BRANZ FACTS

SEISMICALLY RESILIENT NON-STRUCTURAL ELEMENTS #3

Restraint systems

The next step in the non-specific design pathway in NZS 4219:2009 *Seismic performance of engineering systems in buildings* is the design and installation of a restraint system for each component that has sufficient capacity to support and resist the forces determined in the earlier design steps.

Anchors, fixings and fasteners

Fixings consist of bolts, welds, anchors, brackets, cleats, gusset plates and so on that connect components and different elements of the restraint system.

All components and associated supports and restraints should be attached to the supporting structure so that seismic forces are properly transferred to the structure. The components should be attached to the building structure in such a way that the earthquake load demands determined earlier in the design process are matched or exceeded.

An exception is a system where components are expected to move but the displacements are not sufficient to cause impact against other components. Elements of the supporting structure (such as concrete floors and ceilings) must also be designed to withstand the additional locally induced seismic forces from the components as well as the normal design loads. Fixings should be designed without considering frictional resistance produced by the effects of gravity.

Where components are fixed to other non-structural elements of the building, such as timber-framed partition walls, the elements must be checked by a seismic specialist to verify they have adequate capacity to resist the applied loads.

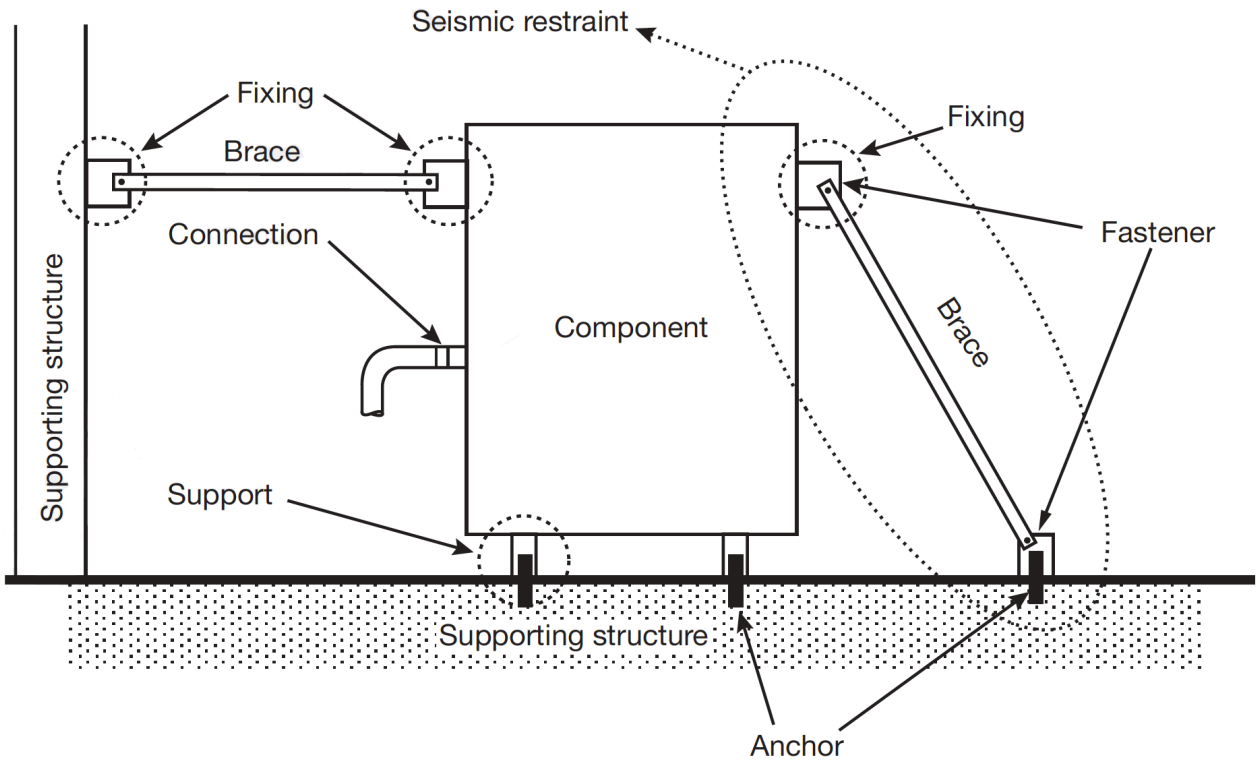

Figure 3.1 Identifying parts of a seismic restraint system (from NZS 4219:2009 Figure 1).
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Wood screws

Wood screw fixings should be made from steel and installed into the side grain of dry radiata pine framing timber. Screws should be pre-bored to 0.8 × screw diameter, except for self-drilling screws. NZS 4219:2009 provides design strengths for wood screws as shown in Table 3.1

Table 3.1 Wood screw design strengths (from NZS 4219:2009 Table 8).

