

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

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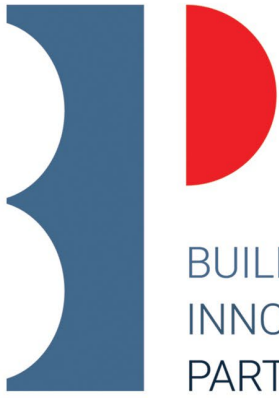
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# Code of Practice for the Seismic Performance of Non-Structural Elements



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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 local communities (BIP White Paper, 2020).

Over the last decade the industry has highlighted 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 (BIP White Paper, 2020; BIP White Paper, 2022).

The Code of Practice for the Seismic Performance of Non-Structural Elements (NSE CoP) provides guidance on the minimum acceptable standards for non-structural seismic design, coordination, selection, and construction to satisfy the performance objectives set out in the New Zealand Building Regulations and meet the minimum New Zealand Building Code requirements including the seismic loadings standard. This is either NZS1170.5:2004, currently cited in New Zealand law, or the recently published superseding technical specification TS1170.5:2025. It 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 NSEs, 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. The CoP seeks to establish consistency across the industry while meeting the performance requirements of the New Zealand Building Code. In general, the content within this guideline is intended to be informative and represent best practice recommendations.

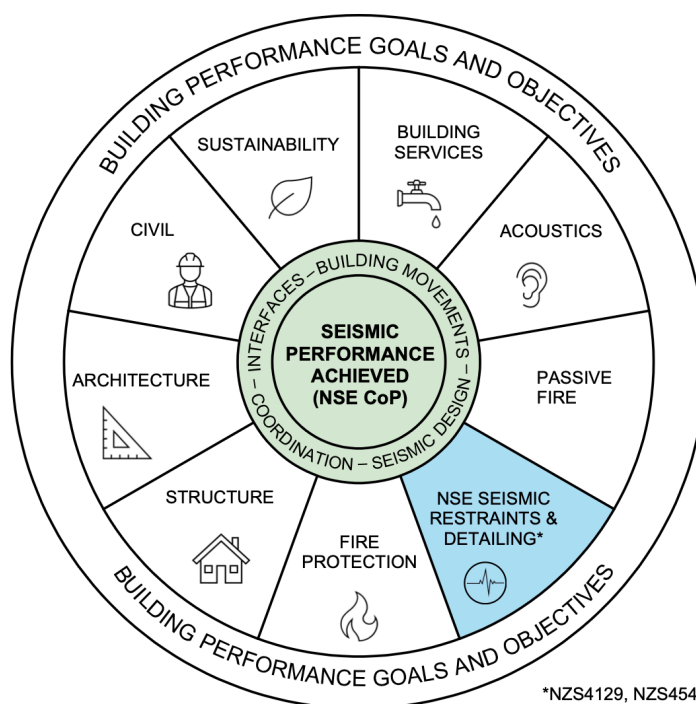
This document provides guidance on how to achieve minimum structural performance requirements of the Code, and how to achieve better-than-minimum Code performance. The NSE CoP is a guideline and should not be deemed a Code compliance document.

The NSE CoP is intended to lift the quality of seismic design and selection of non-structural elements (NSEs), and to improve coordination between disciplines through the use of 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 can be damaged when the building moves during earthquakes
- Allows suppliers to categorise their products for apples-for-apples comparisons.
- Provides recommended quality assurance requirements.

This guideline focuses on how to design and construct NSEs to achieve the seismic performance, and ultimately the overall building performance, expectations of clients. 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 stakeholders may use these guidelines are noted below.

#### *Clients and their representatives*

- Helps them understand what good seismic performance of NSEs means in relation to their building/facilities so they can develop Project Brief Requirements aligned with their business goals and business continuity plans with the performance of the building/facility.
- Helps them set projects up for success in terms of design approaches and procurement processes to ultimately achieve their functional performance requirements both on a day-to-day basis and following earthquake events of varying magnitudes.

#### *Insurance companies and Insurance Council NZ*

- Improves their understanding of seismic risk of buildings.

#### *Project managers and quantity surveyors*

- Provides a common language for NSE components and detailing, which helps them provide appropriate costings for the building/facility to achieve the Project Brief Requirements, and costs associated with meeting them, for seismic performance of non-structural elements can be estimated early in the project.



*Architects, structural engineers, building services engineers, fire engineers, façade engineers, specialist NSE technical designers, quantity surveyors and project managers*

- Assists in the design, coordination, selection of appropriate components and component detailing, and the integration and installation of NSEs during construction.

*Contractors and subcontractors*

- Assists in the design, coordination and selection of appropriate components, and component detailing when components are designed during the construction phase.

*NSE suppliers*

- Helps them understand expectations of clients and design teams regarding the components and equipment they supply to the market and potential need for testing to a common standard.

*Contractors and subcontractors, architects, structural engineers, building services engineers, fire engineers, façade engineers, specialist NSE technical designers*

- Helps with quality assurance inspections.

*Consenting officials*

- Helps them confirm that NSEs installed in buildings have achieved compliance with the 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 primarily 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** is primarily directed towards design managers and multi-disciplinary project teams, suppliers, contractors and subcontractors. It defines the seismic performance requirements for NSEs and provides general technical information to support meeting the seismic performance. 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** is primarily directed towards structural engineers and NSE technical designers. It provides technical guidance on the seismic design of NSEs. 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	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.
Building Movement Strategy	A strategy that documents and addresses all expected building movements (thermal, acoustic, vibration, passive fire, and seismic) throughout the life of the building. The strategy confirms zones/locations where movement is necessary and locations where movement is restricted. Where conflicts occur multi-discipline agreement on what can be compromised and why the decision was made.
Code Compliance	Meets the minimum requirements of the New Zealand Building Code.
Damage	Non-structural component or seismic restraint that requires repair or has experienced the loss of function or structural integrity due to excessive deformation or acceleration demands.
Drift-Sensitive NSE	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. A key goal of LDSD is to deliver buildings that are less likely to be damaged and thereby limit disruption and losses in future earthquakes.
NSE Seismic Designer	Non-structural element seismic designer, refer Section A.5.3. Note that seismic restraint is only one part of the seismic design of non-structural elements.



NSE Seismic Strategy	In collaboration with the full design team determine the strategy for seismic design of NSEs e.g. use individual restraints, multi-service restraints, modular construction of services and seismic restraints, seismic design of ceilings and determine the strategy for NSEs crossing seismic gaps and partition wall design and construction (seismic joint above ceiling or full height).
Non-Structural Element (NSE)	Any part of the building that is not part of the primary or secondary load-bearing structural system, such as ceilings, partitions, HVAC systems, electrical systems, plumbing and drainage etc.
Operational State	<p>A description of the operational state of a building at a given point in time. Typical operational states are listed below.</p> <p><u>Normal operations:</u> 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).</p> <p><u>Full functionality:</u> 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.</p> <p><u>Partial (basic) functionality:</u> 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.</p>



	<p><b>Shelter in Place:</b> 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.</p> <p><b>Not occupiable:</b> 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.</p>
Performance Goal	Performance-based design defines various performance goals. Each performance goal has an objective and performance-based criteria that when met result in achieving the performance goal by controlling the likelihood of reaching defined damage states.
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 the Current Version of NSE CoP

#### **Version 3.2 – April 2026**

Updated qualification and verification guidance in Part B.

#### **Version 3.1 – February 2026**

This version of the NSE CoP provides further clarity on seismic qualification, verification and testing of plant and equipment, use of BIM for coordination during design and construction, and includes general updates to content included in Version 2.1.

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<sup>1</sup> (the Guidelines).

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<sup>1</sup> The Seismic Assessment of Existing Buildings [www.eq-assess.org.nz](http://www.eq-assess.org.nz)



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

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: Prioritisation of NSEs in terms of need of guidance**

Non-structural elements	Included in this version of NSE CoP	Examples
Lightweight partition walls	Y	Timber partitions Cold-form steel partitions
Suspended ceilings	Y	Exposed grid suspended ceilings Concealed grid suspended ceilings
Linear 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
Lifts	Y	Lifts
Contents	Y	Large computer and comms equipment (speakers, monitors), artwork (e.g. museum pieces),
Wall mounted equipment	Y	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
Escalators	N	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,



Non-structural elements	Included in this version of NSE CoP	Examples
Hazardous storage	N	Compressed gas cylinders (O2, CO2, NH3, etc), batteries,
Computer access floors	N	Raised access floor

### 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, however specific additional performance requirements and clarifications may be identified for the project in addition to the minimum Building Code requirements. To ensure building performance meets post-earthquake functionality and operational needs, the requirements need to be outlined at the beginning of the project, preferably before the start of design.

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

- A 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 (to reduce seismic loads/accelerations on the artwork), or consideration of a structural system that minimises accelerations, along with consideration of above-Code ventilation in a dedicated room(s).
- A 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 remain functional in SLS2 or ULS building movements as an above-Code requirement (as opposed to SLS1 building movement).
- A 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 performance. 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 seismic 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.



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 the project brief is completed as part of project establishment, or as early as possible. 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 this approach has often 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.

TS1170.5 defines the performance requirements and seismic demands for design of non-structural elements for life-safety (ULS), continued operation (SLS2) and avoiding damage (SLS1). 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, and detailing of elements to accommodate drift demands without considering interactions, 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 different NSEs 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 introduction 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 (DFR) 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 revised and developed throughout the design process.

When developing 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**. It is essential that this is raised with the client.

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.

### **Building movements considerations in base isolated buildings**

Base isolation reduces drifts and accelerations which improves the seismic performance of non-structural elements. The principles of holistic design, development of the Building Movement Strategy and project team coordination as described in this guideline are the same for Base Isolated Buildings.

As the displacements across the isolation plane will be significant, the design team also need to develop a strategy for the location of the isolation plane and what services and non-structural components will cross the isolation plane. To minimise the risk of damage and expensive detailing, it is important that the design team develop a holistic strategy for choosing, detailing and coordinating NSEs that cross the isolation plane early in the design.

## **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 uses 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 (from Steneker, 2023) can be used to aid 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.

One recommended way to document these responsibilities is to prepare a design responsibility matrix 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 all items that require coordination between design disciplines. It is important to address all design elements during the design phase to ensure that it has been considered as part of the design. This will ensure the right design allowances are made during the design phase and allow for finalizations during the construction phase. Not considering a design element during the design phase can lead to coordination issues.

It is recommended to outline the design progression of each design element clearly. This could be documented as part of a DFR or Specification to communicate the coordination and level of design development during the design phases.

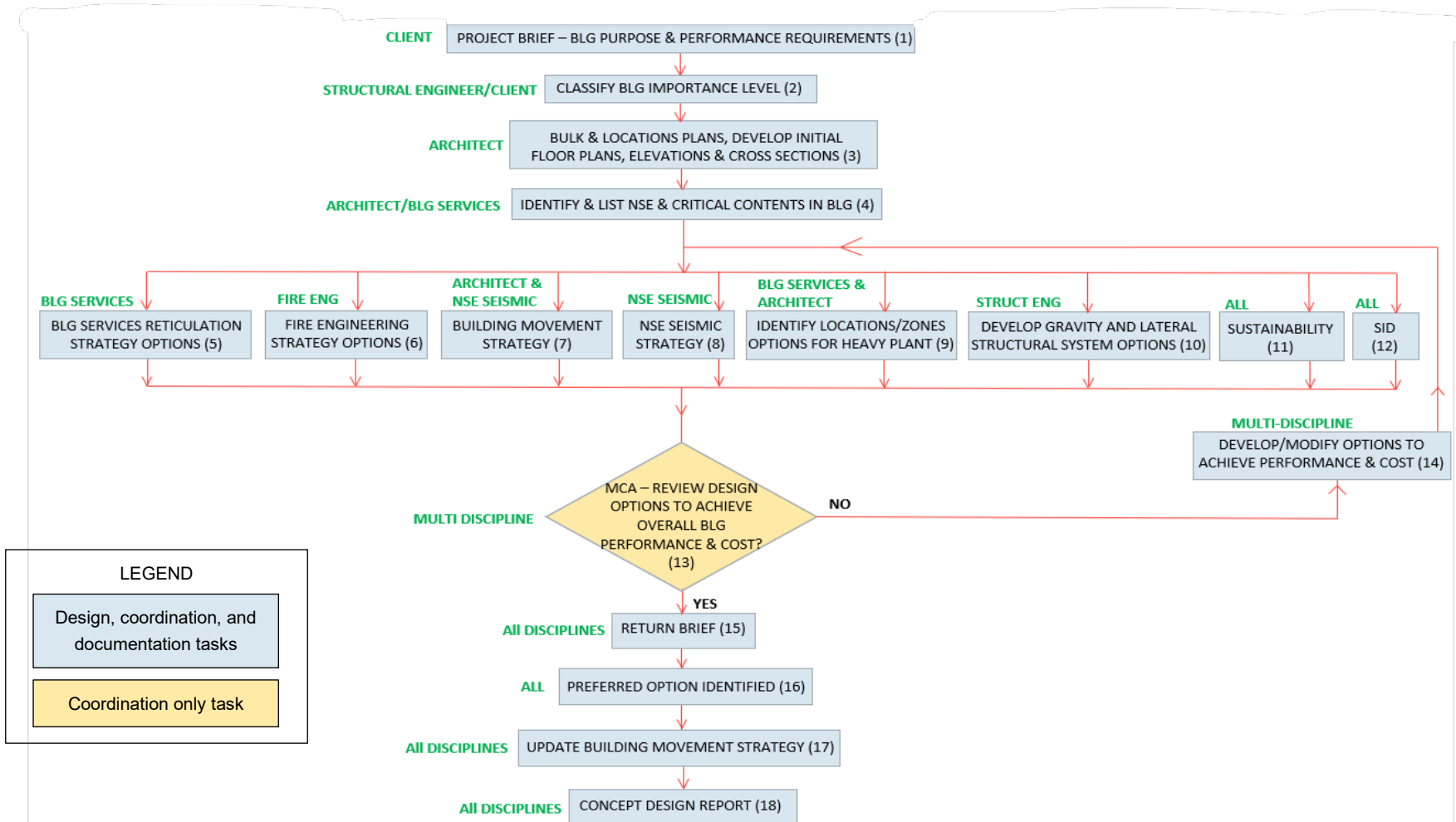
NSE Group	Designer (pre-tender)	Contractor (post-tender)	Designer (post-tender)
Linear services, e.g. pipes, ducts, cable trays supported from <b>above</b>	Seismic brace and fixing details. Seismic brace layouts & maximum brace spacings. Spatial planning for seismic restraints, flexibility & clearances. 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 <b>below</b>	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 (9) 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 (10).



**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	Design team to identify the key non-structural elements that will be included in the building. 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. Identify likely congested areas e.g. congested suspended services, plant rooms with significant amount of plant and equipment and linear services. Communicate to all disciplines.
5	Building Services Reticulation Strategy	High level description of 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, including clarifying inter-storey drift objectives and targets – refer Section A.4.1.2.
8	NSE Seismic Strategy	Using holistic design principles develop the NSE Seismic Strategy in collaboration with the architect, building services engineers, fire engineer and structural engineer for acceleration and drift sensitive NSEs, e.g. use individual restraints, multi-service restraints, modular construction, partition design and construction options (seismic joint above ceiling or full height). The NSE Seismic Strategy should include clarification of the seismic design responsibilities for the design engineer and the contractor (refer Sections A.4.2.7 and A.4.2.8 for more information).
9	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.



10	Develop structural gravity & lateral load Strategy	Mark up conceptual structural options on floor plans and cross sections. Advise alternative options with associated estimate of inter-storey drifts and accelerations (noting this is only conceptual design level, may be discussed in relative terms between options) for each option.
11	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.
12	Safety in design	High level consideration of safety in design and how the building will be operated and maintained.
13	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 strategy for each discipline. Include consideration of inter-storey drift implications of primary structural system options. 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.
14	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.
15	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.
16	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 can be confirmed.
17	Update Building Movement Strategy	Update the Building Movement Strategy following confirmation of the holistic integrated (i.e. all disciplines) concept design.
18	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.

