can sustain and achieve the required performance requirements.

> *Drift sensitive non-structural elements are those components that are most adversely affected by the change of shape of a building when it moves out of plumb in an earthquake. An example is a partition wall which is built plumb and level and uses large sheet materials that suffer damage when pushed out of square, whereas a suspended light fitting can sway back and forth and as long the support has sufficient load capacity that component is not damaged and is therefore not a drift sensitive non-structural element.*

To achieve the target seismic performance for drift sensitive NSEs, structural engineers need to communicate drift demands to the NSE designers who, in turn, need to inform suppliers of the performance requirements to align to their product development, testing & specification. The NSE drift classification system is therefore expected to be used by both design teams and the construction industry to communicate what performance is needed and how to select NSE components/systems accordingly. Over time it is expected that this NSE Drift Classification System will be embedded in the industry and suppliers will include the Drift Class in product/system data sheets.

The classification system for Drift Sensitive NSEs described in this section provides five drift classes, D1 to D5, with each drift class achieving SLS and ULS performance states at higher levels of drift. Using this Drift Classification system, the engineer would communicate the design requirements by simply referencing this guideline and the required Drift Class, for example, the specification could state the partitions and glazing are required to be Drift Class D2 for a certain building.

It is expected that this system will support quantity surveyors to build up knowledge of the estimated costs for drift sensitive NSEs subjected to varying design drifts and performance state requirements. This knowledge would benefit design development particularly in the conceptual design phase when different structural systems are considered allowing for a more holistic cost-benefit assessment of the various structural systems.

Refer to Table B2 for the drift limits for various performance states for each NSE Drift Class. For a NSE to achieve a drift class it must pass all of the stated limit state checks for that drift class.

Table B-2: Classification for drift-sensitive NSEs

NSE Drift Class	Median Drift Capacity		
	SLS		ULS*
	No Damage (SLS1)	SLS2/DCLS	Life Safety
D1	0.25%	0.50%	0.75%
D2	0.5%	0.75%	1.5%
D3	0.75%	1.0%	2.0%
D4	1.0%	1.25%	2.5%
D5	1.5%	2.0%	>2.5%

* Only applicable for NSEs where failure of the component would pose a life-safety threat

B.3. Data Sharing Requirements for Building Products

The minimum building product information provided by manufacturers and importers for non-structural elements should meet the requirements of MBIE Building Code Compliance ‘*Product Assurance and Certification Scheme*’. Further information on the requirements of this scheme can be found in the following links.

https://www.building.govt.nz/building-code-compliance/product-assurance-and-certification-schemes/building-product-information-requirements/information-requirements/

https://www.building.govt.nz/assets/Uploads/building-code-compliance/certifications-programmes/guidance-complying-with-building-product-information-regulations-2022.pdf

The new regulations require that manufacturers and importers supply technical information, including confirming which Building Code clauses are relevant to the product, within its intended scope of use, and how the building product is expected to contribute to compliance with those Building Code clauses (using references to one or more of the following):

- Any applicable options for compliance set out in Section 19 of the NZ Building Act (other than the product certificate referred to in Section 19(1)(d) or the manufacturer's certificate referred to in Section 19(1)(da)).
- Any other standards or technical document that describes the performance of the building product or the relevant specifications to which the building product was manufactured.

B.4. Seismic Qualification of Plant and Equipment

This section is intended to provide interim guidance on the specification of equipment to meet seismic performance requirements. Note that Seismic Qualification of Equipment is also often referred to as Seismic Certification of Equipment.

Responsibility for the specification of plant (including specification of seismic performance, and which elements of plant are required to maintain functional continuity) lies with the building services engineer. The NSE Seismic Designer should provide support to the services engineer in relation to seismic matters.

The recommended basis of seismic qualification is that given in ASCE 7-22 (ASCE/SEI, 2022). Internationally, ASCE 7-22 defines systems requiring special seismic certification, with OSHPD PIN 55 specifically exempting certain components. This reflects the principle that it is generally not considered economic to seismically certify all services components.

Within a New Zealand context, NZS4219 states that proprietary building services equipment shall meet specified seismic performance criteria, and comments that performance “should be verified”. It should be noted that according to this wording the practice of seismic qualification is “advised or recommended”.

Note that for all the methods of seismic qualification discussed in this section, **the items of plant or equipment for which testing has previously been completed must be confirmed to be the same piece of plant and equipment installed in the same manner that it has been certified**. For example, if an item was certified via shake table testing with antivibration mounts (AV mounts) the item must be installed with the same AV mounts, or otherwise analysed to confirm that the installed AV mounts do not significantly affect the component’s dynamic response. Also, it is important that the supplier provides written confirmation that equipment test certification/testing is the same in terms of design and construction to the same brand item supplied to the NZ market.

B.4.1. Components that require seismic qualification/certification

Seismic qualification shake table testing is useful to determine the seismic performance of equipment that possess many different parts and components. This equipment may have installed electronic, chemical, or fluid elements/components whose functionality after an earthquake cannot be determined through engineering analyses involving the determination of stresses and strains.

However, the time and cost of seismic qualification can be significant, and it is generally recognised that verification of all proprietary equipment is not warranted from a cost perspective. It is recommended that the seismic qualification testing is undertaken on plant and equipment as provided in Table B-3:

Table B-3: Seismic qualification testing

NZS 1170.5 Part Category*	Part Category Description	Structural Integrity Seismic Qual Testing Required?	Operational Integrity Seismic Qual Testing Required?
P1, P2 & P3	Component that represents a hazard to life outside of the building or within the building.	**Yes** (ULS)	No
P4	Component necessary for the continuing function of the evacuation and life safety systems within the building	**Yes** (ULS)	**Yes** (operation following ULS)
P5	Component of a system required for operational continuity of the building	**Yes** (ULS)	**Yes** (operation following SLS2)
P6	Component for which the consequential damage caused by its failure is disproportionally great	**Yes** (ULS)	**Yes** (operation following SLS2 or seismic hazard defined by client)
P7	All other components (i.e. components that do not represent hazard to life (≤7.5kg and cannot fall more than 3m), do not convey hazardous or explosive materials, is not required for operational continuity following SLS2 or required for evacuation following ULS seismic event)	No	No
P1, P2, P3, P4, P5, P6 & P7	Component is **inherently rugged** (see definition and Table B-4 below)	No	No

Notes
* note components often fall into more than one Part Category

B.4.1.1. Inherently Rugged Equipment

Any mechanical or electrical equipment that must remain operable **need not be certified** if it can be shown that the component is inherently rugged by comparison with similar seismically qualified components. The definition of a rugged component is defined in ASCE 7-22 as "*A non-structural component that has been shown to consistently function after design earthquake level or greater seismic events (based on past earthquake experience data or past seismic testing) when adequately anchored or supported. The classification of a non-structural component as rugged shall be based on a comparison of the specific component with components or similar strength and stiffness.*" Table B-4 provides a list of inherently rugged equipment.

Table B-4: Inherently rugged equipment

Component	Limitations	Structural Integrity Seismic Qual Testing Required?	Operational Integrity Seismic Qual Testing Required?	Reference
Valves	Not in cast-iron housing, except for ductile cast iron	No	No	OSHPD CAN 2-1708A.5 (2009)
Pneumatic operators				
Hydraulic operators		No	No	OSHPD CAN 2-1708A.5 (2009)
Electric motors & motor operators	No size threshold	No	No	ASCE 7-22, OSHPD CAN 2-1708A.5 (2009) & OSHPD PIN 55 2022
Base mounted horizontal and vertical pumps	≤ 20kW	No	No	ASCE 7-22, OSHPD PIN 55 2022
Air compressors		No	No	ASCE 7-22
Sterilisers		No	No	OSHPD CAN 2-1708A.5 (2009)
Lift cabs		No	No	OSHPD CAN 2-1708A.5 (2009) & OSHPD PIN 55 2022
Underground tanks		**Yes**	No	OSHPD CAN 2-1708A.5 (2009) & OSHPD PIN 55 2022
Pipes, ducts & conduits		No	No	OSHPD CAN 2-1708A.5 (2009) & OSHPD PIN 55 2022
Cable trays	≥ 7.5kg/m	**Yes**	No	OSHPD PIN 55 2022, OSHPD OSP
Controllers, switches, circuit protection	≤ 7.5kg / 63A	No	No	OSHPD OSP
Generators	≤ 25kW	No	No	OSHPD OSP

Heat exchanger (water/water plate & gasket)	≤ 60kW, excludes all other heat exchangers such as Air/Air, Air/Water etc.	**Yes**	No	ASCE 7-22
Lift machines & governors		No	No	ASCE 7-22, OSHPD PIN 55 2022
Miscellaneous equipment	< 25kg direct supported on structure, or surface mounted on components not requiring SSC	No	No	OSHPD PIN 55 2022
Certified subcomponents	≤ 4.5kg	No	No	OSHPD PIN 55 2022

B.4.2. Seismic Certification Pathways

Designers can choose an Alternative Solution to confirm seismic certification that considers international standards, including ASCE 7-22 and provide necessary evidence as to why the Alternative Solution achieves NZ Building Code compliance. It is noted that should an Alternative Solution be considered, it would require communication and coordination with the Client and NSE Seismic Designer.

Note that for all the methods of qualification discussed in this section, the items of plant or equipment must be installed in the same manner that it has been certified. For example, if an item was certified via shake table testing with antivibration mounts (AV mounts) the item must be installed with the same AV mounts, or otherwise analysed to confirm that the installed AV mounts do not significantly affect the component's dynamic response.

The following methods are based on ASCE 7-22 certification pathways and can be used for seismic certification:

1. **Analysis**.
   Certification of components through analysis. Refer to ASCE 7-22 Clause 13.2.3(3) for further information.

2. **Testing**.
   Active mechanical/electrical equipment and components with hazardous contents that must maintain containment along with their supports and attachments may be certified by approved shake table testing in accordance with Section 13.2.6 of ASCE 7-22 using a recognised testing standard procedure, such as ICC-ES AC 156, refer to Section B.5 of this guideline for more information.

   Noting the practical limitations and potential cost implications of testing equipment for use in New Zealand, building services engineers (with support from NSE Seismic Designer) are encouraged to liaise with suppliers to agree testing regimes that provide reasonable surety of the ability to operate following vigorous shaking.

3. **Experience Data**
   Mechanical/electrical equipment, and components with hazardous contents that must maintain containment may be certified by experience data in accordance with Section 13.2.7 of ASCE 7-22. Note as NZ does not yet have nationally recognised testing procedures it is expected that qualification using experience data would only be used in exceptional cases and more likely than not would not be applicable.

   When experience data is used to certify equipment/components, it should be shown that the database used contains the similar type/model equipment that is manufactured with the similar structural integrity with similar supports and attachments. The Owner of the special seismic certification should maintain a quality assurance program that will continually evaluate the performance of installed equipment experiencing new earthquake to determine if a new type of failure may exist.

4. **Pre-qualification**
   Items of plant and equipment possibly can be selected from the Department of Health Care Access and Information (HCAI) register accessed from their website. New Zealand engineers and contractors are warned that the HCAI qualification database may not be relevant due to HCAI prequalification equipment not being applicable in the New Zealand market.

   It is noted that like-branded equipment in the USA will likely be a different design/construction altogether compared to that supplied to the New Zealand market. Note that it is likely that this inconsistency may not be self-evident from the HCAI register.

