



CODE OF PRACTICE

for the seismic design and installation of
non-structural internal walls and partitions

JULY 2018



The purpose of this Code of Practice is to assist the construction industry, building consent authorities, architects, engineers, builders, installers and specifiers to comply with the New Zealand Building Code.

Association of Wall and Ceiling Industries of New Zealand Inc.

The Association of Wall and Ceiling Industries of New Zealand Inc. is a grouping of building industry organisations, including contractors, tradespeople, manufacturers and suppliers, established to represent the interests of members and their customers for interior wall and ceiling lining systems and related products.

The Association was formed in 1992 as the Interior Systems Association incorporating existing trade groups of suspended ceilings, plasterboard and fibrous plaster. The name of the association was changed in November 2005.

AWCINZ membership is open to any interested party.

For further information, please contact admin@awcinz.org.nz or go to www.awcinz.org.nz.

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This Code of Practice was prepared by a project team comprising:

John Keen	–	USG Boral	Greg Preston	–	Quake Centre, University of Canterbury
Nick Molcisi	–	Rondo			
Andrew Clemmet	–	Potter Interior Systems	Sahin Tasligedik	–	Quake Centre, University of Canterbury
Scott McPherson	–	Potter Interior Systems			
Scott Simpson	–	Tracklok	Matt Bishop	–	BVT Engineering
Hans Gerlich	–	Winstone Wallboards	Phil Mowles	–	BRANZ

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Author	–	Alide Elkink
Editor	–	
Design and layout	–	David Ronalds

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Foreword

The Canterbury earthquakes of 2010-2011 and the Wellington earthquake of 2016 highlighted the need to consider the design and installation of non-structural elements including internal partitions in buildings. The collapse of non-structural walls and partitions in an earthquake can injure or even kill people, block escape routes and prevent the continued use of buildings after an earthquake.

Where non-structural partitions are damaged but do not collapse, there is a likely loss of fire, acoustic or thermal rating of the elements. The loss of fire rating of internal partitions in particular can be potentially fatal to building occupants.

This new Code of Practice focuses on the seismic design and installation of non-structural internal walls and partitions so that they are able withstand light to moderate seismic movement without experiencing significant damage and so the building is able to have continued functionality. It also focuses on the roles and responsibilities of all groups involved in the design and installation of non-structural internal walls and partitions and the need for coordination between all groups.

The Ministry congratulates the Association of Wall and Ceiling Industries on its initiative in producing this Code of Practice. It is encouraging to see industry groups creating their own guidance and codes of practice to complement Ministry guidance and Acceptable Solutions and Verification Methods. Note, however, that this Code of Practice is not part of the Ministry's Acceptable Solutions, Verification Methods or guidance documents.

Improving the compliance and performance of non-structural internal walls and partitions will rely on greater awareness of responsibilities for design and installation from those involved in the construction industry. To this end, we hope that this Code of Practice will assist the industry with the procurement, design and installation of non-structural internal walls and partitions.

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1

Introduction

Background – the need for seismic solutions for non-structural internal partitions

Until recently the focus of earthquake engineering has been on the performance of the building structure and mitigation of structural damage to buildings but damage to non-structural building elements and the consequences of the damage have not been considered. However, both the Canterbury earthquakes of 2010-13 and the Wellington earthquake in November 2016, in which a significant number of buildings were unusable due to the damage to their non-structural systems despite suffering little structural damage¹, highlighted the need to consider the seismic design of non-structural elements in buildings.

There has been a large increase in the knowledge and understanding of seismic design for structural systems in the past 50 years, to the extent that modern buildings are able to withstand the effects of moderate to severe earthquakes and continue to perform well with regard to building functionality and operation and the life safety of building occupants.

At the same time, there has been little advancement on the seismic design of non-structural elements and almost no consideration given to the seismic design of interior partitions and walls. This has resulted in different levels of serviceability of buildings following seismic events, as was evident after both the Canterbury and the Wellington earthquakes. Following these earthquakes, it was found that while the structure of buildings may have suffered relatively low or minimal damage, the damage to the non-structural systems, such as collapsed ceilings, damaged partitions, fallen cupboards

and shelves, and computers and monitors tumbling from desktops, was often sufficiently severe to render buildings unusable.

Non-structural elements of a commercial building typically make up between 60-80% of the initial construction cost of the building so damage to these elements can result in a significant financial loss, both due the repair costs to damaged fixtures and fittings and the loss of revenue due to downtime to the business.

Surveys conducted following the Canterbury and Wellington earthquakes have shown that:

- over 50% of the costs associated with the Christchurch earthquakes, now estimated at over \$40 billion, have been attributed to non-structural damage, and
- the damage caused to non-structural elements in the BNZ building (constructed in 2009) in Wellington in the 2013 magnitude 6.5 earthquake, resulted in closure of the building for 6 months, took 15 months to get the building fully functional again and had an estimated cost of repair of \$10 million. It sustained extensive damage again in the 2016 earthquake and at present, the building's future is unknown².

Investigation into the construction cost distribution of components for various types of buildings (Taghavi and Miranda, 2003) shows that the costs for non-structural components in each of the building types is significantly higher than for the building structure or contents. Although these figures are from the USA, the relative building costs in New Zealand will be similar. The graph in Figure 1 shows typical building construction costs for three types of buildings. A report to the Canterbury

1 From: Design of low damage seismic drywalls in practical applications – Research paper by Ali Sahin Tasligedik, Ho-Hyung (Frank) Kang, Hans Gerlich, University of Canterbury Quake Centre, Christchurch, NZ.

2 From: BVT Engineering Professional Services at: <https://www.bvt.co.nz/articles/faq-seismic-restraint-of-non-structural-building-elements/>

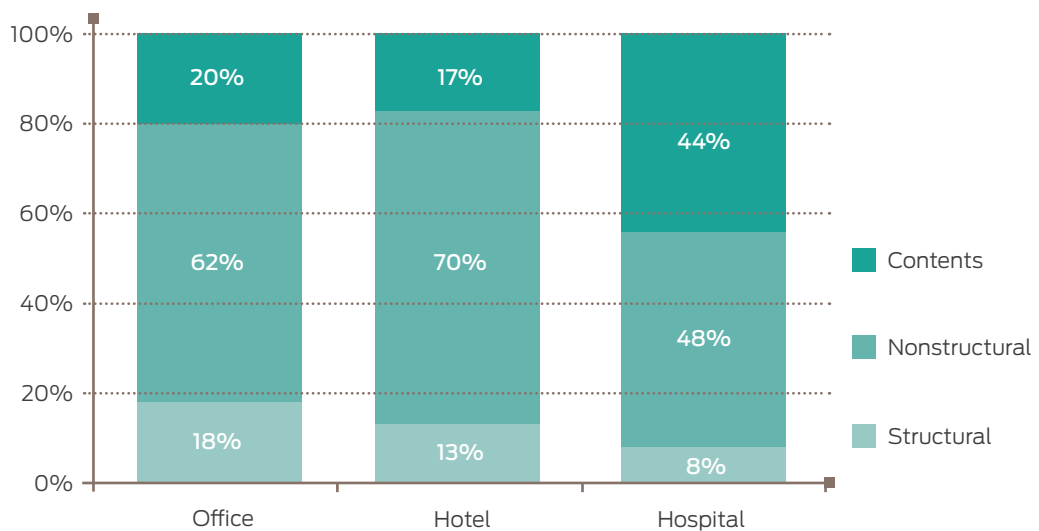


Figure 1: Cost breakdown of office buildings, hotels and hospitals

(Reference Taghavi and Miranda³)

Earthquakes' Royal Commission⁴ estimated that almost every building in Canterbury experienced non-structural damage of some type during the 2010–11 earthquakes. While the bulk of the damage and cost of repair was to non-structural elements such as building services (mechanical, electrical, HVAC, sprinklers) and external cladding systems, the Canterbury earthquakes also resulted in significant damage to non-structural partitions in commercial buildings.

Damage was particularly pronounced where non-structural partitions continued past floor levels, such as in vertical shafts and stairwells in multi-storey buildings, but damage also occurred to partitions fixed to the underside of suspended ceilings and to full height partitions that extended to the underside of the floor above. The type of damage observed included cracked sheet joints, crushed sheet edges, popped fixings, and in some cases substantial sheet fracturing and sheets that had been dislodged from frames. The level of damage that occurred to non-structural partitions represented a significant economic cost.

Of additional concern was the loss of functionality of the fire, acoustic or thermal ratings of partitions. Fire rated partitions in

particular must retain the rating during and following a seismic event. For example, a partition providing separation between an occupied space and a safe exit route from the building is required to be fire rated under the Building Act and the integrity of the fire rating must be maintained. It was observed following the earthquakes that the level of damage that occurred to partitions often meant they no longer had an effective fire rating. If the partition or wall is damaged and the fire rating compromised, the safety of building occupants will be at risk.

Consequences of partition failure

The consequences of partition failure are significant yet until recently, designing non-structural partitions and walls to be able to withstand seismic movement has not been considered necessary. In addition to the loss of the fire resistance rating of the partition, partition failure can present a falling hazard or block escape routes preventing occupants from leaving the building.

While they are subjected to the same levels of deflection and displacement, damage will generally occur to non-structural building elements at levels of building movement that cause little damage to the building structure.⁵

3 Taghavi, S. & Miranda, E. (Sept 2003). Response assessment of non-structural building elements. Peer Report 2003/05, Pacific Earthquake Engineering Research Centre, College of Engineering, University of California, Berkeley.

4 From Canterbury Earthquakes' Royal Commission reports at: canterbury.royalcommission.govt.nz

5 Taghavi, S. & Miranda, E. (Sept 2003). Response assessment of non-structural building elements. Peer Report 2003/05, Pacific Earthquake Engineering Research Centre, College of Engineering, University of California, Berkeley.

This is primarily due to the lack of seismic resistance of non-structural elements.

Non-structural partitions and walls are typically constructed with a monolithic, seamless and jointless finish and there are often long lengths of walls whose surfaces are unbroken by visible joints. This type of construction does not allow for any movement tolerance, particularly seismic movement.

There are three types of potential risk from the consequences of damage to non-structural partitions:

- danger to life safety – there is a likelihood that people may be injured or even killed
- property damage – as non-structural elements including non-structural partitions and walls account for approximately 80% of the initial construction costs of a commercial building, damage to non-structural elements can be significant
- functional loss – there may be significant post-earthquake downtime to the building function and operations that may result in business downtime or closure and both with a loss of income.

Reasons for a lack of seismic design

As the non-structural elements and components of a building are not part of the structural load path, they have tended to be overlooked in the building design and construction. Reasons for this include:

- poor coordination between the different parties involved in a building project
- poor understanding of each party's responsibilities
- poor procurement processes

- seismic performance and expectations for partitions is ambiguous and undefined
- a view that partitions are someone else's problem

Bringing about change

There are currently no industry standards or guidelines for the seismic performance of non-structural interior partitioning systems. Yet the building industry recognises that changes to the design and installation of non-structural internal partitions must occur. Factors that will help bring about changes include:

- involving all groups involved in a building project at the early stages of the project
- incorporating seismic design into all elements and components at the design stage
- educating building practitioners on the importance and need for seismic design of building elements and components
- educating building owners to understand the post-earthquake financial benefits of:
 - less or no downtime due to interior building damage
 - reduced costs of reparation
 - reduced insurance premiums if seismic restraint and low-risk construction is employed
- encouraging industry to incorporate seismic design in non-structural building elements.

Scope of the guidelines

This Code of Practice aims to provide standardised, industry agreed-upon solutions for the design and installation of internal partitions and walls that can withstand the effects of low to moderate earthquake events with no or minimal damage, and to:

- reduce the risk of injury caused by the failure of interior partition systems

- reduce the level of earthquake damage and the associated repair costs to interior partition systems
- provide an industry reference for installing non-loadbearing, internal partitions to meet required seismic performance limits
- provide consistent technical details and specifications agreed upon by the industry sector.

It will focus on best practice solutions for installing lightweight non-structural, plasterboard-lined and glazed partition systems that will:

- be able to withstand low to moderate earthquake events, and
- limit damage to partitions to minimise any loss of functionality so the building can continue to operate as intended.

This Good Practice Guidelines deals with lightweight, non-loadbearing partitions only. The term “partition” is generally used when referring to non-structural partitions and walls.

The solutions are intended to apply primarily in commercial and industrial situations but may be used in any non-structural partition system installation.

The focus is on the effects from low to moderate earthquake events as the damage to non-structural internal partition systems is of no consequence where a severe earthquake results extensive or total damage to the building structure and complete loss of building functionality.

Seismic solutions

This Good Practice Guidelines contains generic details of installation for non-structural,

plasterboard-lined and glazed internal partitions.

The plasterboard-lined, framed partition installation details are based on the results of testing carried out by Tasligedik et al at the University of Canterbury.

The glazed partition details are based on recommendations made by the glazing industry following observations of the types of damage that occurred during the Christchurch and Wellington earthquakes. However, it must be noted that the installation details for glazed partitions have not been tested and at this stage are recommendations for installation only.

Who is this GPG intended for?

This Good Practice Guidelines is intended to be used by:

- architects and designers
- engineers
- project managers
- contractors
- subcontractors
- building consent authorities
- interior systems suppliers and installers.

Who is involved in the publication?

It is a joint effort publication that has been brought together jointly by:

- the research community – University of Canterbury Quake Centre
- Ministry of Business, Innovation and Employment (MBIE)
- manufacturers and distributors – Winstone Wallboards, USG Boral, JSK Consulting Engineers, installers
- Association of Wall and Ceiling Industries (AWCI) members.

2

Overview of non-structural internal partitions

Internal partitions in commercial buildings are non-structural elements that provide separations within an occupancy or create divisions between occupancies in the building. Most internal partitions are non-structural, i.e. they are lightweight, non-loadbearing elements that do not contribute to the structural stability of the building.

Partitions between occupancies will have a fire rating and possibly an acoustic rating, and will be full height to the underside of the structure above. Partitions within occupancies may or may not have a fire or acoustic rating and often only extend to the underside of the suspended ceiling.

As an integral part of a building fit-out, partitions allow the layout of internal spaces to meet the specific requirements and configurations for the building occupants and contribute to the overall design, appearance and quality of the internal spaces.

Defining non-structural elements

A definition of non-structural elements, given in the MBIE Practice Advisory 19, is:

“Non-structural elements are those elements within a building that are not considered to be part of either the primary or secondary structural systems. Examples of non-structural elements include components such as ... light non-loadbearing partitions ...”

NZMP 4212: 1998 Glossary of building terms defines the terms as follows:

- an **element** is “Part of a building or structure having its own functional identity.”

- a **partition** is “Any wall dividing a floor area. A partition can be non-loadbearing and movable.”
- a **wall** is “A vertical construction 1) enclosing a building or structure, 2) dividing the internal space, or 3) serving as a fence.”

Current methods of construction

Non-structural partitions in commercial buildings generally consist of either:

- a solid partition system comprising a framed and lined construction,
- a glazed partition system, or
- a combination of the two.

Solid partition systems

Construction for framed and lined partitions consists of either light gauge steel or timber framing that is fully and rigidly fixed to the building structure and lined on both sides with a sheet lining material such as plasterboard, plywood* or a proprietary product to create a monolithic system.

**Note: Although other lining materials are also used with framed and lined partition systems, plasterboard is the most commonly used lining material, so this Good Practice Guidelines will refer to partitions with plasterboard lining. The installation of partition systems with other types of linings should use the same principles of installation.*

Partition framing consists of studs running between horizontal top and bottom plates. A fire or acoustic-rated partition has the top plate fixed to the underside of the structure above, either the floor slab, the roof structure or a structural beam. Where no rating is required,

6 From: Improving earthquake performance of non-structural elements: MBIE Practice Advisory 19 – Building Performance website at: <https://www.building.govt.nz/building-code-compliance/b-stability/b1-structure/practice-advisory-19/improving-earthquake-performance-non-structural-elements/>

the partition may extend to the underside of the suspended ceiling only. In the past the top plate was often fixed only to the ceiling so the partition had no lateral stability. Top plates of partial height partitions must be secured to the building structure using a seismic bracing or restraint system. There are proprietary bracing systems available for this purpose.

Bottom plates are fixed to the floor and studs run vertically between the top and bottom plates at regular spacings. End wall studs are fixed to the building structure such as a column, an external wall or a structural return wall or to another partition perpendicular to the stud framing being fixed.

Steel framing is more commonly used than timber framing for commercial construction and particularly high-rise construction, because of the lower weight of the framing, the ease of construction and the stability of steel compared to timber (i.e. timber moves significantly as a result of changes of moisture and humidity).

Steel framing consists of roll-formed, galvanised, 0.50 or 0.55 BMT gauge (G500 or G550), high tensile steel. It is available in thicknesses of 0.55, 0.75, or 0.95 mm and typical sizes are 78 or 90 mm wide by a range of depths between 35-47 mm.

Timber framing is generally pinus radiata, either untreated or treated to hazard class H1.2 in accordance with NZS 3640, and available in a range of sizes but most commonly 90 mm by 45 mm.

Sheet linings are fixed to both sides of the framing. Standard plasterboard is generally

10 mm thick but 13 mm and thicker sheets are available for fire and acoustic rated partitions. Standard sheet width is 1200 mm and sheet lengths range between 2400 to 6000 mm.

Specific use plasterboards are available for wet areas, or fire and acoustic-rated partitions. Additional layers of plasterboard may be installed to one or both sides of a partition to increase the fire and/or acoustic rating. The acoustic rating of a partition may also be increased by installing bulk insulating material between the studs or by using furring channels and resilient clips, creating a physical break across the partition by.

The plasterboard sheets may be fixed horizontally or vertically. Fixing is by gluing and screwing sheets to studs and top and bottom plates (and dwangs or nogs if used) at all edges and across the face of the sheets. Nails specifically designed for use with plasterboard may be used instead of screws. The sheet joints and fixings are plastered over to create a monolithic appearance and the whole system is rigidly fixed to the building structure.

Glazed partition systems

Glazed partitions are defined as either framed or frameless systems although in both cases aluminium framing is required to support the panes of glass.

A framed glazed partition system generally refers to a system where each sheet of glass is continuously supported at all four edges, i.e with top and bottom tracks and vertical mullions between each pane of glass. Transoms may sometimes be used to separate glass panes horizontally, generally as a design feature.

A frameless glazed partition system also requires continuous top and bottom tracks to support the glass, but vertical framing support is at the edges of the partition only. The vertical frames are fixed to the building structure, either a column or a wall, or fixed to non-structural partitions. The vertical joints between adjacent sheets of glass are simply butted and siliconed.