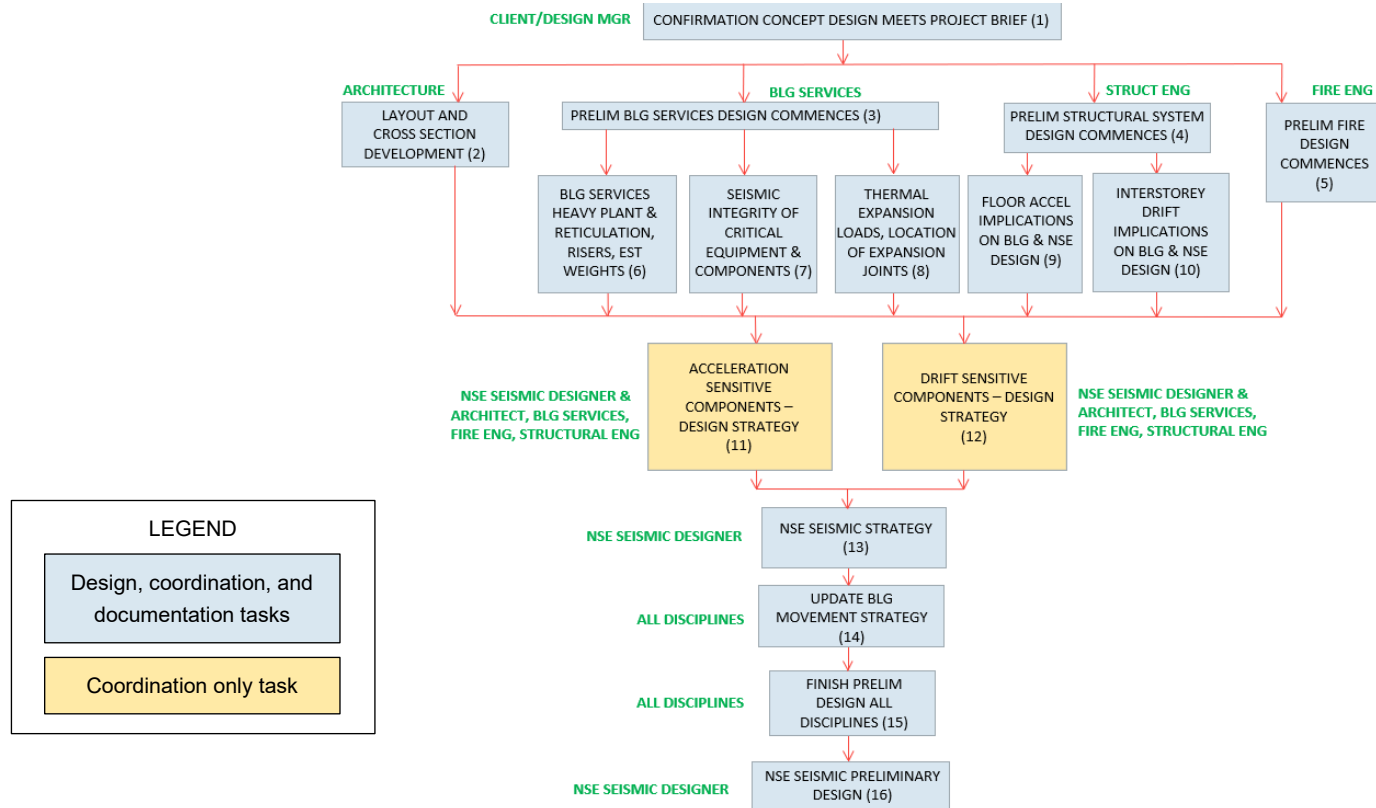


Figure A-4: Preliminary Design process flowchart



**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	Review the NSE Seismic Strategy for acceleration and drift sensitive NSEs that was developed during concept design and update as needed. 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). For projects with intensive building services, it may be worth undertaking sample modelling of congested areas. If this modelling indicates relocation of some services is warranted do this at the start of developed design.
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 late 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 late 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.
- Confirmation of the level of coordination and constructability considerations to which the documentation has been produced.

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

Outputs from detailed design during the 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 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 NSE 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 'NSE Seismic Coordinator' is identified as part of the Contracting team 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 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 seismic performance of the entire building.** 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 **Error! Reference source not found.** 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**

The Structural Engineer's role is to ensure the primary structure can accommodate both gravity and seismic actions from non-structural components. Beyond allowing for superimposed dead loads (UDL), they must identify and design for discrete point loads and local reactions from heavy equipment, including overturning and uplift forces on suspended floors. They are also responsible for communicating expected seismic movements, including inter-storey drifts and seismic gap movements so non-structural elements can be detailed to withstand those demands.

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.

Where there are unique seismic demands, e.g. due to base-isolation or the use of viscous dampers, the structural engineer should also specify the floor accelerations.

The Structural Engineer should also indicate locations where it is acceptable (or not acceptable) for the NSE Seismic Designer to anchor to the primary structure. i.e. outside of plastic hinge zones or imposing significant lateral loads on the bottom flange of beams.

#### **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.

It is important that the seismic restraint engineer and structural engineer coordinate and communicate any significant point loads on structure, particularly from equipment overturning reactions, so that floor slabs, beams, and fixings are sized accordingly.

#### **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:

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

For plant rooms where services are often supported from both above and below, a practical rule of thumb is to suspend items with support points above approximately 2.4 m and floor support items below that, subject to checks for inter-storey drift, vibration/isolation requirements and access/maintenance clearance requirements.

#### **A.5.7. NSE Seismic Coordinator**

The main contractor should have a NSE 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.

### Roles and Responsibilities Matrix table legend

	Primary Role, Responsible		Secondary Role, Coordination responsibility, Input required
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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 as per NZCIC)
8	Concept Design	NSE Seismic Strategy	Architectural plans & cross sections (3), Project Brief (1), Critical Content (4)																					Options Memo with Markups (design strategy as per NZCIC)
9	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 as per NZCIC)
10	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 as per NZCIC)
11	Concept Design	Sustainable design	Architectural plans & cross sections (3), Project Brief (1), Critical Content (4)																					Report
12	Concept Design	Safety in Design	Architectural plans & cross sections (3), Project Brief (1), Critical Content (4)																					Report
13	Concept Design	Multi Criteria Assessment Workshop	All information from (1),(2),(3),(4),(5),(6),(7),(8),(9)																					Workshop, Workshop Notes
14	Concept Design	Develop/modify all design options to achieve performance & cost	Output from Workshop (10)																					Options Memo with Markups
15	Concept Design	Return brief	Output from Workshop (10), Project Brief (1)																					Memo; section in DFR (NZCIC)
16	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)
17	Concept Design	Update building movement strategy	Project Brief (1), preferred option (13)																					Report
18	Concept Design	Concept design report	Project Brief (1), preferred option (13)																					Concept design deliverables NZCIC

Table A-5: Concept Design roles & responsibility 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.	Information from (6), architectural layout plans & cross sections				■				■	■					■	■	■	■				Part of DFR or Memo
11	Preliminary Design	Workshop to confirm NSE seismic 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	Update 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	All information from (6), (7), (8), (9), (10), (11), (12), (13), (14)				■				■	■	■	■			■	■	■	■	■			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 & update prelim design report and dwgs.

Table A-6: Preliminary Design roles & responsibility 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.

#### **NSE Seismic 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 of where movement occurs in the building/building structure	Structural Engineer
Identification of which NSEs are impacted by the building movement	Building Services Designer, Architect, Fire Engineer
Confirmation on where movement should be absorbed/accommodated by the NSE (caused by restraint set-out)	NSE Seismic Designer
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**

<b>Design element</b>	<b>Primary Responsibility</b>
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 <i>(coordinated output required due to opposing design interests – Movement vs. Restraint)</i>
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: Equipment/system selection interfaces**

<b>Design element</b>	<b>Primary Responsibility</b>
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-11: Ceiling / partition selection interfaces**

Design element	Primary Responsibility
Drift at various performance limits	Structural Engineer
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
Location of control joints	Architect (input from NSE Seismic Designer)
Identify probable clash areas and resolve congested locations	Architect, NSE Seismic Designer, Building Services, Passive Fire, Structural Engineer, Acoustic Engineer
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 <i>Contractor to allow for pricing of testing if suitable evidence not available</i>

**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

## A.6. BIM and Modelling

### A.6.1. Overview

Building Information Modelling (BIM) is a powerful tool for design coordination and is strongly recommended for planning and detailing both seismic performance elements and seismic restraint systems. Its ability to visualise, integrate, and coordinate inputs across disciplines helps reduce conflicts, improve constructability, and support informed decision-making throughout the project lifecycle.



To realise these benefits, it is essential that early and clear discussions take place to determine the required Level of Development (LOD) for seismic elements. This includes understanding the scope, responsibility, and design intent at each design stage.

It is also recommended that a meeting or workshop (depending on the complexity of the project) is held between the NSE Seismic Designer and those responsible for modelling the NSE to ensure restraint strategies are clearly conveyed. Early coordination helps position NSE in ways that support seismic restraint requirements, reducing later rework and cost.

Those modelling NSEs are critical to project success, yet issues often arise when restraint considerations are not fully understood. A small amount of forethought during modelling can make achieving compliance much easier.

It is also important to recognise that LOD may be defined differently across design disciplines. What constitutes LOD 300 for a structural engineer may differ from LOD 300 for building services elements. These differences should be clarified and aligned early in the project to avoid miscommunication or misaligned expectations.

The following sections of this guideline aim to provide practical information and recommendations for using BIM effectively in the modelling of NSE seismic performance and restraint elements. The goal is to support better collaboration, more predictable outcomes, and a coordinated approach to seismic compliance.

Further BIM resources for projects can be found here <https://www.biminanz.co.nz/nz-bim-handbook>

## A.6.2. Levels of Development (LOD)

Level of Development (LOD) in Building Information Modelling (BIM) refers to the degree of reliability, completeness, and detail of a building element within a model at a specific point in the project lifecycle. It defines how much information—both graphical (geometry, size, location) and non-graphical (specifications, performance data, cost, etc.)—is included for each element.

The LOD framework allows project teams to clearly communicate the expected content and reliability of BIM elements as the design progresses, ensuring better coordination, accountability, and decision-making across disciplines.

The LOD requirements should be outlined in a project BIM Execution Plan (BEP). A BEP should be available and agreed upon for every project that includes BIM. The BIM Forum Level of Development Specification is typically regarded as the industry standard for LOD definitions. However, it does not have clear definitions for the modelling of seismic restraint and support elements. It is only mentioned in the specification as an accessory requirement for service elements achieving LOD350. This can lead to some modelling ambiguity.

In the following section we introduce the definition of **NSE CoP Seismic Application** for seismic restraint components. These definitions are based on the Fundamental LOD definitions set out by AIA (American Institute of Architects) Contract Documents and expanded upon using the BIM forum LOD specification.

Further BIM LOD resources for projects can be found here: <https://bimforum.org/resource/level-of-development-lod-specification/>

<https://learn.aiacontracts.com/articles/6523765-introducing-aia-contract-documents-2022-bim-documents/>

### A.6.2.1. LOD 100 – Conceptual

**AIA Contract Documents Definition:** The Model Element may be graphically represented in the Model with a symbol or other generic representation but does not satisfy the requirements for LOD 200. Information related to the Model Element (e.g., cost per square foot, tonnage of HVAC, etc.) can be derived from other Model Elements.

**BIMForum Expansion:** LOD 100 elements are not necessarily geometric representations. Examples are information attached to other model elements: symbols showing the existence of a component but not its shape, size, or precise location; or space reservation volumes. In essence, if information about an element can be derived from the model but the element is not at LOD 200 it is said to be at LOD 100. Any information derived from LOD 100 elements must be considered approximate.

**NSE CoP Seismic Application:** LOD 100 is conceptual design without any detailed information. At this stage, the presence of seismic design requirements should be acknowledged, but no specific components are modelled. However, elements such as space-reserving volumes and zones modelled to aid in early coordination would be considered LOD 100. Examples of these include high-level placeholders to identify a seismic gap between buildings for all other disciplines to understand that this should stay empty to allow building movement.

### A.6.2.2. LOD 200 – Schematic / Approximate

**AIA Contract Documents Definition:** The Model Element is generically and graphically represented within the Model with approximate quantity, size, shape, location, and orientation.

**BIMForum Expansion:** LOD 200 elements are generic placeholders but are recognizable as the components they represent (e.g. a pump, a light fixture, a beam, etc.). Any information derived from LOD 200 elements must be considered approximate.

**NSE CoP Seismic Application:** At LOD 200, the restraint elements are generically and graphically represented within the model with approximate quantity, size, shape, location, and orientation to help convey the design intent. At this level of development, clash coordination of individual elements will be of minimal value, as modelling of elements is approximate so clashes may not represent real-world clashes and potentially identify numerous false positives. It is also likely that many clashes can be readily resolved by a competent contractor by adjusting restraint elements as required.

Rather than being used for specific elemental clash detection, the focus of LOD 200 modelling should be to coordinate and communicate basic spatial and coordination requirements—such as the spatial allowance for seismic restraints, the need for seismic separation or movement allowances. Seismic movement elements required for dynamic movement zones, such as movement panels or joints, activated service panels or flexible connections should be modelled. This helps spatially guide structural and services coordination.

### A.6.2.3. LOD 300 – Detailed / Specific

**AIA Contract Documents Definition:** The Model Element, as designed, is graphically represented within the Model such that its quantity, size, shape, location, and orientation can be measured.

**BIMForum Expansion.** LOD 300 elements are sufficiently developed to fully convey the design intent for the represented item. Note that while neither the LOD definitions nor this Specification specify who models the element, designers rarely generate model elements higher than 300. See interpretation of LOD 350 below.

**NSE CoP Seismic Application:** At LOD 300, seismic elements are to be modelled with sufficient detail to represent the actual design intent, including size, geometry, placement, and integration with structural and architectural systems. At this point, graphical representation of seismic elements such as bracing and seismic movement joints should be developed and represented in the model.

Non-graphical data, such as restraint type, movement capacity, performance level, and connection requirements could be assigned to relevant components.

The key advantage of LOD 300 is that the modelled element can be measured directly from the model, without having to refer to drawings, notes, or other sources. This enables real 3D spatial coordination, clash detection and seismic clearance reviews.

Note that for building services elements to achieve LOD 350 this requires seismic restraint elements to be included to LOD 300. It is recommended to separate out the LOD requirements in the BEP to identify clearly the modelling objectives for different seismic elements.

### A.6.2.4. LOD 350 – Coordinated

**AIA Contract Documents Definition:** The Model Element, as designed, is graphically represented within the Model such that its quantity, size, shape, location, orientation, and interfaces with adjacent or dependent Model Elements can be measured.

**BIMForum Expansion:** LOD 350 is intended to define requirements for model elements that are sufficiently developed to support construction-level coordination. This LOD usually requires craft knowledge, thus the caveat in the LOD 300 discussion above that designers rarely generate elements at LODs higher than 300. It should be remembered, though, that neither the LOD definitions nor this Specification specify who models the element – if a design team has craft knowledge available, they might choose to develop elements to LOD 350 or higher.

**NSE CoP Seismic Application:** LOD 350 expands upon LOD 300 to include more specific connections and interfaces between systems. These specific and individual elements are modelled with additional detail beyond LOD 300 to aid with construction-level coordination. Example: modelling modular frame connections and service to channel connections to coordinate the spatial requirements of the connections. Due to the additional effort in modelling connections, LOD 350 is generally used for identifying high risk clash items that require additional care in modelling and coordination.

Self-check: If the modelled element cannot be fixed to the supporting NSE in the modelled location with the shown details derived from the model or the drawings, then LOD 350 is not achieved.

#### **A.6.2.5. LOD 400 – Fabrication**

**AIA Contract Documents Definition:** The Model Element is graphically represented within the Model with detail sufficient for fabrication, assembly, and installation.

**BIMForum Expansion.** LOD 400 describes a model element developed to the level of shop drawings – in most cases, if a project’s specifications call for shop drawings of an item, the project team might model the item at LOD 400. Thus, most models contain few LOD 400 elements.

**NSE CoP Seismic Application:** Modelled elements include fabrication, assembly, and installation details. These fabrication models generally require accurate modelling of all elements in an assembly, including every bolt, plate and connection, etc.

Self-check: If a detailed drawing derived directly from the modelled element will not or cannot be used to fabricate or assemble the component, then LOD 400 is not achieved.

#### **A.6.2.6. LOD 500 – As-Built**

**AIA Contract Documents Definition:** The Model Element is a graphic representation of an existing or as-constructed condition developed through a combination of observation, field verification, or interpolation. The level of accuracy shall be noted or attached to the Model Element.

**BIMForum Expansion.** LOD 500 does not indicate a higher level than LOD 400, rather it indicates that the element’s geometry is determined through observation of an existing item rather than design of a future item. The LOD 500 definition requires that the model element’s accuracy be specified – BIMForum recommends USIBD’s Level of Accuracy (LOA) Specification for this purpose

**NSE CoP Seismic Application:** As-built, field-verified information representing the final constructed conditions. LOD 500 is used for any modelling of existing as-built elements. The actual level of detail can vary depending on the level of coordination needed, thus the accuracy of the modelled element must be clearly specified. Note that LOD 500 assumes an element was modelled to at least LOD 200 prior to installation. It is challenging to make the jump from LOD 200 to LOD 500

### **A.6.3. Project BIM Planning for NSE Seismic Performance & Restraints**

The LOD requirements for NSE seismic performance and restraint elements should be outlined in a BIM Execution Plan (BEP). A BEP should be available and agreed upon for every project that includes BIM.

When developing the NSE seismic related aspects of the BEP, it is important that the LOD of the restraints at each stage in the project is appropriate in relation to the LOD of the elements being restrained. Seismic restraint LOD should not be higher than the LOD of the element it is restraining, i.e. it is not sensible to model LOD 300 restraints for a LOD 200 service element.

Several factors mean the modelling of NSE seismic restraints needs careful planning to avoid inefficiencies and rework. Key factors that can influence the planning and appropriate LOD for NSE seismic performance and restraint design include:

- LOD progression of building services, architectural or structural components
- Contractor-designed elements
- Construction-phase selections or substitutions
- Manufacturer detailing of components
- Gravity support requirements

Further recommendations on how to plan for the above considerations is provided in the following sections.