B.4.3. Considerations of equivalency

A particular challenge regarding the seismic qualification of equipment is relating results from dynamic testing conducted abroad with the loading requirements of NZ Standards. Three important aspects need to be considered:

i. The test reports should provide information on the capacity of the equipment (e.g. peak floor acceleration) at the performance state (e.g. functionality) that the equipment is supposed to maintain at a design shaking level in a building.

ii. The spectrum used in testing, such as AC156, will be based on some demand and performance parameters, such as ground acceleration, floor amplification factor, component amplification factor, importance and ductility factors. The results from testing conducted abroad should be interpreted for use in NZ buildings by taking into consideration the appropriate values of the demand and performance parameters in the NZ standards.

iii. A frequency sweep should be undertaken to determine relevant resonance frequencies for the equipment being tested. The test response spectrum (determined in accordance with the relevant test standard) should envelope the applicable portion of the required response spectrum (determined in accordance with NZS1170.5) at all relevant equipment frequencies.

B.5. Testing Protocols for Non-Structural Elements

NZS4219:2009 Section 4.5.1 (SNZ, 2009) allows testing to be used as a means of verifying the seismic performance of components of equipment.

To identify the damage states and the damage limits for an NSE, static or dynamic testing could be undertaken. The type of testing would depend on the engineering parameter (acceleration vs. drift or both) related to expected damage in an NSE caused by an earthquake. Both testing schemes (acceleration and drift) require a loading protocol. The sections below provide useful information on the use of existing protocols for static and dynamic testing.

Testing regimes may be simpler than those specified in ASCE 7-22 if they are deemed appropriate for the project.

B.5.1. Testing protocols for dynamic testing

A dynamic testing protocol for seismic qualification of NSEs based on the loading requirements of NZS1170.5 (SNZ, 2004) is not available in NZ. It was found during correspondence with industry professionals that the AC156 test protocol (ICC-ES, 2010) is commonly used for testing various NSEs in the NZ industry. It is recommended that until NZ develops its own test protocol consistent with the requirements of NZS 1170.5 (SNZ, 2004), the AC156 protocol is used using proper engineering judgment. Some guidance on the use of AC156 spectrum is provided below:

The AC156 spectrum is characterized by two parameters as shown in Figure B-1.

$A_{RIG-H} = 0.4\ a_p\ S_{DS}(1+2(z/h))$ (quantifies the peak floor acceleration)

$A_{FLX-H} = 0.4\ a_p\ S_{DS}\ (1+2(z/h))$ (quantifies the plateau of the spectrum)

where,

a_p = component amplification factor, equal to 1.0 for A_{RIG-H} and 2.5 for A_{FLX-H} ($C_i(T_p)$ in NZS1170.5, Section 08);

$0.4S_{DS}$ = ground acceleration (C(0) in NZS1170.5, Section 08);

(1+2(z/h)) = floor amplification factor (C_{Hi} in NZS1170.5, Section 08)

Once the testing is complete, the peak floor accelerations recorded at the occurrence of major damage states (such as malfunction in an equipment) can be specified in seismic qualification reports. This would enable an easy selection of equipment with certain acceleration capacities for use in buildings with a particular floor acceleration demand provided by the Structural Engineer.

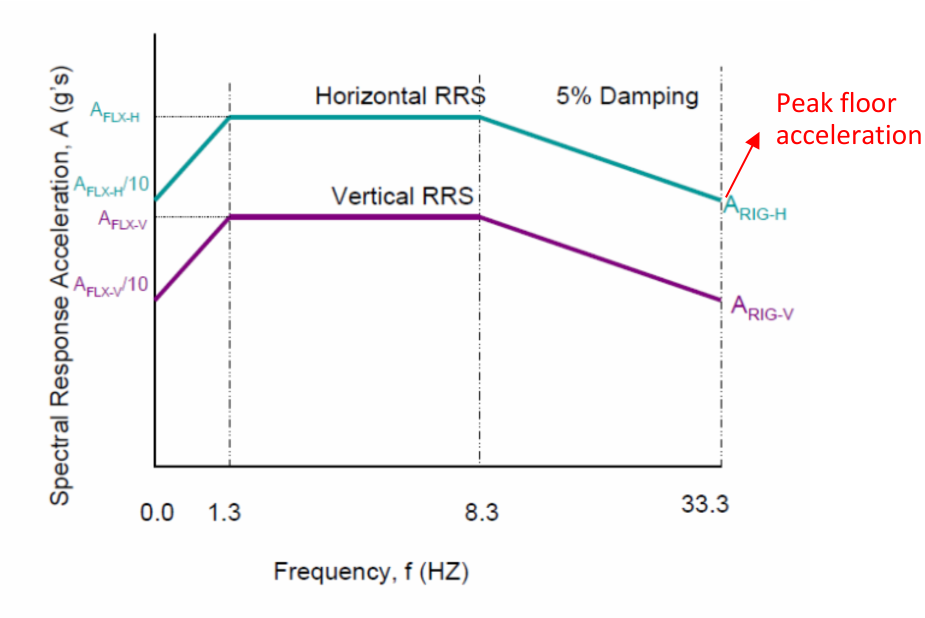


Figure B-1: AC156 spectrum used for dynamic testing (ICC-ES, 2010)

B.5.2. Testing protocols for static cyclic testing

The NZ standards do not refer to any specific loading protocol for drift sensitive NSEs, such as partition walls and claddings. The FEMA 461 (FEMA, 2007) and ACI374.1-05 (ACI, 2005) protocols have been used for testing partition walls and cladding by NZ academia (Sahin et al., 2015) and Jitendra et al., 2022). The standard for building facades, NZS4284 (SNZ, 2008), includes a testing protocol, which has been used in testing commercial glazing systems (Arifin et al., 2020).

The FEMA 461 (FEMA, 2007) protocol has specifically been developed for testing NSEs. Hence, it is recommended for testing drift-sensitive NSEs, if the relevant NZ standards do not provide any guidance on loading protocols. Some guidance is provided on the use of this protocol below:

- Some prior knowledge of the drift limits at which different damage states occur in an NSE is essential. This would depend on the material of the NSE and its connections with the supporting structure and among its different elements. Large displacement increments could miss the drifts at which major damage states occur, whereas small displacement increments could lead to very large testing times.
- Guidance can be obtained on appropriate displacement increments for different NSEs from Sahin et al. (2015), Arifin et al. (2020), Jitendra et al. (2022).

Part C: Technical Guidance

C.1. Introduction

This part of the NSE CoP presents seismic performance guidance tailored to individual NSEs, aligning with the previous section that defines the performance states.

Each NSE section is structured in the following format:

- Description – overview of the NSE included in the section.
- Design Methodology – description of best-practice design methodology based on applicable design standards.
- Performance Characterisation – table providing performance descriptions for specific NSE related to performance state based on drift or acceleration demand.
- Performance Considerations – list of considerations that affect seismic performance.
- References – related content and references.

While there is currently an emphasis on design, guidance is also provided that is applicable to the construction, seismic assessment or testing of that NSE. It is intended to expand these areas into separate sections in future revisions of this NSE CoP.

These sections don't intend to provide exhaustive guidance on each NSE. As introduced previously, the content is intended to be informative as well as represent best practice recommendations. The boundaries between what is 'acceptable' and 'unacceptable', especially when it comes to serviceability, are often poorly defined. Designers are encouraged to evaluate every situation on its own merit.

C.2. Seismic Loading and Part Ductility

The following general approaches for selection of appropriate part ductilities are recommended for each of the previously introduced Performance States (unless otherwise recommended within the respective component sub-sections in Part C):

- SLS1: $\mu = 1.0$
- SLS2: $\mu = 1.25$. Note, when using SNZ TS1170.5:20XX, the μ=1.25 indicated in Cl. 8.6 should be used on the project. (Rather than the μ=1.0 for SLS2 suggested in Table C8.3).
- DCLS: The recommendations for SLS2 should be applied.
- ULS: Apply Table C8.3 of NZS1170.5 (or SNZ TS1170.5:20XX if used on the project). These tables provide ductility recommendations that reflect inherent damping and non-linear behaviour of NSE (which can include slip of fasteners etc). There is limited available research currently available to suggest alternative values.

Larger values of ductility may be justified where a special ductility study or testing has been undertaken, or if supported by developing research.

C.3. Code Compliance

Designers should work to the Standard they are using to show Code Compliance. Designers are reminded that it is not acceptable to cherry pick clauses from different Standards, as different codes and standards take different approaches to achieve the required margin against failure. Where a cited Standard e.g. NZS4219 does not fulfil the needs of a particular project, designers can choose an Alternative Solution compliance pathway, noting the requirements for an Alternative Solution to provide sufficient evidence to show how the design solution meets the NZBC Performance Requirements.

C.4. Supports, Fixings and Anchorages

The following are general requirements for supports and fixings for non-structural elements of all types.

C.4.1. Supports

Supports include suspended, wall and floor/roof mounted support frames, and all rigid seismic bracing. Design should be undertaken to the relevant New Zealand standards:

- AS/NZS4600:2018 Cold formed steel structures
- NZS3404:1997 Steel structures
- NZS3603:1993 Timber structures
- AS/NZS1720.1:2022 Timber structures (not yet cited)

Materials should comply with the relevant New Zealand standards where available. The following are relevant material specifications provided for reference.

- Channels – AS/NZS1365, AS1594, AS/NZS4680, ISO1461
- Bolts, Nuts, Washers – AS1111.1, AS1112.3, AS4291.1, AS4291.2
- Wire Rope - ASTM A475m JIS G 3525, ISO2408-85, EN12385

C.4.2. Fixing and Anchorage

Fixings include cables, guys, stays, brackets, anchors, bolts, screws, coach screws, threaded rods, nuts, washers, pipe clamps, saddles and the like. Materials should comply with the relevant New Zealand standards. Specific requirements for concrete fixings are noted below.

C.4.2.1. Selection of Anchors

When selecting the anchor types the NSE Design Engineer should consider the location and substrate that the anchors are fixed into. They should consult with the structural engineer and agree appropriate fixing locations and strategies.

There is no clear, New Zealand specific, recommendations related to the specification of appropriate seismic qualifications for post-fixed anchors. Engineers will need to satisfy themselves of the appropriateness of selection in any application.

The selection and specification of seismically qualified concrete anchors for the applicable gravity and seismic loads should generally be as follows:

- Design should be to NZS3101, ACI 318 Appendix D, EOTA TR-045, or EN 1992-4. Note that EN 1992-4 supersedes EOTA TR-045 and should generally be used, however it is not yet referenced by NZS3101, so should be listed as an Alternative Solution.
- Follow manufacturers recommendations (in particular for installation into proprietary pre-cast and composite metal deck floor systems).
- Fixings into potential plastic hinge zones or other high deformation areas should be avoided.
- Anchors should be designed elastically. i.e., assume μ=1.0 for anchors.

It is recommended that if practical, seismic qualified anchors be used for all support fixings. This avoids the risk of non-qualified anchors to be available on site and are used for a seismic application by mistake.

In practice, seismic fixings for some non-structural element support and restraints may not be available. In these instances, the non-structural element designer is expected to provide a design appropriate to the lower levels of validated resilience. This may be done, through redundancy in load path or by providing residual capacity in these elements.

Due to confusion over the appropriate use of C1/C2 rated anchors, and the unavailability of C2 rated anchors for all existing floor substrates, the following risk-based approach is suggested:

Low-Risk Anchorage

Most distributed, suspended non-structural elements (i.e., general services, ceiling), and floor mounted plant constitute a higher level of support redundancy, a lower consequence of failure and a significantly lower life safety risk than that associated with primary structural elements. Category C1 (or ACI 355.2) anchors are generally considered appropriate for low-risk applications.