Glass panes may be full height, i.e. floor-to-ceiling, or partial height i.e. sill-to-ceiling. Glazed partitions may be a combination of both full height and partial height glass. The glass is typically 6-12 mm thick and must be toughened or laminated safety glass. It is available as clear, tinted, or partially or fully opaque and may be patterned in a variety of ways.

The extruded aluminium frames are available in a wide range of profiles and finishes including anodising and powdercoating. An anodised finish may be coloured or left the natural silver colour of the aluminium, while powdercoating is available in most paint colours. The frames generally hold the glass in place using glazing beads and gaskets, and wedges and blocks are used to support the glass.

Glazed partitions cannot be used where a fire-rated partition is required so they are only full height (i.e. to the underside of the building structure) where there is no suspended ceiling. If an acoustic-rated glazed partition is required, a double or 'twin' glazing system similar to IGU systems, is installed.

Types of seismic damage to non-structural partitions

Non-structural building elements such as partitions are damaged by earthquakes in a variety of ways, including as a result of:

- building deformation causing inter-storey drift
- impact between elements across separation or movement joints
- impact between adjacent non-structural elements.

Inter-storey drift

During an earthquake a building is subjected to movement in the same direction as the ground movement. However, while the base of a building moves with the ground there is a delayed response higher up the building, referred to as inertial delay. This results in different degrees of movement going up the height of the building relative to the movement at the base and the ground. The effect of the inertial delay is also amplified up the building so the higher up the building, the greater the degree of movement relative to the lower levels. As well as the height of the building, other factors that may also increase the effect of inertial delay and the associated amplification of movement are the building mass and the acceleration or severity of the shaking.

The lateral or sideways movement on a building during an earthquake causes vertical elements such as columns and walls to be deformed as they move slightly out of square, first in one direction then in the opposite direction. This movement is called inter-storey drift. The amplification of the movement going up the building means the amount of sideways movement is slightly different at each floor level.

Impact between elements across movement joints

Separation or movement joints are gaps between different parts of the building structure or between different buildings where they have

been connected internally, to allow independent movement from one another. In an earthquake, there is likely to be different rates of movement of different parts or elements of the building. If there is insufficient movement allowance, elements are likely to impact against one another causing them to be damaged.

In order to provide continued functionality of the building following an earthquake, the materials and finishes across movement joints must be able to accommodate the same degree of movement as the joint itself.

Impact between adjacent non-structural elements

In an earthquake, there will be different rates of movement between adjacent non-structural elements so if they are inadequately secured and too close to one another, they are likely to knock against one another and be damaged. This was a major cause of damage to buildings in the New Zealand earthquakes. Non-structural elements such as services pipes and ducting that were inadequately secured and in close proximity, pounded against one another causing damage to both. It was also observed that where services pipes and ducting passed through partitions with no allowance for movement around the opening, the partition was also significantly damaged.

Partition failure during the New Zealand earthquakes

The 2010/2011 earthquakes in Canterbury and the 2013 earthquake in Wellington highlighted the poor performance of many non-structural internal partitions in multi-storey commercial buildings. One of the most common observations was that although the building structure performed well, the non-structural

internal partitions often suffered damage that ranged from moderate to significant and required extensive reparation or complete replacement.

Typical partition damage was as a result of:

- in-plane movement, i.e. movement parallel to the wall that occurs as a result of storey drift (Figure 2). Damage included deformation of the framing and connection failure.
- out-of-plane movement, i.e. movement perpendicular to the wall due to storey drift or from floor deflections. Damage was typically to the connections at the top of the partitions, sometimes resulting in complete failure and overturning of the partition. This type of failure can endanger building occupants by causing injury and blocking egress routes as people attempt to leave the building.

The most significant damage occurred to partitions with large areas of plasterboard lining and where the linings were continuous past floor levels such as in vertical shafts and stairwells of multi-level buildings. Typical damage included cracked sheet joints, crushed sheet edges, popped fixings, fractured sheets, and sheets that had dislodged from the framing. The levels of damage meant that where partitions were fire rated such as between an exitway and an occupied space or where a pressure differential between spaces was required to control the movement of smoke, the fire resistance rating and therefore the safety of building occupants were potentially compromised.

Other types of damage that were observed included that many partition failures occurred due to a lack of adequate seismic restraint of partial height partitions to the building structure.

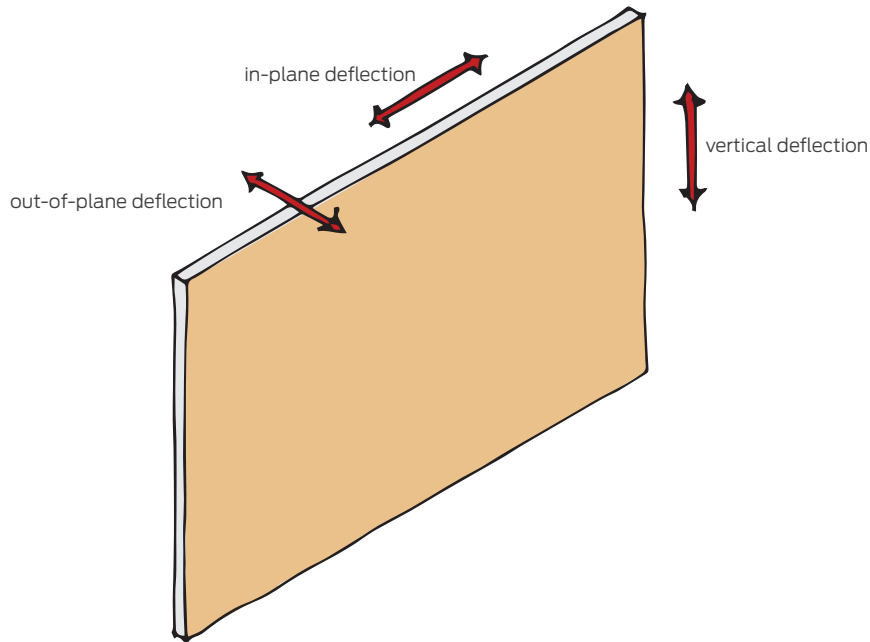


Figure 2: In-plane, out-of-plane and vertical deflections

It was noted that in even recently constructed buildings, partial height partitions are often installed without effective seismic restraint and in some situations, no seismic restraint at all. The damage that occurred highlighted the need for adequate seismic bracing.

Partitions that supported book or storage shelves or were used to provide lateral support for floor-supported storage shelves, equipment or other non-structural items, also fared particularly badly. The design of partitions does not generally consider the additional loads imposed on the partitions but following the earthquakes it was observed that partitions with heavy fixtures attached suffered more damage than partitions that carried no additional load. This is because a partition supporting a load

moves at a different rate and travels a greater distance in one direction before moving back in the opposite direction than the same partition without additional loading. This often results in a greater level of damage to the partition supporting additional loading.

Reasons for the lack of seismic restraint

While the structural engineer focuses on the structural design of a building, the non-structural elements such as internal partitions are not generally included in the structural engineer's brief. In fact, the design and installation of non-structural components typically occurs after the building consent documentation has been processed by the BCA and is often undertaken by the system supplier or the subcontractor.

This means that the non-structural partitioning system seldom undergoes a seismic design review or bracing installation check. And as BCAs do not require specific design or construction producer statements for seismic bracing of the non-structural partitioning systems, they are not generally provided.

There are a number of reasons for the lack of consideration for seismic restraint or building movement accommodation in non-structural partitioning, including:

- lack of understanding for the need for seismic restraint in non-structural partitioning
- seismic performance expectations are ambiguous or unspecified
- no engineering involvement as the structural engineer's responsibility is typically restricted to the building structure with little or no involvement in the design and monitoring of non-structural elements
- late involvement of non-structural partition supplier
- late selection of non-structural partition system often not occurring until after the building consent process has been completed and therefore not part of the approval process
- poor communication between the designer and the contractor
- poor tender and procurement processes, e.g. seismic restraint may be tagged out of a tender to allow a more competitive tender price but if the tag is not identified as being required, it may be omitted altogether
- when the focus is on initial capital cost not life cycle costs, so the continued functionality of the building after an earthquake event is not considered
- inadequate monitoring as non-structural partitions are typically installed later in the

building project when structural monitoring may no longer be occurring.

- new partitioning may be installed into an existing building without applying for a building consent, so there may be no oversight to ensure that adequate seismic restraint is also installed.

Research on non-structural partition performance during seismic events

Types of damage observed

Research⁷ was undertaken by the University of Canterbury on the seismic performance of plasterboard-lined (drywall) partition systems and the ability of the systems to withstand movement as a result of inter-storey drift. Testing included both timber and steel framed systems. The research found that although both types of framing systems suffered damage, the responses differed between the two. It was observed that:

- steel-framed partitions began to show signs of failure at 0.2–0.3% drift
- timber-framed partitions began to show signs of failure at 0.75% drift.

The types of damage observed also differed:

- Steel-framed partitions began to show signs of cracking vertically at the plasterboard sheet lining junctions and most of the subsequent damage occurred along these interfaces.
- Timber-framed partitions suffered plate anchor failure in shear particularly at the bottom corners, but significant shear stress at the upper corners was also observed. Although the partitions remained serviceable for a longer period at relatively low levels of inter-storey drift once the damage occurred, it was also greater. See Figure 3.

⁷ Research undertaken by A.S. Tasligedik, S. Pampanin and A. Palermo for the Civil and Natural Resources Engineering Department, University of Canterbury (VEESD 2013)

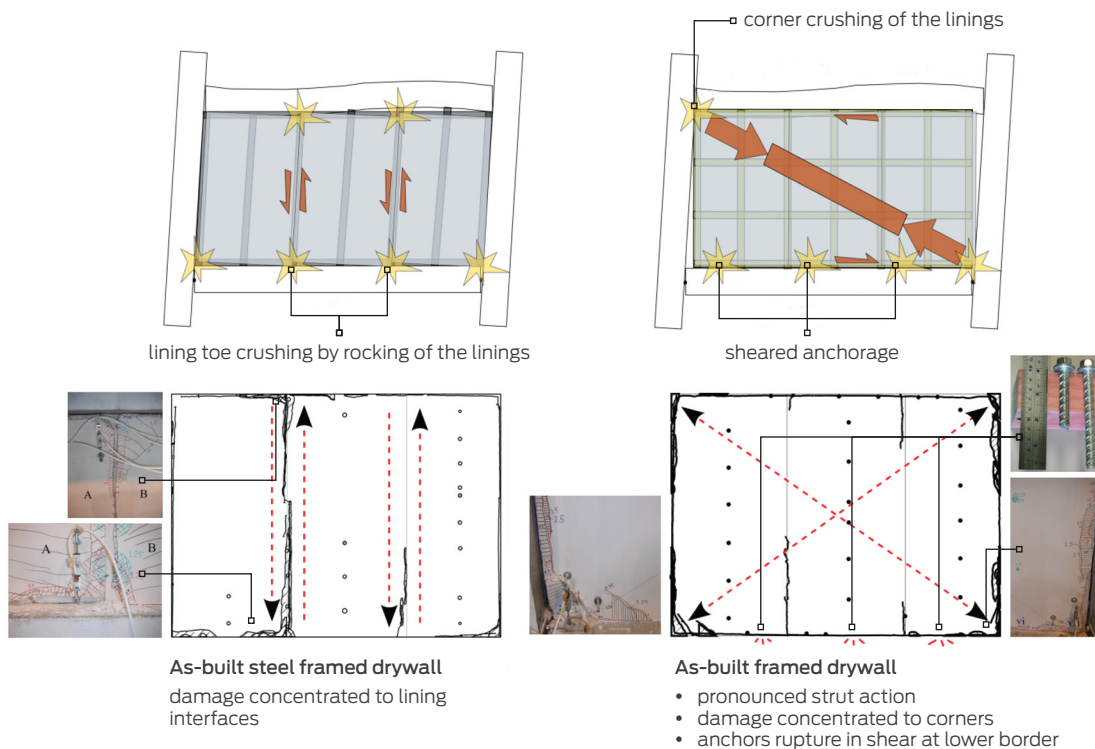


Figure 3: Damage to conventionally-built steel and timber framed drywalls⁸

It was determined that the reasons for the differences in damage between the two framing systems was due to the different methods of installation and fixing:

The vertical studs in steel-framed construction are able to rotate about the screw connections to the steel channel bottom plate. This put additional stress along the vertical joints between lining sheets creating displacement.

The dwangs (horizontal timber blocking between studs) in the timber-framed construction resulted in more rigid partitions than with steel-framing. Deformation of the building structure (i.e. moving out of square) on the timber framing caused diagonal

compression across the sheets causing stress damage at the corners of the partitions.

Other types of damage were also observed including:

- In steel framing:
 - top and bottom track movement due to inadequately secured fastening
 - studs coming out of the top and/or bottom tracks
 - partitions detaching from the building structure
- in both steel and timber framing, linings:
 - cracked around openings and penetrations
 - compressed where the partitions were butted to the building structure
 - cracked at the perimeters of the sheets

⁸ Tasligedik, A.S. Pampanin, S. Palermo, A. (2013). Design of low damage seismic drywalls in practical applications. Civil and Natural Resources Engineering Department, University of Canterbury (VEESD 2013), Figure 4

- in taller framing (e.g. double height partitions) for both steel and timber:
 - linings detached from framing.

From the types of damage observed, it was determined that steel framed partitions are ductile, i.e. have a more flexible response to building movement but this only occurred at low drift levels, whereas the timber framed partitions are non-ductile, i.e. have a less flexible response to building movement but they are able to withstand higher drift levels.

Based on the level of damage to partitions, it was also found that existing construction practices result in partitions that are not able to withstand the drift levels that a building may be subjected to during a low to moderate earthquake. New methods of partition construction are therefore required to limit the degree of damage that currently occurs during earthquakes of a magnitude that do not result in major structural damage to the building.

Proposed changes to partition installation

The report of the research findings proposed that the seismic performance of drywall partition systems could be improved by making a simple change to the way partitions are installed. The proposal is to separate or isolate the partitioning system from the building structure so that partitions are able to move independently within the building structure.

Numerical analysis modelling was carried out on a 10-storey reinforced concrete building using an isolated partition system. This demonstrated that the partitions could accommodate moderately high levels of building drift without damage. The partitions began to show signs of damage at

around 2.0% drift. However, the damage that consisted of minor cracking in the plasterboard at aluminium edge trims, did not compromise the fire (and acoustic) rating of the partitions.

The modelling also demonstrated that an isolated partition system would not affect the structure of the building or alter the period (i.e. the interval of time between successive oscillations or cycles) of the building. In comparison, existing drywall partitions that are rigidly connected to the building structure, were observed to have some effect on the structural system by altering the building's period up to 10%.

The numerical analysis modelling results therefore concluded that when the internal partitions are separated from the building structure:

- the degree of damage to internal partitions is significantly reduced
- the effect of the structural/non-structural interaction is sufficiently low that there is no need to factor this into the design of a non-structural partition system.

The report also concluded that the change to partition installation can be achieved using current construction methods with little or no additional cost, materials or workmanship skills required.

Seismic performance of glazed partitions

In an earthquake, a glazed partition is likely to fail in one of two ways:

- if there is insufficient frame edge cover to the glass, it may fall out of the frame
- if the frame has insufficient separation from the structure to accommodate inter-storey drift, the glass may break under the pressure of the frame deformation.

Glazed partitions must be able to withstand both in-plane and out-of-plane movement without imposing any load to the glazing as glass is a brittle material that cannot accommodate deformation across its surface or withstand a load on its edges. The glass is held in position

in pockets or rebates in the frame that must be deep enough to continue to hold the glass under frame deformation that may occur during an earthquake and there must be sufficient glass-to-frame clearance to accommodate inter-storey drift (Figure 4(a)-(c)).

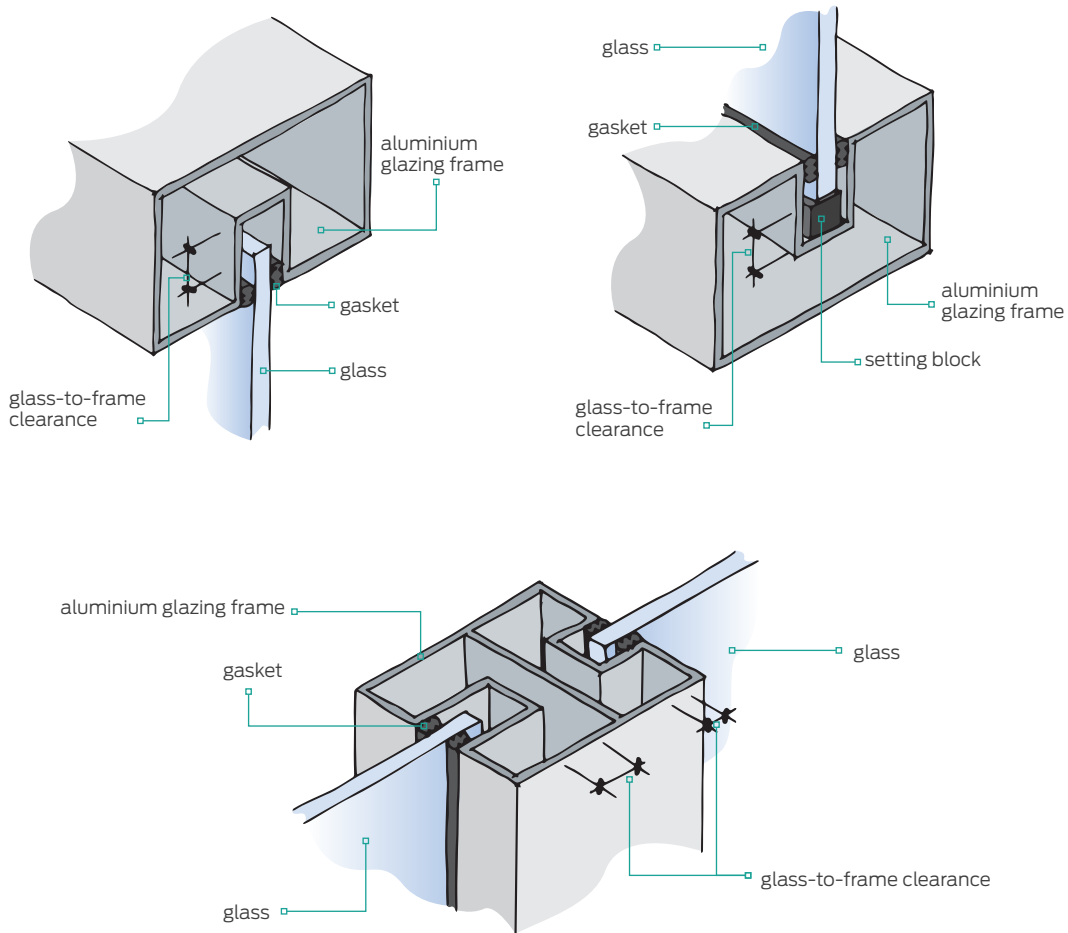


Figure 4: Glass-to-frame clearance

3

Statutory requirements

There are currently no specific statutory requirements that apply to non-structural internal partitions in commercial buildings and a building consent is not required to install non-structural partitions. Nevertheless, all building work must comply with the Building Act 2004 and the New Zealand Building Code (NZBC).