#### **A.6.3.1. Out-of-Phase Modelling of NSE Seismic Restraints**

The modelling of NSE seismic restraints is often dependent on the progression of other elements, such as building services, architectural or structural components, which frequently need to be advanced before NSE seismic restraints can be modelled. This dependency creates a need for a modelling lag during the project programme, ensuring upstream disciplines are sufficiently developed before seismic restraint modelling progresses. If a design lag is to be adopted, it is important that this is agreed within the project. An alternative to this approach is implementing an early 'model freeze', which identifies the elements which are to be 'frozen' prior to delivery, and which seismic restraint designs rely. Clear communication and agreed milestones and workflows are essential to managing dependencies effectively and avoiding unnecessary rework.

#### **A.6.3.2. Tiered LOD of NSE Seismic Restraints**

Defining two different Levels of Development for seismic restraints within a project is an effective approach to improve modelling efficiency. It is recommended that definitions of these two tiers are based on the complexity or congestion of areas within a project. For example, seismic restraints may be modelled at a lower LOD than building services in areas where there is ample space for seismic restraints, and therefore the benefits of matching the building service LOD are minimal. In areas with high congestion, it is recommended to model the seismic restraints to the same LOD as the other modelled elements.

One practical scenario would be modelling seismic restraints to LOD 200 in areas where the flexibility of restraint elements allows for easy resolution of potential clashes, while in areas where there are high levels of congestion, the seismic restraints are modelled to LOD 300 to match other elements. This tiered approach enables projects to realise the advantages of seismic restraint modelling without incurring the potentially costly burden of modelling all restraints to a high LOD. This strategy also ensures effort is focused on areas that gain the most value from higher modelling accuracy.

Another similar approach includes modelling placeholder elements, such as preliminary restraint positions based on initial service layouts or assumed brace angles for suspended services during early stages. If a tiered approach is to be adopted, the areas of different tiered LODs should be agreed upon and documented in the BEP.

### **A.6.3.3. Construction Phase Modelling of NSE Seismic Restraints**

Not all systems may be fully modelled during the design phase – particularly contractor-designed elements. Examples may include electrical for mechanical systems (such as drives, switchboards, and cable trays), control systems (including control panels and tray layouts), as well as specialised services like compressed air or reverse osmosis (RO) systems and many more. These systems are typically specified to be design & build items by the contractor and often introduced later in the design and construction process and may significantly impact spatial arrangements, particularly in constrained areas like plantrooms.

While placeholder elements may exist in the model during design, the design or detailing seismic restraints for these contractor-designed elements cannot often proceed until construction phase. Seismic restraint solutions for such systems should be similarly crude, since if seismic restraints are locked in prematurely, the model may not accommodate critical infrastructure when it is eventually coordinated, leading to rework or compromises in performance and compliance.

It is also common that final building services equipment selections may change the size, dimensions and/or location of the equipment. It is therefore important that the contractor coordinates the final restraint requirements considering final equipment selections.

### **A.6.3.4. Gravity Support Items**

As introduced in Section A.5.6, many of the modelling issues that exist for seismic elements also exist for gravity support elements. While gravity support design is still more commonly undertaken as a construction phase activity, the modelling of gravity supports is becoming more commonplace, particularly in heavily congested projects. While not covered in any further detail in this document, much of section A.6 can also apply to gravity support elements. As such, the implementation of gravity support modelling requires the definition of scope, responsibility, and design intent at each design stage, which should be captured within a project BEP.

Modelling gravity supports is most beneficial where it adds coordination value to the project. For example, large support framing or plinths that extend beyond the service/equipment footprint, significant trapezes, or prefabricated frames. Modelling may also be warranted for simple gravity supports when ceiling plenums are heavily congested, or the primary supporting structure is non-typical, as non-standard details or precisely located fixing points may be required. In these cases, modelling helps confirm tolerances, maintenance and access clearances, and that egress routes remain unobstructed. Conversely, for simple hold-down bolts within the equipment footprint or typical gravity hangers in uncongested ceilings with flexible placement, detailed modelling is unlikely to add meaningful value.

# Part B: Seismic Performance Framework for NSEs

## B.1. Introduction

This part of the document provides a general framework for the seismic performance of non-structural elements (NSEs). This is not specific to any NSE and is intended to provide seismic performance principles that are broadly applicable to all NSEs. The seismic performance of non-structural elements is based on minimum acceptable standards to satisfy the performance objectives set out in the New Zealand building regulations and meet the minimum New Zealand Building Code requirements including the seismic loadings standard NZS1170.5 (or TS1170.5 when published).

Minimum performance requirements for NSEs are defined by limit states defined in NZS1170.5 (or TS1170.5 when published). The intention of this section is to describe the physical performance, with reference to damage states, using easily understandable terms that non-engineers can understand. NSE-specific guidance is provided in Section C.

Guidance is also provided on how to quantify, calculate, or test different NSEs to confirm minimum seismic performance has been achieved. This aims to highlight existing methods that are aligned with NZ regulations and promote ready-to-use solutions that can be immediately implemented.

*The current NSE CoP refers to the upcoming technical specification TS1170.5 which is used in New Zealand practice to derive design seismic actions on NSEs (there called Parts and Components). References here are based on the draft technical specification DZ TS1170.5:2024 and final revisions to numbering and some contents may occur in the final release. Note that where a building is designed using either NZS1170.5 or TS1170.5, it is appropriate use the entirety of the standard and provisions cannot be taken from both in the same design.*

## B.2. Seismic Performance Requirements and Limit States

The performance of NSEs in this guideline is based on the Damage States associated with each limit state described in Table B-1. These descriptions provide definitions in the context of NSEs and are in alignment with definitions used elsewhere for applications in New Zealand, such as AS/NZS1170.0 Structural Design Actions, the seismic loading standard (currently NZS1170.5:2004, to be superseded by TS1170.5) and the Low Damage Seismic Design Guide (2025).

**Table B-1: Damage states for NSEs**

Design Limit State	Key Focus	Description
Serviceability Limit State 1 (SLS1)	Serviceable	The element does not require repair. <sup>1</sup>
Serviceability Limit State 2 (SLS2)	Functional	The non-structural element is able to maintain operational continuity. <sup>2</sup>
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. <sup>3</sup>
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 timeframe agreed with the client, 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 in demand (acceleration and drift) between first damage and the damage that impacts operational continuity. An example of this is glazing where first damage results in loss of watertightness, leaks, and air seal, but usually you can maintain operations until the damage has moved to the next damage state, i.e. glass breakage. Note that loss of watertightness and air seal still require replacement, so whilst operations may continue, restoration will be required at some point following the earthquake event to bring that component back to full functional performance, which may require decanting or shutdown.

### **B.3. NSE Sensitivity to Displacement and Seismic Forces**

The seismic performance of NSEs depends on the types of actions that cause them to sustain damage and their capacity to resist these actions. Elements may be sensitive to how much the non-structural element displaces during seismic actions (this is known as drift), or to the amount of force exerted on the NSEs (this is known as acceleration), or both. Accordingly, seismic performance checks should be conducted considering the sensitivity to damage for each NSE by considering the drift and acceleration demands that will be imposed on the NSE and the capacity the drift and/or acceleration capacity of the NSE.

### **B.3.1. Drift Sensitive Non-Structural Elements**

Drift sensitive NSEs 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, also called inter-storey drift. These elements span vertically from floor to floor or across multiple floors and are damaged by the relative movement of one floor compared to another. An example of a drift sensitive element is a partition wall which is built plumb and level using large sheet materials. When one floor moves horizontally relative to another, the wall is pushed out of square along its length and thus suffers damage. Similarly, a pipe installed to a fixed-down air handling unit (AHU) with the pipework continuing onto the floor above (fixed up) may be damaged by this relative movement. Conversely, a suspended light fitting is attached to the underside of a floor or roof and can sway. Its seismic performance will not depend on the relative movement of the floors/roof and is therefore not a drift sensitive non-structural element.

The seismic capacity of a drift sensitive NSE is governed by the amount of deformation it can sustain while achieving the required performance requirements. The seismic demands on a drift sensitive NSE are imposed by the amount of structural deformation that occurs during an earthquake.

### **B.3.2. Acceleration Sensitive Non-Structural Elements**

Acceleration sensitive NSEs are those components that are most adversely affected by the amount they move in total, driven by the movement of the building and their own overall inertia response. These elements are predominantly suspended and freestanding architectural elements, contents or electrical and mechanical equipment that is damaged by its motion relative to its supports.

The seismic capacity of an acceleration sensitive NSE is governed by the peak acceleration that it can sustain. Seismic demands on an acceleration sensitive NSE depends on the peak floor acceleration at the location of attachment, resonant-type behaviour from the vibration properties of the building and NSE, the ability for the NSE to deform and reduce resonant behaviour, and more. An approach for accounting for key physical behaviours was recently included in the revision of the seismic loading standard for NSEs, TS1170.5.

To achieve the target seismic performance for acceleration 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. Based on part risk classification, qualification of some NSEs may be required.

## **B.4. 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.

### B.4.1. Design Standards

NSE seismic design should be undertaken to the relevant New Zealand standards:

- AS/NZS4600:2018 – Cold formed steel structures
- AS/NZS1720.1:2022 – Timber structures (not yet cited)
- AS/NZS2785:2020 – Suspended ceilings, design and installation.
- AS/NZS5131:2016 – Structural steelwork – Fabrication and erection
- NZS1170.0 – Structural Design Actions; Part 0 – General Principles
- NZS1170.1 – Structural Design Actions; Part 1 – Permanent, imposed & other actions
- NZS1170.5 Amendment 1:2016 – Structural Design Actions; Part 5 – Earthquake Actions – New Zealand
- NZS3101.A3:2017 – Concrete structures standard
- NZS3404:1997 – Steel structures
- NZS3603:1993 – Timber structures
- NZS4219:2009 – Specification for seismic resistance of engineering systems in buildings.
- NZ4541:2020 – Automatic fire sprinkler systems
- TS1170.5:2025 – Structural Design Actions; Part 5 – Earthquake Actions – New Zealand.

Note that the seismic loading standards cannot be used piecewise. NSE designs and primary structure must be designed using the same standard in its entirety, either TS1170.5 or NZS1170.5.

The following international design standards are also applicable, notably relating to post-installed mechanical anchors in concrete:

- ACI 318 – Building Code Requirements for Structural Concrete: Appendix D, Anchoring to Concrete.
- ACI 355.2 – Qualification of Post-Installed Mechanical Anchors in Concrete.
- ETAG 001 Annex E – European Organisation for Technical Approvals: Guideline for European Technical Approval of metal anchors for use in concrete: Annex E: Assessment of Metal Anchors under Seismic Action.
- EOTA TR-045 – European Organisation for Technical Approvals: Technical Report; Design of metal anchors under seismic action.
- ICC-ES AC 193 – Acceptance Criteria for Mechanical Anchors in Concrete Elements.

### B.4.2. Building Importance Level

NSE seismic design actions shall be derived using the same Importance Level (IL) as the building they are contained within or are servicing.

In some instances, building services may service multiple buildings or pass through multiple buildings of various importance levels. In such instances, the NSE seismic actions for building services that service multiple buildings shall be designated at the higher importance level. Refer below for further examples.

- Equipment such as fire pumps, chillers, etc. that service both an IL2 and IL3 building shall be designated as IL3.
- All systems within a critical post-disaster facility like an emergency department must meet ULS IL4 requirements, even if other parts of the building may not be required for post-disaster function.

- Seismic Design Actions for a fit-out within an IL3 building shall be IL3.

### **B.4.3. Part Risk Classification**

It is expected that the user of the NSE CoP will determine the risk classification of parts and components. It should be noted that components often fall into more than one Part Category. Further guidance is provided in B.5.4.

### **B.4.4. 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 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 to the consideration of 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<sup>2</sup>.

### **B.4.5. MBIE Product Assurance and Certification Scheme**

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. Note that certification does not refer to seismic certification, as defined in B.5.3.

<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>

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<sup>2</sup> <https://d39d3mj7qio96p.cloudfront.net/media/documents/BRANZ-Facts-NS-4-Seismic-clearance.pdf>

These regulations require manufacturers and importers supply technical information, including the Building Code clauses relevant to the product, within its intended scope of use, and how the building product is expected to contribute to compliance with those clauses. When referencing compliance to Building Code clauses include specific reference to cited standards and the requirements of those standards, e.g. NZBC Clause B1 cites NZS 4219 as a verification method, and NZS 4219 requires seismic qualification of plant and equipment in Clauses 2.2 & 2.4.

The technical information that is required to confirm compliance with the relevant Building Code clauses (and associated cited standards), should use 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.5. Seismic Qualification & Verification for Plant and Equipment**

The process of determining if the design seismic performance of non-structural elements will be met by the products specified by the designer is undertaken in many ways and goes by many names. It is common for terminology of “verification”, “qualification”, “certification”, “performance checks” and “validation” to be used interchangeably. This can refer to processes including shake table testing, design analysis, or even the final check that the design capacity is sufficient to meet design demands. Clarity and consistency in definition for these terms, as well as means to undertake these processes, is provided in this guideline.

### **B.5.1. Seismic qualification**

Seismic qualification is the characterisation of the seismic capacity of equipment, elements, devices, or plant. In New Zealand design standards, these are categorised as “parts and components”. Seismic Qualification is a **demonstration of the capacity** (strength, deformability, etc.) of a non-structural element during an earthquake. This should be done with reference to shaking intensities that result in the loss of i) functionality and/or ii) structural integrity. This relates only to the element and its seismic restraints and is therefore applicable to all building applications.

**Operational integrity** can be defined as the ability of equipment, elements, devices or plant to continue to perform their intended function.

**Structural integrity** can be defined as the ability of equipment, elements, devices or plant (including their supports, fixings and attachments) to not collapse, topple, lose support or rupture.

### B.5.2. Seismic verification

Seismic verification of a non-structural element is the process of **checking that the capacity** derived from seismic qualification **is equal to, or greater than, the seismic demands** that will act upon it in the building being considered/designed. This relates to the specific NSE, its seismic restraints, the building it is situated in, and the seismic hazard at the site. This can only be undertaken on a project-specific basis.

The seismic performance of NSEs is inherently risk-based. On this basis, not all NSE systems require strict numerical values (derived from analysis or testing) to demonstrate capacity. Verification may also be achieved using documented engineering judgement.

### B.5.3. Seismic certification

Seismic certification is the provision of impartial third-party attestation documentation that demonstrates compliance against specific legal requirements. A formal scheme for building products is typically a structured framework that defines the requirements, processes, and outcomes for conformity assessment activities. No such scheme exists for certification of seismic performance of non-structural elements in New Zealand.

Internationally, an example of certification is the HCAI OSHPD Special Seismic Certification Preapproval (OSP), which certifies building elements from suppliers have sufficient capacity against design loads for hospitals in California (<https://hcai.ca.gov/facilities/building-safety/preapproval-programs/osp/>). These certificates could be used as part of a qualification pathway for New Zealand under thorough equivalency. Further guidance under this 'pre-qualification' pathway is provided in Section B5.6.

### B.5.4. Seismic Qualification Pathways

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

Where seismic qualification, verification, or certification has previously been completed for an item of plant or equipment, it must be confirmed that the same piece of plant and equipment is installed in the same manner that it has been tested or verified. 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.

The following methods in Table B-2 are based on ASCE 7-22 and ISO13033:2013 qualification pathways and can be used for seismic certification:

**Table B-2: Seismic Qualification Procedures**

<b>Seismic Qualification Process</b>	<b>Benefits and limitations</b>	<b>Relevant Guidance</b>
Analysis	<p>Benefits:</p> <ul style="list-style-type: none"> <li>+ No direct physical costs.</li> <li>+ Complexity of modelling can be scaled as appropriate.</li> </ul> <p>Limitations:</p> <ul style="list-style-type: none"> <li>- Guidance is limited.</li> <li>- No direct validation of results.</li> </ul>	<p>ASCE 7-22 Clause 13.2.3(3)</p> <p>ISO 13033:2013 Clause 9.2</p>
Testing	<p>Benefits:</p> <ul style="list-style-type: none"> <li>+ Most direct means of qualification.</li> <li>+ Efforts to improve testing ongoing.</li> </ul> <p>Limitations:</p> <ul style="list-style-type: none"> <li>- Cost and availability limitations.</li> </ul>	<p>ASCE 7-22 Clause 13.2.6</p> <p>ISO 13033:2013 Clause 9.3</p> <p>ICC-ES AC 156</p>
Pre-Qualification	<p>Benefits:</p> <ul style="list-style-type: none"> <li>+ Able to be used with limited technical background.</li> <li>+ Does not require new qualification to be undertaken.</li> </ul> <p>Limitations:</p> <ul style="list-style-type: none"> <li>- No formal process in NZ.</li> </ul>	<p>HCAI OSHPD OSP</p>
Experience Data	<p>Benefits:</p> <ul style="list-style-type: none"> <li>+ Further testing not required.</li> </ul> <p>Limitations:</p> <ul style="list-style-type: none"> <li>- Onerous to demonstrate demands, limited data.</li> </ul>	<p>ISO 13033:2013 Clause 9.4</p> <p>ASCE 7-22 Clause 13.2.7</p>

### 1. Analysis

Components may be certification through design analysis. This may range from simple calculations to finite element approaches. ISO 13033 recommends that the complexity, value and importance of non-structural elements should be compared with the cost of conducting analytical modelling when selecting the level of detail and analysis approach. It may be preferable to make conservative assumptions to facilitate a more simplified and practical design approach. These approaches are often described in vague terms in guidance documents, however, owing to the variety of modelling approaches available. Refer to ASCE 7-22 Clause 13.2.3(3) or ISO 13033:2013 Clause 9.2 for further information.