Gauge	Diameter (mm)	Minimum penetration (mm)	Tension (kN)	Shear (kN)	Minimum edge distance (mm)	Minimum end distance and spacing (mm)
8	4.17	30	1.10	1.10	20	45
9	4.52	32	1.28	1.25	23	45
10	4.88	35	1.51	1.45	25	50
12	5.59	40	1.98	1.87	28[1]	55
14	6.30	45	2.50	2.33	32[1]	65

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[1] Edge distances require fixing into double studs (assuming 100 × 50 mm dressed studs with the short side facing the wall lining). Their use is limited to wall framing specifically coordinated with service component fixing requirements. Consider using coach screws for greater wall framing flexibility.

Coach screws

Coach screw fixings should be installed into the side grain of dry radiata pine framing timber. Screws should be pre-bored to 0.8 × screw diameter. NZS 4219:2009 provides design strengths for coach screws as shown in Table 3.2.

Table 3.2 Coach screw design strengths (from NZS 4219:2009 Table 9).

Diameter (mm)	Minimum penetration (mm)	Tension (kN)	Shear (kN)	Minimum edge distance (mm)	Minimum end distance and spacing (mm)
8	80	5.38	3.54	40[1]	80[1]
10	100	7.49	4.42	501	100[1]
12	120	9.91	7.28	60[1]	120[1]

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[1] NZS 4219:2009 edge distances require all coach screws to be fixed into double studs (assuming 100 × 50 mm dressed studs with the short side facing the wall lining). Consider using the bolt spacings, edge and end distances given in NZS 3603:1993 *Timber structures standard* clause 4.5 instead to enable the use of coach screws in single-stud walls.

Bolts

Where bolts are used to connect the ends of steel components, NZS 4219:2009 provides design strengths for bolts as shown in Table 3.3.

Table 3.3 Capacities of bolts in shear (from NZS 4219:2009 Table 10).

Bolt size	Minimum end distance (mm)	Strength for one bolt in shear (kN)
M8	16	6.1
M10	20	10.1
M12	24	15.1
M16	32	28.6
M20	40	45

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Cast-in anchors

Cast-in anchors should be at least grade 4.6 bolts or threaded rods installed into wet concrete or into concrete masonry before it is grouted.

The anchors must be provided with a positive means to prevent rotation while tightening the connecting nut.

The design strength of anchors cast in to concrete (with a strength of 25 MPa or greater) can be determined from Figures 3.2 and 3.3.

To use these graphs, the anchors cast in to concrete shall have minimum embedment depths and spacings given in Table 3.4 below.

The design strength of bolts embedded in concrete masonry can be obtained from Table 3.5 below.

For bolts cast in to concrete masonry, the minimum edge distance, measured from the centre of the bolt to the outer face of the masonry, should be not less than the embedment depth, and spacing between adjacent bolts should be at least twice the embedment depth.