Whilst selecting C1 anchors may be viewed as unconservative according to the reference ground acceleration thresholds given in table 5.1 of ETAG 001, this recommendation is considered appropriately aligned with its intent when adopting elastic loading and deriving loads directly from AS/NZS1170.5, especially as applied to lightweight and low risk applications. Category C1 is generally equivalent to ACI 355.2.

Higher Risk Anchorage

For higher risk applications, including elements such as suspended heavy plant, there is less support redundancy and/or a higher consequence of failure. Category C2 anchors are generally consider appropriate.

C.4.2.2. Fixings to Concrete – Qualifications

The following standards outline the requirements for seismically qualified anchors in concrete.

- ETAG 001 Annex E (2013)
  - Seismic Category C1 (for low-risk anchorage only)
  - Seismic Category C2
- ACI 355.2 (equivalent to ETAG 001 Annex E Seismic Category C1—for low-risk anchorage only)
- ACI 355.4
- ICC ES AC308

C.4.2.3. Assumptions related to concrete cracking

Advice should be sought from the structural engineer as to which concrete elements are likely to remain uncracked during a design level event. As a guide, the following initial assumptions can usually be made:

- Concrete columns and beams: These will often be uncracked concrete. Do not fix within plastic hinge zones as defined by the Structural Engineer, as these can be subject to extreme cracking and spalling.
- Concrete walls: Generally uncracked. Advice should be sought from the Structural Engineer about potential hinging zones to avoid.
- Floor slab on grade: Cracked.
- In-situ conventionally reinforced slabs including proprietary composite metal deck floor systems: Uncracked, except in high strain areas. It is generally expected that floor diaphragms should be designed elastically and can be assumed to remain uncracked for the purposes of NSE design. However, exceptions may exist in areas which are highly strained due to deformation compatibility with certain structural systems (for example, link slabs or areas of slab near EBF links). Confirmation should be sought from the Structural Engineer including identification of any high strain areas.
- Post-tensioned floor systems and prestressed concrete: Uncracked, except at joints between precast units or at high strain areas (as for conventionally reinforced slabs).
- Concrete floors (other than above) and concrete/masonry walls: Uncracked.

C.5. Clearances

Seismic clearances are required to reduce the risk of damage due to interactions between elements, or elements and structure during a seismic event.

Clearance requirements are provided in Table 15 in NZS4219. Where possible these clearances should be achieved. Where it is not possible to achieve the clearance specified in Table 15 in NZS4219 specific assessment could be carried out to demonstrate that the risk of damage to the elements is sufficiently low. Whilst there is no formalised methodology for such assessment, engineering judgement can be applied that should consider relative displacements, likely force of impact, and robustness of materials. For example, it would not be necessary to provide 50mm clearances between linear services at beam penetrations provided the linear services are restrained adjacent to the beam penetration (making it impossible that the service could displace 50mm). BRANZ NSE Factsheet #4 provides useful information on clearances, particularly related to services penetrating walls, floors and structure[2].

[2] https://d39d3mj7qio96p.cloudfront.net/media/documents/BRANZ-Facts-NS-4-Seismic-clearance.pdf

C.6. Seismic Design of Lightweight Partition Walls

C.6.1. Description

Lightweight partitions are constructed from timber or cold-form steel with gypsum wall board linings. As well as creating rooms and spaces within a building, they often provide key functions related to fire/acoustic/airtightness which need to be considered when characterising the seismic performance.

The construction methodology of lightweight partition walls impacts how the partition interacts with the structure and other non-structural elements. Partition walls should always have a deflection head track to accommodate movement of adjacent building levels without damaging the partition. These building movements are both vertical due to gravity and live loads, and horizontal, due to seismic/wind loads. The most typical partition wall arrangements are listed below:

a) Full height wall with studs spanning between floors. The deflection head-track is located at the underside of structure.

b) Full height wall with braced downstand. The downstand is suspended off the floor above, and the deflection head track is located at the bottom of the downstand. This arrangement assists in accommodating movements between services passing through the partition since the braced downstand moves with the floor above.

c) Partial height wall that terminates below or just above the ceiling level. Lateral out-of-plane restraint of partial height walls is achieved by one of the following:

   a. The top of the wall is braced to the structure above.

   b. Regular return walls are provided, or a self-bracing box to floor below (sometimes referred to as ‘pods’ or ‘box in box’ construction).

   c. Cantilevered off floor below with internal steel structure. This approach is often required at the isolation plane of base-isolated buildings since it can accommodate large inter-storey movements.

C.6.2. Design Methodology

Partition seismic design should consider both the in-plane and out-of-plane earthquake demands on the partition.

In-plane racking capacity of plasterboard lined partitions can be determined using a bracing unit approach of NZS3604 (SNZ, 2011). Note that the scope of NZS3604 is limited. There is guidance provided by Engineering NZ on the use of P21 outside the scope of NZS3604, noting that the capacities derived from the BRANZ P21 test method are not characteristic values but represent the average of peak loads recorded for three nominally identical specimens (ENGNZ, 2022).

Out-of-plane capacity of partition studs, top-plate/head-tracks, bracing and fixings should be determined by the appropriate material standard, e.g. NZS3603 (or NZS AS 1720) for timber (SNZ, 1993), AS/NZS4600 for cold-formed steel (SNZ, 2018).

The stud design should include out-of-plane serviceability consideration to avoid excessive mid-height deflections, this can often govern the design. The detailing should allow for inter-storey movement and the interactions resulting from these.

Design guidance is provided by the Association of Wall and Ceiling Industries (AWCI) for the seismic design and installation of non-structural internal walls and partitions (AWCI, 2018).

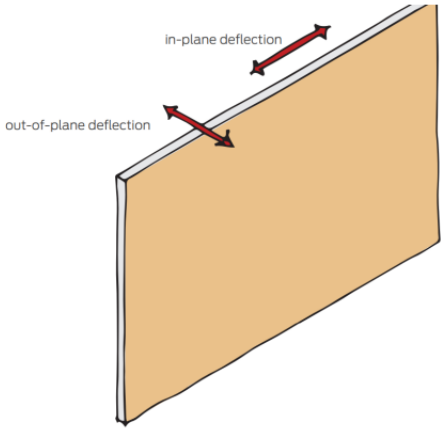


Figure C-1: Design actions on partition walls (AWCI, 2018)

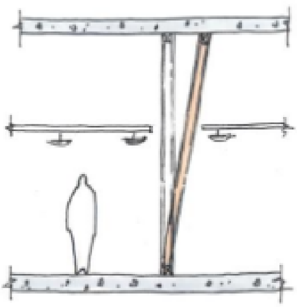
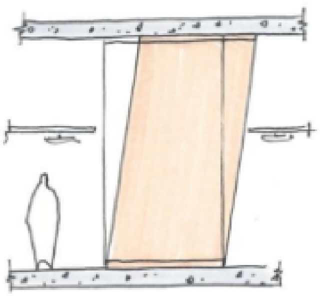
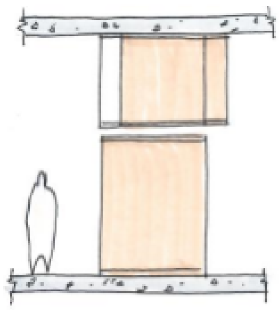
Out of Plane (Leaning)	Racking (in plane)	Sliding (in plane)
		

Figure C-2: Partition movements (Health NZ, 2024)

C.6.3. Performance Characterisation

Table C-1: Seismic performance characterisation of lightweight partition walls

Engineering Demand Parameter	Performance State	Performance Description	Design Limit State	Recommended Criteria or Design Limit
Floor Acceleration	Out-of-plane deformation of partition	Onset of damage to linings	SLS1	H/180 at mid-height with an upper limit of 15mm[1]
		Minor damage to linings, e.g. an acceptable level of fire rating is maintained	DCLS / SLS2	H/150 at mid-height[2]
		Loss of support of partition or loss of support of components attached to the partition	ULS	Out of plane capacity of partition studs, top-plate/head-tracks, bracing elements
Inter-storey Drift	In-plane racking of partition	Onset of damage to linings	SLS1	0.2-0.4% drift[2,3,4,5]
		Minor damage to linings, e.g. an acceptable level of fire rating is maintained	DCLS / SLS2	0.4-0.7% drift[3,5]
		Loss of support of partition or loss of support of components attached to the partition	ULS	In-plane racking capacity of partition

[1] – Shelton, R.H. (2007). The Engineering Basis of NZS 3604. BRANZ Study Report No. 168.

[2] – NZS 1170.5 (2004). Structural Design Actions, Part 5: Earthquake Actions – New Zealand Commentary. New Zealand Standards

[3] – Retamales R., Davies R., Mosqueda G., Filiatrault A. (2010). Experimental seismic fragility assessment of light gauge steel studded gypsum partition walls, Proceedings of the 9th U.S. National and 10th Canadian

[4] – NZS 1170.0 (2002). Structural Design Actions, Part 0: General Principles. New Zealand Standards

[5] – FEMA P-58 (2018). 0.2% drift can be considered 'essentially undamaged' since below this limit most partitions can respond elastically and any damage would be similar to normal wear and tear. 0.4% drift is where linings are sufficiently undamaged that airtightness can remain in-tact for (normal) mechanical air control measures or fire rating can be maintained.

C.6.4. Performance Considerations

The following describes key considerations for the design of partitions walls:

- Experimental observations indicate a range of drift values for onset of damage. Consideration should be made to factors such as number of linings and repairability of partition.

- The seismic performance requirements should consider the functional purpose of the partition, e.g. fire rating, smoke separation, acoustic, air-tightness, etc. since this can significantly impact detailing requirements of partitions, particularly for movements and interactions with services passing through partitions.

- The list below outlines the key parties that may need to be involved in the development and coordination of partition seismic performance:
    - Architect: Generally responsible for specifying the type of partition, linings, etc. Note that the overall responsibility for the partitions often lies with the Architect. Agreement needs to be reached between architect and seismic restraint designer about how to best document the design information. For example, the Architect would typically document deflection head locations, and the NSE Designer would document lateral restraint requirements. Agreement should be made on who is specifying stud size, stud spacing, base fixings, top plate size, deflection head size, etc. to avoid contradictions in design information.
    - NSE Seismic Designer: Seismic design of partitions and their restraint. Overall coordination of partition seismic performance.
    - Structural Engineer: Building drifts and interface with structure.
    - Services Engineer: Interface with services penetrating partitions.
    - Fire Engineer: Fire performance requirements of partitions.
    - Acoustic Engineer: Acoustic performance requirements of partitions.
    - Ceiling designer: Interface with ceiling. Ceiling type and coordination often by the Architect.
- For standard partition walls that are not fire rated, not acoustically rated, and not adjacent to egress paths the SLS2 requirements of the Performance Characterisation table need not be considered.
- The criteria provided in the Performance Characterisation table are for lined partition walls. The intent of the performance requirements above could be considered by the designer, along with appropriate research to understand the performance requirements for alternative partitions, e.g. glazed partition walls.
- Internal wind pressure and post-fire stability loads should be included alongside seismic loads when designing partitions as the former can govern.
- Table C8.3 of NZS1170.5 provides ductility recommendations that are suitable for ULS design. Conservative ductility assumptions are recommended for SLS1/DCLS/SLS2 checks due to limited availability of research.
- Consideration should be given to acoustic and fire requirements of partition when determining how seismic movements are accommodated. This should include checking solutions exist to accommodate the movements at the service and partition interface.
- Bracing unit approach of NZS3604 is intended for residential buildings so when the structure falls outside of the scope of this standard the engineer must consider the impacts of using a bracing unit design in conjunction with Specific Engineering Design (SED).