### 2. Testing

Non-structural elements may be qualified 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. This is commonly required for functionality and structural integrity checks for active mechanical/electrical equipment, components with complex assemblies, and components with hazardous contents that must maintain containment, along with their supports and attachments. Refer to Section C.4 of this guideline for more information. Testing may be conducted locally or internationally, noting the discussion on equivalency into the New Zealand framework in Sections B.5.6 & C.4 of this guideline.

### 3. Pre-qualification

There is no nationally recognised pre-qualification procedure in New Zealand.

Items of plant and equipment can possibly be selected from the Department of Health Care Access and Information (HCAI) OSHPD Special Seismic Certification Preapproval (OSP) 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. Note that it is likely that this inconsistency may not be self-evident from the HCAI register. It is recommended instead that test results from this database be used with equivalency considerations using sections B.5.6 and C.4 of this guidance.

*An HCAI OSHPD-type approval system has been considered for New Zealand but had historically been discounted as too onerous for a small country. Future work may look at the perceived barriers that underpin this belief and seek to address them. Seismic prequalification may also be an attractive means to avoid costly project-specific testing which is thought to often lead to repetition of work in the New Zealand construction industry.*

### 4. Experience Data

Use of experience data to qualify non-structural elements is permitted by some standards where “substantiated” performance data is available, as measured against the demands imposed by a “verifiable” ground motion and in-structure response. This was adopted in ISO13033 and ASCE 7-22, and features in guidelines by the Electric Power Research Institute (EPRI, 2007), amongst others.

When experience is used to certify equipment/components to establish seismic functional capacity, data must be provided about:

- The observed seismic capacity from recorded behaviours compared with the imposed recorded demand (comparison with a bounding spectrum),
- Conformance with earthquake experience database cautions and inclusion rules,
- Verification of the NSE [non-structural components] anchorage, and
- Verification of seismic interaction.

It is expected that qualification using experience data would only be used in exceptional cases. Although appearing to be easily modified for use in conventional buildings under other earthquake loading conditions, significant limitations with this approach have been identified. As acknowledged in the ASCE 7-22 commentary and in guidance from the US Nuclear Regulatory Commission (U.S. Nuclear Regulatory Commission (NRC), 2009), this approach should only be used when considering how design and manufacture of non-structural elements have changed since experience data was obtained. It is further limited by the scarcity of data, with few strong motion records corresponding to equipment types that meet the strict criteria and fall within reasonable equivalency.

***Possible future certification pathway: seismic resistance rating classification system.** There is ongoing work developing a seismic verification classification system that could reduce a key barrier to qualification: the commonality of language across industry and understanding of seismic performance by professionals without technical engineering expertise. This may be an alphabetical or numerical rating system which quantifies the functional or structural performance of the NSE against minimum thresholds. Current research efforts are ongoing internationally.*

### **B.5.5. Plant & Equipment that Require Seismic Performance Considerations**

The seismic performance of NSEs is inherently risk-based. On this basis, not all NSE systems require strict numerical values (derived from analysis or testing) to demonstrate capacity. Verification may also be achieved using documented engineering judgement.

Verification that the capacity of all NSEs to maintain structural and operational integrity at all earthquake shaking intensities is not required. Procedures for determining capacity are stated in Section B.5.4.

Requirements for seismic verification of non-structural elements are included within normative text of only one New Zealand standard, NZS4219:2009, which states that “all components of the engineering system equipment shall be verified as complying with the criteria of [NZS4219 Section] 2.2”:

- (a) Components representing a hazard (classification P1, P2, P3 [sic]) will not collapse, rupture or lose support after an Ultimate Limit State (ULS) earthquake;
- (b) Components required for emergency evacuation (classification P4 [sic]) will not collapse, rupture or lose support after an ULS earthquake;
- (c) Components required for operational continuity (classification P5 [sic]) within buildings of importance level 4 are restrained in a manner so that the system is able to continue to perform its functions after a Serviceability Limit State 2 (SLS2) earthquake; and
- (d) All components are restrained in a manner so that the system retains its structural and operational integrity without requiring repairs after a Serviceability Limit State 1 (SLS1) earthquake.

These criteria align with the objectives of the standards used to derive seismic loading, NZS1170.5:2004 A1 2016 and TS1170.5:2025.

Only criteria (c) and (d) use the language “...are restrained in a manner so that the system...” which could be interpreted to verify that the seismic restraint system does not compromise expected performance of NSEs, rather than verification of the component itself. This interpretation contradicts the apparent objective of the P.5 of ensuring that engineering systems maintains operability which only achieved by the active mechanical or electrical component itself.

Criterion (d) may be interpreted as requiring all NSEs to be verified to not require repair under SLS1 earthquake shaking intensity. This would apply to NSEs that do not have additional performance requirements given in P.1 to P.5 (i.e.: equivalent to P.7). This interpretation is likely to result in a significant increase in requirements above conventional industry practice.

Requirements for P.1 to P.3 (criterion (a)) appear aligned with international codes. Unlike USA, New Zealand does not explicitly distinguish between life safety hazards posed by NSEs that may release hazardous materials and those that may fall and crush.

The verification of P.6 does not fall neatly as a structural integrity or operational integrity check and is not explicitly stated in Section 2.2 of NZS4219:2009. Instead, verification should be conducted considering the mechanism that would result in significant losses greater than the losses.



It is instead recommended here that verification be conducted considering a hierarchy of the consequence of failure. NSEs that upon failure may impede emergency response, cause injury (e.g. falling or release of hazardous material) or impede egress should be addressed first (P.1 to P.5). Considerations for seismic verification for mechanical and electrical equipment based on part categories are shown in Table B-3.

It may be appropriate to conduct seismic verification to demonstrate performance above the minimums described in Table B-3. This may include verification that project-specific requirements are met such as of the protection of high value contents or maintaining positive pressure in a controlled environment like a manufacturing or medical facility.

**Table B-3: Recommended minimum seismic verification considerations for mechanical and electrical plant and equipment using definitions from NZS1170.5, TS1170.5 and NZS4219.**

Category <sup>1</sup>	NZS1170.5.2004 A1 2016 Criteria	TS1170.5:2025 Criteria	NZS4219:2009 Criteria	Examples from TS1170.5:2025	Design loading <sup>2</sup>	Structural Integrity Consideration <sup>3</sup>	Operational Integrity Consideration <sup>3</sup>
P.1	Represents a hazard to human life outside the structure		Components representing a hazard to life outside the building	Cladding panels Glazing systems Verandas Signs or hoardings Vessels containing hazardous materials	100% ULS	Yes <sup>4</sup>	Not required
P.2	Represents a hazard to human life within the structure		Components representing a hazard to a crowd of greater than 100 people within the building	Vessels containing hazardous materials Warehouse Racking Heavy partitions	100% ULS	Yes <sup>4</sup>	Not required
P.3	Represents a hazard to human life within the structure		Components representing a hazard to individual life within the building	Ceiling systems Items exceeding the weight and fall limitations provided in Table 8.1 Lift support systems			
P.4	Required for the continuing function of the evacuation (after earthquake) and human life support systems within the structure		Component necessary for the continuing function of the evacuation and life safety systems within the building	Emergency lighting systems (not egress signage) Emergency stairs Partition adjacent to a primary egress route Rescue systems Lift support systems	100% ULS	Yes <sup>4</sup>	Yes

P.5	<p>IL4 buildings: Required to maintain operational continuity</p> <p>All buildings: Required to be operation/functional for the building to be occupied</p>	<p>Importance Level 4 buildings: Parts or components required to maintain operational continuity</p>	<p>Components of a system required for operation continuity of the building</p>	<p>Communications equipment in Fire, Ambulance and Emergency management facilities</p> <p>Appliance exit doors in Ambulance and Fire stations</p> <p>Operations facilities, essential lighting, reticulation facilities in major hospitals</p> <p>Fire-protection systems</p> <p>Lifts</p> <p>Standby generators (incl. fuel tanks &amp; distribution pipework)</p> <p>Battery racks</p> <p>Services systems necessary for building code compliance for occupation</p> <p>Ventilation systems in buildings without opening windows (from TS)</p> <p>Egress systems</p>	100% SLS2	*4	Yes
P.6	<p>Where the consequential damage caused by the part or component failure is disproportionately great</p>	<p>All buildings: A part or component the failure of which causes damages which is disproportionately greater than the loss of the part or component itself</p>	<p>Components for which the consequential damage caused by this failure is disproportional great</p>	<p>Water systems, including pipework, above perishable goods</p> <p>Fire protection systems, including sprinkler heads and pipework droppers, over areas containing water sensitive items</p>	200% SLS1	*6	*6

P.7 <sup>1</sup>	All other parts	All parts and components	All other components	Lightweight partitions not adjacent to an egress way Lightweight suspended ceiling teils Lighting systems with secondary suspensions Small services cabinets	100% SLS1	Not required <sup>6</sup>	Not required <sup>6</sup>
P.1-P.7	Component is <i>inherently rugged</i> (see descriptions in Section B.5.4.1 and examples in Table B-4).			N/A	N/A	Not required	Not required

**Table Notes:**

1. Components often fall into more than one Part Category. Note that P.7 applies to all parts under the normative text of TS 1170.5 and NZS4219 effectively characterises all parts as P.7 under criteria (d) of Section 2.2.
2. This refers to the seismic demands derived under the loading standard.
3. Seismic qualification can be conducted using the pathways in Section B.5.5. Requirements for verification should not be conflated with requirements for dynamic shake table testing. The extent of seismic qualification needed to gain sufficient confidence in expected performance should be evaluated with engineering judgement.
4. This aligns with NZS4219 requirements. Under ASCE 7-22 this applies for all NSEs containing hazardous materials (i.e.: with an importance factor  $I_p=1.5$ ) and for all NSEs of sufficient weight to pose a life safety hazard under significant shaking intensities for all NSEs ( $I_p=1.0$ , SDC D). An engineering interpretation of whether an element poses a life safety hazard should be made.
5. Seismic verification of P.6 NSEs should confirm the capacity of the mechanism that would result in consequential damage rather than explicit structural / operational integrity checks (i.e.: a pipe connection may still allow sufficient flow to be operable and may still be suspended overhead but excessive deformations have caused a leak that has caused widespread water damage).
6. Verification is required under an interpretation of NZS4219. This may be overly onerous and should be evaluated on a project-specific basis.

### B.5.5.1. Inherently Rugged Non-Structural Elements

Some NSEs possess sufficient resilience to seismic loading as to not require rigorous seismic verification and can, instead, be assumed to always behave in an acceptable manner. These elements may be deemed to be inherently rugged. Any mechanical or electrical equipment that must remain operable **need not be qualified** if it can be shown that the component is inherently rugged by comparison with similar seismically qualified components. The movement of the building under earthquake loading, as detailed in the building movement strategy, and the bracing system of the NSE may still impact the seismic performance of inherently rugged NSEs (e.g.: pipes themselves are inherently rugged, but may be damaged by inter-storey drift, relative movement over seismic gaps or from poor restraint if not properly designed).

A rugged NSE is defined in ASCE 7-22 (11.2 Definitions) 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 of similar strength and stiffness. Common examples of rugged components are AC motors, compressors and base-mounted horizontal pumps.”*

Despite the widespread international use of the inherently rugged categorisation, there does not appear to be well established criteria for what qualifies as inherently rugged, relying instead on engineering judgement. Future work is looking to progress a more robust scientific basis of this criterion, developing qualitative and quantitative criteria for its use. This is likely to lead to more NSEs being added to this category thereby reducing the requirements for seismic verification in practice.

Table B-4 provides a list of non-structural elements that may reasonably be expected to be inherently rugged. The list was derived based on the guidance in ASCE 7-22, OSHPD PIN 55 2022, OSHPD CAN 2-1708A.5 (2009) and from input from New Zealand practice. This should be used with engineering judgement.

**Table B-4: Equipment that may reasonably be expected to be inherently rugged**

Component	Limitations	Structural Integrity Check Required	Operational Integrity Check Required
Valves	Not in cast-iron housing, except for ductile cast iron	No	No
Hydraulic operators		No	No
Electric motors	No size threshold	No	No
Base mounted horizontal pumps	No size threshold	No	No
Base mounted vertical pumps	≤ 20hp		
Compressors		No	No



Sterilisers		No	No
Lift cabs		No	No
Pipes, ducts & conduits		No	No
Controllers, switches, circuit protection	$\leq 7.5\text{kg} / 63\text{A}^*$  *Note: based on OPSPD training documentation and adjusted from 10A to 63A to suit NZ market.	No	No
Emergency generators	$\leq 25\text{kW}$	No	No
Lift machines & governors		No	No
Certified subcomponents	$\leq 4.5\text{kg} (10\text{lbs})$	No	No
Equipment and components supported directly on structures or surface mounted equipment	$< 23\text{kg} (50\text{lbs})$	No	No

### B.5.6. Considerations of Equivalency for Verification against Design Loading

It is common that data used for seismic verification will be in a different format than the terminology and parameters used in the New Zealand seismic loading standards, NZS1170.5:2004 A1 2016 or the upcoming superseding technical specification TS1170.5:2025. This is due to the limited availability of testing facilities in New Zealand, the relative size of the New Zealand construction market, and the prevalence of NSEs manufactured abroad.

For practical verification of seismic capacity against design loads, data must be interpreted from overseas frameworks to be equivalent to the specifications of the loading requirements of NZ Standards.

Important aspects that need to be considered include:

- The requirements of the *performance limit state* being verified. This requires the maintaining of functionality at SLS2 and structural integrity at ULS, unless it is a category P4 component which requires the component to maintain function at ULS.
- The performance of the NSE in each *direction of loading*: the two horizontal and one vertical directions. This includes the sensitivity of the NSE to the actions imposed in each direction (e.g.: precast panels may be drift-sensitive in both horizontal directions, acceleration-sensitive out-of-plane but not acceleration-sensitive in-plane or vertically). Mass and stiffness distribution and geometric properties are likely to result in different characteristics in each direction (e.g.: a fan will exhibit different properties loaded across the blades than through the blades, a pallet rack may have different load conditions and perform differently along its length (moment resisting frame) than across its depth (braced frame)).
- For acceleration-sensitive elements, the vibrational properties of the NSE in each verified loading direction should be considered. This may be as simple as rigid/flexible classification, which may be described based on the time it takes for the element to complete one vibration cycle under dynamic loading (i.e.: the *resonant/natural/fundamental period/frequency* of the NSE).
- The *intensity* of the motion that the element was able to sustain while performing as required at the limit state.

Section C.4.1 outlines the recommended procedure for equivalency to verify capacities derived from results from testing conducted in accordance AC156 against seismic demands derived from TS1170.5.

# Part C: Technical Guidance for Seismic Design of NSEs

## 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 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 ductility values 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  $\mu=1.25$  indicated in Cl. 8.6 should be used on the project. (Rather than the  $\mu=1.0$  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 is undertaken or if supported by developing research.

### **C.3. Materials, supports, fixings and anchorages**

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

#### **C.3.1. Materials**

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
- Threaded Rods, Bolts, Nuts, Washers – AS1111, AS1112, AS/NZS 1252.1, AS4291.1, AS4291.2
- Wire Rope – ASTM A475, JIS G 3525, ISO2408-85, EN12385
- Steel Sections – AS/NZS3679.1, AS/NZS 5131
- Welding – AS/NZS 1554.1
- Corrosion Protection – AS/NZS 2312
- Galvanising – AS/NZS 1214, AS/NZS 4680

#### **C.3.2. Supports**

Supports include suspended, wall and floor/roof mounted support frames, and all rigid seismic bracing. Materials should comply with the relevant New Zealand standards.

#### **C.3.3. 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 in the following sections.

##### **C.3.3.1. 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 deem that the selection of anchors is appropriate 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  $\mu=1.0$  for anchors.

It is recommended that, if practical, anchors qualified for seismic actions should be used for all support fixings. This avoids the risk of non-qualified anchors being available on site and 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 (TS 1170.5 when issued), 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 considered appropriate.

### **C.3.3.2. 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.3.3.3. 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.4. 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.

Shake table testing offers a direct method to demonstrate that a non-structural building element has the capacity to resist the dynamic loading conditions of an earthquake. It is also useful to determine the seismic performance of equipment that possess many different subcomponents. This equipment may house electronic, chemical, or fluid elements/components whose functionality after an earthquake cannot be determined through engineering analyses involving the determination of stresses and strains.

It is often not financially feasible to test every configuration of a product line of equipment. Instead, representative test specimens are selected from the product line, each commonly referred to as a Unit Under Test (UUT), following AC156 (ICC-ES, 2010). Seismic qualification of equipment not tested is then characterised by extrapolation or interpolation. UUT selection rationale must be provided, as measured against selection criteria which consider:

- structural features,
- mounting features,
- subassemblies,
- mass distribution, and
- component variation.

The sections below provide useful information on the use of existing protocols for dynamic and static testing.