New Zealand Building Act

The New Zealand Building Act 2004 defines the rules for building work in New Zealand. It requires that all building work complies with the New Zealand Building Code (NZBC), even when the work does not require a building consent. The NZBC, contained in Schedule 1 of the Building Regulations 1992*, sets out performance standards for building work to meet the requirements of the Building Act. While it sets how a building must perform, it does not set out how performance should be achieved, i.e. it is a performance-based building code.

*(*Note that the Building Regulations were revoked in 2005 and Schedule 1 the only part of the regulations that have been retained.)*

The New Zealand Building Act and the New Zealand Building Code are the mandatory (statutory) legislative documents relating to construction work in New Zealand.

New Zealand Building Code

The NZBC consists of three general clauses and 38 technical clauses divided into eight broad categories of building work covering all aspects of building work including structural stability, fire safety, access, moisture control, durability, services and facilities, and energy efficiency of buildings.

Each of the clauses consists of three categories:

- Objectives
- Functional requirements
- Performance criteria.

If the performance criteria of a clause are met, the objectives and functional requirements for the clause are also met.

Not all clauses in the Building Code are relevant to all buildings or parts of buildings. For non-structural internal partitions the clauses that must be considered are:

- B1 Structure
- B2 Durability
- C1-C6 Protection from fire
- F2 Hazardous building materials

Clause B1 Structure

The NZBC Clause B1 Structure:

- The objective requires buildings to be constructed in such a way that:
 - people are safeguarded from injury or loss of amenity due to structural failure of the building, and
 - other property is not damaged as a result of structural failure.
- The functional requirement of clause B1 states that:
 - "... building elements... shall withstand the combination of loads that they are likely to experience during construction or alteration and throughout their lives".
- The performance criteria of clause B1 require that:
 - (B1.3.1): "Building elements... shall have a low probability of rupturing, becoming unstable, losing equilibrium, or collapsing... throughout their lives."

- (B1.3.2): “Building elements... shall have a low probability of causing loss of amenity through undue deformation, vibratory response... throughout their lives.”
- (B1.3.3): “Account shall be taken of all physical conditions likely to affect the stability of ... building elements including... earthquakes...”
- (B1.3.4): “Due allowance shall be made for (a) the consequences of failure, (b) the intended use of the building.”

All three categories are relevant and applicable to non-structural partitions.

Clause B2 Durability

NZBC Clause B2 *Durability* requires that a building must continue to satisfy the performance requirements of this code for the specified intended life of the building with only normal maintenance. For non-structural partitions and walls, the specified intended life is at least 5 years.

Clause C Protection from fire

Clause C *Protection from fire* is set out differently from the other Building Code clauses. It consists of six clauses, C1-C6 that cover all aspects of building fire protection. Clause C1 provides the objectives for each of the C clauses. These are to:

- safeguard people from the risk of injury or illness due to fire
- prevent fire from spreading to other properties
- facilitate firefighting.

Clauses C2-C6 deal with specific aspects of fire safety construction based on the occupant risk groups. Each clause is divided into parts. *Part 4 – Control of internal fire and smoke spread*

applies to internal partitions and walls and includes requirements for:

- fire stopping (i.e. dealing with penetrations through fire-rated separations),
- controlling the spread of smoke, and
- internal surface finishes of building elements.

While Clause C does not specifically apply to mitigating seismic damage to non-structural partitions, it does require that the fire resistance rating of partitions is maintained for a specified time after an earthquake event.

Clause F2 Hazardous building materials

Clause F2 *Hazardous building materials* requires that potentially hazardous building materials may only be used in such a way that they pose no undue risk to building occupants.

This clause refers primarily to glazed partitions and requires glazing to meet the requirements of the referenced standards.

Acceptable solutions and verification methods

Each of the Building Code clauses contains prescriptive solutions (acceptable solutions), methods of testing (verification methods), and references to New Zealand Standards and other documentation as means of meeting the requirements of the Code for that particular clause of the Building Code.

When a building design that is submitted for building consent application complies with an acceptable solution, a verification method, a referenced Standard or other referenced documentation, it must be accepted by a Building Consent Authority (BCA) as being compliant with the relevant clause of the Building Code.

Compliance with the NZBC can be achieved in a variety of ways including:

- following an acceptable solution or verification method
- using an alternative solution,
- or using a range of other paths to demonstrate compliance with the Building Code.

The acceptable solutions, verification methods and other referenced material in the Building Code are not mandatory and other means of demonstrating compliance may also be used. These are submitted as alternative methods of construction and require evidence to be supplied to the BCA to demonstrate that the proposed alternative method will comply with the requirements of the relevant Building Code. If an alternative method is accepted, it will become an alternative solution.

Most NZBC clauses provide no references or means of compliance for non-structural interior partitions. There are no acceptable solutions or verification methods providing a means of compliance for interior partitions and the only references to New Zealand Standards relevant to non-structural interior partitions are contained in clauses B1 and F2.

Compliance with Clause B1

The New Zealand Standards relevant to non-structural partitions are referenced in *Acceptable solutions and verification methods* for NZBC Clause B1 are:

- AS/NZS 1170.0 Part 0: 2002 Structural design actions – General principles
- NZS 1170.5 Part 5: 2004 Structural design actions – Earthquake actions – New Zealand
- NZS 4223.1 Part 1: 2008 Glazing in Buildings – Glass selection and glazing

- NZS 4223.3 Part 3: 2016 Glazing in buildings – Human impact safety requirements.

Verification method B1/VM1 section 2 to NZBC Clause B1, references the AS/NZS 1170 suite of standards generally as a means of achieving structural compliance.

Specific references include to:

- AS/NZS 1170.0 for evaluating risk and loading levels when designing to the ultimate and/or serviceability limit states.
- NZS 1170.5 Section 8 for specific references to internal, non-structural partitions. This section addresses the requirements for parts and components and states that all parts of structures and non-structural components (including partitions) and their connections and part supports must be able to withstand earthquake actions, deflections and displacements.
- NZS 4223.1 for general glazing requirements and provides the design criteria, guidance for specific design and procedures for glass selection, and glazing in buildings.
- NZS 4223.3 for glass design for internal partitions, including requirements for the area and thickness of glass, containment and edge cover to the glass.

Compliance with Clause F2

The New Zealand Standard relevant to non-structural partitions is referenced in *Acceptable solutions and verification methods for NZBC Clause F2* is:

- NZS 4223.3 Part 3: 2016 Glazing in buildings – Human impact safety requirements.

4

Seismic design requirements for non-structural partitions

Although there is no specific requirement in the NZBC, non-structural partitions should be able to perform at least as well as the building structure in a low or moderate earthquake event. That is, if the building structure is not damaged, there should be no or minimal damage to interior partitions and where partitions are required to be fire rated, the fire resistance rating must be fully maintained.

Non-structural partitions and walls must be able to resist seismic movement in all directions, both horizontally (laterally) and vertically.

Based on both the findings from the research by the University of Canterbury into how partition systems responded to inter-storey drift and observations of the seismic performance of plasterboard-lined partition systems, two proposals for improving the seismic resilience of non-structural internal partitions were made. These are for:

- seismic separation, that is isolating or separating the non-structural partitions from the building structure, and
- seismic bracing, that is restraint of partial height partitions (i.e. to the underside of a suspended ceiling) to the building structure.

If partitions are to be used to provide support or lateral restraint to non-structural components such as cupboards or shelving, the walls and seismic bracing must be able to resist the additional loading.

Seismic design and detailing for non-structural partition installation should be included in building consent application documentation.

Seismic separation

Seismic separation of non-structural partitions from the building structure allows the partitions to move independently, reducing the likelihood of damage by impact from the building structure. The seismic separation can be achieved by providing gaps at the top and the sides of partitions. These can be designed as negative or shadow line details or filled with a compressible filler material that can accommodate seismic movement.

The amount of separation to accommodate lateral movement is based on the calculated inter-storey drift at the particular level of the building. Half of the inter-storey drift should be accommodated as a gap or seismic separation at each end of the length of wall to avoid major damage in the event of an earthquake.

Vertical movement allowance at the top of plasterboard lined walls should be incorporated to accommodate floor deflections (Figures 5(b) and (c)).

Strips of plasterboard or a similar material should be used as packers between all top and side wall frame edges and the building structure. Where partitions are required to be fire-rated, the packing material must be plasterboard or a proprietary fire barrier material.

Control joints are required in partitions where there are long unbroken partitions or wall runs and where structural control joints occur in the primary structure. They can be achieved by installing double studs separated by

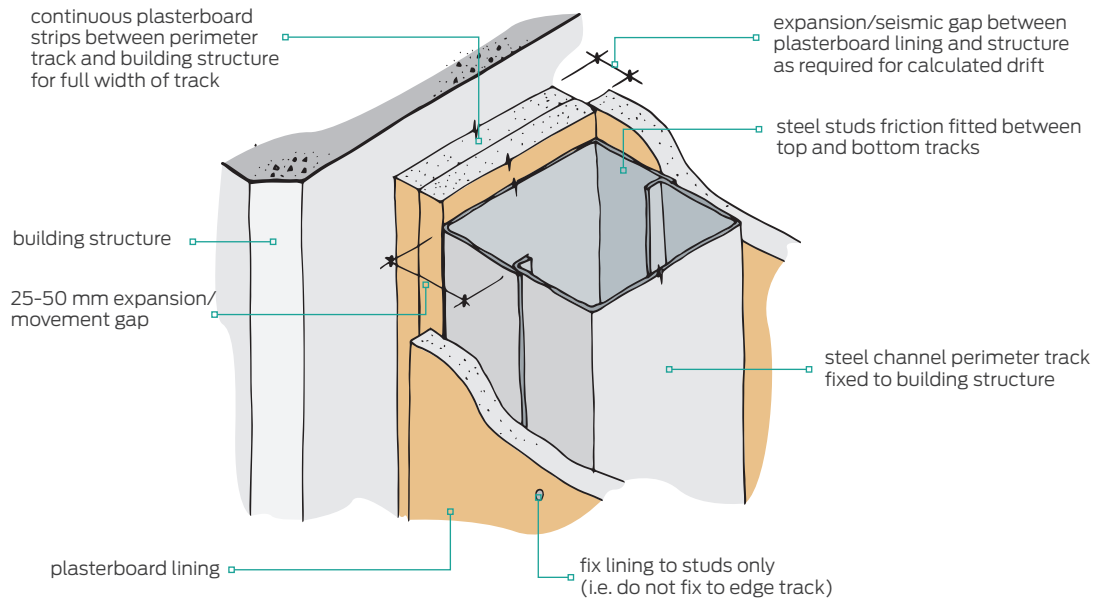


Figure 5(a): Seismic separation – partition edge

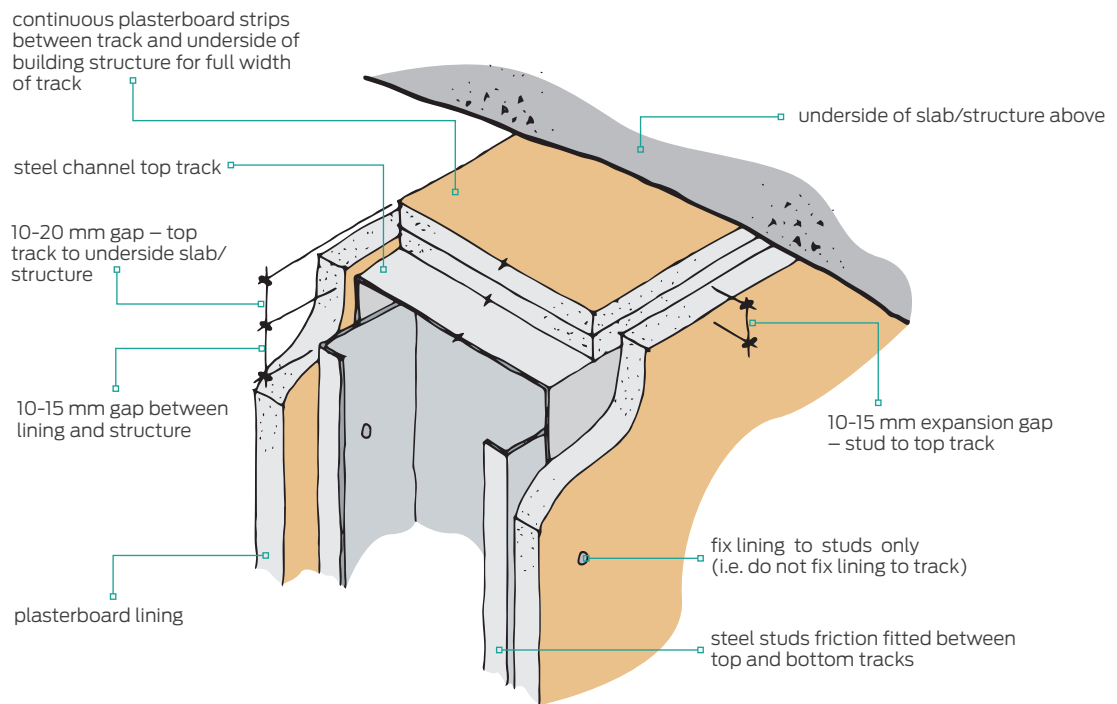


Figure 5(b): Seismic separation at partition head – steel channel/steelstud

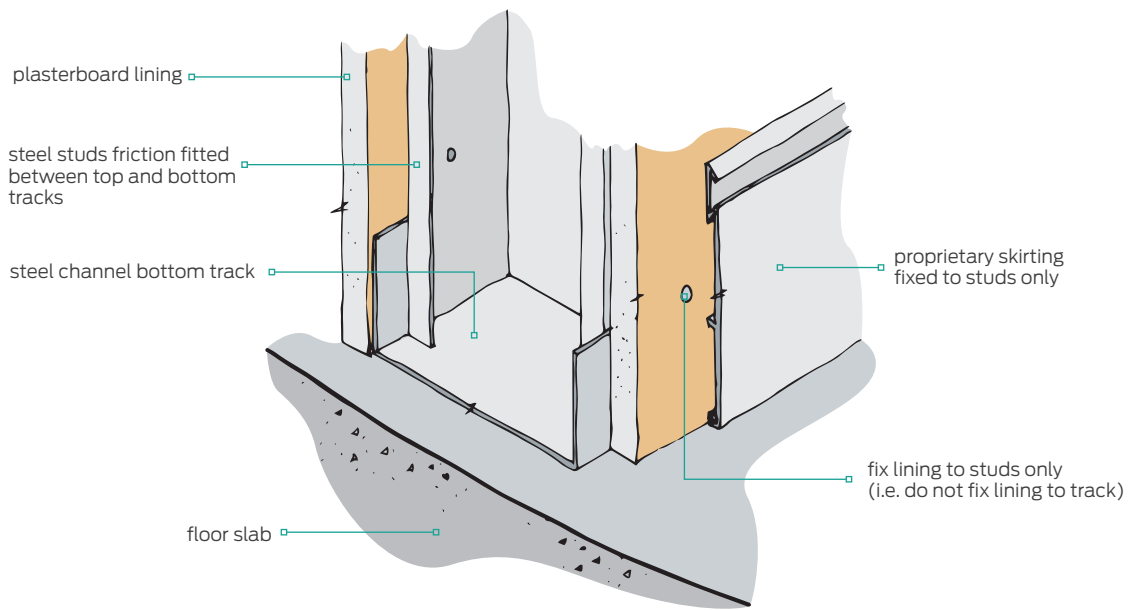


Figure 5(c): Seismic separation at partition base – steel channel/steel stud

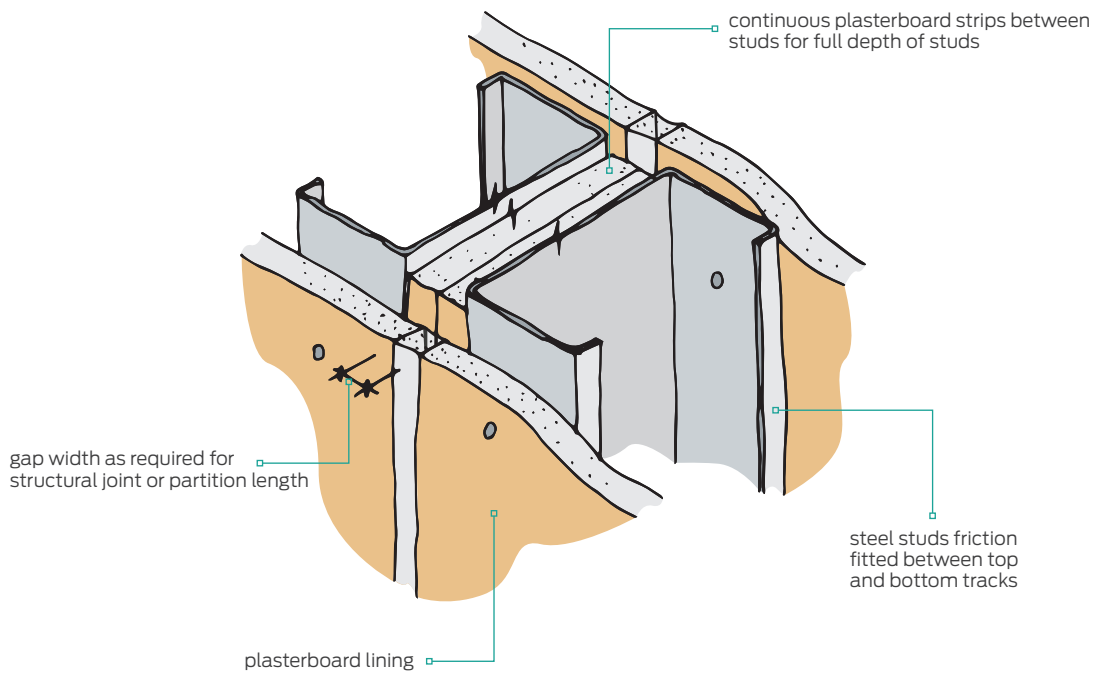


Figure 5(d): Seismic separation – vertical movement control

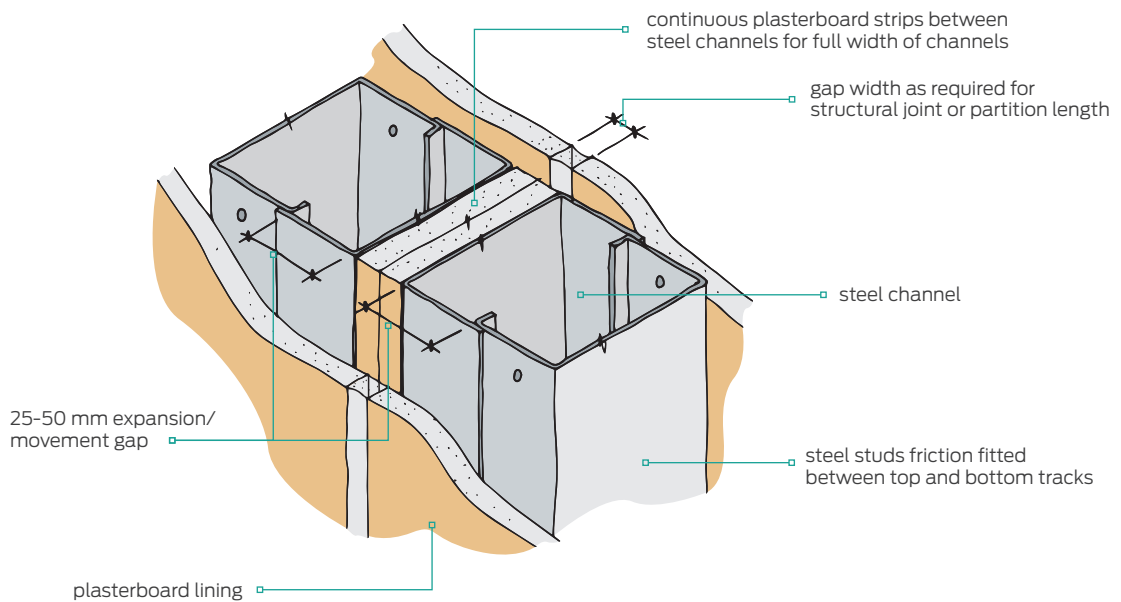


Figure 5(e): Seismic separation – vertical movement control joint

plasterboard strips or a similar packing material (Figures 5(d) and (e)). A range of proprietary jointers are also available to accommodate the gaps between sheet lining materials if required.