- If ceilings are restrained by the partition, this load should be considered in the design of the partition. If specific design information is not available, a line load of 1kN/m is a reasonable ceiling load assumption based on the capacity of typical ceiling perimeter connections.

- Allowance should be made for shelving, wall mounted equipment loads and contents attached to the partition walls. It is recommended that a nominal allowance of 5kg/m^2 is allowed for all partition walls to allow for pictures, TVs, etc. In areas that are likely to require significant amounts of shelving, joinery etc, higher loads should be allowed for. This may range from 25kg/m^2 for moderate shelving to 50kg/m^2 for full-height shelving or bookcases.

- Special consideration should be made to the design criteria, methodologies and detailing for membraned wet areas, e.g. showers and bathrooms in multi-storied apartment buildings. Damage to partitions that interact with water barriers have significantly increased consequences and hence require careful consideration.

- Consideration of deflection head height should be made when considering how seismic movements are accommodated. Deflection heads should ideally be at a consistent level across floor level. Vertical slip joints may be required where deflection head heights change, which can add significant cost/complexity and performance risk.

- The use of deflection head tracks located 50-250mm above ceiling level is a commonly adopted and effective means to manage displacement compatibility issues where services/structure are passing through partitions. When using this approach, early detailing coordination between Architect, Services Engineer, and NSE Seismic Designer should be undertaken to consider detailing practicalities and spatial implications.

- Further guidance on the interaction of services, restraints, partitions and structure can be found in BRANZ FACTS: Seismically Resilient Non-Structural Elements #4, Seismic clearance at penetrations (BRANZ, 2015).

- The design basis for fire walls is based on prescribed compliance pathways which include testing of components and systems. There is not a clearly established means to quantify how well these components and systems may continue to perform their fire protection requirements after having suffered damage.

- The displacement incompatibility between services and partitions (including fire rated partitions) can sometimes be accommodated by accounting for the many small flexibilities that exist within the whole system. These include:

    - Flexibility of services between their nearest restraint and the wall. This can often be in the order of 5-10mm. For this reason, services should not be transversely restrained close to partition walls.

    - Flexibility in the restraints (to services and to walls). This can often be in the order of 5mm.

    - Local wall flexibility. This may include some local damage around stiff services if considered acceptable by the design team. This can often be in the order of 5mm.

- Flexibility of fire stopping. This should be determined in consultation with the fire stopping supply. Typical fire stopping products only provide approximately 5mm of flexibility. Some products are available on the market that provide flexibility up to 20mm, though these need to be specifically discussed with suppliers.

- Fire rated walls that use braces for support should preferably be braced on both sides. This means that one brace will always be on the protected side of the wall, and thus avoids the need for fire rating of braces.
- In-plane racking requirements should include interactions at return wall intersections, as shown in Figure C-3.
- Services and/or structural elements passing through partitions need to be able to accommodate inter-storey movements, as shown in Figure C-3. This can be achieved by flexibility in service for flexible services or small drifts or can require a braced downstand wall to accommodate larger movements.

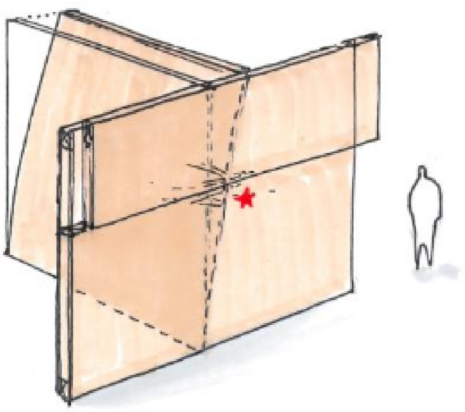
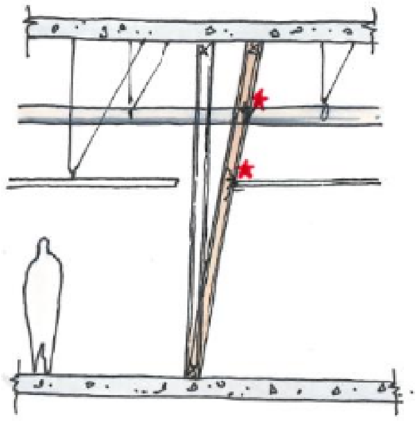
Partition to Partition incompatibility	Partition to Service/Ceiling incompatibility
	

Figure C-3: Displacement incompatibility (Health NZ, 2024)

C.6.5. Reference Documentation

AWCI (2018). Code of Practice for the seismic design and installation of non-structural internal walls and partitions. Association of Wall and Ceiling Industries of New Zealand Inc. (AWCI)

NZS1170.5C (2004). Structural Design Actions, Part 5: Earthquake Actions – New Zealand Commentary. New Zealand Standards

Mulligan, J. (2020). Experimental Study on the Seismic Performance of Low Damage Systems for Non-structural Light Framed Plasterboard Partition Walls, Master's Thesis, University of Canterbury.

Retamales R., Davies R., Mosqueda G., Filiatrault A. (2010). Experimental seismic fragility assessment of light gauge steel studded gypsum partition walls, Proceedings of the 9th U.S. National and 10th Canadian Conference on Earthquake Engineering, Toronto, ON, Canada, 25–29 July

Shelton, R.H. (2007). The Engineering Basis of NZS 3604. BRANZ Study Report No. 168

Davies, D. R. et al. (2011). Experimental Study on the Seismic Performance of Low Damage Systems for Non-structural Light Framed Plasterboard Partition Walls, Technical Report, MCEER-11-0005, University at Buffalo.

Engineering NZ (2022). Using P21 Tested Bracing Units Outside the Scope of NZS 3604

Mulligan, J., Sullivan, T., & Dhakal, R. (2020). Experimental study of the seismic performance of plasterboard partition walls with seismic gaps. Bulletin of the New Zealand Society for Earthquake Engineering, 53(4), 175–188. https://doi.org/10.5459/bnzsee.53.4.175-188

Jitendra Bhatta, Rajesh P. Dhakal & Timothy J. Sullivan (2022) Seismic Evaluation of Rocking Internal Partition Walls with Dual-Slot Track Under Quasi-Static Cyclic Drifts, Journal of Earthquake Engineering, DOI: 10.1080/13632469.2022.2162629

Jitendra Bhatta, Rajesh P. Dhakal, Timothy J. Sullivan, Jordan Bartlett & Glen Pring (2023) Seismic Performance of Internal Partition Walls with Slotted and Bracketed Head-Tracks, Journal of Earthquake Engineering, 27:12, 3435-3470, DOI: 10.1080/13632469.2022.2137709

Tasligedik, A.S., Pampanin, S. & Palermo, A. Low damage seismic solutions for non-structural drywall partitions. Bulletin Earthquake Eng 13, 1029–1050 (2015). https://doi.org/10.1007/s10518-014-9654-5

C.7. Seismic Design of Suspended Ceilings

C.7.1. Description

Suspended ceilings are used to conceal elements like pipework, HVAC systems and electrical wiring to enhance the aesthetics of a space. They could also serve other functions related to acoustics, insulation, and lighting etc. Suspended ceilings typically fall into one of two categories:

- Exposed grid ceilings – suspended support structure visible, e.g. tile and grid ceilings
- Concealed grid ceilings - suspended support structure hidden, e.g. plasterboard lined ceilings

C.7.2. Design Methodology

Suspended ceiling seismic design primarily considers the horizontal acceleration of the ceiling and the transfer of these forces back to the structure via the grid, connections, and bracing elements.

There are two typical approaches to transfer these forces:

1. Perimeter restraint – transfer of the seismic forces to the structure via the grid to the perimeter structure (typically partition walls). This is typically achieved by connecting on two adjacent walls and allowing the ceiling to 'float' on the opposing two walls.
2. Back-bracing – transfer of the seismic forces to the structure via the grid and diagonal braces to the structure above. In this configuration the ceiling is typically floating on all sides.

In both approaches, the capacity of the ceiling grid, connections and the overall system needs to be sufficient to transfer seismic loads. Where ceilings are back-braced, the capacity of the back-bracing element should be designed to transfer the seismic load from the tributary area associated with the brace. The connection between the back-brace and the grid should also be sufficient to transfer the seismic load of the brace.

Design guidance is provided by the Association of Wall and Ceiling Industries (AWCI) for Design, Installation and Seismic Restraint of Suspended Ceilings (AWCI, 2015).

C.7.3. Performance Characterisation

Table C-2: Seismic performance characterisation of suspended ceilings

Engineering Demand Parameter	Performance State	Performance Description	Design Limit State	Recommended Criteria or Design Limit
Floor Acceleration	Lateral demands on ceiling system	Damage to ceiling system that could lead to disruption in function	DCLS / SLS2	Seismic restraint of ceiling as per AS/NZS2785[1]
		Loss of support of ceiling	ULS	Seismic restraint of ceiling as per AS/NZS2785[1]
Inter-storey Drift	Seismic gap movement requirements	Onset of damage to ceiling system	SLS1	Relative drift between floor and ceiling at Design Limit State[2]

		Damage to ceiling system that could lead to disruption in function	DCLS / SLS2	Relative drift between floor and ceiling at Design Limit State[2]
		Loss of support of ceiling	ULS	Relative drift between floor and ceiling at Design Limit State[2]

[1] – AS/NZS2785:2020 Suspended Ceilings – Design and Installation.

[2] – Association of Wall & Ceiling Industries (AWCI) Code of Practice for Design, Installation and Seismic Restraint of Suspended Ceilings (AWCI, 2015).

C.7.4. Performance Considerations

The following considerations apply in the design, construction, assessment and testing of suspended ceiling systems:

- The seismic design of suspended ceilings is typically limited by connections between grid members or connections to structure. It is necessary to check the capacity of the ceiling system includes:
    - Axial capacity of main tee / cross tee or furring channel / top rail
    - Connection capacity of grid connections, including splices
    - Connection of perimeter bracket to perimeter wall (if perimeter restrained)
    - Connection of back-brace to grid (if back-braced)
    - Axial capacity of back-brace (if back-braced)
    - Connection of back-brace to structure (if back-braced)
- As ceilings grids are proprietary products, it is often necessary to rely on the capacity of the above elements and connections from suppliers. Unfortunately, there is often limited information available from ceiling supplier's and this information may not be supported by appropriate testing or similar validation. Care should be taken when determining ceiling capacity is sufficient for seismic loads. If the technical information from the supplier is insufficient for the designer to have confidence that the ceiling system meets the requirements of the Building Code, there may be an opportunity to require further technical information under the MBIE Building Code Compliance '*Product Assurance and Certification Scheme*', refer section B.3 of this guideline.
- If ceilings are perimeter restrained, the perimeter structure needs to be sufficient to withstand the seismic load of the ceiling. Where lightweight partitions are the perimeter structure, these should be designed with an allowance for this ceiling load. If specific design information is unavailable, a line load of 1kN/m is a reasonable ceiling load assumption based on the typical capacity of ceiling perimeter connections.
- The minimum services load allowance of $3kg/m^2$ prescribed in AS/NZS2785 may not be sufficient, and advice should be sought from the services engineer for an appropriate project specific allowance.

- Vertical accelerations are not explicitly included in suspended ceiling design, however, shake table testing has found that the vertical component of earthquake shaking may have a significant effect on the behaviour of grid and tile ceilings (Ryan, 2022) and therefore consideration should be given to vertical accelerations if these are expected to be significant. This might include more robust hangers or ensuring tiles are clipped.