### C.4.1. Procedures for seismic qualification using dynamic shake table testing

There is no nationally recognised dynamic testing protocol for seismic qualification of NSEs based on the design loadings of NZS1170.5 (SNZ, 2004) or TS1170.5 (SNZ, 2025) available in NZ. Accordingly, there is no formal certification procedure. Instead, data from testing, as summarised in the test report, can be used to show performance for compliance as an Alternative Solution.

The AC156 test protocol (ICC-ES, 2010) is commonly used for testing various NSEs in the NZ industry. A unique testing protocol for NZ faces barriers of adoption from economic considerations and international compatibility. Work in this area is ongoing locally and internationally, including upcoming revisions of AC156. Other testing protocols (e.g.: ISO13033, FEMA461, IEEE 693) may also be used with care and are not discussed in detail here.

It is recommended that the existing AC156 procedure is used with proper engineering judgment to align test results to the requirements of NZS 1170.5 (SNZ, 2004) or TS1170.5 (SNZ, 2025). Some guidance on the use of AC156 test results is provided below.

#### **C.4.1.1. Conducting Testing in Accordance with AC156**

AC156 procedure for dynamic testing involves several steps. At a high level, this must include at least:

*Pre-Testing Inspection and Functionality Checks* – The UUT must be visually verified to be undamaged before the test. Functionality benchmarks must be established and are likely to vary for different elements. Guidance on functionality checks are provided elsewhere in Section C of the NSE CoP and should be agreed upon with the supplier of test specimens.

*Mounting of UUT* – The UUT specimen must be attached (i.e. seismically restrained) to the shake table platform using mounting that will be used in actual service. Alternate attachment methods require additional tests.

*Monitoring of Seismic Response* – The motion of the shake table platform must be monitored to accurately record the actions upon the UUT. The response of the UUT is to be monitored using sensors, placed and recorded at the discretion of the laboratory.

*Resonant Frequency Search for Dynamic Identification* – The UUT is to be subjected to a sinusoidal sweep motion between 1.3 and 33.3Hz to identify damping and vibrational periods in each tested orthogonal direction (2 horizontal and 1 vertical). Sine sweep intensity and rates are provided in AC156. Note ISO13033 also permits white noise, resonance and static push back methods for dynamic identification.

*Dynamic Testing* – The UUT is to be subjected to an artificial motion of 30 seconds, with 5 seconds build and decay time either side of 20 seconds of strong motion. The frequency content of the motion is specified by a required response spectrum (RRS) which must be enveloped by the recorded test response spectrum (TRS), which is permitted to be no greater than 130% of the RRS. Exceptions for matching apply down to 90% RRS.

*Reporting* – AC156 compliance requires strict reporting to be provided. This includes the observed performance, specified test data for key parameters, and descriptions of the previous steps.

#### **C.4.1.2. Equivalency between AC156 and TS1170.5**

Table C-1 states the equivalent cases for NSE verification between AC156 and TS1170.5. The acceleration at which capacity was demonstrated during testing against AC156 ( $A_{FLX-H}$  and  $A_{RIG-H}$ ) are equivalent to the design response coefficient for parts and components from Section 8 of TS1170.5 ( $C_p(T_p)$ ).

This is based on the rigid/flexible classification of NSEs, related to the vibration properties of the NSE. For this, use the reported resonant (shortest) frequency of the NSE tested in each direction,  $f_n$ .

AC156 test report values for  $f_n$  can be converted to the (longest) vibrational period of the part,  $T_p$ , as used in TS1170.5, by taking the inverse using Equation C-1:

$$T_p = \frac{1}{f_n} \quad (\text{Eqn. C-1})$$

**Table C-1: Equivalent cases for NSEs using capacities derived from AC156 testing and design demands derived using Equation C-4 with parameters from Section 8 of TS1170.5.**

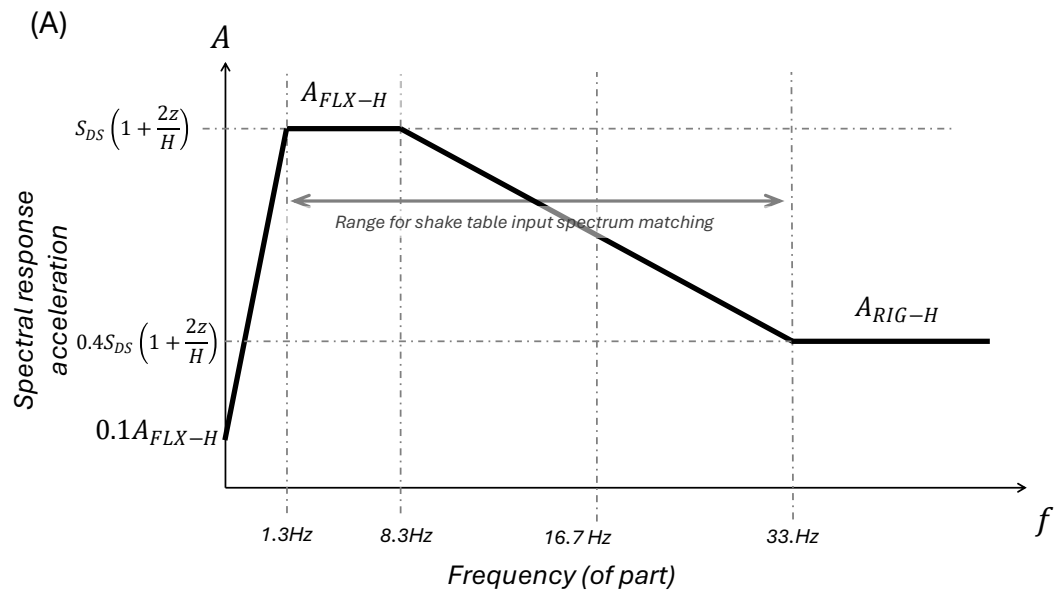
	Floor mounted		Ground mounted	
	Capacity, AC156	Demands, TS1170.5 using $C_p(T_p)$	Capacity, AC156	Demands, TS1170.5 using $C_p(T_p)$
Rigid NSEs $T_p < 0.06$ s $f_n > 16.7$ Hz	$A_{RIG-H}$ $z/H = 1$	PGA use Section 3.3 $C_{Hi}$ use Eq. 8.4 $C_{str}$ use Eq. 8.6 $C_i(T_p) = 1.0$ $C_{ph} = 1.0$	$A_{RIG-H}$ $z/H = 0$	PGA use Section 3.3 $C_{Hi} = 1.0$ $C_{str} = 1.0$ $C_i(T_p) = 1.0$ $C_{ph} = 1.0$
Flexible NSEs $0.06$ s $< T_p < 0.77$ s $1.3$ Hz $< f_n < 16.7$ Hz	$A_{FLX-H}$ $z/H = 1$	PGA use Section 3.3 $C_{Hi}$ use Eq. 8.4 $C_{str}$ use Eq. 8.6 $C_i(T_p) = 4.0$ $C_{ph}$ use Table 8.3 <sup>1</sup>	$A_{FLX-H}$ $z/H = 0$	PGA use Section 3.3 $C_{Hi} = 1.0$ $C_{str} = 1.0$ $C_i(T_p) = S_{as} / PGA$ $C_{ph}$ use Table 8.3 <sup>1</sup>
Very flexible NSEs $T_p > 0.77$ s $f_n < 1.3$ Hz	Test spectrum not matched to required response spectrum. Unable to be used for verification			

<sup>1</sup> The part ductility factor  $\mu_p$ , used in TS1170.5 Table 8.3, should be set considering the sources of nonlinear response observed during testing. Where test reports state only that “the UUT maintained structural integrity and remained functional per manufacturer requirement after shake table test”, a nominal value of 1.25 should be used unless demonstrated to be greater.

#### C.4.1.3. Interpretation of AC156 Test Results to Demonstrate Seismic Capacity of NSE

AC156 test reports state the intensity of the shaking of the table rather than direct measurements of the test NSE specimen. The required response spectrum (RRS) governs the frequency content of the motion, and strict acceptable ranges are enforced for the response spectrum computed from the data recorded by accelerometer(s) mounted on the table. Accordingly, the reported values for  $A_{RIG-H}$  and  $A_{FLX-H}$  correspond to the RRS that is enveloped by the spectrum from the recorded table motion (TRS). It can then be considered that the NSE was able to perform as described in the test report (functional and structural integrity) where the loads were between 90% and 130% these reported values.  $A_{RIG-H}$  is equivalent to what AC156 calls the zero-period acceleration (i.e. PGA or PFA) and  $A_{FLX-H}$  corresponds to the spectral acceleration.

The AC156 required response spectrum is shown in Figure C-1.



**Figure C-1: Required response spectrum (RRS) from AC156 described using (A) part frequency and (B) part period.**

Where AC156 test results are provided in terms of the ASCE 7-22 short period spectral acceleration,  $S_{DS}$ , this can be converted to an equivalent PGA using Equation C-2:

$$PGA = \frac{S_{DS}}{2.5} \quad (\text{Eqn. C-2})$$

#### C.4.1.4. Interpretation of TS1170.5 Design Loads to Derive Seismic Demands on NSEs

When undertaking a verification check of capacities derived from shake-table testing, design loads can be derived from TS1170.5 using the horizontal design earthquake action on a part,  $F_{ph}$ , which is equivalent to the horizontal force imposed by an earthquake that needs to be resisted by the NSE. This is computed using Equation C-3:

$$F_{ph} = \frac{C_p(T_p)}{\Omega_p} R_p W_p \quad (\text{Eqn. C-3})$$

Where:

- $R_p$  is the part risk factor, as summarised in Table B-2 of the NSE CoP;
- $W_p$  is the weight of the part; and  $\Omega_p$  is the part reserve-capacity factor, which considers the ratio of the likely strength to the design strength.
- $C_p(T_p)$  is the design response coefficient for parts and components, calculated using Equation C-4:

$$C_p(T_p) = PGA \left[ \frac{C_{Hi}}{C_{str}} \right] \left[ \frac{C_i(T_p)}{C_{ph}} \right] \quad (\text{Eqn. C-4})$$

Where:

- $C_{Hi}$  is the floor-height coefficient, describing the how much larger the demands felt at the floors are compared to the ground;
- $C_{str}$  is the structural-nonlinearity-reduction factor, describing how the acceleration movement of the floors reduces in strong earthquakes due to nonlinear structural response;
- $C_i(T_p)$  is the part or component spectral-shape coefficient, describing how a flexible NSE moves more when the NSE period is close to a period of the building itself. Rigid NSEs do not experience this so the value is 1.0;
- $C_{ph}$  is the part-response or component-response factor, describing how a flexible NSE can be designed for lower strength requirements if the NSE can develop nonlinear response (e.g: through bolt slip, permanent deformation, or other).

Table C-1 recommends some values for the parameters used in Eqn. C-4, as well as stating where in Section 8 of TS1170.5 the values can be found.

Note that the references to TS1170.5 are based on the draft technical specification DZ TS1170.5:2024 and final revisions to numbering and content will likely occur in the final release.

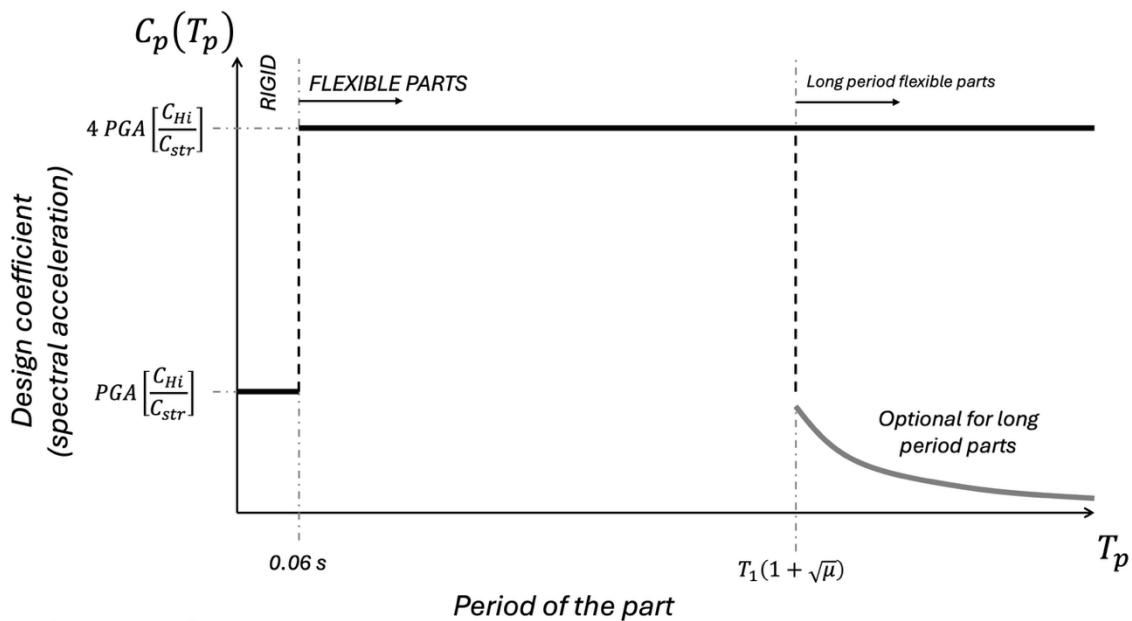


Figure C-2: Design response spectrum of seismic loads on parts connected to building floors derived using the Parts and Components section of TS1170.5.

#### C.4.1.5. Upper Limits for Design Seismic Loading for Test Comparison

TS1170.5 provides an upper limit of design seismic loading that a given acceleration-sensitive NSE may experience as a horizontal force. This can be divided by the weight of the NSE itself to give the maximum acceleration likely to occur based on a peak floor acceleration, as in Eqn. C-5:

$$\frac{F_{ph}}{W_p} = \frac{7.5PGA}{\Omega_p} R_p \quad (\text{Eqn. C-5})$$

This assumes that  $C_p(T_p)$ , from Eqn C-4, is taken using:

- $C_{Hi}$  of 3.5, the least favourable amplification of *PFA* to *PGA* taken at roof level;
- $C_{str}$  of 1.3, assuming some nonlinearity from site-soil interaction, other NSEs, (etc.);
- $C_i(T_p)$  of 4.0, the amplification of the response of a flexible NSE compared with *PFA*;
- $C_{ph}$  of 1.4, assuming some source of nonlinearity in the NSE such as bolt slip.

The design horizontal force is indexed to the peak ground acceleration, *PGA*, which varies based on the local seismic hazard, soil class, and design limit state (specified against the annual probability of exceedance, *APoE*). Although this considers some nonlinearity which may not be directly observed in a test, this upper limit applies to the design force and can therefore be directly compared with the spectral acceleration from testing.

The upper limit of a flexible NSE mounted anywhere within a building, considering  $R_p$  of 1.0 and the worst-case soil class at each limit state for the most populated areas of New Zealand and the nationwide worst case, is given in Table C-2. Other cases are derived by changing the parameters listed in Eqn. C-4, as specified in the caption of Tables C-3, C-4 and C-5.

**Table C-2: Upper limit design force  $F_p / W_p$  for flexible NSEs anywhere in a building for major centres in New Zealand.  $R_p = 1.0$ , least favourable soil class. Compare these demands with 5% damped spectral acceleration from testing.**

Limit State	SLS1	SLS2, IL4	ULS, IL2	ULS, IL3	ULS, IL4
APoE	1/25	1/500	1/500	1/1000	1/2500
Whangārei	0.23 g	1.26 g	1.05 g	1.40 g	1.95 g
Auckland	0.23 g	1.26 g	1.05 g	1.40 g	1.95 g
Tauranga	0.45 g	1.56 g	1.30 g	1.70 g	2.30 g
Hamilton	0.23 g	1.26 g	1.05 g	1.40 g	1.95 g
Napier	1.13 g	4.08 g	3.40 g	4.75 g	7.20 g
Palmerston North	1.20 g	4.62 g	3.85 g	5.20 g	7.50 g
Wellington	1.35 g	5.46 g	4.55 g	6.25 g	8.95 g
Nelson	0.90 g	3.00 g	2.50 g	3.25 g	4.60 g
Christchurch	0.75 g	2.58 g	2.15 g	2.80 g	3.80 g
Queenstown	0.75 g	2.58 g	2.15 g	2.75 g	3.80 g
Dunedin	0.45 g	1.68 g	1.40 g	1.80 g	2.55 g
Nationwide max	<b>1.35 g</b>	<b>6.30 g</b>	<b>5.25 g</b>	<b>7.25 g</b>	<b>10.60 g</b>

Further upper limits can be derived by changing the parameters in Equation C-4, as specified in the caption of the corresponding case. The relevant checks against test parameters are indicated.