Seismic restraint requirements

Non-structural internal partitions must be braced to the building structure. Seismic restraint of non-structural internal partitions may be achieved by:

- using details or proprietary systems that have been verified as being compliant with the Building Code
- using specific engineering design details that have been designed by an engineer with competency in the application of earthquake actions such as a Chartered Professional Engineer (CPEng).

A range of proprietary, pre-engineered partition restraint systems that connect the partition top plate to the underside of the structure above, are available for different situations including:

- bracing for steel and timber framed partitions
- bracing for aluminium glazed partitions
- retrospective bracing for existing unbraced partition systems
- bracing that is installed horizontally to brace partitions perpendicular to one another for situation where there is insufficient ceiling space for bracing to be installed
- low-profile systems are available for use where:
 - a large amount of vertical deflection must be accommodated
 - the plenum or ceiling space is high
 - there is little room for bracing due to the large number of services in the ceiling space.

Seismic restraint systems are generally installed at angles ranging between 30-60° in plan to the partition being braced and perpendicular in plan to partition returns or to straight partitions with no return walls (Figure 6). They can generally accommodate up to 50 mm of inter-storey drift, 90 mm of in-plane wall deflection and 20 mm of out-of-plane wall deflection.

Installation of proprietary restraint systems should be in accordance with the manufacturer's or supplier's instructions which may also require installation by specialist installers.

Seismic requirements for glazed partitions

The same principles for providing seismic separation and restraint of framed and lined partitions must also be applied to glazed partitions.

Seismic separation can be achieved by providing a minimum 50 mm deep channel in the head and side glazing frames to accommodate seismic movement without imposing force on the glass.

Seismic restraint for glazed partitions is the same as for framed and lined partitions and is required wherever glazed partitions do not extend to the underside of the building structure.

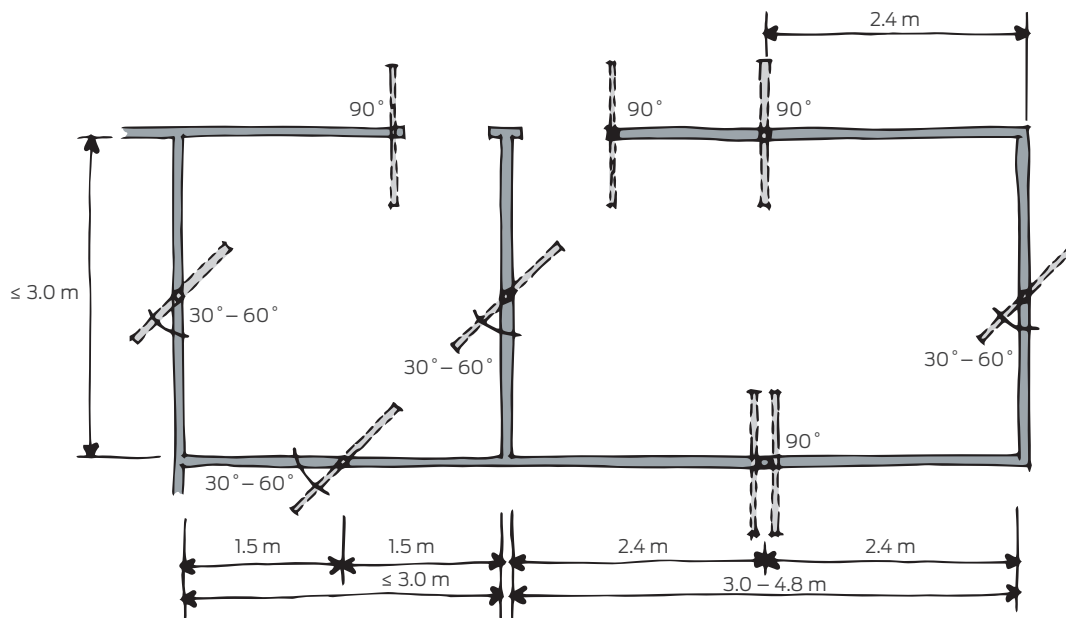


Figure 6: Typical layout of seismic bracing for non-structural partitions

Some framing systems have removable glazing beads that hold the glass in place in the frame. A glazing bead allows the sufficient depth of the pocket housing the glass to provide both the edge cover and the movement allowance required. However, some framing systems have fixed pockets on two or more sides of a frame (i.e. they do not have removable glazing beads). This means that the frame rebate depth must be minimal in order to be able to install the glass. Following the New Zealand earthquakes, it was observed that in some situations the glazed partitions failed because the edge cover was below the depth required to contain the glass.

Non-structural glazed partitions must be self-supporting and there must be no loads applied from above or the sides of the partition. Any wall element above a glazed partition should be isolated, either by being suspended from above or with a lintel installed so that there is no weight on the glazing or mullions.

Summary of design considerations for non-structural interior partitions

As part of the interior partition design process, a number of issues should be considered:

- the potential damage to non-structural components that may occur as a result of the deformation of structural components
- the need to accommodate seismic separations in the building
- where partition systems are located in the building as inter-storey drift increases higher up the building
- whether building services systems must pass through a non-structural partition, which means the potential for impact damage during seismic activity must be addressed
- whether fire, acoustic or thermal ratings must be maintained
- the integrity of partitions separating exitways that provide a safe means of exiting the building in the event of an emergency, must be maintained.

5

Design non-structural partitions using New Zealand Standard

Designing non-structural partitions using AS/NZS 1170

As there are no acceptable solutions containing specific reference or guidance for non-structural partitioning systems, specific engineering design (SED) with reference to AS/NZS 1170 is required. Verification method B1/VM1 to Clause B1 of the NZBC references the AS/NZS 1170 suite of New Zealand Standards. Relevant parts of the standard include:

- AS/NZS 1170.0: General Principles
- NZS 1170.5: Earthquake actions – New Zealand.

These Standards should be referred to when designing the installation of non-structural partitions.

AS/NZS 1170.0 requires buildings to be designed and constructed so that during their design working life, they are able to withstand all actions and environmental influences that may be imposed on them.

Section 3 of AS/NZS 1170.0 requires that buildings must be able to withstand seismic actions so that:

- the building does not collapse
- parts of the building do not collapse if they present a hazard to people inside the building
- the non-structural systems that will enable people to evacuate the building do not collapse.
- Determining level of seismic restraint required
- The first step in designing the non-structural partitioning system is to obtain the building information required to determine the level of seismic restraint required. This includes:

- geographic location of the building
- building type – to establish building importance level
- building importance level (IL)
- ultimate limit state (ULS)
- serviceability limit state (SLS)
- annual probability of exceedance
- consequences of building failure
- classification of building parts.

The methods to determine the building information required are provided in AS/NZS 1170.0 and NZS 1170.5 and are summarised in Table 1.

Geographic location and building type

Under NZS 3604:2011 Timber framed buildings, New Zealand is divided into zones based on environmental features including earthquake, wind snow load and exposure.

NZBC Clause A1 classifies buildings according to type in seven categories. A building with a given classified use may have one or more intended uses under the Building Act. The broad classifications are:

- housing
- communal residential
- communal non-residential
- commercial
- industrial
- outbuildings
- ancillary.

Building Importance Level

Buildings have an importance level (IL) based on the consequences of building failure after

Standard	Section/table	Information
AS/NZS 1170.0	Section 3.3 and Table 3.2	Building importance level (IL)
	Sections 3.2 and 3.4, Table 3.3	Annual probability of exceedance
	Table 3.2	Building type
	Table 3.1	Consequences of failure for importance levels
	Section 2.2	Ultimate limit state (ULS) design procedure
	Section 2.3	Serviceability limit state (ULS) design procedure
NZS 1170.5	Section 2.3	Ultimate limit state (ULS) verification
	Section 2.4	Serviceability limit state (ULS) verification
	Section 8	Requirements for parts and components
	Table 8.1	Classification of building parts

Table 1: Determining building information from AS/NZS 1170.0 and NZS 1170.5

a major event, and the risk to human life, the economic cost and the ability for the building to continue to function or be repaired. There are five levels of importance, defined in NZBC Clause A3 as follows:

- **Level 1:** Buildings and structures that present a low degree of hazard to life or property, such as outbuildings, fences and walls.
- **Level 2:** Buildings not included in the other categories, such as timber-framed houses, car parking buildings or office buildings.
- **Level 3:** Buildings that may have contents of high value to the community or pose a risk to a large number of people in close proximity, such as conference centres, stadiums and airport terminals.
- **Level 4:** Buildings that must remain functional immediately after an earthquake or major event, such as hospitals, communications centres and other critical post-disaster buildings.
- **Level 5:** Structures whose failure poses a catastrophic risk to a large area or a large number of people, such as a dam or a biological containment centre.

AS/NZS 1170.0, which is referenced from NZBC Clause B1 Structure, also uses the building importance levels to define ultimate limit state (ULS) and serviceability limit state (SLS) for the impact of wind, snow and earthquake levels on buildings. AS/NZS 1170.0 also defines the consequence of building failure in relation to the building importance level. This is shown in Table 2.

(Note: Although Clause A3 states that the building importance levels refer only to NZBC Clause C Protection from fire, they align with the importance levels given in AS/NZS 1170.0)

When determining building importance levels, if a building has multiple uses, the importance level for the whole building shall be the highest applicable level for any use in the building.

Limit state design

The structural design of buildings requires consideration of all the loads that could potentially act on a building over its lifetime,

Importance level	Type of building	Examples	Consequences of failure*
1	Building that present a low risk to life or other property	Structures with a total floor area less than 30 m ²	Low
2	Normal buildings and those not in other importance levels	Single family dwellings	Ordinary
3	Buildings that may have large numbers of people, pose a risk to crowds or contain items of high value to the community	Schools, healthcare facilities, correctional facilities, multi-occupancy residential, commercial, industrial, office and retail buildings, public assembly buildings, theatres and cinemas	High
4	Structures with special post-disaster functions	Buildings and facilities designated as essential, or with a special post-disaster function, medical emergency and surgical facilities	High

*Note: For definitions of consequences of failure, refer to the descriptions given in AS/NZS 1170.0, Table 3.1

Table 2: Description and examples of building importance levels (from AS/NZS 1170.0: 2002, Tables 3.1 and 3.2).

ranging from the ongoing in-service loads to rare events such as a severe earthquake.

While the in-service design load is an appropriate design level for ongoing loads on a building, it does not deal with the loads that may be imposed on rare occasions. This has resulted in the development of the limit state design.

A limit state is the condition of a building beyond which it no longer meets the specified design criteria including the structural integrity, functionality, durability or serviceability of the building. and is the result of a level of loading or some other action that is beyond the ability of the building to withstand.

Two basic limit states are defined by AS/NZS 1170:

- the ultimate limit state (ULS), and
- the serviceability limit state (SLS).

A structural engineer must provide both ULS and SLS deflection criteria.

Ultimate limit state (ULS)

The ultimate limit state (ULS) requires that a building remains standing after being subject to its peak load such as may occur during a major earthquake.

AS/NZS 1170 requires ULS design levels for buildings based on their importance level and design working life to be able to withstand seismic events between 1-in-100 to 1-in-2500-year probability. For example, the ULS design level for an importance level 2 (IL2) building and a 50-year design working life is based on a 1-in-500-year earthquake.

Serviceability limit state (SLS)

The serviceability limit state (SLS) is the level of load that a building of a particular importance

level can withstand after an earthquake and still be used for its intended purpose without repair. This means the level of load defined for this limit state is low as it is a state expected to be reached several times during the life of most buildings in New Zealand.

There are two categories of serviceability limit state (SLS): SLS1 and SLS2. These are defined in AS/NZS 1170.0: 2002, 3.4.2 as follows:

- SLS1 – where structural and non-structural components do not require repair after an SLS1 earthquake, wind or snow event
- SLS2 – where the building must remain functional after an SLS2 earthquake.

The higher serviceability limit state, SLS2, is required for buildings with a high importance level 4 (IL4) such as hospitals, emergency services buildings and so on, as it is required that they will be fully operational within minutes or hours, rather than days, following a seismic event.

A SLS1 design level applies to building with importance levels 2-4 and must be able to withstand an earthquake based on a 1-in-25-year earthquake.

For more information, refer to the BRANZ Seismic Resilience website at:

<http://www.seismicresilience.org.nz/topics/resilient-design/earthquake-engineering/limit-state-design/>

Serviceability limit state guidelines

Appendix C, Table C1 in AS/NZS 1170.0: 2002, provides guidelines and serviceability parameters for the design of building elements and components. For non-structural internal partitions, these are shown in Table 3.

Annual probability of exceedance

The annual probability of exceedance is the probability of an event (such as an earthquake) occurring in any year. It is based on the building's:

- design working life
- importance level
- ULS
- SLS (either SLS1 or SLS2).

AS/NZS 1170.0: 2002, Table 3.3 sets out the annual probability of loadings (exceedance) for earthquake, wind and snow for:

- ultimate limit state (ULS) for buildings with designated importance levels 1-4, and
- serviceability limit states 1 and 2 (SLS1 and SLS2) for buildings with designated importance levels 2-4.

Classification of building parts and components

A **building part**⁹ is defined as:

- “a member that is either attached to and supported by the structure but is no part of the structural system, or
- an element of the structural system that can be loaded by an earthquake in a direction that it is not usually designed for”.

A **building component**¹⁰ is defined as “part of a building too complex to be called a building element, e.g. wall door, etc. which may be built from several elements”.

An alternative definition of a **part**¹¹ is “an element that is not intended to participate in the overall resistance of the structure to horizontal displacement under earthquake conditions for the direction being considered”.

9 From NZS 1170.5, p. 56

10 From NZMP 4212, p. 29

11 From NZS 1170.5, p. 59

Element		Phenomenon controlled	Serviceability parameter	Element response ⁽¹⁾
Walls General	face loaded	discerned movement	mid height deflection	height/150
		impact: soft body	mid height deflection	height/200 but < 12 mm ^{(2) (3)}
		supported elements rattle	mid height deflection	height/1000
Walls ⁽⁴⁾ Plaster/gypsum	in plane	lining damage	mid height deflection	Height/300
	face loading	lining damage	mid height deflection	Height/200
Glazing	Glazing system	bowing	mid span deflection	Span/400
	Fixed glazing system	glass damage	mid span deflection	2 x glass clearance ⁽⁵⁾

Notes:

- 1 The span or height ratios used in the deflection criteria are the clear spacing between parts of support.
- 2 Walls and partitions require stiffness control to minimise disturbance such as neighbours on the other side of an inter-tenancy wall. The stated deflection criteria (height/200 from a concentrated load of 0.7 kN at mid-height) has been simplified for ease of application and is based the impact of a person running and falling against a wall.
- 3 Internal partitions may also be subjected to differential pressures as a result of wind pressure. A net coefficient of 0.5 may be considered appropriate when used in conjunction with the serviceability wind pressures.
- 4 Different wall linings have different movement tolerances so some are identified.
- 5 The surface finish and size of partitions may affect the observed deflections of ceilings and floors, e.g. the reflective surface of glass amplifies apparent bowing by the reflected images as they move with the surface distortions. Ripple effects are more apparent on flat surfaces, while textured surfaces tend to disguise ripple effects. Large surface areas appear to move more than smaller surface areas. Where the texture of the surface is unknown, design should be to a higher deflection limit.

Table 3: Suggested serviceability limit state criteria (from AS/NZS 1170.0: 2002, Appendix C, Table C1)

According to these definitions, partitions and non-load bearing walls can be defined as both building parts and components.

NZS 1170.5: 2004 is the design actions standard cited by verification method B1/VM1 to NZBC clause B1 Structure. Section 8 of NZS 1170.5 addresses the seismic performance requirements for building parts and components and classifies them into one or more categories, P1-P7, based on specific performance criteria.

Under each category there is also an associated ULS or SLS requirement. These are summarised in Table 4. Note that the category requirements apply to the parts and components following an earthquake but do not apply to fire safety and safe egress if there is a fire.