- Where clipping can be practically achieved without interfering with maintenance requirements, its use is encouraged. Otherwise, strategies for securing tiles should ensure any tiles containing fittings such as sprinkler heads, lighting and electrical fittings, ventilation diffusers and the like cannot become dislodged. This is particularly true for ceilings where tile loss could adversely impact post-disaster function, such as key egress routes.

- Seismic performance of ceilings is often influenced by interactions with above-ceiling services, it is therefore recommended to consider how the ceiling seismic and gravity supports are to be coordinated with above ceiling services. An example of this includes considering whether there is sufficient space to achieve seismic clearances for both seismic and gravity supports.

- Suspended ceilings are typically the last suspended element to be installed and are therefore at higher risk of not having adequate space to installation of bracing. Perimeter restraint of ceilings reduces the need to install and coordinate braces so should be prioritised where possible. Otherwise, the spatial requirements for ceiling bracing should be coordinated with other above ceiling elements.

- Suspended ceiling seismic design is a rapidly developing area. It is recommended that designers actively seek out latest research and best practice, including the latest version of this document.

C.7.5. Reference Documentation

AS/NZS2785:2020 Suspended Ceilings – Design and Installation.

AWCI (2015) Code of Practice for Design, Installation and Seismic Restraint of Suspended Ceilings Association of Wall & Ceiling Industries (AWCI)

Ryan KL (2022) "Influence of Vertical Floor Accelerations on the Seismic Performance of Building Non-Structural Elements". Fifth International Workshop on the Seismic Performance of Non-Structural Elements (SPONSE/ATC-161), 5-7 December 2022, San Francisco, USA, pp. 46-56.

C.8. Seismic Design of Linear Suspended Services

C.8.1. Description

Linear suspended services reticulate air, water, and electricity throughout buildings. They include HVAC ductwork, cable trays, plumbing and drainage. For suspended equipment, such as fans, refer Section C.9.

C.8.2. Design Methodology

The design of linear suspended services systems should follow the requirements of NZS4219 (SNZ, 2009). This includes the requirements for the selection or specific design of appropriate brace spacing for the suspended services.

NZS4219 provides limited guidance on bracing requirements for ducts or cable trays. For these services the design and spacing of seismic restraints for linear NSEs will be governed by the following considerations:

- The capacity of linear NSE to span acting like a beam between transverse restraints while maintaining the required physical state. Consideration should be given to both strength and displacement. It is recognised that very limited information currently exists for ducting and cable tray products.
- The capacity of the brace connection to the NSE.
- The capacity of the brace system.

The design of seismic bracing for suspended services should ensure the capacity of the brace assembly and its anchorage to the structure exceed the lateral force demands based on the tributary mass of services acting at the brace. This is typically equal to the brace spacing.

It is recommended that capacity design principles be followed to avoid brittle failure in the components of brace assemblies or the anchorage if ductility-based reduction factors are used in the design.

C.8.3. Performance Characterisation

Table C-3: Seismic performance characterisation of linear suspended services

Engineering Demand Parameter	Performance State	Performance Description	Design Limit State	Recommended Criteria or Design Limit
Floor Acceleration	Lateral demands on linear suspended services	Damage to system that could lead to disruption in function	DCLS / SLS2	Seismic restraint of service as per NZS4219[1]
		Loss of support of service	ULS	Seismic restraint of service as per NZS4219[1]
Inter-storey Drift	Seismic gap or riser movement requirements	Onset of damage to system	SLS1	Relative drift between service and partition or floor at Design Limit State
		Damage to system that could lead to disruption in function	DCLS / SLS2	Relative drift between service and partition or floor at Design Limit State

[1] – NZS4219 (2009). Seismic performance of engineering systems in buildings. New Zealand Standards

[2] - ASHRAE Practical Guide to Seismic Restraint (ASHRAE, 2012).

C.8.4. Performance Considerations

The following considerations apply in the design, construction, assessment and testing of linear suspended services.

- Weight assumptions should include an allowance for the following:
  - Insulation/lagging, supports, flanges, fittings, seams, etc. This can comprise an addition 20% for ducting as per AS4254.2
  - Additional load that might be added in the future, e.g. additional cables.
- The following values for pipe fluid content weight calculations are recommended:

Pipework	Equivalent Water Content (% full)	
	Gravity Loads	Seismic Loads
Water distribution	100%	100%
Drainage	100%	50%
Overflow systems	100%	10%
Stormwater	100%	10%
Vent pipework	0%	0%
Gas pipework	0%	0%

Figure C-4: Recommended pipe fluid contents for weight calculations

- Limited codified information is available for restraint of cable trays. It is common practice to use the Mason Industries Seismic Restraint Guidelines (Mason Industries, 2016) which recommends the following cable tray spacing:
  - Up to 1.0g – 12.2m and 24.4m
  - Up to 2.0g – 6.1m and 12.2m
  - In the absence of recommendations for accelerations beyond 2.0g, it is considered appropriate to extrapolate the values given above.
- NZS4219 allows linear suspended services to be unbraced if the service is suspended close to the structure (refer Standard for hanging limits). It should be noted that larger clearances are required if services are unbraced.
- Avoid changing the brace system along any linear system service run. This should also avoid bracing to different structural elements where practicable.
- Ensure fixings to components are adequately distributed to avoid tear out. In the case of ducting, fixings should minimise leakage by avoiding penetrating the ducting. Acceptable solutions include clamping of ductwork.

- Where a linear system does not have sufficient inherent flexibility to accommodate seismic movements, flexible elements or flexible couplings are typically required.

- Restraints for linear systems should be provided within 1.2 m of end of service run and within 600mm of at least one side of flexible couplings.

- When using a guide or code to determine restraint spacings, designers should be cognisant of the other requirements of that code.

- The ductility recommendations for linear systems from Table C8.3 of NZS1170.5 may be appropriate for life-safety considerations, but these will not capture the consequence that failure of linear systems may represent, e.g. flooding from failure of a water pipe. It is recommended when applying SLS2/DCLS considerations to limit the ductility demands for liquid containing systems to $\mu=1.25$ unless specific testing is available showing that these higher ductilities can be achieved whilst still maintaining liquid containment.
- It is necessary to consider thermal expansion/contraction requirements and to check that the seismic restraint approach is not in conflict with these requirements. The following considerations should be made:

  - Thermal expansion is primarily a concern in pipework undergoing significant temperature change (e.g. hot water pipes). For many linear services in buildings, it is likely that nominal thermal expansion can be relieved by normal joint slippage.

  - Some materials will undergo more thermal expansion than others. When selecting materials consideration should be given to selecting materials that will undergo lower thermal expansion if thermal expansion is going to create conflict with seismic restraint requirements.

  - The thermal expansion that will occur along a length and how this will affect longitudinal restraints. A common approach is to locate a single longitudinal restraint in the middle of a run and to achieve the balance of the required bracing capacity, also use transverse restraints located near returns.

  - The effects thermal expansion will have on knee joints where there are transverse restraints located in close proximity to the knee. For these situations the transverse restraint should be located close enough to provide restraint but far enough away to avoid stress on the joint.

  - It might be appropriate to break long runs up into smaller runs using expansion loops or bellows. However, this can have impacts on pressure (system efficiency) and the overall set out. The strategy should be considered and agreed at concept/preliminary design.

  - Due to the spatial impacts, expansion joint locations should be identified during the early design phases.

  - Piping material selections sometimes undergo construction phase changes that may require major rework of detailed flexibility / restraint / fire stopping designs. Care should be made to consider wider implications of piping material substitution.

- Seismic restraints of services penetrating partitions should not be located directly adjacent to partition walls where possible in order to minimise potential interactions between services and partitions. Restraints should only be placed close to partitions at fire damper breakaway joints where a flexible connection is required between the service and the break-away joint.

- NZS4219 does not apply to fire sprinkler pipework, refer Section C.11 and NZS4541.

C.8.5. References Documentation

NZS4219 (2009). Seismic performance of engineering systems in buildings. New Zealand Standards

AS4254.2 (2012). Ductwork for air handling systems in building. Australian Standards

ASHRAE Practical Guide to Seismic Restraint (ASHRAE, 2012).

EPRI, (2006). Seismic evaluation guidelines for HVAC duct and damper systems (No. 1007896), Electric Power Research Institute.

Mason Industries (2016). Mason Industries Seismic Restraint Guidelines for Suspended Pipes, Ductwork, Electrical Systems and Floor Mounted Equipment

C.9. Seismic Design of Suspended Equipment

C.9.1. Description

Suspended equipment includes in line or individually suspended items of plant and equipment. Often suspended equipment is associated with HVAC systems, e.g. fans, VAV boxes, heat exchangers, etc. Suspended services also include elements that are supported within the ceiling grid such as cassette units, grilles, diffusers, chilled beams, etc.

C.9.2. Design Methodology

i. The design of suspended equipment should include the selection of appropriate bracing for the service as per NZS 4219 (SNZ, 2009). Design of suspended equipment should consider the element as a stand-alone element and should not rely upon any other elements unless these have been specifically designed for this load.

ii. Dynamic testing of equipment could be required to determine the floor acceleration at which the equipment no longer functions to satisfy requirements of continued functionality or to determine the acceleration at which some life-safety hazard could be posed from damage to the equipment. The dynamic testing protocol must be consistent with the seismic demand requirements of Section 8 in NZS1170.5 (SNZ, 2004). Recommendations for testing of equipment and a dynamic testing protocol are provided in Sections B.4 and B.5.

C.9.3. Performance Characterisation

Table C-4: Seismic performance characterisation of suspended equipment

Engineering Demand Parameter	Performance State	Performance Description	Design Limit State	Recommended Design or Design Limit
Floor Acceleration	Horizontal acceleration of equipment	Equipment functionality	DCLS / SLS2	To be determined by shake take testing for individual equipment[1]
		Loss of support of service	ULS	Seismic restraint of service as per NZS4219[2]
Inter-storey Drift	N/A	N/A	N/A	N/A

[1] – Refer Section B.5. for Testing Protocols for Non-Structural Elements.

[2] – NZS4219 (2009). Seismic performance of engineering systems in buildings. New Zealand Standards

C.9.4. Performance Considerations

The following considerations apply in the design, construction, assessment and testing of suspended equipment:

- Suspended Vibration Isolated Components: Fix vibration isolators direct to structure (i.e. not at bottom of hanger), with snubbers to limit upward and rebound motion. Use cable bracing, installed so cable braces do not carry any dead loads, and with minimum sag due to cable weight but without additional slack.

- Seismic restraints should make no rigid connection between vibration isolated component(s) and the building structure or other building elements that degrade the specified noise and vibration isolation systems.
- While inter-storey drift is not a key input for seismic performance of suspended equipment, any services connected to the equipment should consider inter-storey movements.
- All equipment installed in line to the duct system (fans, VAV boxes, heat exchangers, humidifiers, etc.) with operating weight > 10 kg should be supported and restrained independently.
- Unless specifically exempted below, positively fix components to the ceiling suspension structure (main or cross runners), via supplementary support members so that components are not supported by ceiling panels / tiles. This includes pan light fittings, emergency lights, illuminated exit signs, air diffusers/grilles, etc.
- Components complying with ALL the following criteria may be positively fixed directly to ceiling panels / tiles, i.e. are exempt from positive fixing to ceiling suspension structure.
    - Suspended elements < 10kg are often restrained by the ceiling system. These should be fixed to the ceiling grid with a minimum of 2 fixings per equipment item, such as clamps, screws or clips. The seismic design of the ceiling system must consider the weight of all suspended equipment.
    - Suspended services > 10kg should be independently supported and restrained, including clearances to the ceiling where possible. Achieving clearance between the services and ceiling components is not practical for units such as cassette style air conditioning units, continuous linear light fixtures, and ceiling mounted diffusers with large plenum boxes. In such instances, an integrated ceiling and services support and restraint system should be designed.
    - Suspended equipment that are supported from wires, chains or otherwise may not require restraint provided the elements avoid all swing interactions with all other building components and structure. The design of the wires, chains or otherwise should consider both the gravity and seismic loads acting concurrently.