**Table C-3: Upper limit design force  $F_p / W_p$  for flexible NSEs mounted at ground level ( $C_{Hi} = 1.0$ ,  $C_{str} = 1.0$ ,  $C_i(T_p) = 2.5$ ,  $C_{ph} = 1.25$ ) for major centres in New Zealand.  $R_p = 1.0$ , least favourable soil class. Compare these demands with 5% damped spectral acceleration from testing.**

Limit State	SLS1	SLS2, IL4	ULS, IL2	ULS, IL3	ULS, IL4
APoE	1/25	1/500	1/500	1/1000	1/2500
Whangārei	0.06 g	0.34 g	0.28 g	0.37 g	0.52 g
Auckland	0.06 g	0.34 g	0.28 g	0.37 g	0.52 g
Tauranga	0.12 g	0.42 g	0.35 g	0.45 g	0.61 g
Hamilton	0.06 g	0.34 g	0.28 g	0.37 g	0.52 g
Napier	0.30 g	1.09 g	0.91 g	1.27 g	1.92 g
Palmerston North	0.32 g	1.23 g	1.03 g	1.39 g	2.00 g
Wellington	0.36 g	1.46 g	1.21 g	1.67 g	2.39 g
Nelson	0.24 g	0.80 g	0.67 g	0.87 g	1.23 g
Christchurch	0.20 g	0.69 g	0.57 g	0.75 g	1.01 g
Queenstown	0.20 g	0.69 g	0.57 g	0.73 g	1.01 g
Dunedin	0.12 g	0.45 g	0.37 g	0.48 g	0.68 g
Nationwide max	<b>0.36 g</b>	<b>1.68 g</b>	<b>1.40 g</b>	<b>1.93 g</b>	<b>2.83 g</b>

Upper limits for rigid NSEs ( $T < 0.06s$ ) given in Tables C-4 and C-5 should be compared with the zero-period spectral acceleration (i.e.:  $PFA$  in-building or  $PGA$  at ground level).

**Table C-4: Upper limit design force  $F_p / W_p$  for rigid NSEs ( $C_i(T_p) = 1.0$ ,  $C_{ph} = 1.0$ ) anywhere in a building for major centres in New Zealand.  $R_p = 1.0$ , least favourable soil class. Compare these demands with peak floor acceleration from testing.**

Limit State	SLS1	SLS2, IL4	ULS, IL2	ULS, IL3	ULS, IL4
APoE	1/25	1/500	1/500	1/1000	1/2500
Whangārei	0.08 g	0.45 g	0.38 g	0.50 g	0.70 g
Auckland	0.08 g	0.45 g	0.38 g	0.50 g	0.70 g
Tauranga	0.16 g	0.56 g	0.47 g	0.61 g	0.83 g
Hamilton	0.08 g	0.45 g	0.38 g	0.50 g	0.70 g
Napier	0.40 g	1.46 g	1.22 g	1.71 g	2.58 g
Palmerston North	0.43 g	1.66 g	1.38 g	1.87 g	2.69 g
Wellington	0.48 g	1.96 g	1.63 g	2.24 g	3.21 g
Nelson	0.32 g	1.08 g	0.90 g	1.17 g	1.65 g
Christchurch	0.27 g	0.93 g	0.77 g	1.01 g	1.36 g
Queenstown	0.27 g	0.93 g	0.77 g	0.99 g	1.36 g
Dunedin	0.16 g	0.60 g	0.50 g	0.65 g	0.92 g
Nationwide max	<b>0.48 g</b>	<b>2.26 g</b>	<b>1.88 g</b>	<b>2.60 g</b>	<b>3.81 g</b>

**Table C-5: Upper limit design force  $F_p / W_p$  for rigid NSEs mounted at ground level ( $F_p / W_p = PGA / \Omega_p$ ) for major centres in New Zealand.  $R_p = 1.0$ , least favourable soil class. Compare these demands with peak floor acceleration from testing.**

Limit State	SLS1	SLS2, IL4	ULS, IL2	ULS, IL3	ULS, IL4
APoE	1/25	1/500	1/500	1/1000	1/2500
Whangārei	0.03 g	0.17 g	0.14 g	0.19 g	0.26 g
Auckland	0.03 g	0.17 g	0.14 g	0.19 g	0.26 g
Tauranga	0.06 g	0.21 g	0.17 g	0.23 g	0.31 g
Hamilton	0.03 g	0.17 g	0.14 g	0.19 g	0.26 g
Napier	0.15 g	0.54 g	0.45 g	0.63 g	0.96 g
Palmerston North	0.16 g	0.62 g	0.51 g	0.69 g	1.00 g
Wellington	0.18 g	0.73 g	0.61 g	0.83 g	1.19 g
Nelson	0.12 g	0.40 g	0.33 g	0.43 g	0.61 g
Christchurch	0.10 g	0.34 g	0.29 g	0.37 g	0.51 g
Queenstown	0.10 g	0.34 g	0.29 g	0.37 g	0.51 g
Dunedin	0.06 g	0.22 g	0.19 g	0.24 g	0.34 g
Nationwide max	<b>0.18 g</b>	<b>0.84 g</b>	<b>0.70 g</b>	<b>0.97 g</b>	<b>1.41 g</b>

#### C.4.1.6. Generic Application of Shake Table Test Results for Verification

Results from any shake table test may be used to qualify the capacity of a test specimen under the following generic framework.

##### ***Rigid NSEs***

Where the NSE (considered as a system with seismic restraint) has a sufficiently low vibrational period (less than 0.06 s) or high natural frequency (more than 16.7 Hz) it is thought to experience the same maximum demand as that of the floor where it is connected. Accordingly, the capacity of the NSE can be taken with reference to the peak acceleration of the table and compared with the demands for rigid NSEs in TS1170.5 (i.e.:  $C_i(T_p)$  of 1.0).

##### ***Flexible NSEs***

Where the NSE (considered as a system with seismic restraint) is not deemed rigid, the peak response of the NSE will not directly correlate to the peak table acceleration. It will instead depend on the properties of the input motion, especially the frequency content. Where available, the full acceleration time record of the table should be used to generate a 5%-damped acceleration response spectrum, from which the spectral acceleration is taken as the median of values over  $0.95 T_p$  to  $1.05 T_p$ , where  $T_p$  is the identified natural period of the NSE from dynamic identification (e.g.: sine sweep or white noise motions). Where the acceleration record or dynamic identification information are not available, such as in a brief test report, the peak acceleration of the table may be used but should be compared with the demands for flexible NSEs in TS1170.5 (i.e.:  $C_i(T_p)$  of 4.0 or  $C_i(T_p)$  of 2.0 if applying NZS1170.5).

#### C.4.2. Testing protocols for static cyclic testing

New Zealand Standards do not refer to any specific loading protocol for drift sensitive NSEs, such as partition walls and claddings. 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; 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 strongly recommended. 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).

## C.5. Movement Joints

### C.5.1. Description

Seismic movement joints are used when the NSE is required to accommodate a movement triggered by a seismic event such as movement between separate building structures and/or floors (inter-story drift, fixed-up vs. fixed-down, crossing base isolation plane, crossing between buildings). Typical seismic movement joints include:

- Flexible hose connections in piping systems
- Flexible duct connections in ducting systems
- Cable loops in electrical systems
- Deflection head tracks in partitions,
- Wall to wall joints in partitions
- Wall to ceiling movement joints
- Wall/floor/ceiling joints for base isolation plane interfaces

### C.5.2. Design Methodology

Movement joints should be designed to accommodate SLS1 movements as a minimum requirement.

Flexible connections should be selected to suit the movement requirements of the system and the size of the movement being accommodated.

A system designed to meet SLS1 performance requires, at a minimum, a seismic movement joint designed or selected to accommodate SLS1 movements. A requirement to accommodate SLS2 movements only exists if the system is required to maintain post-disaster functionality (i.e. operational continuity), however clients may choose to achieve better than minimum Building Code performance and seek to achieve partial functionality at DCLS or SLS2 performance for IL2 and IL3 buildings in which case the movement joint must accommodate DCLS/SLS2 movements.

Systems containing hazardous substances (such as steam pipes, gas pipes, high-temperature hot water pipes, etc.) should be designed to remain essentially undamaged following ULS movements due to the risk to occupants from the leakage of hazardous materials.

### C.5.3. Performance Characterisation

**Table C-6: Seismic performance characterisation of movement joints.**

Engineering Demand Parameter	Performance State	Performance Description	Design Limit State	Recommended Criteria or Design Limit
Movement	Relative movement	Onset of damage	SLS1*	Select element to accommodate movement at design limit state
		No damage or leakage that impacts functions for operational continuity	DCLS / SLS2	Select element to accommodate movement at design limit state
		Loss of support for general NSE or leakage of hazardous substances	ULS	Select element to accommodate movement at design limit state

#### **C.5.4. Performance Considerations**

The following describes key considerations for the design of movement joints:

- When defining the movement allowance for flexible connections, it is important to consider whether the component should have a P6 classification, which is where the consequential damage caused by failure of the component is disproportionately great. For detailed guidance on Part Classification, refer to NZS 1170.5 (TS1170.5 when issued). One example includes leakage from a water system which could damage equipment, components and finishes below. The part risk factor  $R_p$  is the mechanism for which SLS1 displacements are amplified to account for higher consequential damaged.  $R_p$  is determined based on a doubling of  $R_u$ . However, it is only to be applied to the SLS1 limit state, i.e. SLS1 displacements.
- It is recommended to consider access to the movement joint and connections to the movement joint for inspections after events.
- If movement is to be accommodated by an articulating joint, it is important to understand the path of travel or movement of the joint during an event to accommodate clearances for this movement.

#### **C.5.5. Reference Documentation**

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

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

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

## C.6. Seismic Design of Lightweight Non-Load Bearing Partition Walls

### C.6.1. Description

Lightweight non-loadbearing 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 non-loadbearing 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

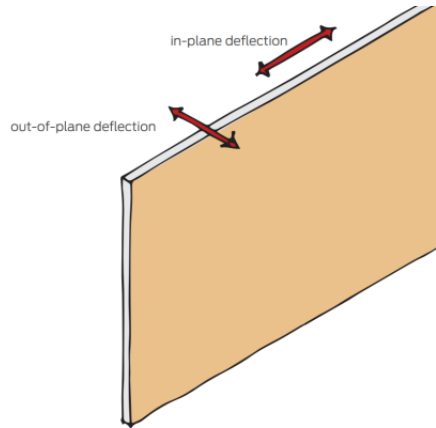
Partition seismic design should consider both the in-plane and out-of-plane earthquake demands on the partition.

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-3: Design actions on partition walls (AWCI, 2018)**

Out of Plane (Leaning)	Racking (in plane)	Sliding (in plane)
<p>A cross-sectional diagram showing a partition wall leaning away from its vertical position. The wall is supported by a base and a top track. A person is shown standing next to the wall for scale.</p>	<p>A cross-sectional diagram showing a partition wall that has distorted into a parallelogram shape, indicating racking. The wall is supported by a base and a top track. A person is shown standing next to the wall for scale.</p>	<p>A cross-sectional diagram showing a partition wall that has shifted horizontally along its base. The wall is supported by a base and a top track. A person is shown standing next to the wall for scale.</p>

**Figure C-4: Partition movements (Health NZ, 2024)**

### C.6.3. Performance Characterisation

**Table C-7: 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 <sup>1</sup>
		Minor damage to linings, e.g. an acceptable level of fire rating is maintained	DCLS / SLS2	H/150 at mid-height <sup>2</sup>
		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 <sup>7</sup>	SLS1	0.2-0.4% drift <sup>2,3,4,5</sup>
		Minor damage to linings	DCLS	0.5% drift <sup>3,5</sup>
		Minor damage to linings, e.g. an acceptable level of fire rating is maintained	SLS2	0.4-0.7% drift <sup>3,5,6</sup>
		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 studed 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.

[6] – Designers should consider the wall functionality, and wall finishes to determine the Design Limit State. For example, damage to partition walls that have tiles over a membrane can cause disproportional damage to the building post-earthquake.

[7] – For partitions that have a watertightness functionality (e.g. wet rooms, bathrooms) achieving the Design Criteria for SLS1 is expected to meet the criteria for DCLS. It is noted that wall types with gaps to the edges are not considered appropriate for these types of walls.

#### C.6.4. Performance Considerations

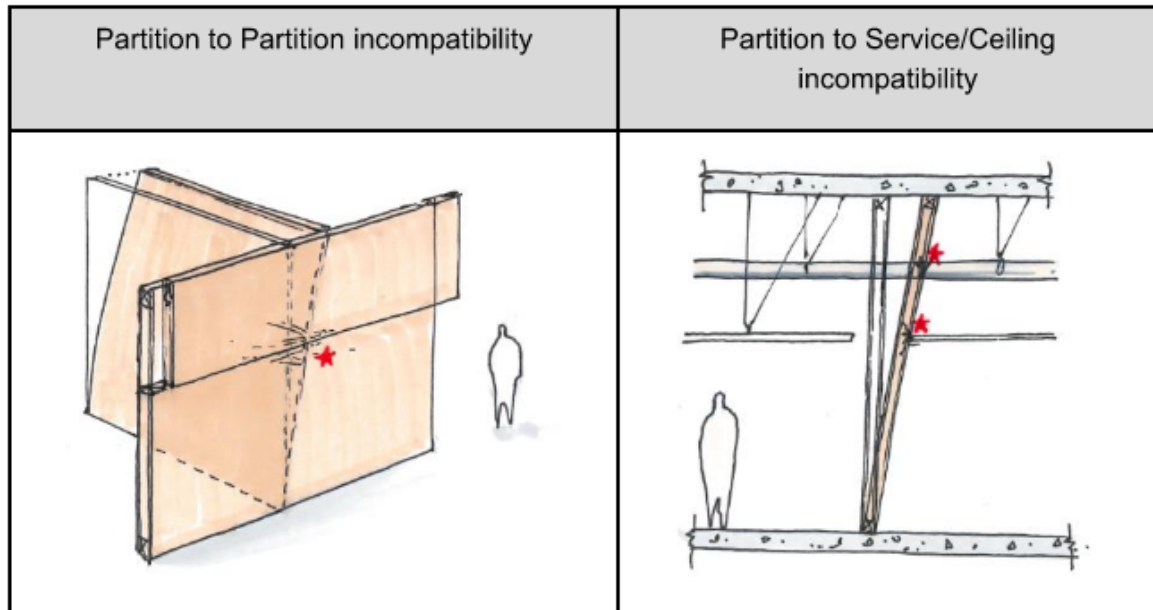
The following describes key considerations for the design of partitions walls:

- 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, airtightness, 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, and their responsibilities:
  - 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, who will locate the seismic restraints for partial height partition walls in the building model and coordinate clashes with other disciplines etc. to avoid contradictions in design information.
  - NSE Seismic Designer: Responsible for the seismic design of partitions and their restraint including overall coordination of partition seismic performance. Refer to Architect description above for responsibilities that need to be agreed between the Architect and the NSE Seismic Designer.
  - Structural Engineer: Responsible for assessing building drifts, interface with structure and impact of the structural response on partition wall performance.
  - Building Services Engineer: Interface with services penetrating partitions. Review details of all building services components which penetrate partitions to ensure the penetration details achieve the performance requirements for the building services components.
  - Fire Engineer: Responsible for ensuring the fire performance requirements of partitions. This includes review of partition details to ensure that if operational continuity is required that the passive fire performance will be maintained after the SLS2 seismic event.
  - Acoustic Engineer: Responsible for acoustic performance requirements of partitions.

- Ceiling Designer: Responsible for the interface of the partitions with the ceilings. The ceiling type and its coordination are often handled 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.
- It is common for partitions around risers and stairwells to be full-height fire walls and, consequently, careful consideration of detailing of the partition walls in these locations is required to meet the required design criteria for the various performance states.
- Consider the top detail for full height fire and acoustic partition walls. Partitions built to the underside of double tee or profiled metal deck flooring systems can be more challenging to build and achieve fire rating and acoustic compliance than slabs with flat soffits. The partition wall design should also allow for movement of structural elements, e.g. main floor beams. Lowering the deflection head below the flanges of double tees is one strategy to simplify the seismic movement zone.
- 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. If ceilings are restrained by the partitions, it is important to ensure coordination with the partition designer.
- 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<sup>2</sup> 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<sup>2</sup> for moderate shelving to 50kg/m<sup>2</sup> for full-height shelving or bookcases.

- Detailing and wall finishes can affect the seismic performance of the partitions. This includes situations where additional linings and finishes are added to the partition wall that reduce the flexibility of the partition. For example, the recommended criteria for in-plane drift damage in Table C-7 would not be applicable to brittle linings.
- 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.
- Consider estimated drift of the building and non-loadbearing wall systems that are appropriate to achieve performance requirements for the drift. Early conversation and coordination with the Building Services Engineer is required if slip joints (either above ceiling or at connection to floor above) are considered.
- 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.
- Any services that enter a partition wall should consider what part of the structure the service is moving with relative to the partition wall and appropriate flexibility provided for SLS1 movements. If the service is passing between upper and lower portions of a partition wall it is necessary to slot the deflection head or top plate to accommodate in-plane movement.
- 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).
- All disciplines should consider minimising penetrations through full-height fire and acoustic walls. The best result will be achieved when this is considered from concept design.
- 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.
- Detailing of partition corners and intersections need specific attention. It is important that the design provides out-of-plane support to the top of the wall while that support must not interfere with the in-plane sliding of a perpendicular partition wall.
- Bracing elements that support the tops of non-loadbearing partitions need to be coordinated with items of in-ceiling services (ducts, pipework, cable trays and vertical gravity hangers), structure and gravity and seismic restraints for ceilings.
- Consider the impact of doors in partitions. Closed doors have greater stiffness than plasterboard partitions and this can lead to damage to the plasterboard linings and residual drift of the partition can result in doors that are difficult to open without considerable force. Consider the use of movement joints in the partition wall to allow for the differential movement between the door and associated framing and the remainder of the partition.
- Gaps around fire doors are smaller than typical doors and therefore there is a higher risk that drift during the earthquake and residual drift will jamb fire doors closed.
- In-plane racking requirements should include interactions at return wall intersections, as shown in Figure C-5.
- Services and/or structural elements passing through partitions need to be able to accommodate inter-storey movements, as shown in Figure C-5. 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.