A system is assigned a part category according to its potential to cause death or injury, or its importance for the continued functioning of the building, or if the consequential damage is high. For example, categories P2 and P3 apply

Category	Criteria	Structure limit state
P1	Building component presents a hazard to people outside the building	ULS
P2/P3	Building component presents a hazard to people inside the building (includes heavy partition systems)	ULS
P4	Building component necessary for the continuing function of the evacuation and life safety support systems in the building	ULS
P5	Building component required for: <ul style="list-style-type: none"> • IL4 building; building required to have operational continuity: • functionality for building to be redeveloped 	SLS2
P6	Where the consequential damage caused by a component failure is disproportionately great	SLS1
P7	All other components	SLS1

Table 4: Classification of building parts and components (from NZS 1170.5:2004 Table 8.1).

where a system represents a hazard to human life inside a building, while category P4 requires parts and components to continue to function to enable the building to be safely evacuated, and for life safety systems in the building to continue to function. The ULS applies for the design of categories P2-P4.

A part is considered a hazard to human life if it weighs more than 7.5 kg and is able to fall more than 3 m. A partition system that comes within these criteria needs to be designed to the ultimate limit state.

Structural design procedures in accordance with Standards

Section 2 of AS/NZS 1170.0 sets out structural design procedures for the ULS (Clause 2.2) and SLS (Clause 2.3).

AS/NZS 1170.0, clause 2.2 sets out the design procedure for the ULS as follows:

- Determine the building importance level (IL) and the associated annual probability of

exceedance for wind, snow and earthquakes from AS/NZS 1170.0, section 3.

- If required, determine the ultimate load for wind from AS/NZS 1170.2.
- Determine the ultimate load for earthquakes from NZS 1170.5.
- Design and detail the structure in accordance with NZS 1170.5 for earthquakes.

AS/NZS 1170.0, clause 2.3 sets out the design for the SLS as follows:

- Determine the type of design serviceability condition to be considered.
- Determine the design situation including serviceability load and serviceability limits for the condition being considered from AS/NZS 1170.0, section 3.
- If required, determine the serviceability load for wind from AS/NZS 1170.2.
- Determine the serviceability limits applicable to earthquake loading from NZS 1170.5.

AS/NZS 1170.0, clause 3.2 sets out design requirements include that buildings must

be able to withstand all actions during their lifetime as follows:

- for earthquakes:
 - to avoid collapse of building parts that present a hazard to life, and
 - to avoid damage to non-structural elements that are necessary for evacuation of the building
- to perform adequately under all expected actions (serviceability requirement).

The information for the design of non- structural partitions should be supplied to the interior partition systems supplier by a structural engineer.

Wind loads on buildings

Wind loads on the building exterior cause pressure changes to the exterior that can result in a pressure differential across the exterior wall, affecting the internal pressure. Internal pressures can be sufficiently significant to need to be considered for interior partition design.

Wind actions on buildings are determined and calculated in accordance with AS/NZS 1170.2: 2011:

- for site wind speeds – paragraph 2.2
- for design wind speeds – paragraph 2.3

- for design wind pressures and distributed forces – paragraph 2.4
- to calculate wind actions – paragraph 2.5.

Designing glazed partitions using NZS 4223.3

Requirements for glazed partitions are set out in NZS 4223.3: 2016 *Glazing in buildings. Part 2 – Human impact safety requirements*.

The NZBC Clause A1 identifies a range of building usages that must be glazed in accordance with NZS 4223.3, sections 3.2, 3.3 and 3.4. These include assembly care buildings such as schools and early childhood centres, communal residential buildings, commercial and industrial buildings, and other buildings where there is a high risk of injury from glazing.

The New Zealand Standard, NZS 4223.3 describes glazing requirements for all glazing that is wholly or partly within 2000 mm from a floor or ground level. Other requirements for glazing include for fully framed, partly framed and unframed partitions.

6

An integrated approach to design

An integrated approach to design

The design and installation of non-structural interior partition systems requires collaboration and integration between all the relevant disciplines involved in the building project. This generally includes:

- the designer or architect
- a structural engineer and/or specialist seismic engineer
- services engineers (MEP and HVAC).

A collaborative approach involves disciplines working together to jointly analyse problems, provide feedback on design options and solutions, and collectively make decisions at each stage of the project. It also includes having regular meetings and maintaining good communication between all relevant parties of a building project and should begin as early as practicable. It is also important to identify and agree on oversight and management methodologies for key coordination issues.

Factors to facilitate the development of the building project include:

- involving all relevant parties as early as possible in the project so that:
 - problems are identified and resolved early in the project rather than becoming major issues during the construction phase
 - critical decisions made in the early stages of the project
 - specialist areas can be designed with the requisite seismic restraints
- obtaining all the required information from relevant disciplines at the start of the project

- ensuring appropriate oversight by employing a specialist non-structural seismic co-ordinator who will be responsible for overseeing all of the interior non-structural partitioning and ensuring that the specified systems and products are installed.

Critical decisions made in the early stages of a project are easier to make, less costly and more effective than when they are made later in the project. Early engagement and interaction between all parties involved can ensure that:

- design objectives are clarified and refined early in the project
- appropriate performance levels are set, and
- the best design solutions are identified early in the design process.

The need for collaboration and coordination

Investigation by the Ministry of Business, Innovation and Employment (MBIE) into building project practices has found that a lack of collaboration is likely to result in:

- misunderstandings and incorrect assumptions
- groups not being aware of changes to the design being made elsewhere.
- delays in progress
- inefficiencies
- the need to repeat work.

An advisory published by MBIE, Practice Advisory 19 Improving earthquake performance of non-structural elements, provides advice to building practitioners on the need for a well-planned and coordinated approach to the design and construction of seismically restrained non-

structural elements in a building. Although the practice advisory refers primarily to building services such as mechanical and electrical plant, ducting, pipework, cable trays and suspended ceilings, the advice can also be applied to lightweight, non-loadbearing partitions.

To see the advisory, refer to MBIE website:

<https://www.building.govt.nz/building-code-compliance/b-stability/b1-structure/practice-advisory-19/improving-earthquake-performance-non-structural-elements/>

The Canterbury Earthquakes Royal Commission recommended that a structural Chartered Professional Engineer (CPEng) should be engaged at the same time as the architect for the design of a complex building. A guidance document, *Improving Collaboration between Architects and Engineers* that was put together by a number of different agencies, strongly recommends collaboration between disciplines. It is available online at:

<https://www.nzrab.nz/Editable/Assets/Newslink2015/CollaborationPublication.pdf>.

Non-structural seismic coordinator

A specialist non-structural seismic coordinator should be included in the design team for larger projects. A suitably qualified coordinator would:

- prepare seismic restraint layout drawings
- design details for the installation of non-structural partitions including all junctions of partitions and walls with building structure
- be responsible for ensuring that non-structural partition systems are designed and installed as specified
- monitor the installation and construction of the seismic restraint system.

Structural information including the seismic design criteria such as SLS and ULS for the proposed building, and specific design information required for the internal partitioning should be provided by the structural engineer. Partition manufacturers also often provide design information such as seismic restraint tables and guidelines.

Establishing design parameters

The design parameters for the non-structural elements should be determined at the preliminary design phase of a building project.

The location of the bracing or seismic restraint for ceiling-height and full-height partitions must be coordinated with other non-structural building components that need to be located in the ceiling space such as sprinkler systems, air-conditioning ducts, cabling ducts, and lighting systems. Ceiling spaces often have very limited space so the design and layout of the ceiling space must be carefully planned to ensure there are no component clashes.

When designing the layout for the seismic restraint of partitions in the ceiling space, considerations should include the:

- characteristics of the building structure
- location of non-structural partitions in the building
- type of anchorage or restraint system
- potential interaction between structural and non-structural elements.

The layout of the ceiling space and the location of all components including seismic restraints in the ceiling space, should be completed and included as part of the building consent documentation the tender process.

Construction Industry Council (CIC) Guidelines

The New Zealand Construction Industry Council's (NZCIC) 2016 Design Documentation Guidelines provides a good template on which to base an integrated design approach. They set out guidelines for all disciplines involved in a building project including:

- roles and responsibilities
- the coordination and design interfaces between parties
- a checklist to define the design processes
- a schedule of activities to be carried out.

The guidelines provide useful general checklists and benchmarks for the design, construction and monitoring of the building project.

Table 5 shows which parties are involved at particular stages of the building project and who should provide the deliverables.

Roles and responsibilities

The process outlining who may be involved and what their roles are is shown in Figure 7. Note that not all steps will be relevant for all construction projects.

Specific roles

The architect or designer is generally responsible for the overall design of the building and oversees the coordination of the design input from the specialist disciplines such as structural, building services (MEP), and fire engineers.

CIC Guidelines (2016) stages	Design principle	Requirements	Parties required to input, assist and coordinate	Deliverables required and parties responsible
Concept design	General	Seismic design	Architect, Project manager	Structural engineer
Preliminary design	General	Seismic design	Architect	Structural, MEP, Fire engineers
Developed design	General	Seismic design	Architect	Structural, MEP, Fire engineers
Detailed design	General Structural/ geotech	Proprietary design	Architect	Structural, MEP, Fire engineers
Procurement	Structural/ geotech	Erection/ construction	Architect, Project manager, Structural, MEP, Fire engineers	
Construction, Administration, Observation	General	Seismic design	Architect, Project manager, Structural, MEP, Fire engineers	Contractor

Table 5: Parties involved in stages of a building project (adapted from CIC Guidelines (2016)).

Who is involved	Procedure	Selection options					
Designer*/ engineer/seismic specialist or coordinator	Determine building importance level (IL)	IL1	IL2	IL3	IL4	IL5	
	Determine building category	P1	P2	P3	P4	P5	P6
Engineer/seismic specialist	Determine the ultimate and service limit states for all elements	ULS		SLS			
				SLS1	SLS2		
Designer	Select partition system	Use manufacturer's installation details	Design by a suitably qualified person (engineer/seismic specialist)				
Engineer/ seismic specialist (coordinate with services specialists)	Determine which services must pass through partitions	Service to pass below ceiling	Service to pass in the ceiling space				
	Design appropriate seismic restraints						
Designer	Apply for building consent including partition design documentation in application						

* Designer refers to architect, architectural designer, specialist interior designer.

Figure 7: Process for the design of a non-structural interior partition system

The structural engineer is responsible for:

- the structural design of the building
- providing the seismic design criteria for the non-structural elements in the building.

Building services engineers (MEP) are responsible for designing and installing specialist building services such as heating and ventilation systems, electrical, data and communication systems, and plumbing and drainage systems.

Fire engineers are responsible for the fire safety design of buildings including materials and construction, means of egress, preventing the spread of fire and firefighting facilities.

The main contractor is responsible for:

- providing the materials, labour, equipment and services required for the construction of a building
- overseeing the construction process
- managing the coordination of seismic solutions and details by relevant trade contractors including services, ceiling and partition subcontractors
- communicating any changes that may affect the seismic design of any of the restraint systems to the architect, designer or specialist non-structural partition coordinator.

Subcontractors and tradespeople are responsible for the installation of building services, fixtures and fittings within the scope of their trade.

Construction monitoring

Construction monitoring involves site visits and reviewing the contract design information to ensure that materials and methods of installation are in accordance with the contract documents, specification and performance

criteria requirements. Traditionally the primary and secondary structural elements of a building, which are engineer-designed and detailed, are closely monitored while non-structural elements tend to be overlooked or poorly monitored and managed during the design, procurement and construction phases of the project.

On-site monitoring is crucial in the construction process to ensure that details of construction such as fixings and anchorages, seismic clearances and movement allowances are constructed or provided as detailed.

Monitoring of internal partition installation should be carried out by the architect or designer, a structural engineer, interior partitioning system designer or, if employed, the non-structural seismic coordinator.

Producer statements

A producer statement is a professional opinion that may be used to contribute to the evidence that proposed work will meet compliance with the Building Code. If a producer statement is used it should be submitted with the construction documentation.

Producer statements are typically used for specialist work or proprietary products that are to be installed by specialist contractors. There are four types of producer statement referring to different statements relating to:

- PS1 – Design
- PS2 – Design review
- PS3 – Construction
- PS4 – Construction review.

A PS3 is sometimes used by the installers of proprietary systems such as partitioning systems.

Procurement

Procurement deals with acquiring (procuring) the goods, services and activities that are essential to the building project. It constitutes the overarching process under which purchasing is one part. Procurement involves a number of processes including:

- recruiting the right contract workers
- sourcing products
- establishing payment terms
- negotiating contracts
- purchasing goods
- logistically managing the transportation of materials between facilities and sites.

Procurement is essential to the success of a construction project as it encompasses the logistical management of goods and services at all levels of the construction project, and is dependent on expertise, industry knowledge and reliable strategies to meet the required objectives of the project.

Issues from design-build projects

Large projects are sometimes fast-tracked by dividing the construction contract into a number of separate tenders that may be negotiated with a single supplier or as a competitive tender. Although the aim of a design-build project is to shorten the time for

a construction project, it can also substantially complicate coordination. There are a number of reasons for this including that:

- the full design team has often not been decided on before the preparation of construction documentation has begun. This can cause problems when decisions about the design must be made early in the project but the parties who will be responsible for particular aspects of the design and construction have not yet been contracted and therefore have no input into design decisions.
- communication among disciplines in fast-track projects is generally more difficult due to the development of separate tender packages resulting in a fragmented design process.
- the demands of a rushed project schedule may mean that aspects of design and fabrication such as shop-drawing preparation, are not always being thoroughly checked by the architect or engineer.
- the complexity of some projects can hinder effective cooperation and coordination between design teams that have not previously worked together. This highlights the importance of adequately defining performance objectives and assigning roles and responsibilities if integrated seismic design and construction is to be achieved.

7

Penetrations through partitions

Services such as ducting, sprinkler pipes, cables, water pipes and fire and smoke dampers in commercial buildings are often able to be installed in the suspended ceiling space, but in some situations, services must pass through partitions. This may occur where there is no ceiling space, or where services must pass from one occupancy to another or from one firecell to another in the same occupancy. Partitions separating different occupancies or firecells within an occupancy must be fire-rated and the fire rating must be maintained for the specified time of the rating at all times.

During an earthquake, suspended services pipes and ducting move and sway but not in synchronisation with the building structure or the partitions. If there is insufficient clearance around a penetration through the partition, the services pipes are likely to knock against the partition, potentially causing damage to both.

The consequences of damage to penetrations, particularly fire-rated penetrations, are severe:

- in the event of a fire, the fire resistance rating (FRR) of the partition is likely to be compromised potentially causing the premature spread of fire from one firecell to another and putting the lives of building occupants at risk
- damage to pipework such as sprinkler and water pipes can cause the pipes to fracture or pull apart and flood the building
- fractured or broken pipes also mean there will be no water available for firefighting.

Some partitions are designed with a thermal or acoustic rating. While the loss of these ratings

is not likely to endanger the lives of building occupants, damage following a low to moderate earthquake can be costly both in terms of repairs and loss of building functionality.

Generally, a situation-specific solution should be designed for each penetration through a non-structural partition but there are some guidelines that should be followed.

Guidelines for penetrations through partitions

Where possible, the building design should avoid requiring the need for services penetrations to go through fire-rated partitions by designing a different route for the service. Where penetrations are unavoidable, there are a number of alternatives to help minimise potential damage such as:

- planning coordinating services during the design phase to avoid penetrations where possible
- combining services to go through the same penetration to minimise the number of penetrations required
- providing adequate clearances around penetrations
- avoiding fixing services components to the partition penetration
- avoiding fixing services components to and part of a lightweight partition.

Clearances around penetrations

NZS 4219:2009 *Seismic performance of engineering systems in buildings* requires a 50 mm clearance around services through penetrations in a structural element such as a

wall or a floor. The clearance is intended to avoid impact or interaction due to differential seismic movement between the service component and the structure. The same principle should be applied where service penetrations pass through non-structural partition systems.

To create a clearance around a penetration through a lightweight framed partition, a frame to provide clearance should be constructed around the penetration (Figure 8). A suitable stopping material is then inserted around the framing.

Fire stopping materials

A range of fire stopping materials is available to provide fire protection for fire stopping and sealing penetrations in fire rated elements including non-structural partitions. Generic products include:

- mineral fibre mats/strips
- foam
- bags/pillows
- plugs/blocks
- pipe closures
- sealants/mastics
- preformed elastomeric seals.

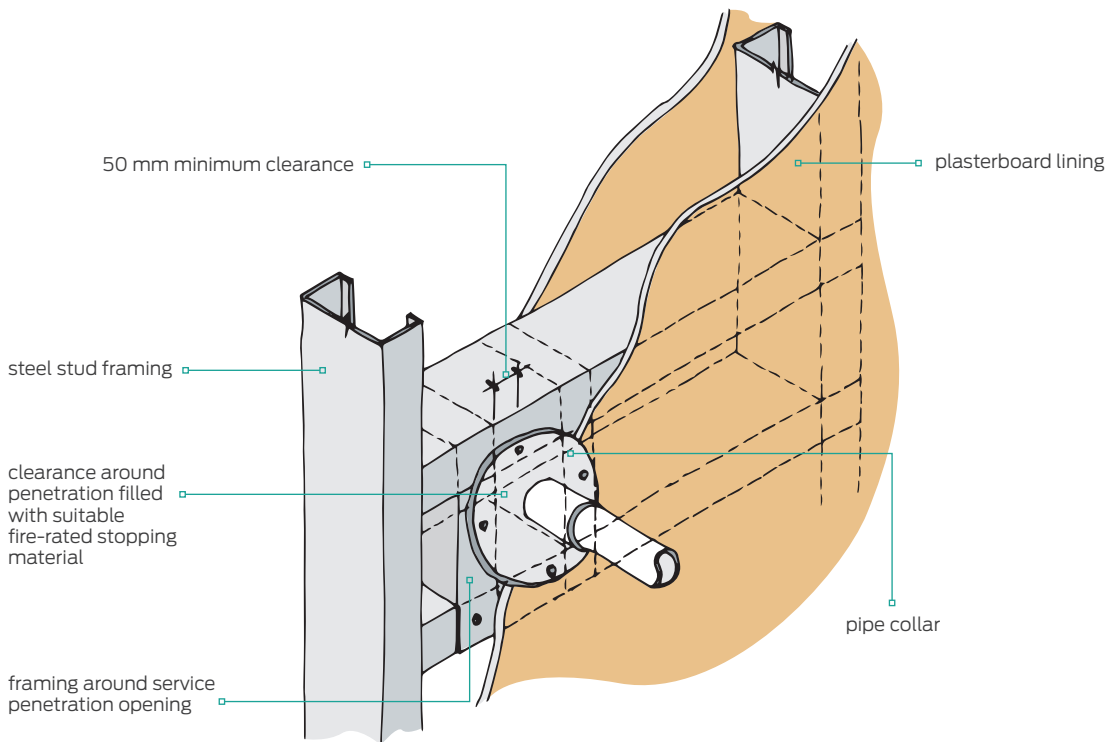


Figure 8: Clearance and fire stopping around a penetration

The selection, use and installation of Fire stopping systems should be selected and installed based on the location where they are to be used and in strict accordance with the manufacturer's or supplier's recommendations.