C.9.5. Reference Documentation

NZS4219 (2009). Seismic performance of engineering systems in buildings. New Zealand Standards.

EPRI, (2006). Seismic evaluation guidelines for HVAC duct and damper systems (No. 1007896), Electric Power Research Institute.

Mason Industries (2016). Mason Industries Seismic Restraint Guidelines for Suspended Pipes, Ductwork, Electrical Systems and Floor Mounted Equipment

C.10. Seismic Design of Floor Mounted Equipment

C.10.1. Description

This is a broad category of NSEs, including plant and other equipment that is directly fixed to structural floors. Similar principles can be applied to equipment mounted on other structure – such as rooftop plant. Examples of floor mounted equipment includes generators, chillers, air handling units, amongst others. This category includes components that are often individual pieces of equipment anchored to one building floor and have other attachments for its function, such as cables, fuel lines, water pipes, bellows, etc.

C.10.2. Design Methodology

Design of floor-mounted equipment should consider overturning and horizontal actions due to seismic forces in the design of the fixing assembly to the supporting structure. This fixing assembly includes anchors (or connection) to structure, attachment brackets, and connection to the equipment.

Dynamic testing of equipment could be required to determine the floor acceleration at which the equipment no longer functions, to satisfy requirements of continued functionality or to determine the acceleration at which some life-safety hazard could be posed from damage to the equipment. The dynamic testing protocol must be consistent with the seismic demand requirements of Section 8 in NZS 1170.5 (SNZ, 2004). Recommendations for dynamic testing protocols are provided in Section B.5.

C.10.3. Performance Characterisation

Table C-5: Seismic performance characterisation of floor mounted equipment

Engineering Demand Parameter	Performance State	Performance Description	Design Limit State	Recommended Design or Design Limit
Floor Acceleration	Horizontal acceleration of equipment	Equipment functionality	DCLS / SLS2	To be determined by shake take testing for individual equipment[1]
		Loss of support resulting in life-safety hazard or damage to surrounding elements	ULS	Strength of anchorage and attachment brackets to resist overturning and horizontal demands
Inter-storey Drift	N/A	N/A	N/A	N/A

[1] – Refer Section B.5. for Testing Protocols for Non-Structural Elements.

C.10.4. Performance Considerations

The following considerations apply in the design, construction, assessment and testing of floor attached equipment:

- While inter-storey drift is not a key input for seismic performance of floor mounted equipment, any services connected to the equipment should consider inter-storey movements. For example, the flexibility of ducting supported from the floor above connecting into a floor mounted air handling unit needs to consider how inter-storey movement is accommodated.

- Gravity and seismic anchorage reaction on the structure should be coordinated with the structural engineer to confirm adequate floor capacity allowances are provided.

- The design of the supporting floor system should aim to accommodate the gravity and seismic reactions from floor mounted plant without the need for additional localised supports or strengthening.

- Particularly heavy plant, such as water tanks or transformers may require spreader beams to distribute loads across a larger area of floor. Ideally, this is done via secondary structural beams designed by the structural engineer.

- Friction between the equipment and floor is typically ignored, with fixings designed to resist the horizontal (and vertical) demands.

- Consideration needs to be made to whether self-weight is included within the vertical demands on fixings as this can be affected by the type of equipment mount used.

- Tall or slender equipment may be better suited to bracing from the top instead of solely floor fixings.

- NZS4219 provides useful examples for design of floor attached equipment, including those with snubbers.

- It is necessary to consider impact factors if snubbers are used, refer NZS4219 (SNZ, 2009).

- Anchorage demands of vibration isolated equipment should consider the effects of flexible mounts and snubbers in accordance with NZS4219.

- Typical floor thicknesses may not provide adequate anchorage, in such circumstances plinths should be used. These can be designed following NZS4219 Section 5.4.

- Vulnerable plant or equipment will be subject to lower shaking if placed at lower levels. It is also typically easier to repair/replace ground level equipment compared to roof mounted equipment after an earthquake.

C.10.5. Reference Documentation

NZS4219 (2009). Seismic performance of engineering systems in buildings. New Zealand Standards

Mason Industries (2016). Mason Industries Seismic Restraint Guidelines for Suspended Pipes, Ductwork, Electrical Systems and Floor Mounted Equipment

C.11. Seismic Design of Automatic Fire Sprinkler Systems

C.11.1. Description

An automatic fire sprinkler system is a specialised pipe system provided to suppress building fires to prevent loss of life and damage to property. It consists of a series of horizontal and vertical pressurised pipes containing water (or sometimes air or nitrogen if it is a dry system).

C.11.2. Design Methodology

The seismic design of sprinkler piping systems should follow the requirements of NZS4541 (SNZ, 2020). This standard is thorough in terms of the requirements for the selection of appropriate brace solutions for sprinkler systems.

The design of seismic bracing should ensure the capacity of the brace assembly and its anchorage to the structure exceed the lateral force demands based on the tributary mass of the sprinkler pipe acting at the brace. This should include the weight of water in the pipe if the sprinkler contains water.

It is recommended that capacity design principles be followed to avoid brittle failure in the components of brace assembly or the anchorage if ductility-based reduction factors are used in the design.

C.11.3. Performance Characterisation

Table C-6: Seismic performance characterisation of sprinkler systems

Engineering Demand Parameter	Performance State	Performance Description	Design Limit State	Recommended Criteria or Design Limit
Floor Acceleration	Lateral demands on pipework	Damage to pipework that could lead to disruption in function	DCLS / SLS2	Pipe capacity determined by working stress analysis
		Loss of support of pipework	ULS	Seismic restraint of pipework as per NZS4541[1]
Inter-storey Drift	Lateral deformation of vertical pipework	Onset of damage to pipework, e.g. sprinkler head interacting with ceilings	SLS1	Relative drift between floor and ceiling at Design Limit State
		Damage to pipework that could lead to disruption in function	DCLS / SLS2	Restraint spacing / 300 with an upper limit of 50mm[2]

[1] – NZS4541 (2020). Automatic fire sprinkler systems. New Zealand Standards

[2] – NZS4219 (2009). Seismic performance of engineering systems in buildings. New Zealand Standards.

C.11.4. Performance Considerations

The following considerations apply in the design, construction, assessment and testing of fire sprinkler piping systems:

- Sprinklers with pressurised water should be considered 100% full of water when calculating the pipe weight.

- Other components and accessories of sprinkler systems, such as pumps and valves should be considered as part of continued functionality requirements at SLS2.

- Sprinkler systems require external certification by a Sprinkler System Certifier (SSC). Because of this, the seismic design of sprinkler systems is typically covered by a design and build contract and are often excluded from the scope of work of the consultant design team. However, it is still recommended to spatially coordinate the sprinkler pipes and restraints. For complex projects there are significant benefits to considering the support of these systems and spatially coordinating braces in highly congested areas during the design phase.

- The design of new sprinkler systems is significantly more compliance focused than many other systems. As such, there can be an inclination amongst sprinkler designers and specifiers to expect compliance is maintained after an earthquake. Amendment 1 of NZS1170.5 clarified that the damage from a large earthquake (ULS or larger) would typically be beyond that which that fire protection system is expected to remain operational.

- Sprinkler heads represent a key seismic vulnerability, therefore the interactions of sprinkler heads with ceilings are extremely important for avoiding significant disruption from loss of containment of the water in the pipework. The following approaches are recommended:

    - Flexible droppers or escutcheon plates should be used to accommodate relative movement between sprinkler heads and suspended ceilings.

    - Suspended ceilings and sprinkler pipework should ideally be designed to minimise relative movements (for example, both systems braced to floor above).

    - Ceiling tiles housing sprinkler heads should be clipped, taped, or otherwise detailed so as to avoid damage to the sprinkler heads.

C.11.5. Reference Documentation

Fleming, R. P. (1998). “Analysis of fire sprinkler systems performance in the Northridge earthquake.” Report No. NIST-GCR- 98-736, National Institute of Standards and Technology.

Miranda, E., Mosqueda, G., and Rodrigo, R. (2012). “Performance of non-structural components during the 27 February 2010 Chile earthquake.” Earthquake Spectra, 28, 453–471.

NZS4541 (2020). Automatic fire sprinkler systems. New Zealand Standards.

Rashid, M., Dhakal, R. P., and Yeow, T. Z. (2018). “Automatic fire sprinkler systems: An overview of past seismic performance, design standards and scope for future research.” NZSEE Conference, Auckland, New Zealand.

Soroushian, S., Maragakis, E. M., Zaghi, A. E., Echevarria, A., Tian, Y., and Filiatrault, A. (2014a). "Comprehensive analytical seismic fragility of fire sprinkler piping systems." Report No. MCEER-14-0002, Multidisciplinary center for earthquake engineering research, Buffalo, NY, United States.

Tian, Y. (2013). "Experimental seismic study of pressurized fire sprinkler piping subsystems." Ph.D. thesis, University at Buffalo, Buffalo, NY, United States.

C.12. Seismic Design of Exterior Glazing Systems

C.12.1. Description

Exterior glazing systems enclose a structure, with the primary function being to:

- Keep water out of the building.
- Control the passage of light, heat (radiation and conduction), air and sound.
- Define the aesthetic image of the building.

A number of different systems exist, but the typical exterior glazing system is made of glass and extruded aluminium framing connected between structural levels.

C.12.2. Design Methodology

Exterior glazing seismic design primary focuses on having adequate strength to resist out-of-plane earthquake demands and sufficient flexibility and/or movement allowance to accommodate in-plane earthquake movements.

The out-of-plane capacity of a glazing system is typically a function of the capacity of the extruded aluminium frame, and determining this should be the responsibility of the frame supplier or specialist façade engineer. This is typically in consultation with the structural engineer to provide earthquake demands and ensure an adequate load path is provided for fixing the frame back to the structure. NZS4223.1 provides guidance on glass section and determining the capacity of the glass itself to resist out-of-plane loads from earthquakes and wind.

The glazing system should be selected such that it is able to accommodate the in-plane serviceability requirements of the building. The ability of the glazing system to accommodate these movements is typically determined by testing and relies on movement between the glass panes and the framing, or within the frame itself (often referred to as a 'seismic frame'). Under serviceability limit state actions, glass should not be subject to in-plane forces from the frame.

The selection of an appropriate framing system should be done in conjunction with the architect and glazing system provider, in consultation with the structural engineer to ensure the system and detailing adequately allows for inter-storey movement and the interactions resulting from these.