**Figure C-5: 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)

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## 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

Ceilings direct fixed to the structure, e.g. via battens fixed to timber trusses, and bulkheads are excluded from this guidance.

### C.7.2. Design Methodology

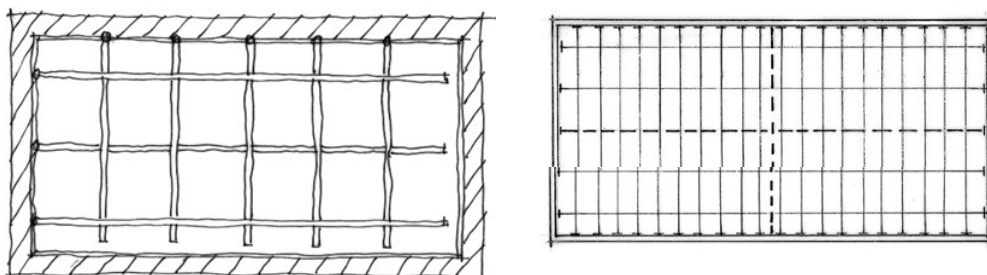
Suspended ceiling seismic design primarily considers the horizontal acceleration of the ceiling and the transfer of these forces back to the structure via the grid, connections, and bracing elements.

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.

The floating edges should consist of sliding joints with sufficient clearance between the ceiling member and the perimeter wall on the opposite edges to accommodate the resulting deflection from the inter-storey drift. Whether the perimeter has two sides connected with sliding joints or free (unconnected) joints will depend upon the seismic forces to be resisted; the capacity of the ceiling grid and perimeter fixing components to transfer load; the capacity of the perimeter fixings to accommodate lateral movement; and the capacity of the perimeter walls to resist lateral loads from the ceiling.

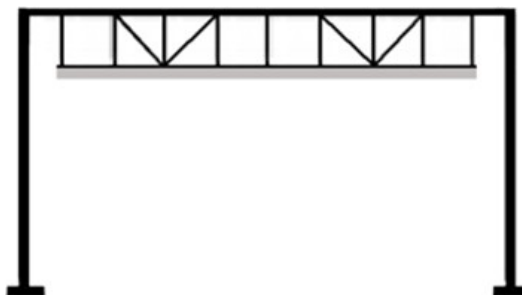
Ceilings can be fixed on all four walls surrounding the ceiling; however, these ceilings require a ‘seismic separation’ provided within the ceiling lining to allow for the deformation of the walls and building drift.



**Figure C-6: Perimeter restrained suspended ceiling. (Source: BRANZ, 2015)**

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.

The seismic bracing for this ceiling is designed to resist the ULS limit state seismic loads. The designer is to check that the stiffness of the seismically restrained ceiling is sufficient for the clearances provided to in ceiling services and adjacent building components.



**Figure C-7: Back-braced suspended ceiling. (Source: AWCI, 2020)**

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, 2020).

### C.7.3. Performance Characterisation

**Table C-8: 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 <sup>1</sup>
		Loss of support of ceiling	ULS	Seismic restraint of ceiling as per AS/NZS2785 <sup>1</sup>
Inter-storey Drift	Seismic gap movement requirements	Onset of damage to ceiling system	SLS1	Relative drift between floor and ceiling at Design Limit State <sup>2</sup>
		Damage to ceiling system that could lead to disruption in function	DCLS / SLS2	Relative drift between floor and ceiling at Design Limit State <sup>2</sup>
		Loss of support of ceiling	ULS	Relative drift between floor and ceiling at Design Limit State <sup>2</sup>

[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, 2020).

#### 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 which 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*'.
- 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.
- Partial height partitions should not be attached to the ceiling system (where partitions terminate just above ceiling level), such that the ceiling provides lateral restraint to the partition, unless the ceiling system is designed for such actions.
- The minimum services load allowance of 3kg/m<sup>2</sup> prescribed in AS/NZS2785 may not be sufficient, and advice should be sought from the services engineer for an appropriate project specific allowance.
- The list below outlines the key parties that may need to be involved in the development and coordination of ceiling seismic performance, and their responsibilities:
  - Architect: Generally responsible for specifying the type of ceiling, linings, etc. Works closely with the building services engineer to identify equipment with independent support and restraint within the ceiling, manage access hatches, and ensure the gravity support and seismic restraint for ducts, pipes, cable trays, etc., located within the ceiling void.

- NSE Seismic Designer: Responsible for the seismic design of ceilings and their restraint including overall coordination of ceiling seismic performance. Refer to Architect description above for responsibilities that need to be agreed between the Architect and the NSE Seismic Designer.
  - Structural Engineer: Responsible for communicating building drifts, interface with structure and impact of the structural response on suspended ceiling performance.
  - Building Services Engineer: Starting at the concept design phase, coordinates the layout of in-ceiling pipes, cables, ducts, service routes, equipment, risers, and plantroom locations to ensure adequate space in the ceiling void and identify any congestion zones. Throughout the design process, the building services engineer works collaboratively with the rest of the design team to resolve clashes between building services components, gravity supports, and seismic restraints.
  - Passive Fire Engineer: Responsible for reviewing fire-rated ceiling penetration details to ensure that passive fire performance is maintained after a seismic event. This includes evaluating all building services components that penetrate ceilings to ensure that the penetration details meet the required performance standards for both the components and the ceiling.
  - Acoustic Engineer: Responsible for coordination with disciplines where acoustic interfaces occur.
- 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.
  - Ceiling tile clips can help retain tiles in a ceiling against vertical movement (and the potential to be dislodged) due to wind pressures or seismic actions. These are used over egress routes, however, in practice these are often removed during maintenance works and not replaced due to the difficulty in accessing the ceiling void. Providing services hatches adjacent to all plant and equipment that may require maintenance and access can be useful to prevent the ceiling tile clips from being removed.
  - 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.
- Ceiling members, gravity hangers and seismic restraints need to be coordinated with in-ceiling services like ducts, pipework, cable trays and their vertical gravity hangers and seismic restraints as the seismic performance of the ceiling is reliant upon good seismic performance of the components within the ceiling void. A holistic consideration is required to achieve overall seismic performance of the building.
- 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 (2024) Code of Practice for Design, Installation and Seismic Restraint of Suspended Ceilings Association of Wall & Ceiling Industries (AWCI)

Badillo-Almaraz, H. Whittaker, A. S. Reinhorn, A. M., Cimellaro, G. P. (2006). Seismic Fragility of Suspended Ceiling Systems. Technical Report MCEER-06-0001

Ryan, K. L. (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.

Ryu, K. P., & Reinhorn, A. M. (2017). Analytical Study of Large-Area Suspended Ceilings. *Journal of Earthquake Engineering*, 23(4), 592–624.

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## C.8. Seismic Design of Linear Services

### C.8.1. Description

Linear services reticulate air, water, and electricity throughout buildings. They include HVAC ductwork, cable trays, plumbing and drainage. Linear services can be either suspended (hung from above) or supported from below. While the focus of seismic restraint of services often emphasises suspended linear services, much of these requirements apply to services supported from either above or below, so this section has been written such that it is applicable to both scenarios. For suspended equipment, such as fans, refer Section C.9. For floor and wall mounted equipment, such as air-handling units, refer Section C.10.

### C.8.2. Design Methodology

The design of linear 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 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 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-9: Seismic performance characterisation of linear services**

Engineering Demand Parameter	Performance State	Performance Description	Design Limit State	Recommended Criteria or Design Limit
Floor Acceleration	Lateral demands on linear services	Damage to system that could lead to disruption in function	DCLS / SLS2	Seismic restraint of service as per NZS4219 <sup>1</sup>
		Loss of support of service	ULS	Seismic restraint of service as per NZS4219 <sup>1</sup>

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 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-8: 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 ductility's 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

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.

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 are provided in Sections B.5 and C.4.

### C.9.3. Performance Characterisation

**Table C-10: 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 <sup>1</sup>
		Loss of support of service	ULS	Seismic restraint of service as per NZS4219 <sup>2</sup>
Inter-storey Drift	N/A	N/A	N/A	N/A

[1] – Refer Section C.4. 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 C.4.

### C.10.3. Performance Characterisation

**Table C-11: 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 <sup>1</sup>
		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 C.4 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-12: 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 <sup>1</sup>
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 <sup>2</sup>

[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.

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## 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.

Several 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-13: 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 <sup>1</sup>
		Minor damage but building remains water-tight	DCLS / SLS2	H/250 at mid-height <sup>2</sup>

		Loss of support of glazing system or loss of support of glass panes	ULS	Out of plane capacity of frame and fixings to structure <sup>3</sup>
Inter-storey Drift	In-plane racking of glazing system	Onset of damage, e.g. frame bowing, glass cracking	SLS1	Glass-to-frame clearance <sup>3</sup>
		Minor damage but building remains water-tight	DCLS / SLS2	2 x glass-to-frame clearance <sup>2</sup>
		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 <sup>3</sup>

[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-9), 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.

- Commercial exterior glazing is often validated by testing to AS/NZS4284, which sets out a method for assessing the performance of representative façade assemblies under simulated wind, water, and structural actions, including racking displacements at serviceability limit state and out-of-plane loading at ultimate limit state. AS/NZS4284 testing is not mandatory for all glazing systems; therefore, care is required when selecting systems to ensure they meet the project's specific performance requirements. Where systems have not been tested to AS/NZS4284 (or equivalent), performance is uncertain and may be inadequate for commercial applications. Following the Canterbury earthquakes, basic residential glazing systems were observed to perform worse than commercial systems in seismic events (Baird, 2011).

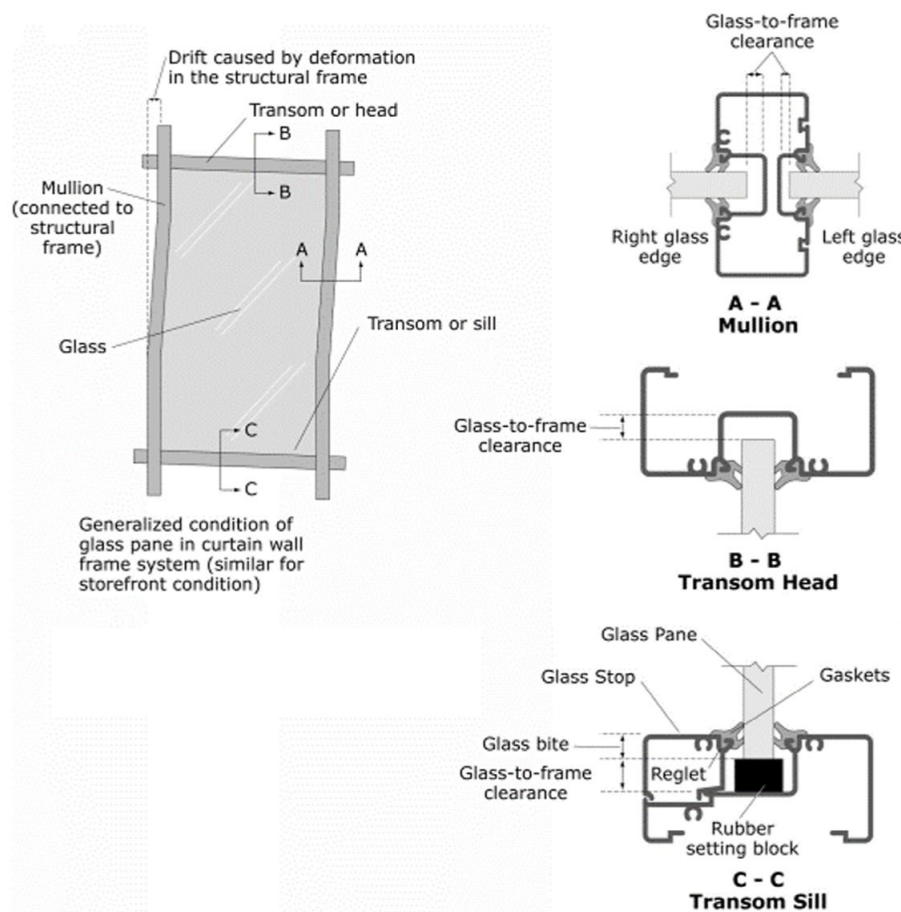


Figure C-9. Typical curtain wall indicating glass-to-frame clearance (FEMA E-74, 2012)

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## C.13. Seismic Design of Lifts

### C.13.1. Description

This section is for passenger carrying lifts that include the following components:

- Lift shaft.
- Lift car and related retaining devices.
- Guide rails.

Note that this section is not intended to provide detailed guidance for the design of lifts or replace existing building standards and guidelines. Rather this section is focused on the seismic design of lifts and intended to act as an overlay to existing standards and provide additional information and considerations for seismic design of lifts.

### C.13.2. Design Methodology

The NZ Building Code compliance pathway for the structural design of passenger lifts is not straight forward:

- NZBC D2/AS1 cites NZS4332 (1997) and BS EN 81-20 (2020) as Acceptable Solutions for the design of passenger lifts. NZS4332 has not been updated since 1997 so lift manufacturers are increasingly adopting EN 81-20 as their preferred compliance pathway.
- NZBC D2/AS1 notes BS EN 81-20 excludes the structural design of the lift installation and the structure supporting it. In particular BS EN 81-77(2022) is used for seismic design of lifts in Europe, however use of the standard in New Zealand requires designers to determine equivalent seismic demands.
- NZBC D2/AS1 requires the structural design of the lift installation to be undertaken by a suitably qualified designer, using NZBC B1/VM1 and BS EN 81-77.

It is recommended that seismic design of lifts is undertaken in accordance with NZBC D2/AS1 via the EN 81-20 compliance pathway described above, with the additional technical criteria detailed below. D2/AS1 cites BS EN 81-77:2013, however this standard has been superseded by BS EN 81-77:2022 and it is recommended the more recent standard be used.

#### C.13.2.1. Seismic Design Responsibilities

Seismic design actions (accelerations and inter-storey drifts) required for the design of lifts should be provided by the project structural engineer.

The structure that supports the lift (i.e. the structure required to support guide rails, lifting and hitching beams, car and counterweight butters etc.) is to be designed by the structural engineer with consideration of the accelerations and drift that will impact the seismic design of the lift(s).

The lift supplier is responsible for providing the structural engineer car and counterweight design loads, as well as other normal operating loads (including lifting beam loads, machine room loads, dynamic rail/pit loads etc.), as necessary for the structural engineer to design the supporting structure.

### C.13.2.2. Seismic Design of Lifts in Accordance with BS EN 81-77:2022

The ULS load combination for strength (refer BS EN 81-20:2020):

$$E_d = [1.2G + 1.5(\gamma_c Q_{bdg} + Q_{lift})]$$

where:

- $E_d$  = ULS design action effect.
- $G$  = permanent action or 'dead' action.
- $Q_{bdg}$  = imposed action due to building occupancy use.
- $Q_{lift}$  = supplied lift loads including dynamic or impact factors.

The 1.5 factor in Eqn 7-1 is only applied to live load for strength combinations and is not used for determining deflections or in seismic load combinations.

For seismic design of lifts in accordance with BS EN 81-77:2022:

- BS EN 81-77 'ad' should be replaced by TS1170.5 (as an alternative solution) parts loads computed using a part ductility factor,  $m_p$ , of 2.0 for ULS (this is in alignment with Annex B of BS EN 81-77 which specifies a behaviour factor  $q = 2$  which is comparable to a TS 1170.5 part ductility factor, and a ductility factor of 2 is considered reasonable for the stress design of the guiderails and is consistent with TS 1170.5).
- For SLS2/DCLS a part ductility factor,  $m_p$ , of 1.25 should be used.
- In accordance with BS EN 81-77 Cl. 6.8.1, guide rails, their joints and attachments should comply with BS EN 81020:2020 Section 6.7, and they should withstand the loads and forces generated by the design acceleration.
- ULS seismic design actions are to be communicated to the lift supplier by the project structural engineer. The lift supplier is to confirm the proposed lift system has the appropriate seismic qualification for these loads.
- SLS2/DCLS design limits (accelerations and drift) for critical elements to be advised by the lift supplier to the structural engineer to allow for continuity of operations.
- As per BS EN 81-77 Cl. 6.8.2.1, where lift seismic retaining devices are not provided, the maximum permissible deflections of the car guide rail system should comply with the requirements of BS EN 81-20:2020 Section 6.7, taking into account the load and forces generated by the lift system, including the forces generated by the design seismic acceleration.
- Guiderail midspan deflection (for a typical rail) should not be more than 12.5mm [CBC (2004) Section 1617.11.21].
- As per BS EN 81-77 Cl. 6.8.2.2, where seismic retaining devices are provided, refer to this clause for the permissible stresses and deflections during seismic events.
- As per BS EN 81-77 Cl 6.4.2, the depth of the seismic retaining device should be limited to avoid collision with guide rail attachments or other fixed devices, but long enough to guarantee a minimum overlapping length between the retaining devices and the guide rail blade of at least 5mm during an earthquake – the drift of the building should be checked to ensure this requirement is met.