Table 6 describes the types of stopping materials available and where they may be used.

Fireboxes

A firebox is designed to prevent the spread of fire through service penetrations in partitions. It consists of a chassis containing fire and smoke-rated brushes and an intumescent fire seal through which service pipes, cables and ducting can pass through the one penetration (Figure 9). It can be fixed to the underside of the concrete

Stopping systems	Description	Recommended use
Mineral fibre mats/strips	Mineral fibre products available in mats, strips and other preformed shapes.	To seal penetrations through FRR walls and partitions.
Foam	A two-part silicone material that foams and increases in volume when mixed.	To seal penetrations particularly where there are multiple or complex shape services.
Bags/pillows	Made of a special fabric case filled with an intumescent material.	Available in different shapes and sizes for a range of uses. As they are also flexible, they can be used where cables penetrate a wall.
Plugs/blocks	Formed from materials such as bonded vermiculite, mineral wool, gypsum or cementitious materials, polyurethane and modified rubber that may be either rigid or flexible.	Available in different shapes and sizes for a wide range of situations. Specifically, shaped plugs are also made for specific locations e.g. to fit the gaps at the underside of trapezoidal metals decking.
Pipe closures (plastic pipes only)	Available as pipe collars or wraps filled with intumescent material that expands on heating, putting pressure on and collapsing plastic pipes and closing the penetration.	Use specifically for plastic pipes and trunking.
Sealants/mastics	Consists of a high viscosity binder such as acrylic, polysulphide or silicone with an intumescent filler, which expands on heating dispersed in it. When it is dispensed, either be dispensed by gun or trowelled into an opening, a curing process creates a flexible or a rigid seal.	Can be used in a wide range of situations, particularly for small openings, complex penetrations and where access is difficult.
Preformed elastomeric sealants	Generally available in strip form and made from elastomeric foam that may also be intumescent.	Typically used between building elements such as wall/floor or wall/column.

Table 6: Generic stopping systems and recommended use

slab of the floor above so it is independent of the partition framing, installed in new partition construction or retrofitted into an existing partition system. Fireboxes are available in a range of sizes that will suit most situations.

When installing a firebox, ensure there is sufficient space on both sides of the unit where it goes through a partition to install cable or pipe hangers as the penetrating services must be supported independently of the firebox.

Fire and smoke dampers

Fire and smoke dampers are installed with ducting systems where the ducting passes through fire rated walls. Under normal conditions

the damper allows air to flow through the duct but if a fire breaks out, the intumescent material within the damper will expand to form a non-combustible, insulating fire stopping barrier.

Fire and smoke dampers must also be fixed independently of partition penetrations. They should:

- be installed using flanges fixed to the fire damper sleeve but not to the wall to allow for thermal expansion during a fire
- have a separation between the fire damper sleeve and the penetration in accordance with the manufacturer's recommendations
- have the gap created by the separation packed with a compressible, non-combustible material.

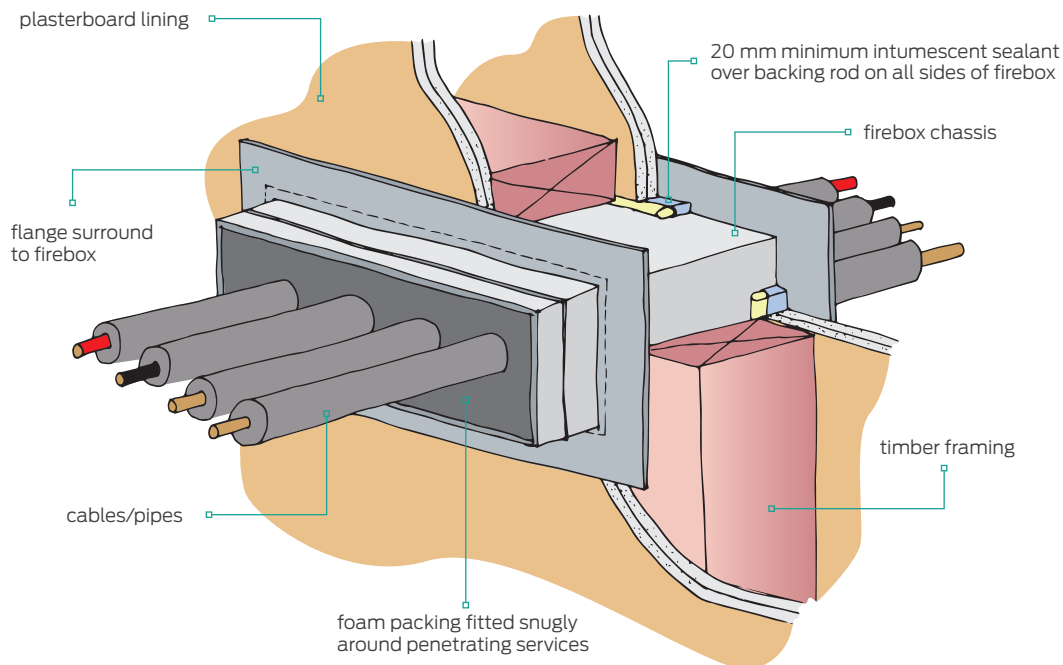


Figure 9: Typical firebox installation through FRR partition

8

Generic details

This section contains generic details showing typical methods of construction for seismic restraint and separation of non-structural internal partitions. Note that when proprietary products are used, manufacturer's instructions should be followed.

Generic details and solutions

New solutions and design details are required to mitigate the damage that occurs to non-structural partition systems during seismic events. Architects and designers must move away from designing internal partitions with a monolithic finish by designing to:

- allow independent movement of non-structural partitions by isolating them from the building structure
- provide lateral stability by bracing partial height partitions to the building structure.

Although there is a preference for a clean finish where joints, junctions and intersections between different materials flowing smoothly and seamlessly from one to the other, this method of construction and finishing has proved to be unsuccessful under seismic conditions.

Alternative finishes could include:

- incorporating shadow lines or negative details at wall junctions and intersections
- breaking up large areas of wall with regularly spaced control joints

- covering gaps with trim finishes that allow movement.

Partition construction

To construct framed and lined partitions with seismic separations:

1. Fix steel channel top and bottom tracks to the floor and the underside of the building structure above (concrete floor, beam, roof) over plasterboard* or similar strips that are full depth of the tracks.
2. Fix steel channel perimeter tracks to the building structure (column, exterior wall or structural wall) over plasterboard* or similar strips that are full depth of the tracks.
** Note that where partitions are required to be fire-rated, the packing material must be plasterboard or a proprietary fire barrier material.*
3. Friction fit studs, either steel or timber, between the top and bottom tracks leaving a 10-15 mm deflection gap between the top of the stud and the top track.
4. Allow a 25-50 mm gap between the edge track and the adjacent stud.
5. Fix lining material at all edges and across the sheets to the studs only. Do not fix the lining to the top, bottom and perimeter tracks.

Refer to Figures 10 to 25.

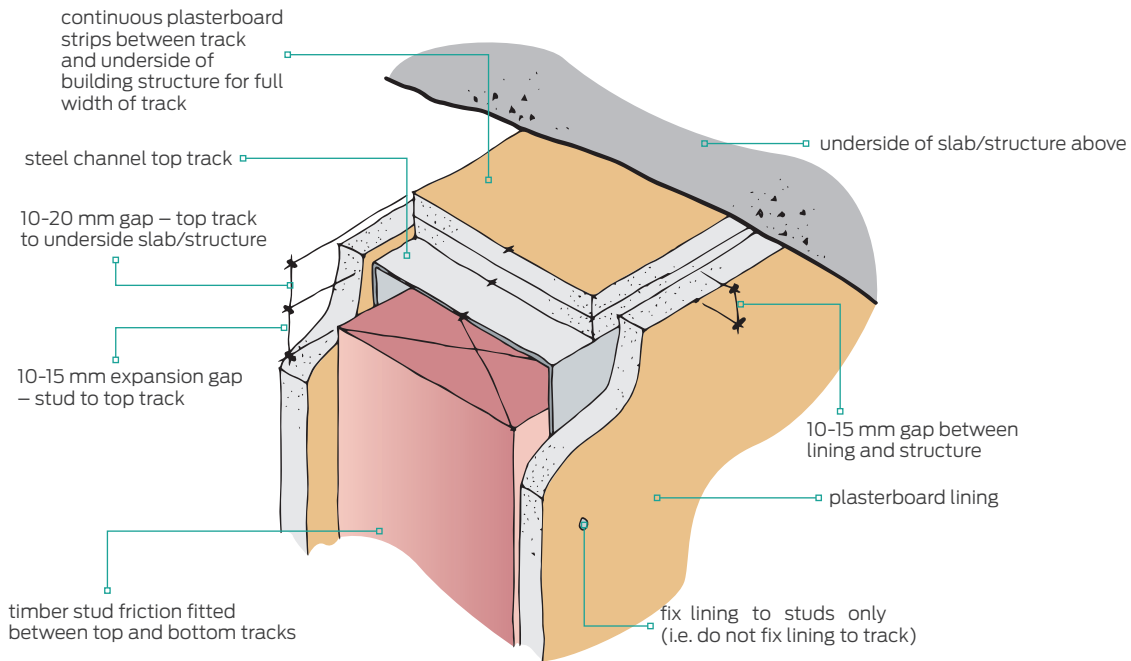


Figure 10(a): Full height FRR partition head detail – steel channel/timber studs

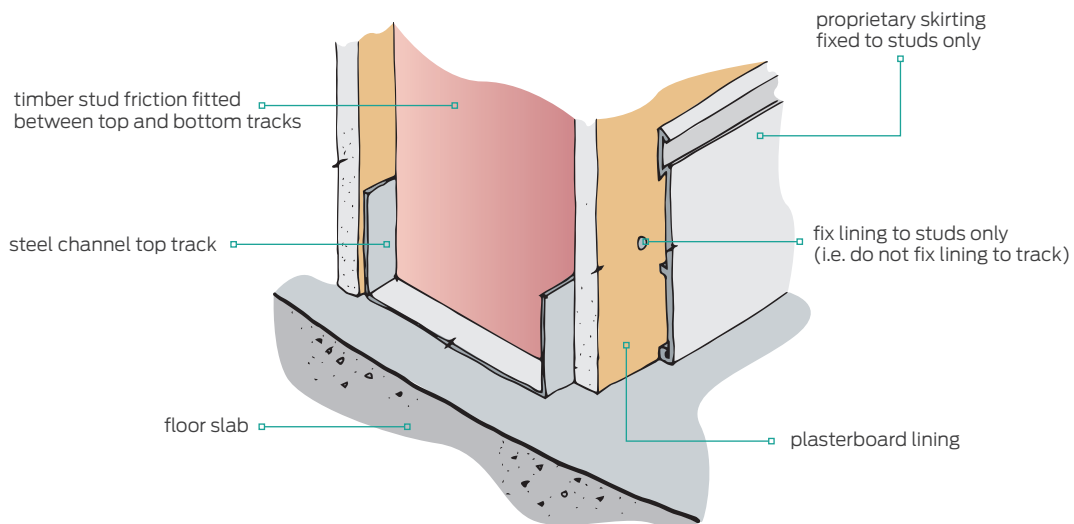


Figure 10(b): Full height FRR partition base detail – steel channel/timber studs

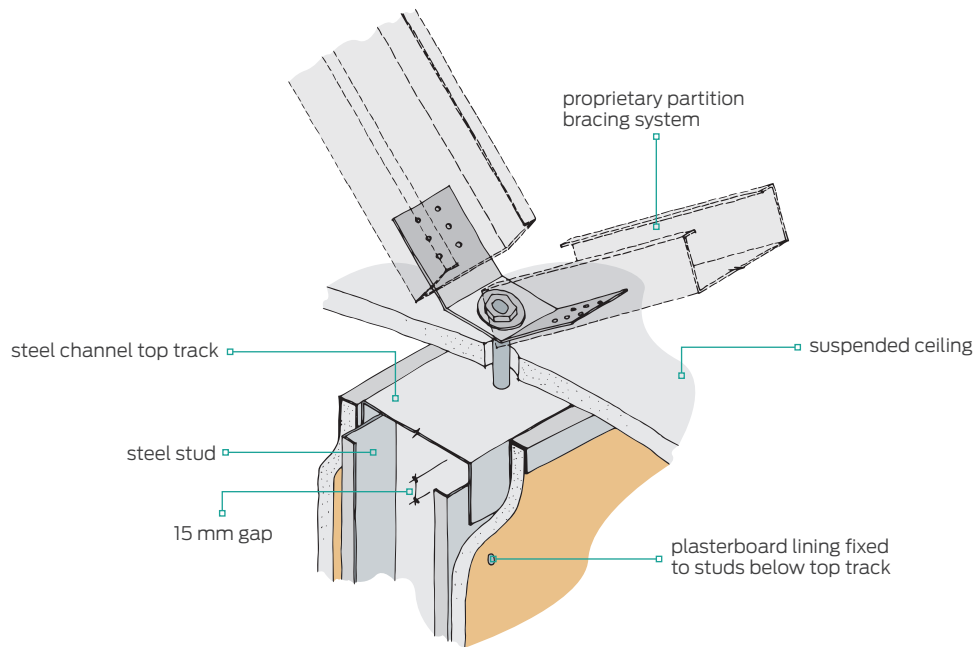


Figure 11: Partial height framed partition – seismic bracing to structure

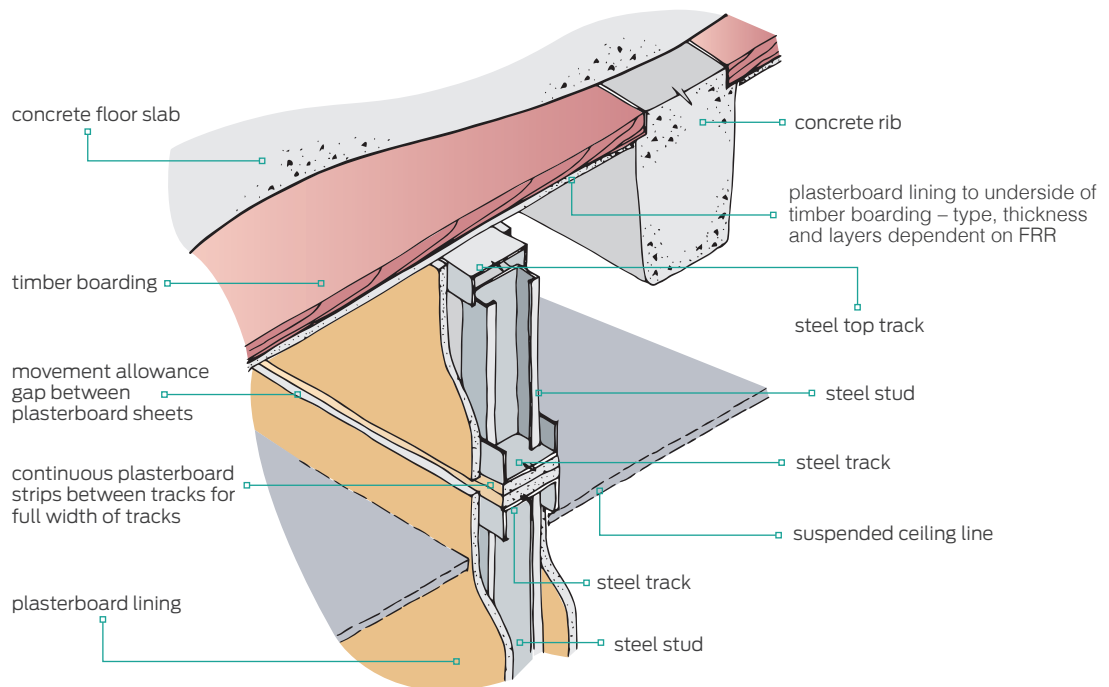


Figure 12a: Full height FRR partition to underside of composite flooring

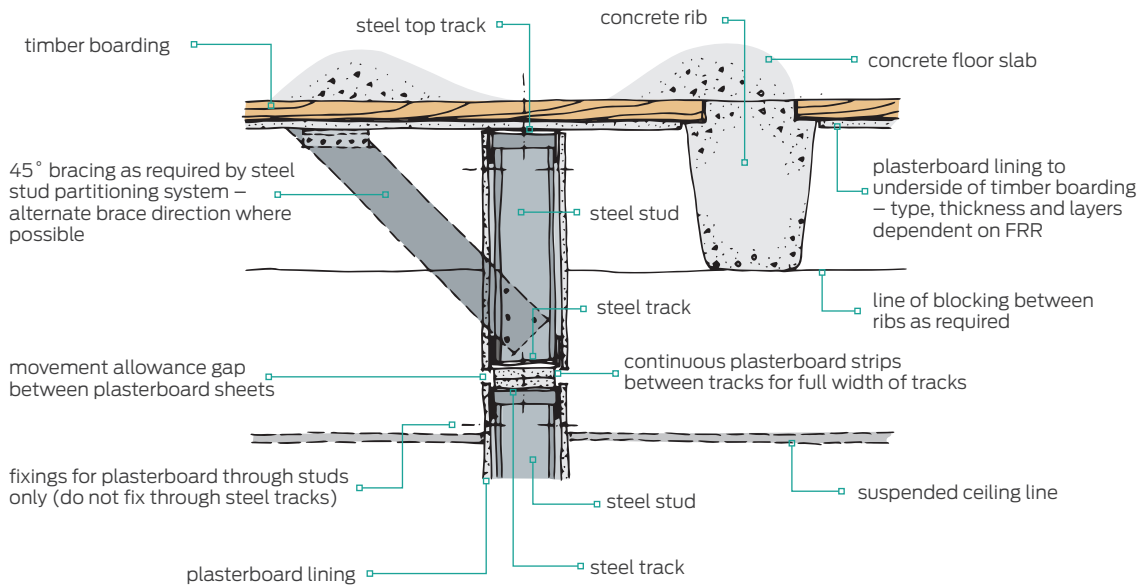


Figure 12(b): Full height FRR partition to underside of composite flooring – section detail