C.12.3. Performance Characterisation

Table C-7: Seismic performance characterisation of exterior glazing systems

Engineering Demand Parameter	Performance State	Performance Description	Design Limit State	Recommended Criteria or Design Limit
Floor Acceleration	Out-of-plane deformation of glazing system	Onset of damage, e.g. frame bowing, glass cracking	SLS1	H/300 at mid-height[1]
		Minor damage but building remains water-tight	DCLS / SLS2	H/250 at mid-height[2]

		Loss of support of glazing system or loss of support of glass panes	ULS	Out of plane capacity of frame and fixings to structure[3]
Inter-storey Drift	In-plane racking of glazing system	Onset of damage, e.g. frame bowing, glass cracking	SLS1	Glass-to-frame clearance[3]
		Minor damage but building remains water-tight	DCLS / SLS2	2 x glass-to-frame clearance[2]
		Loss of support of glazing system or loss of support of glass panes	ULS	1.25 x seismic displacement capacity of glazing system as determined by testing[3]

[1] – NZS1170.5C (2004). Structural Design Actions, Part 5: Earthquake Actions – New Zealand Commentary. New Zealand Standards.

[2] – NZS1170.0 (2002). Structural Design Actions, Part 0: General Principles. New Zealand Standards.

[3] – NZS4223.1 (2008). Code of practice for glazing in buildings - Glass selection and glazing, Standards New Zealand, Wellington, NZ.

C.12.4. Performance Considerations

The following considerations apply in the design, construction, assessment and testing of exterior glazing systems:

- A significant range of exterior glazing systems exist, and the seismic performance of these systems can vary widely. It can often be difficult to distinguish between similar systems, e.g. glazed systems with 'seismic frames' versus residential systems, the latter of which are typically much less rigorously tested or able to accommodate seismic movement without damage.

- Often mixed façade systems make up the exterior of a building and it is necessary to consider how these systems interact in terms of load paths and seismic movements. For example, a glazed system between stiff timber or concrete spandrel panels often increases the relative drift needed to be accommodated by the glazed system.

- Consideration of the type of glass to be installed should be made. Annealed, strengthened, tempered, or laminated glass will perform differently when it fails. The use of tempered or toughened glass reduces the life-safety hazard to those outside the building as when damaged this type of glass shatters into small pieces that do not present a significant hazard. This is in contrast to laminated glass which will remain as one large, broken piece of glass.

- While glass-to-frame clearance is recommended as the main criteria for determining seismic performance (refer Figure C-5), it should be noted that seals and gaskets can be ejected or fail at movements below these recommended limits and hence compromise the water-tightness of the building. This depends on many factors, including the flexibility of the gasket/sealant, whether the system is wet or dry glazed, and whether a seismic (two-part) frame is used.

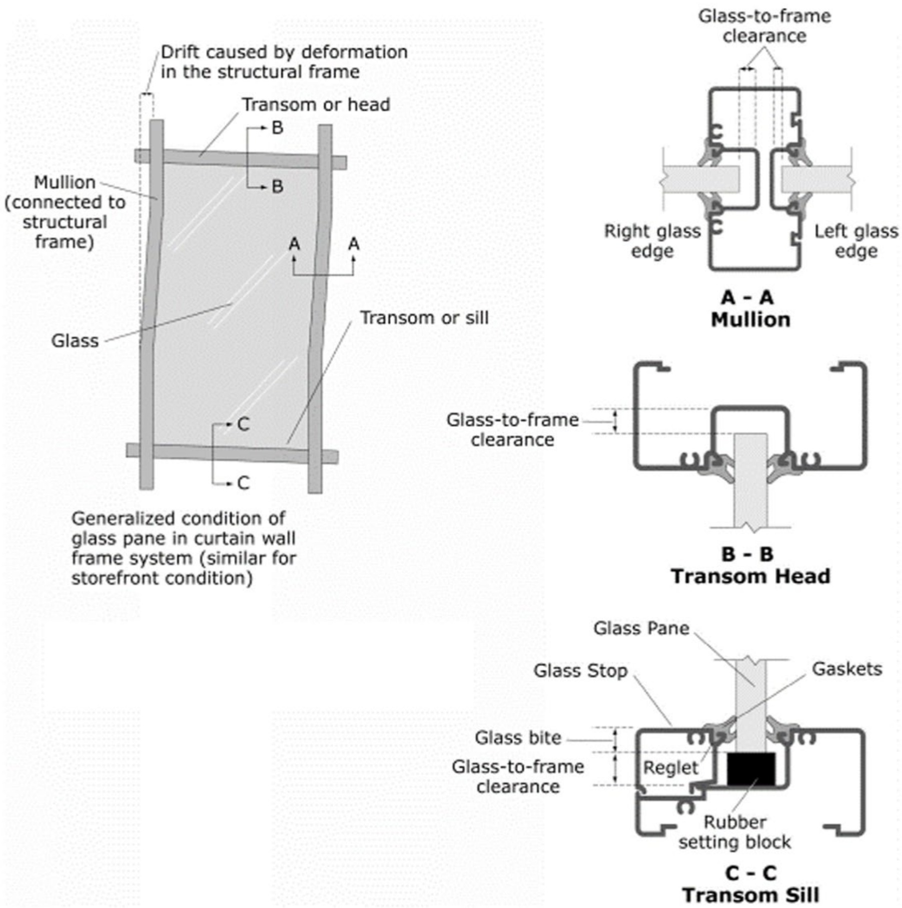


Figure C-5. Typical curtain wall indicating glass-to-frame clearance (FEMA E-74, 2012)

C.12.5. References Documentation

Arifin, F., Sullivan, T.J., Dhakal, R., 2020, Experimental Investigation into the Seismic Fragility of a Commercial Glazing System, Bulletin of the New Zealand Society for Earthquake Engineering, (Accepted for Publication).

Arifin, F., De Francesco, G., Sullivan, T.J., Dhakal, R.P., 2020. Developing guidelines for the seismic assessment of glazing systems. Annual Conference of NZ Society for Earthquake Engineering (NZSEE20), Wellington, 10pp.

Baird, A., Palermo, A. and Pampanin, S. (2011). Façade damage assessment of multi-storey buildings in the 2011 Christchurch earthquake, Bulletin of the New Zealand Society for Earthquake Engineering, Vol. 44, No. 4, 368-376 (available http://www.nzsee.org.nz/db/Bulletin/Archive/44(4)0368.pdf).

Behr, R.A. (2009). Architectural glass to resist seismic and extreme climatic events, Woodhead Publishing Limited, UK.

King, A.B. and Lim, Y.K. (1991). The behaviour of external glazing systems under seismic in-plane racking, Building Research Association of New Zealand, BRANZ Study report SR39, Judgeford, NZ.

NZS4223.1:2008. Code of practice for glazing in buildings - Glass selection and glazing, Standards New Zealand, Wellington, NZ.

Wright, P.D. (1989). The development of a procedure and rig for testing the racking resistance of curtain wall glazing, Building Research Association of New Zealand, BRANZ Study report SR17, Judgeford, NZ.

APPENDICES

Appendix A – References

References

Arifin F., De Francesco G., Sullivan T., Dhakal R.P. (2020). Developing guidelines for the seismic assessment of glazing systems, NZSEE 2020 Annual Conference'.

AWCI (2018). Code of practice for the seismic design and installation of non-structural internal walls and partitions, Association of Wall and Ceiling Industries of New Zealand Inc.

Baird, A., Muir, C., Pourali, A., Kam, W.Y (2022). Improving Seismic Restraint Design Implementation. Fifth International Workshop on Seismic Performance of Non-Structural Elements (SPONSE). December 2022. Stanford, CA. USA.

Building Innovation Partnership (BIP), (2020). "Design, Construction and Seismic Performance of Non-Structural Elements", Building Innovation Partnership, bipnz.org.nz, https://bipnz.org.nz/design-construction-and-seismic-performance-of-non-structural-elements/

Dhakal, R.P., Pourali, A., Tasligedik, S., Yeow, T., Baird, A., MacRae, G., Pampanin, S. and Palermo, A. (2016). "Seismic performance of non-structural components and contents in buildings: An overview of NZ research". Earthquake Engineering and Engineering Vibration, 15(1): 1-17. https://doi.org/10.1007/s11803-016-0301-9.

Dhakal, R.P., Rashid, M., Bhatta, J., Sullivan, T.J., MacRae, G.A., Clifton, G.C., Jia, L.J., Xiang, P., (2019). Shake Table Tests of Multiple Non-Structural Elements in a Low–Damage Structural Steel Building. 4th International Workshop on Seismic Performance of Non-Structural Elements (SPONSE), 22-23 May, Pavia, Italy.

FEMA (2007). Interim Testing Protocols for Determining the Seismic Performance Characteristics of Structural and Nonstructural Components, Federal Emergency Management Agency.

FEMA E-74, (2012). Reducing the Risks of Non-structural Earthquake Damage, Federal Emergency Management Agency.

FEMA P-58, (2018). Guidelines for Performance-Based Seismic Design of Buildings, Federal Emergency Management Agency.

FEMA P-2090, (2021). Recommended Options for Improving the Built Environment for Post-Earthquake Reoccupancy and Functional Recovery Time, Federal Emergency Management Agency. FEMA, NIST SP-1254.

Filiatrault, A., Sullivan, T., (2014). "Performance-based Seismic Design of Non-structural Building Components: The Next Frontier of Earthquake Engineering", Earthquake Engineering and Engineering Vibration, 13(Supp.1), pp. 17-46.

Galloway, B. and Ingham, J. M. (2015). "The 2014 South Napa earthquake and its relevance for New Zealand." Bulletin of the New Zealand Society for Earthquake Engineering, 48(1), 1–30.

Geldenhuys, B., Szakats, G., Stuart, G., Burling, M. (2016). “Survey of seismic restraint of non-structural elements in existing commercial buildings – Report on Stage 2 – Full Study Volume 1”, KOA & MBIE Report, November 2016, KOA, Wellington, New Zealand. https://www.mbie.govt.nz/assets/178a7534c9/survey-of-non-structural-elements-in-20-commercial-buildings.pdf , 35 pages.

Health NZ (2023). Design Guidance Note – Technical Guidelines for the Seismic and Structural Design of Hospital Buildings. Draft Interim Release. February 2024. Version 0.

ICC-ES (2010). "AC156 - Seismic Certification by Shake-table Testing of Nonstructural Components." International Code Council Evaluation Service, California, United States.

Jitendra B., Dhakal R., Sullivan T., Lanyon M. (2022). Low-damage rocking precast concrete cladding panels: Design approach and experimental validation. Vol 26, Issue 9, Journal of Earthquake Engineering (p 4387-4420).

Kestrel Group (2022). Understanding and Improving the Seismic Resilience of Hospital Buildings, technical report.

Merino R.J., Perrone D., Nascimbene R., Filiatrault A., (2023). Performance-based seismic classification of acceleration-sensitive non-structural elements. Special Issue Article, Earthquake Engineering Structural Dynamics Journal 2023.

Miranda, E., Mosqueda, G., and Rodrigo, R. (2012). “Performance of non-structural components during the 27 February 2010 Chile earthquake.” Earthquake Spectra, 28, 453–471.

Ministry of Education (MOE), (2020). “Designing Schools in New Zealand, Structural and Geotechnical Requirements”, Version 3.0, October 2020, https://assets.education.govt.nz/public/Documents/Primary-Secondary/Property/Design/Design-guidance/Structural-and-Geotechnical-Requirements-Version-3.0.pdf

NZS1170.5:2004 “New Zealand Standard – Structural design actions – Part 5: Earthquake actions – New Zealand”. Standards New Zealand, Wellington, NZ.

NZS4219:2009 “New Zealand Standard – Seismic Performance of Engineering Systems in Buildings”. Standards New Zealand, Wellington, NZ.

Rashid, M., Dhakal, R., & Sullivan, T. (2021). Seismic design of acceleration-sensitive non-structural elements in New Zealand: State-of-practice and recommended changes. Bulletin of the New Zealand Society for Earthquake Engineering, 54(4), 243–262, https://doi.org/10.5459/bnzsee.54.4.243-262.