- As per BS EN 81-77 Cl 6.4.2, the car structure and the retaining device should withstand the loads and forces imposed on them, including forces generated by the design acceleration, without permanent deformation, where the maximum clearance between the guide rail and retaining device should not exceed 5mm and the dimensions chosen should not cause accidental tripping of the safety gear during an earthquake.

### C.13.3. Performance Characterisation

**Table C-14: Seismic performance characterisation for lift systems**

Engineering Demand Parameter	Performance State	Performance Description	Design Limit State	Recommended Criteria or Design Limit
Floor Acceleration	Lateral demands	Guide rails, their joints and attachments	SLS1	No damage
		Lift supplier to identify critical elements for operation	DCLS / SLS2	Meet supplier requirements to maintain operation
		Loss of support of guide rails, their joints and attachments	ULS	Capacity of components and fixings to structure
Inter-storey Drift	Lateral deformation	Guide rails, their joints and attachments	SLS1	No damage that requires repair
		Lift supplier to identify critical elements for operation	DCLS / SLS2	Meet supplier requirements to maintain operation
		Guide rail mid-span deflection	ULS	12.5mm <sup>1</sup>
		Max clearance between guide rail and retaining device	ULS	5mm <sup>2</sup>

[1] – CBC (2004), Section 1617.11.21. California Building Code.

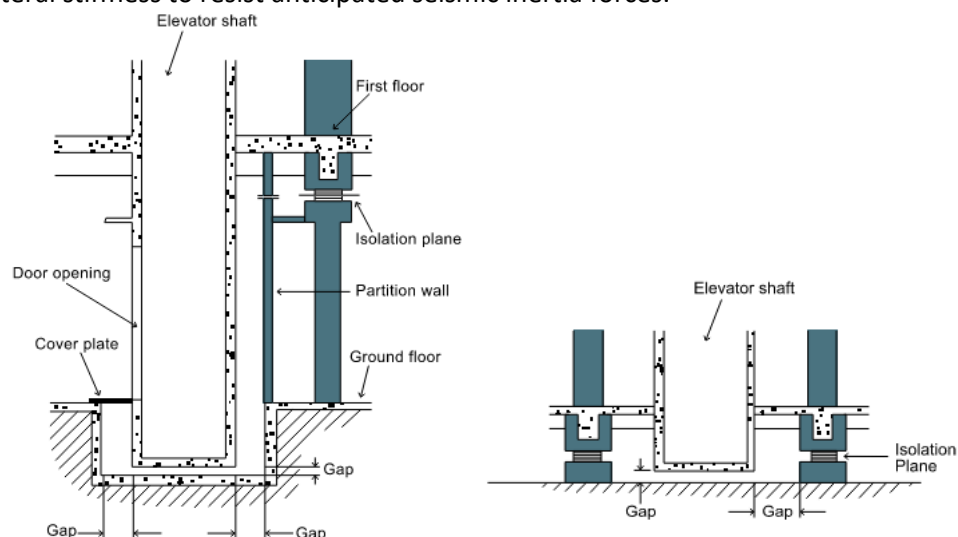
[2] – BS EN 81-77 (2022). Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Lifts subject to seismic conditions.

### C.13.4. Performance Considerations

The following considerations apply in the design, construction, assessment and testing of passenger lifts:

- Seismic switch and annunciator power supply: The seismic switch and the annunciator shall be connected to the essential electrical system.
- Go slow feature: After a seismic switch has been triggered, the elevator shall have the ability operate at a “go slow” speed until the elevator can be inspected. “Go slow” speed is defined as travel speed of not more than 0.76 m/s. [CBC (2022), Section 3009.1.3]
- Governor tail sheave sensor: For cable-operated elevators, an additional sensor switch shall be installed on the governor rope/sheave. The sensor shall prevent car movement when the governor tail sheave is dislodged from its normal position.

- Direction of Door Opening: Earthquake reconnaissance reports indicate there is a strong correlation between the direction of earthquake shaking, damage to rails and rail brackets, and inter-story drift locking up door movement. To enhance resiliency, it is recommended that door openings are oriented so that not all are parallel to one another. This will be difficult in most buildings since the elevators are typically on one side of a lobby or on opposite sides, so the doors are rotated at either zero degrees to another or 180 degrees to one another, and thus they all experience the same earthquake shaking direction. Orienting at least one elevator at 90 degrees to the other elevators means that it is expected that at least one elevator will experience a lower level of shaking in the key direction of interest.
- Observations from past earthquakes and industry feedback has found counterweight derailment due to rail distortion (FEMA, 2018) tends to be the primary seismic damage state for lifts in terms of magnitude of damage and repair cost. Porter (2016) provides a detailed description of damage to lifts in past US earthquakes. Through discussions with the industry, Griffiths & Chu (2023) identified a preliminary insight that other common failures in lifts (e.g. rail failure and realignment) are secondary to counterweight derailment.
- Lifts typically contain seismic movement sensors which detect if the counterweight displaces. Upon detecting movement that exceeds this limit, the sensor triggers safety mechanisms within the lift control system, stopping the lift at the nearest floor and opening the doors to allow occupants to exit. Such sensors are commonly activated during significant earthquakes and are effective at reducing damage to lifts.
- Lifts in base-isolated buildings:
  - Care is required when lift shafts extend through isolation planes in base isolated buildings to ensure the seismic isolation plane is maintained. Referring to Figure C-10, an approach that is commonly used is to hang the lift shaft from the superstructure. The lift shaft is also braced to the superstructure above to ensure it has adequate lateral stiffness to resist anticipated seismic inertia forces.



**Figure C-10. Examples of seismic isolation plane detailing at lift shafts (NZSEE, 2019)**



### **C.13.5. References Documentation**

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## C.14. Seismic Design of Contents & Wall Mounted Equipment

### C.14.1. Description

This section is for the seismic performance of contents and wall mounted equipment. Examples of seismic performance considerations for contents and wall mounted equipment include:

- To enable a building to continue to function following a seismic event.
- Movement, response or failure of contents and wall mounted equipment may be a life safety hazard.
- Movement of contents may block egress routes causing a life safety hazard.
- Movement of contents and wall mounted equipment may cause consequential damage to other building components.
- Contents and wall mounted equipment may be important due to the high value of the contents e.g. retail and data storage, museum and art gallery exhibits, hospital and laboratory equipment.

This section provides advice for the following types of contents and wall mounted equipment:

- Built-in joinery and furniture.
- Loose furniture and joinery items.
- Desking.
- Shelving systems
- Mobile compact shelving.
- Safes.
- Computers and monitors.
- Audio Visual Equipment.
- IT Server racks.
- Equipment including printers, copiers etc.
- Appliances.
- Loose contents like glassware, crockery etc.
- Artworks.
- Valuable or irreplaceable items.

This section excludes seismic performance considerations for contents and wall mounted equipment that contain hazardous substances.

### C.14.2. Design Methodology

The seismic restraint of contents and wall mounted equipment, also referred to as furniture, fixtures and equipment (FF&E) is not typically a requirement for building consent. Exceptions to this exist based on risk, for example the design of pallet storage racking requires a consent due to the height, size and permanence of it making it deemed a 'structure' as opposed to FF&E.

While the seismic design of contents does not have a consenting requirement, it is necessary to consider and manage the potential hazard that building contents present under the Health and Safety at Work Act. This considers building contents that may injure occupants during an earthquake as a workplace hazard and hence a PCBU has the responsibility to proactively manage this hazard. Seismically restraining contents is one method to manage this hazard. While not a cited Standard, the New Zealand Standard NZS4104 *Seismic Restraint of Building Contents* provides acceptable methods of restraining contents.

Reducing the risk of damage to contents during an earthquake is usually achieved by one of the following methods:

- Individual base isolation for the item.
- Bracing the item to the fitout, building fabric or structure.
- Where appropriate, allowing the item to slide

Reducing the risk of damage to wall mounted equipment during an earthquake is usually achieved by:

- Checking the design capacity for the full load path from the wall mounted equipment back to the building structure. Often the weak links are discreet connections within the load path.

### C.14.3. Performance Characterisation

**Table C-15: Seismic performance characterisation for contents and wall mounted equipment**

Engineering Demand Parameter	Performance State	Performance Description	Design Limit State	Recommended Criteria or Design Limit
Floor Acceleration	Lateral demands	Contents are not damaged	SLS1	No damage
		Response does not impact function of building	DCLS / SLS2	Meet supplier requirements to maintain operation
		Contents do not fall/fail to cause a life safety hazard <sup>1</sup>	ULS	Capacity of content and fixings to structure

[1] – Definition of life safety hazard, refer TS 1170.5 Section 8.1. Part category P2 & P3.

### C.14.4. Performance Considerations

The following considerations apply in the design and installation of contents and wall mounted equipment:

- Mobile compact shelving can impact structural response due to the dynamic loads that can develop during an earthquake. Generally, this type of shelving should be discouraged in the upper floors of buildings in areas of high seismicity.
- Many items of contents and some wall mounted equipment are provided and installed by tenants or users without the knowledge or input of the design team. Where the knowledge exists, advice should be given for these items. This could be in the form of a Tenant Design Guide.

It is recommended to follow the steps below when considering the seismic design of contents and wall mounted equipment:

- During the concept design phase, identify any unusual or important contents and wall mounted equipment that may impact function or cause a life safety hazard.
- Consider the best locations for large/heavy contents. The location can impact seismic response of the building, or seismic performance locally.

- Consider moving large/heavy contents to lower floors to reduce the seismic demands on the content.
- Consider the best location for contents and wall mounted equipment if the proposed location can impact the time to return the building to an operational state.
- Coordinate with the partition designer for all contents and wall mounted equipment that require wall restraint, to ensure the partition wall provides a robust load path.
- Consider the full load path from the item of content and wall mounted equipment to the building structure. Often the weak links are discreet connections within the load path, e.g. what is the capacity of fixings to a high value painting? How are the fixings connected to the art connected to the partition wall? Is there framing in the partition wall to connect to, not just the wall lining?
- Consider the deformation and movement of contents and wall mounted equipment to ensure contents/wall mounted equipment and other building components do not impact each other.
- The structural engineer can provide floor accelerations and appropriate amplification factors to determine seismic demands. Alternatively, calculate the horizontal and vertical seismic demand and amplification factor from TS1170.5.
- Yeow et al. (2018) provides estimates of dynamic coefficients of friction for common office furniture. These can be compared to the seismic design actions provided by the structural engineer or derived from TS1170.5.
- FEMA P-58 Appendix K can be used to calculate the sliding and overturning capacities of unrestrained building contents.

NZS4014 and FEMA E-74 provide examples of good detailing solutions which can be used to restrain various types of contents and wall mounted equipment.

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# APPENDICES

# Appendix A – References

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# Appendix B – Forms & Tools

## Appendix 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	<ul style="list-style-type: none"> <li>• Refer Section A.3 for key considerations in relation to defining the building performance requirements.</li> <li>• Key considerations for this phase include:               <ol style="list-style-type: none"> <li>a) Are the project requirements clear and understood by all disciplines?</li> <li>b) Does the Project Brief provide clarity regarding the business resilience requirements of the client/tenant?</li> <li>c) Are the seismic performance requirements for the building clear?</li> </ol> </li> </ul>
Concept Design	<ul style="list-style-type: none"> <li>• Refer to Section A.4.2.3 for the concept design flowchart and design tasks</li> <li>• Refer to Table A-3 for scope of tasks to be undertaken during Concept Design</li> <li>• Refer to Table A-5 for Roles &amp; Responsibilities for the tasks undertaken during Concept Design</li> <li>• Refer to Section A.5.9.1 for key interfaces and coordination between design disciplines</li> <li>• Refer to Section A.5.9.2 for interfaces that need to be coordinated across disciplines.</li> <li>• Development of a high-level Building Movement Strategy (refer Section A.4.1.2) with multi-discipline input.</li> <li>• Identification of critical services and components needed for operational continuity.</li> <li>• Key design tasks and considerations for this phase include:               <ol style="list-style-type: none"> <li>a) Coordination and collaboration between the disciplines is an important aspect of concept design.</li> <li>b) Consideration of inter-storey drifts and thermal expansion cannot be left until construction phase.</li> <li>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.</li> <li>d) Primary structural system options have been considered in the wider context of the building to achieve overall building</li> </ol> </li> </ul>

	<p>seismic performance requirements (architectural objectives and holistic seismic performance of building).</p> <p>e) Primary building services reticulation strategy</p> <p>f) Estimated weights and locations of heavy equipment</p> <p>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).</p>
<p>Preliminary Design</p>	<ul style="list-style-type: none"> <li>• Refer to Section A.4.2.4 for the preliminary design flowchart and design tasks</li> <li>• Refer to Table A-4 for scope of tasks to be undertaken during Preliminary Design</li> <li>• Refer to Table A-6 for Roles &amp; Responsibilities for the tasks undertaken during Preliminary Design</li> <li>• Refer to Section A.5.9.1 for key interfaces and coordination between design disciplines</li> <li>• Refer to Section A.5.9.2 for interfaces that need to be coordinated across disciplines.</li> <li>• Development of the multi-discipline Building Movement Strategy (refer Section A.4.1.2) with multi-discipline input</li> <li>• Key design tasks and considerations for this phase include:             <ul style="list-style-type: none"> <li>a) Coordination and collaboration between the disciplines is an important aspect of preliminary design</li> <li>b) Further development of the considerations of inter-storey drift implications for NSEs throughout the building</li> <li>c) NSE seismic restraint strategy/ies developed based on holistic consideration of disciplines, e.g. structure, services and architectural schemes</li> <li>d) NSE seismic load path into primary structure</li> <li>e) Thermal expansion identified on primary heating and cooling pipework (above dia. 100mm)</li> <li>f) Partition and ceiling strategy</li> <li>g) Design criteria should be frozen by the end of Preliminary Design</li> </ul> </li> </ul>
<p>Developed Design</p>	<ul style="list-style-type: none"> <li>• Refer to Section A.4.2.5 for developed design which references NZCIC guidelines for tasks, coordination and roles &amp; responsibilities to be undertaken during Developed Design</li> <li>• Refer to Section A.5.9.1 for key interfaces and coordination between design disciplines</li> <li>• Refer to Section A.5.9.2 for interfaces that need to be coordinated across disciplines.</li> <li>• Multi-discipline coordination and implementation of the Building Movement Strategy (refer Section A.4.1.2)</li> <li>• Key design tasks and considerations for this phase include:             <ul style="list-style-type: none"> <li>a) Coordination and collaboration between the disciplines is an important aspect of developed design</li> </ul> </li> </ul>

	<ul style="list-style-type: none"> <li>b) NSE Seismic restraint design and coordination</li> <li>c) Full services equipment table documented with Part Category identified for each component</li> <li>d) NSE seismic load path is confirmed where secondary structure required</li> <li>e) Structural &amp; operational integrity of services equipment confirmed to be able to meet seismic performance requirements for the building</li> <li>f) Spatial coordination considerations, particularly for heavily congested areas</li> </ul>
Detailed Design	<ul style="list-style-type: none"> <li>• Refer to Section 0 for detailed design which references NZCIC guidelines for tasks, coordination and roles &amp; responsibilities to be undertaken during Detailed Design. This section also provides the expected minimum documentation requirements for the NSE Seismic Designer.</li> <li>• Refer to Section A.5.9.1 for key interfaces and coordination between design disciplines</li> <li>• Refer to Section A.5.9.2 for interfaces that need to be coordinated across disciplines.</li> <li>• Confirmation that the detailing and components align with the Building Movement Strategy (refer Section A.4.1.2)</li> <li>• Key design tasks and considerations for this phase include: <ul style="list-style-type: none"> <li>a) Coordination and collaboration between the disciplines is an important aspect of detailed design</li> <li>b) Further coordination of seismic restraint layouts indicating location and orientation of restraints</li> <li>c) Seismic restraint details, both standard and bespoke</li> <li>d) Spatial coordination of seismic restraint solutions</li> <li>e) Design features report that summarises design criteria, design actions, assumptions, inputs, design solutions, and other design considerations for future reference</li> <li>f) The design of all building components required for coordination, costing and Building Consent should occur during the design phases.</li> <li>g) Provide documentation and coordination with the contractor, refer Section A.4.2.7</li> </ul> </li> </ul>
Design Elements during Construction	<ul style="list-style-type: none"> <li>• 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.</li> <li>• Refer to Section A.4.2.7 for construction phase design and coordination scope</li> <li>• Key design tasks and considerations for this phase include: <ul style="list-style-type: none"> <li>a) Design of construction phase items that require equipment selection or contractor input, e.g. equipment hold-downs, gravity dominant plant support frames</li> <li>b) Confirmation of operation and structural integrity of final plant and equipment selections</li> </ul> </li> </ul>



	c) Shop drawings (as needed)
Construction	<ul style="list-style-type: none"><li>• Coordination as installation progresses</li><li>• Construction observation</li><li>• Quality Control</li><li>• Documentation to be provided at Practical Completion</li><li>• Signoff</li></ul>



## 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 Bldg?
<b>ARCHITECTURAL COMPONENTS</b>			
	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 Bldg?
	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		
<b>BUILDING SERVICES COMPONENTS</b>			
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 Bldg?
	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 Bldg?
	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		
<b>CONTENTS</b>			
	Conveyor		
	Storage racks		
	Hazardous storage		
<b>OTHER</b>			