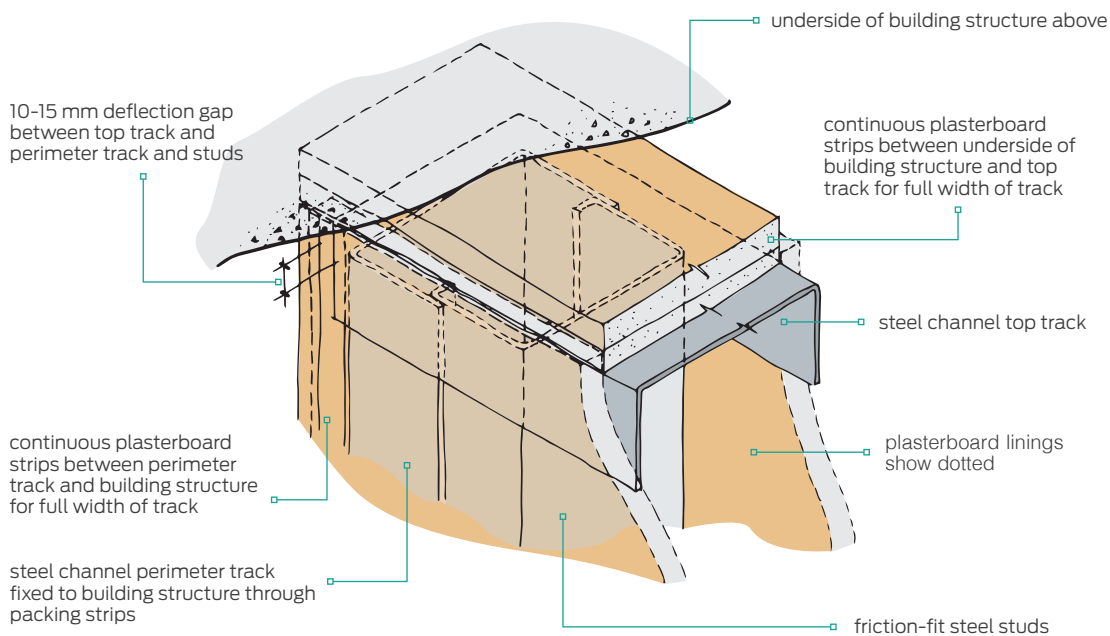


Figure 13: Full height FRR partition top corner detail – steel stud framing

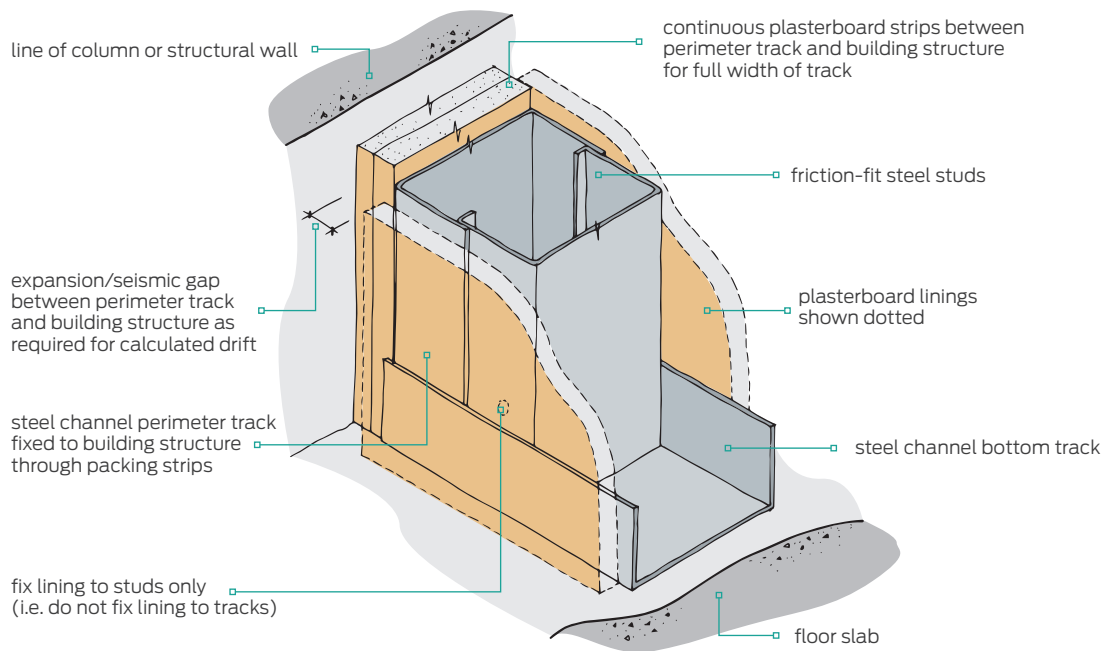


Figure 14: Full height FRR partition bottom corner detail – steel stud framing

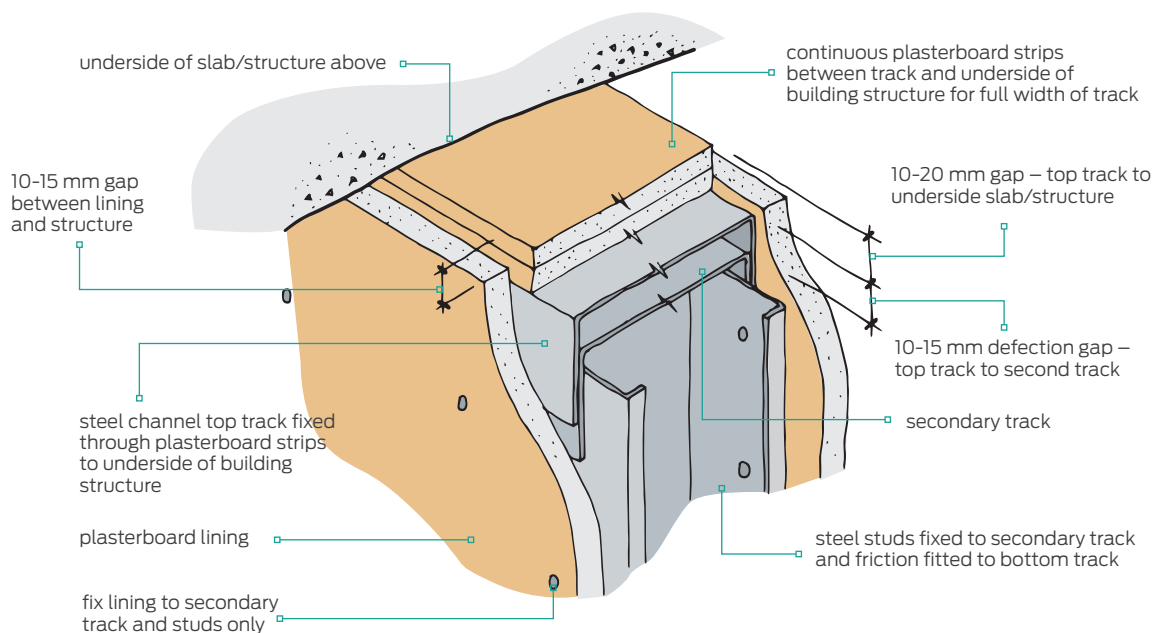


Figure 15: Alternative partition head details – (a) Double top track detail

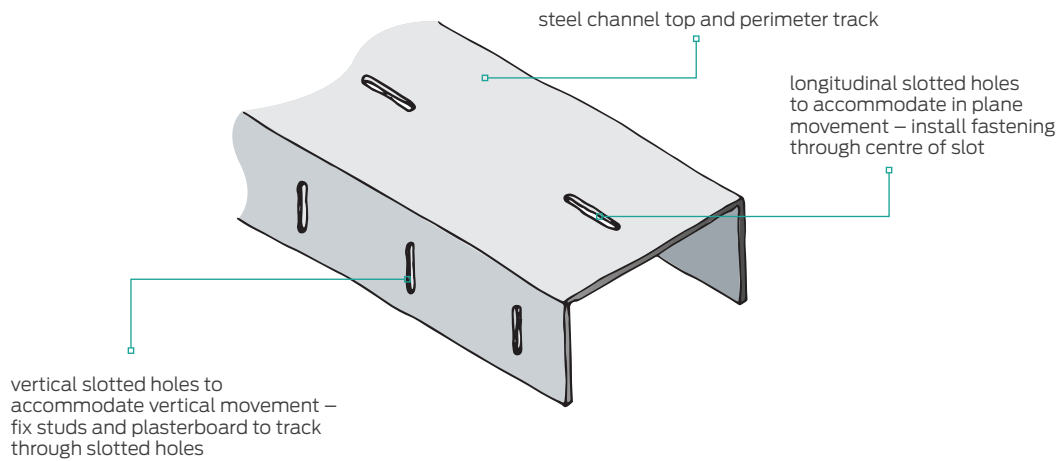


Figure 15: Alternative partition head details – (b) Steel channel track with slotted holes for vertical and in plane movement accommodation

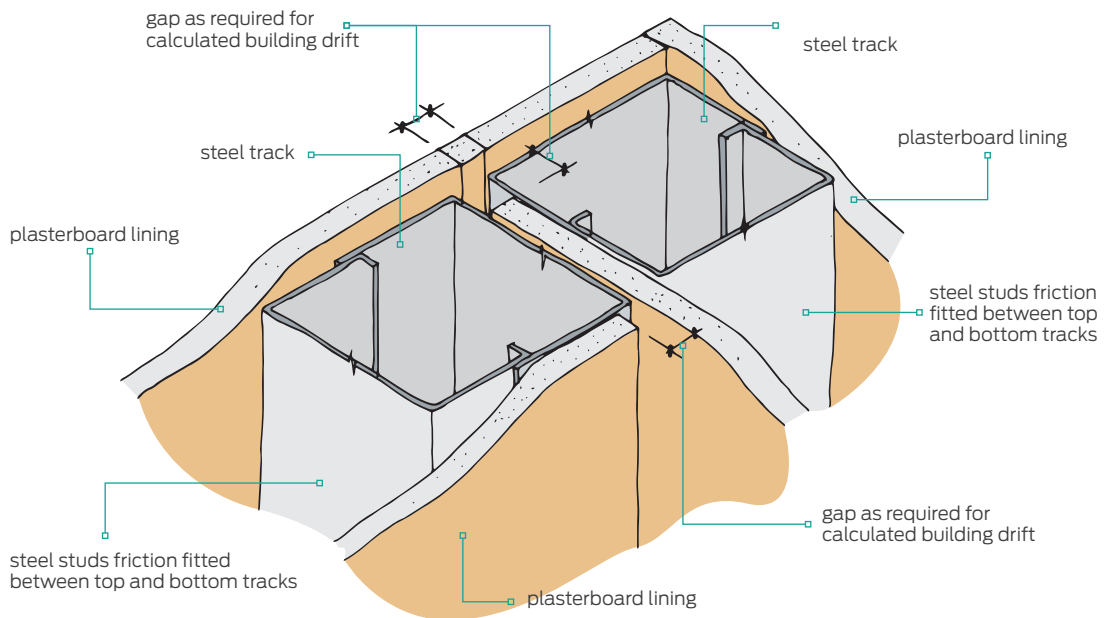


Figure 16: Corner detail – steel stud framing

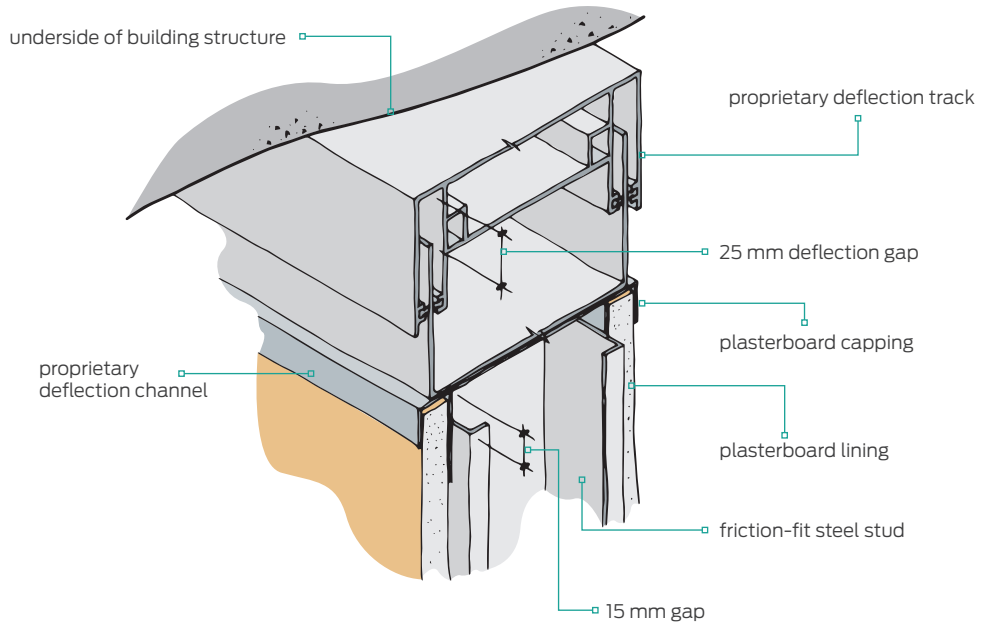


Figure 17: Full height partition head detail – proprietary deflection track

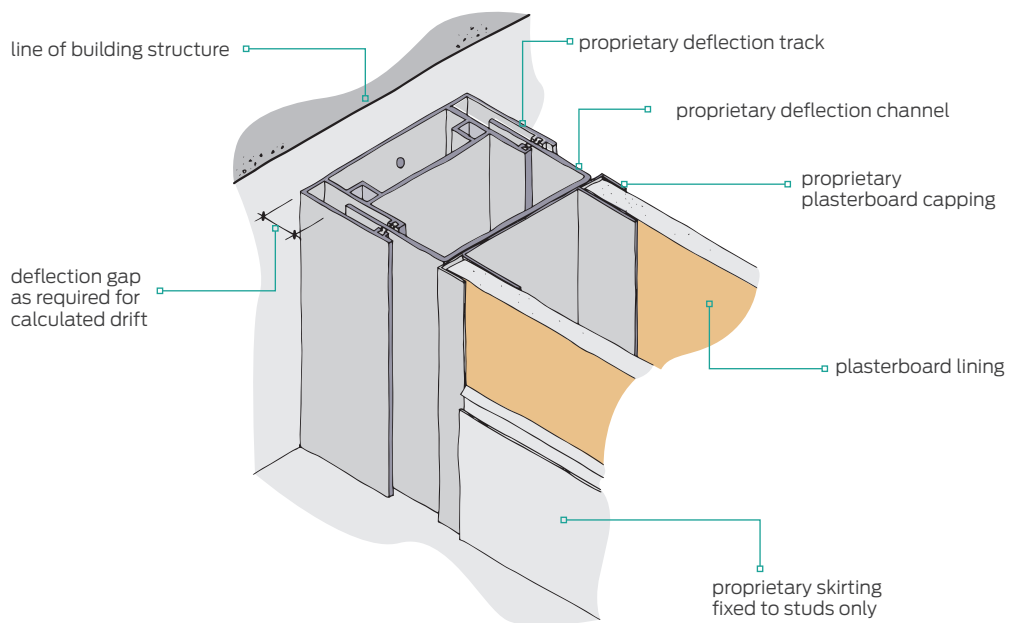


Figure 18: Partition edge detail – proprietary deflection track

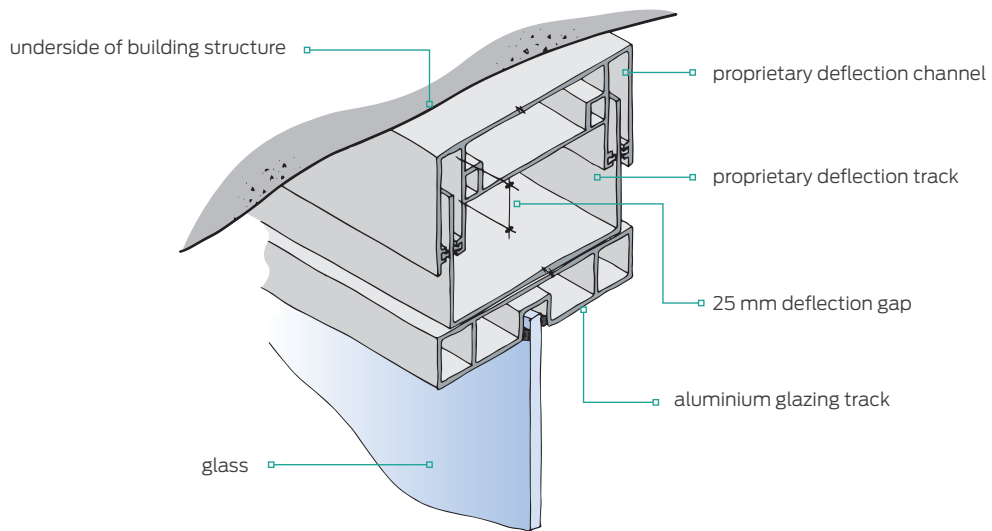


Figure 19: Glazed partition head detail – proprietary deflection track/standard aluminium glazing track