Resilient Building Project (RBP), (2022). “Societal expectations for seismic performance of buildings – Detailed report on focus groups”, NZSEE & EQC, New Zealand, 2022. https://www.nzsee.org.nz/wp-content/uploads/2022/07/Focus-Group-Report-final.pdf.

Ryan KL (2022) “Influence of Vertical Floor Accelerations on the Seismic Performance of Building Non-Structural Elements”. Fifth International Workshop on the Seismic Performance of Non-Structural Elements (SPONSE/ATC-161), 5-7 December 2022, San Francisco, USA, pp. 46-56.

Sahin Tasligedik A., Pampanin S., Palermo A., (2015). Low Damage Seismic Solutions for Non-Structural Drywall Partitions. Vol. 4 2015 Bulletin of Earthquake Engineering.

SESOC (2022). Interim Design Guidance Design of Conventional Structural Systems. October 2022

SPUR (2012). Spur Report 01/2012 Safe Enough to Stay. San Francisco: San Francisco Bay Area Planning and Urban Rescue Association. Retrieved from https://www.spur.org/sites/default/files/2013-09/SPUR_Safe_Enough_to_Stay.pdf

Stanway, J., Sullivan, T., Dhakal, R., Hinz, S., James, M., Davis, M., (2021). "Design, Construction and Seismic Performance of Non-Structural Elements in New Zealand – Current Challenges and Steps for the Future – August 2021", SESOC – SEAOC Paired Article, SESOC newsletter, April 2022.

Steneker, P; Stanway, J; Parker, W; Le Heux, M; Mery, M; Arnod, D; Campbell, P; Ghodsi, T; Jacques, C; Johnston, W; Mastschuch, R; Morales, Y (2023). "Informing Clients on the Business Case for Seismic Resiliency", Canadian Conference – Pacific Conference on Earthquake Engineering 2023, Vancouver, June 25 – 30 2023.

Sullivan T.J., Dhakal R.P., Stanway J.M. (2020). A Framework for the Seismic Rating of Non-structural elements in Buildings. 17th World Conference on Earthquake Engineering, Sendai, Japan 2020.

Villaverde, R., (1997). "Seismic Design o- f Secondary Structures: State of the Art", Journal of Structural Engineering, Vol 123, Issue 8 – August 1997.

Appendix B – Forms & Tools

Appendix B-B1 – Key design tasks, considerations and coordination at each NZCIC design phase

This table provides the key design tasks, considerations and coordination recommended at each NZCIC design phase. It is expected that scopes of work will reference this table and be used throughout the design and construction phases by the Project Manager, Design Manager, discipline leads, construction phase NSE coordinator, subcontractor and suppliers.

Table B-B1: Key tasks, considerations and coordination for each NZCIC design phase

NZCIC Design Phase	Design Tasks, Considerations & Coordination
Project Establishment	• Refer Section A.3 and A.4.2.2 for key considerations in relation to defining the building performance requirements. • Key considerations for this phase include: a) Are the project requirements clear and understood by all disciplines? b) Does the Project Brief provide clarity regarding the business resilience requirements of the client/tenant? c) Are the seismic performance requirements for the building clear?
Concept Design	• Refer to Section A.4.2.3 for the concept design flowchart and design tasks • Refer to Table A-3 for scope of tasks to be undertaken during Concept Design • Refer to Table A-5 for Roles & Responsibilities for the tasks undertaken during Concept Design • Refer to Section A.5.9.1 for key interfaces and coordination between design disciplines • Refer to Section A.5.9.2 for interfaces that need to be coordinated across disciplines. • Development of a high-level Building Movement Strategy (refer Section A.4.1.2) with multi-discipline input. • Identification of critical services and components needed for operational continuity. • Key design tasks and considerations for this phase include: a) Coordination and collaboration between the disciplines is an important aspect of concept design. b) Consideration of inter-storey drifts and thermal expansion cannot be left until construction phase. c) Designers should not focus on 70% of the project and ignore the 30% that will be designed and specified by the contractor, the wider NSEs and just focus on seismic restraint. The design needs to consider all building components and response of the building as a whole – this holistic design needs to commence at concept design. d) Primary structural system options have been considered in the wider context of the building to achieve overall building

	seismic performance requirements (architectural objectives and holistic seismic performance of building). e) Primary building services reticulation strategy f) Estimated weights and locations of heavy equipment g) Return brief – explain to client how the design will achieve the Project Brief (e.g. the Museum artefact storeroom ventilation will be designed to ULS to ensure continues operation after earthquakes to protect the art stored inside this room, the artefact storeroom is located on the ground floor to limit accelerations from building response).
Preliminary Design	• Refer to Section A.4.2.4 for the preliminary design flowchart and design tasks • Refer to Table A-4 for scope of tasks to be undertaken during Preliminary Design • Refer to Table A-6 for Roles & Responsibilities for the tasks undertaken during Preliminary Design • Refer to Section A.5.9.1 for key interfaces and coordination between design disciplines • Refer to Section A.5.9.2 for interfaces that need to be coordinated across disciplines. • Development of the multi-discipline Building Movement Strategy (refer Section A.4.1.2) with multi-discipline input • Key design tasks and considerations for this phase include: a) Coordination and collaboration between the disciplines is an important aspect of preliminary design b) Further development of the considerations of inter-storey drift implications for NSEs throughout the building c) NSE seismic restraint strategy/ies developed based on holistic consideration of disciplines, e.g. structure, services and architectural schemes d) NSE seismic load path into primary structure e) Thermal expansion identified on primary heating and cooling pipework (above dia. 100mm) f) Partition and ceiling strategy g) Design criteria should be frozen by the end of Preliminary Design
Developed Design	• Refer to Section A.4.2.5 for developed design which references NZCIC guidelines for tasks, coordination and roles & responsibilities to be undertaken during Developed Design • Refer to Section A.5.9.1 for key interfaces and coordination between design disciplines • Refer to Section A.5.9.2 for interfaces that need to be coordinated across disciplines. • Multi-discipline coordination and implementation of the Building Movement Strategy (refer Section A.4.1.2) • Key design tasks and considerations for this phase include: a) Coordination and collaboration between the disciplines is an important aspect of developed design

	b) NSE Seismic restraint design and coordination c) Full services equipment table documented with Part Category identified for each component d) NSE seismic load path is confirmed where secondary structure required e) Structural & operational integrity of services equipment confirmed to be able to meet seismic performance requirements for the building f) Spatial coordination considerations, particularly for heavily congested areas
Detailed Design	• Refer to Section A.4.2.6 for detailed design which references NZCIC guidelines for tasks, coordination and roles & responsibilities to be undertaken during Detailed Design. This section also provides the expected minimum documentation requirements for the NSE Seismic Designer. • Refer to Section A.5.9.1 for key interfaces and coordination between design disciplines • Refer to Section A.5.9.2 for interfaces that need to be coordinated across disciplines. • Confirmation that the detailing and components align with the Building Movement Strategy (refer Section A.4.1.2) • Key design tasks and considerations for this phase include: a) Coordination and collaboration between the disciplines is an important aspect of detailed design b) Further coordination of seismic restraint layouts indicating location and orientation of restraints c) Seismic restraint details, both standard and bespoke d) Spatial coordination of seismic restraint solutions e) Design features report that summarises design criteria, design actions, assumptions, inputs, design solutions, and other design considerations for future reference f) The design of all building components required for coordination, costing and Building Consent should occur during the design phases. g) Provide documentation and coordination with the contractor, refer Section A.4.2.7
Design Elements during Construction	• Refer to Section A.4.2.7 for construction phase interface, key design considerations and interfaces considered throughout the design, along with meeting to run through the design with design team in particular the NSE Seismic Designer. • Refer to Section A.4.2.7 for construction phase design and coordination scope • Key design tasks and considerations for this phase include: a) Design of construction phase items that require equipment selection or contractor input, e.g. equipment hold-downs, gravity dominant plant support frames b) Confirmation of operation and structural integrity of final plant and equipment selections

	c) Shop drawings (as needed)
Construction	• Coordination as installation progresses • Construction observation • Quality Control • Documentation to be provided at Practical Completion • Signoff

Appendix B-B2: Form to identify NSE & Critical contents during concept design phase

Discipline/Sub-Category	Component	Does this NSE exist in this building?	Is this NSE critical for operation or seismic performance of Blg?
ARCHITECTURAL COMPONENTS			
	Adhered veneer		
	Anchored veneer		
	Prefabricated concrete panels		
	Other cladding panels		
	Framed exterior wall systems		
	Glazed exterior wall system		
	Glass Blocks		
Interior Partitions	Heavy		
	Light		
	Glazed		
	Fire		
	Acoustic		
	Wet area - membraned		
Interior Veneers	Stone & tile		
Bathrooms	Toilets		
	Showers		
Ceilings	Suspended lay-in tile ceiling systems		
	Ceilings applied directly to structure		

Discipline/Sub-Category	Component	Does this NSE exist in this building?	Is this NSE critical for operation or seismic performance of Blg?
	Suspended heavy ceilings		
	Suspended plasterboard ceilings		
	Floating feature ceilings		
Floors	False floor		
	Computer access floors		
Parapets & Appendages	Concrete, reinforced masonry, timber framed		
	Unreinforced masonry		
Canopies, Marquees & Signs	Canopies, Marquees & Signs		
Chimneys and Stacks	Concrete, reinforced masonry, timber framed		
	Unreinforced masonry		
Stairways	Stairways		
Freestanding walls and fences	Freestanding walls and fences		
Lifts and escalators	Lift, cables, counterweights, guiderails		
	Escalators		
BUILDING SERVICES COMPONENTS			
Mechanical Equipment	Boilers, furnaces, pumps, chillers & HVAC		
	General manufacturing & process machinery		
	HVAC equipment with vibration isolation		
	HVAC equipment without external vibration isolation		
	HVAC equipment suspended in-line with ductwork		

Discipline/Sub-Category	Component	Does this NSE exist in this building?	Is this NSE critical for operation or seismic performance of Blg?
	Heat pumps/heat exchangers		
	Fans/blowers/filters		
	Air compressors		
	Vents and flues		
	Suspended equipment		
Storage tanks & water heaters	Structurally supported tanks and vessels		
	Flat bottomed tanks and vessels		
	Compressed gas cylinders/storage		
	Water heaters		
	Fuel tanks		
Pressure Piping	Suspended pressure piping		
	In-line valves and pumps		
	Flexible connections, expansion joints & seismic		
	Pipe risers		
	Floor mounted supports		
	Roof mounted supports		
	Wall mounted supports		
	Penetrations		
	Gas piping		
Fire Protection Piping	Suspended fire protection piping		
Fluid piping not fire protection	Hazardous materials piping		
	Non-hazardous materials piping		
Ductwork	Suspended ductwork		

Discipline/Sub-Category	Component	Does this NSE exist in this building?	Is this NSE critical for operation or seismic performance of Blg?
	Air diffusers		
Electrical and Communications Equipment	Control panels, motor control centres		
	Emergency generator		
	Transformers		
	Batteries and battery rack		
	Photovoltaic (PV) power systems		
	Control panels, motor controls, switchgear		
	Distribution panels		
	Heavy light fixtures		
	Pendant light fixtures		
	Large computer and comms equipment (speaker, monitors, etc.)		
	Communications Antennae		
Electrical and Communications Distribution	Electrical raceways, conduit and cable trays		
	Electrical distribution panels		
CONTENTS			
	Conveyor		
	Storage racks		
	Hazardous storage		
OTHER			