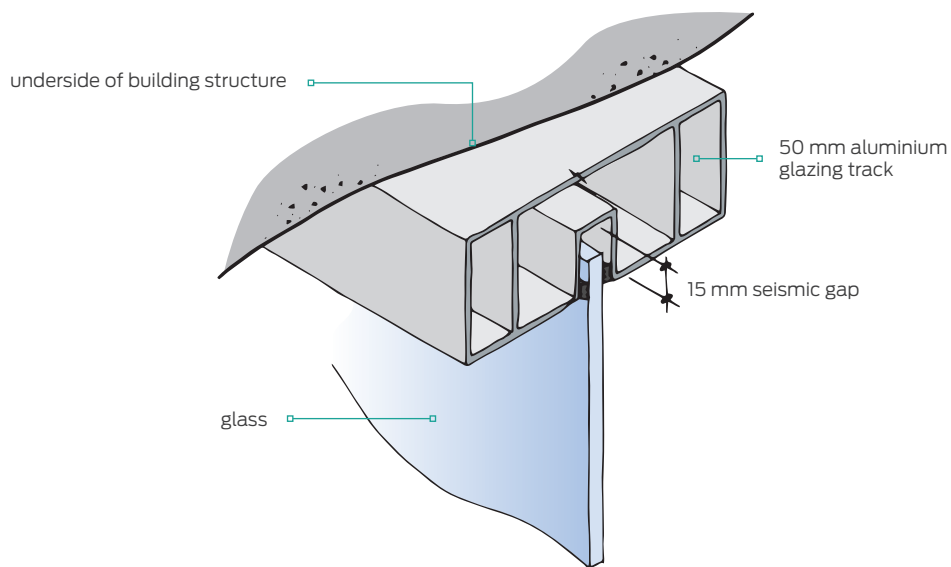


Figure 20: Glazed partition head detail – 50 mm aluminium glazing track

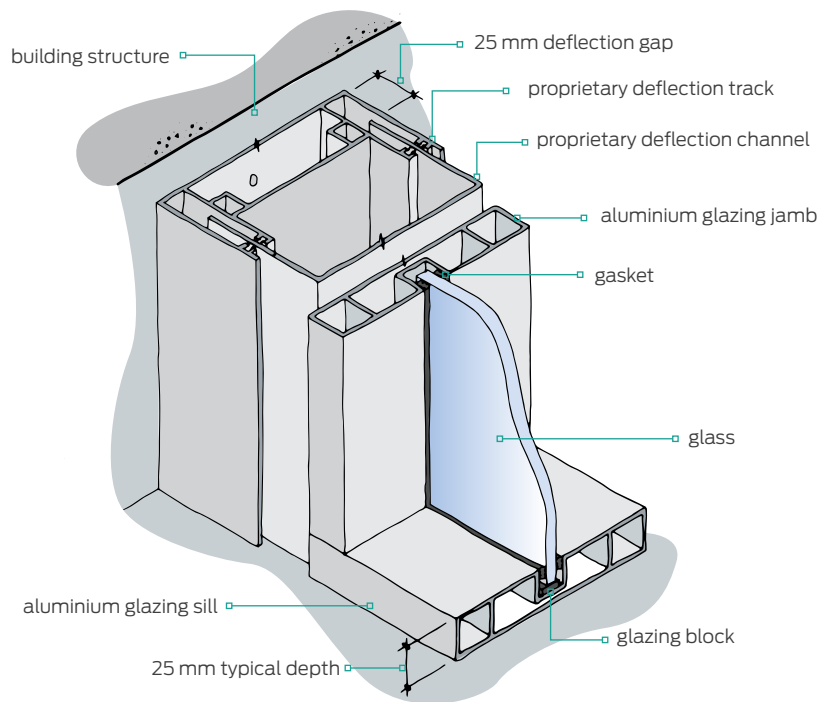


Figure 21: Glazed partition jamb/sill detail – proprietary deflection track/standard aluminium glazing track

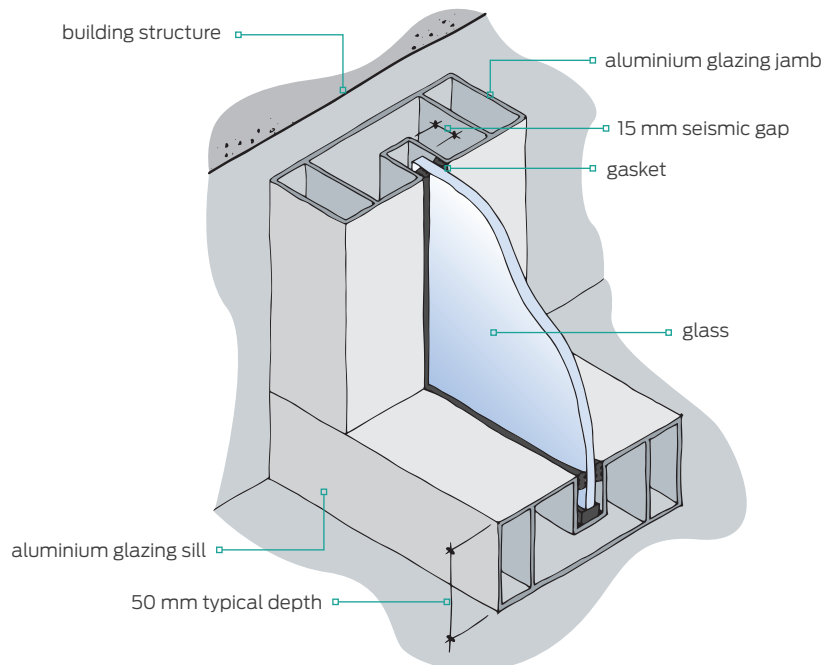


Figure 22: Glazed partition jamb/sill detail – 50 mm aluminium glazing track

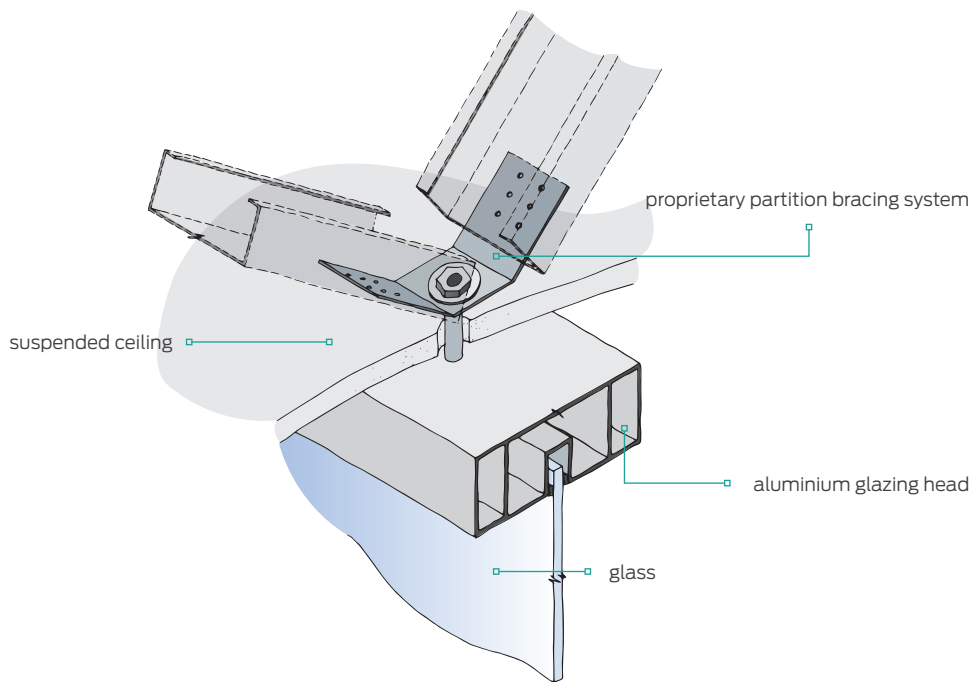


Figure 23: Glazed partition head detail – seismic bracing to structure/50 mm aluminium glazing track

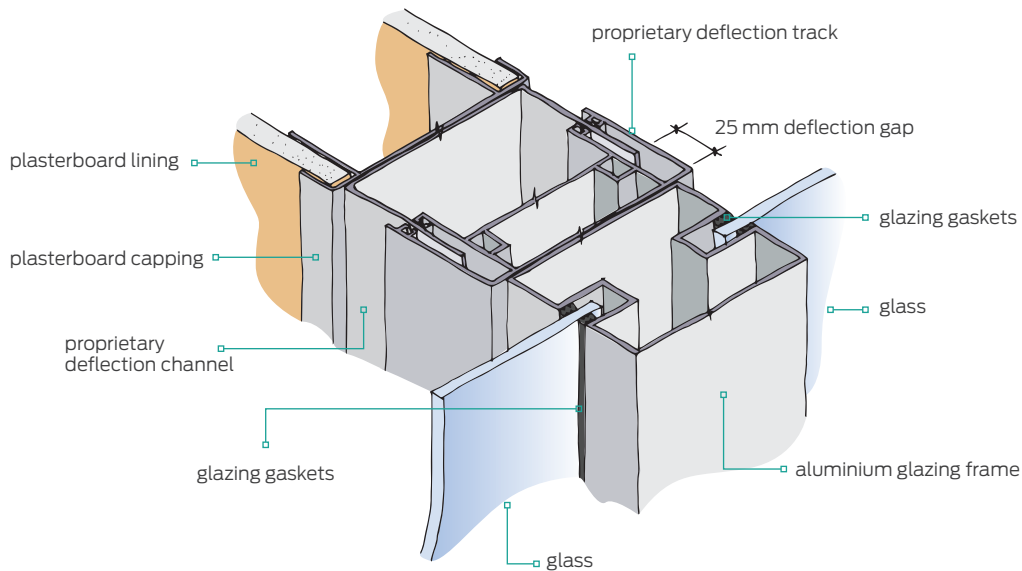


Figure 24: Steel frame/plasterboard lined partition/j glazed partition junction

Improving the seismic performance of non-structural partitions

A paper presented to the 2014 New Zealand Society for Earthquake Engineering conference¹² proposed the following actions for improving the seismic performance of non-structural partitions:

- **Include the structural design criteria directly on the drawings** – this information should be provided by the structural engineer and include both seismic load and drift expectations. It will provide contractors, manufacturers and the designers of non-structural partitions with the design requirements for the partitions.
- **Identify and provide a list of the design and inspection requirements** for non-structural components as part of the building consent documentation.
- **Require a PS1 (design)** to be submitted by the appropriate design engineer, contractor or an engineer employed by the contractor for the identified non-structural elements [to] provide clarity of design responsibility for these elements with regulatory overview provided by building officials. It should be linked to the list of design and inspection requirements provided as part of the building consent documentation.
- **Require a PS4 (construction review)** for specified non-structural elements. [This] will address concerns surrounding construction review and verification of most non-structural elements.
- **Review the New Zealand Building Code and standards** relating to non-structural bracing
- **Encourage bracing for non-structural elements and systems** to be listed separately from the equipment in tenders.
- **Encourage education of all involved in the construction industry** (including designers, contractors and building owners) about damage limitation and prevention, the benefits of damage limitation, and how this can be achieved. Education across the industry is vital to improve the performance of non-structural elements in earthquakes.

¹² From *Seismic performance of non-structural elements within building* presented by H. Ferner, M. Wemyss, A. Baird & A. Beer (Beca Ltd, Auckland, New Zealand) D. Hunter (Fletcher Construction, Auckland New Zealand), p.7

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Building Information Modelling (BIM)

Overview of BIM

Over the past 30 years, CAD software has evolved from 2D drawings into 3D integrated building information modelling (BIM) applications that coordinate and integrate all the information about the building. The BIM model contains information and data about the design, construction and maintenance of the building throughout its life from initial conception and design to demolition.

The concept of BIM is a virtual building model that functions in the same way as the actual building model will once it has been built. This is achieved by embedding the data about the building into a 3D model to integrate and coordinate the building information supplied by all different groups involved in the construction project. It can update the data automatically when changes are made to the model and as a 3D model, it can provide easy visualisation of the project.

The BIM model can be made accessible to everyone involved in the project so when changes are made, they will be available to everyone, potentially eliminating many of the problems that arise from issues such as clashes between building elements.

Once the model has been built, it can be developed, analysed, tested, tweaked, and altered in its virtual format, before the actual building is constructed. A clash detector can be run by the BIM manager to ensure that clashes between the building structure and elements and components of the building do not occur.

Drawings including plans, sections, elevations and details can be derived from any direction or vantage required from the model and schedules of materials and quantities can be generated from the model. When the project goes out to tender, tenderers and contractors can have access to the model and data.

The BIM model can facilitate the tracking and location of critical elements and services as well as the logging all lifecycle work such as servicing and replacing equipment and building elements through the life of the building.

Features of BIM modelling

The most significant features of BIM methodology include:

- the building model is combined in a single file
- real architectural elements are used for modelling
- issues of design are apparent and can be dealt with in the virtual model
- automatic updating of documentation occurs when changes are made
- clash detection means conflicts between services or elements can be identified and remedied in the virtual model avoiding costly on-site clashes
- data associated with the model can be used for quantity take-offs and costings
- changes to design can be made in the modelling phase rather than during actual construction, potentially reducing delays, wastage, cost over-runs and so on.

Facilitating collaboration

BIM systems can facilitate collaboration and

cooperation between all members of the design team and help mitigate or avoid many of the issues and conflicts that often occur during construction.

Benefits of BIM

Benefits that BIM provides include:

- the model can show the spatial relationships between elements and components
- the relationships are updated as changes are made to the model
- as it is one model containing all the building information, there are less likely to be errors in the documentation
- coordination in the virtual model facilitates coordination during construction
- 3D models are more comprehensible to most people and therefore less susceptible to misinterpretation than 2D drawings
- information about materials and quantities are associated with elements and components as embedded data
- simulations of different design and performance options such as structural, thermal, acoustic, lighting and fire performance, can be tested and optimised
- when changes are made, the revised performance of the building can easily be recalculated
- it allows for better planning of site activities and construction sequences
- prefabricated elements can be modelled, documented and manufactured with greater precision
- data generated during the design and construction of the building can be passed on to a facility manager to assist in the

operation and maintenance of the completed building.

BIM and non-structural partitions

BIM requires the early involvement of all groups involved in the project including non-structural partition designers, manufacturers and installers. The ability for sub-contractors to have early input into the model means they also have input into the seismic bracing and seismic resistance of the systems.

A BIM system can also help identify possible brace locations and orientations within existing buildings to assist in retrofitting non-structural element bracing.

BIM and the NZCIC Design Documentation Guidelines

The second addition of The New Zealand BIM Handbook was published jointly by the BIM Acceleration, Committee, BRANZ and MBIE in November 2016. It is available online at: www.biminnz.co.nz/bim-tools.

The aim of the Handbook is to:

- provide guidelines for a consistent approach to using BIM in New Zealand, and
- provide information on how BIM should be implemented.

The New Zealand Construction Industry Council (NZCIC) Design Documentation Guidelines are coordinated with and refer to the BIM Handbook.

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The future

Improved collaboration

The Canterbury and Wellington earthquakes have reinforced the need for better collaboration between architects, engineers and consultants from the early stages of a building project. In its report, the Canterbury Earthquakes Royal Commission said: 'A structural Chartered Professional Engineer should be engaged at the same time as the architect for the design of a complex building.'¹³

In a paper, *Improving Collaboration Between Architects and Engineers*, prepared jointly by the Institution of Professional Engineers New Zealand (IPENZ), New Zealand Institute of Architects (NZIA), and the New Zealand Registered Architects Board (NZRAB and MBIE, it states that:

In their collective view, the Canterbury Earthquakes Royal Commission's statement, cited above, is correct. A change in professional thinking is required, so that both architects and engineers better understand how, in the design of complex buildings, they need to work together from the beginning to maximise the contribution that both professions bring to the design process.¹⁴

This approach means that the major industry organisations wish to see improvement in all aspect of the seismic performance of New Zealand buildings.

Tools

A range of tools to facilitate seismic design and performance assessment are being developed in New Zealand and overseas¹⁵. These include:

- **Damage Control Limit State (DCLS)** – The concept of damage control limit state

is a limit state where a certain amount of repairable damage is acceptable, but the cost of repair should be significantly less than the cost of replacement. While this is not a limit state defined by NZS1170.5, it is generally comparable with the SLS2 requirement for critical post-disaster designated buildings which requires that the structures are designed so they can be returned to a fully operational state in a short timeframe (minutes to hours, rather than days). DCLS would provide a mechanism for discussion with building owners about the performance objectives for their of the building in an earthquake.

- **Performance Assessment Calculation Tool (PACT)** – This is an open-source software system, developed by the Applied Technology Council (ATC) of America, that assesses the seismic vulnerability, or fragility, of each structural and non-structural component as well as providing a component value breakdown of a building. It provides a simple method of calculating the expected damage and costs associated with different non-structural components.

Into the future

Following the earthquakes in recent years, there is a greater appreciation that New Zealand regularly experiences earthquakes ranging in magnitude from very low that occur unnoticed to severe earthquakes causing extensive damage to buildings. The cost is high in financial loss, loss of property and loss of life. But there is much that can be addressed to improve the seismic performance of buildings. This is an ongoing issue and there will undoubtedly continue to be ongoing research and investigation into the seismic performance of buildings in New Zealand.

¹³ Canterbury Earthquakes Royal Commission (2012). Final report, volume 5, summary and recommendations in volumes 5–7 Christchurch, the city and approach to this inquiry. Canterbury Earthquakes Royal Commission, Christchurch.

¹⁴ From *Improving Collaboration Between Architects and Engineers* at: <https://www.nzrab.nz/Edittable/Assets/Newslink2015/CollaborationPublication.pdf>

¹⁵ From *Seismic performance of non-structural elements within building* presented by H. Ferner, M. Wemyss, A. Baird & A. Beer (Beca Ltd, Auckland, New Zealand) D. Hunter (Fletcher Construction, Auckland New Zealand), pp.7-8

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Appendices

Glossary

BMT

Base metal thickness

Building part

A member that is either attached to, and supported by, the structure but is not part of the structural system of the building

Component

A building material formed into units of specified dimensions

Design working life

Duration of the period during which a structure or a structural element, when designed, is assumed to perform for its intended purpose with expected maintenance but without major structural repair being necessary

Dwang

A short (usually horizontal) member fixed between framing timber. Also known as a nog

Element

Part of a building or structure having its own functional identity e.g. a roof

Firecell

A space or series of spaces within a building enclosed by a combination of smoke separations, external walls, roofs and floors

FRR

Fire resistance rating

HVAC

Heating, ventilation and air conditioning

IGU

Insulated glazing unit

Inter-storey drift

The difference in sideways movement between two adjacent storeys

Intumescent

The ability of a material to expand or swell

Load

A force applied to a structure

MEP

Mechanical, electrical and plumbing

Mullion

A vertical bar separating panes of glass

Nog

See dwang

Partition

A wall dividing a floor area that may also be non-loadbearing and moveable

Period (seismic movement)

The interval of time between successive occurrence of the same state in an oscillatory or cyclic phenomenon

Plenum

An enclosed space such as a space above a suspended ceiling

Primary structure

The structural system provided to carry the inertial action effects generated in the structure by earthquake actions to the ground.

Secondary structure

The structural system provided to carry actions other than the earthquake actions generated in the structure

SLS

Buildings that can still be used for their intended purpose after an earthquake of the magnitude that can be expected once or twice during the life of the building

Structure

Organized combination of connected structural elements designed to provide some measure of resistance.

Transom

A horizontal bar separating panes of glass

ULS

To remain within its ULS, a building must still be standing after being subjected to its peak design load – concerned with life safety

Wall

A vertical construction a) enclosing a building or structure, b) dividing an internal space, c) serving as a fence