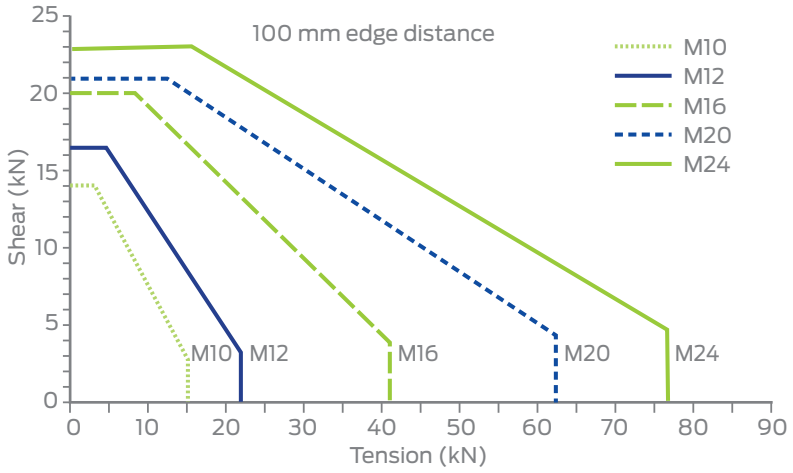

Figure 3.2 Design strengths of bolts cast in concrete with 100 mm edge distance (from NZS 4219:2009 Figure 11(a)).
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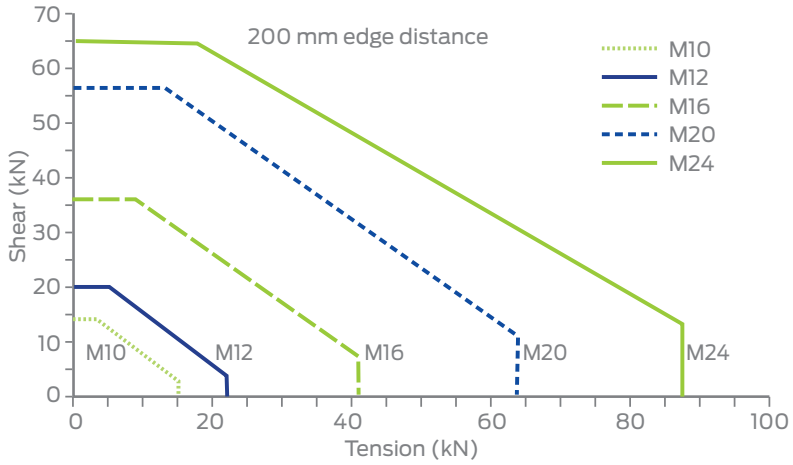

Figure 3.3 Design strengths of bolts cast in concrete with 200 mm or greater edge distance (from NZS 4219:2009 Figure 11(b)).
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Table 3.4 Design strengths of bolts cast in concrete (from NZS 4219:2009 Figure 11).

Bolt size	Minimum embedment (mm)	Minimum spacing (mm)
M10	75	200
M12	100	300
M16	125	375
M20	150	450
M24	175	500

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Table 3.5 Design strength of bolts embedded in concrete masonry (from NZS 4219:2009 Table 11).

Diameter (mm)	Minimum embedment (mm)	Tension and shear (kN)
12	100	10
16	125	15
20	150	25
24	175	35

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Proprietary anchors

NZS 4219:2009 requires that all post-installed and proprietary anchors (excluding screw and adhesive anchors) used to restrain engineering systems must have passed the seismic qualification test stipulated in ACI 355.2 *Qualification of Post-installed Mechanical Anchors in Concrete and Commentary*.

Building services contractors should select suitably qualified post-installed concrete fixings for both seismic and gravity supports, based on use in cracked or uncracked concrete as applicable. Selection should be made in accordance with NZS 3101:2006 *Concrete structures standard*, which refers to ACI 318 *Building Code Requirements for Structural Concrete and Commentary* Appendix D.

The design strength of the anchor in tension and shear should be obtained from the manufacturer. It must be verified to comply with the requirements of NZS 4219:2009 before installation.

Expansion anchors should not be used for non-vibration- isolated mechanical equipment rated over 8 kW or where the edge distance is less than the minimum specified by the manufacturer.

Table 3.6 Specification for brace and fastener materials (from NZS 4219:2009 Table 12).

Brace or fastener type	Material standard	Grade
Angles	AS/NZS 3679.1:2010 *Structural steel - Hot-rolled bars and sections*	Grade 300
Flats	AS/NZS 3679.1:2010 *Structural steel - Hot-rolled bars and sections*	Grade 300
SHS	AS/NZS 1163:2009 *Cold-formed structural steel hollow sections*	Grade C350LO
Bolts	AS 1111.1-2000 *ISO metric hexagon bolts and screws - Product grade C - Bolts*	Property class 4.6
Threaded rods	AS 1111.1-2000 *ISO metric hexagon bolts and screws - Product grade C - Bolts*	Property class 4.6
Nuts	AS 1112.3-2000 *ISO metric hexagon nuts - Product grade C*	

Braces and supports

All braces used to provide seismic restraint to components of engineering systems should be designed to match or exceed the earthquake demands determined earlier in the design process.

Where brace angles are greater than 30º to the horizontal, the vertical support system design must allow for the additional vertical reactions resulting from seismic brace loads (both tensile and compression reactions for rigid bracing and compression reactions only for cable bracing).

The inherent limits of manual cable tensioning means cable bracing allows for more thermal movement than rigid bracing.

All structural steel braces and fasteners should be fabricated to comply with the material standards and grades shown in Table 3.6.

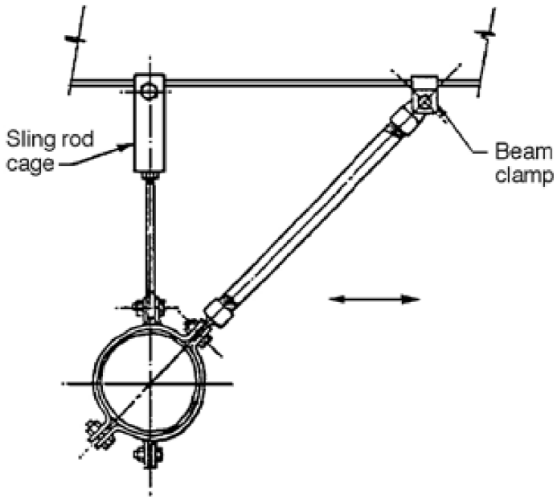

Figure 3.4 Example of transverse pipework restraint (from NZS 4219:2009 Figure 17).

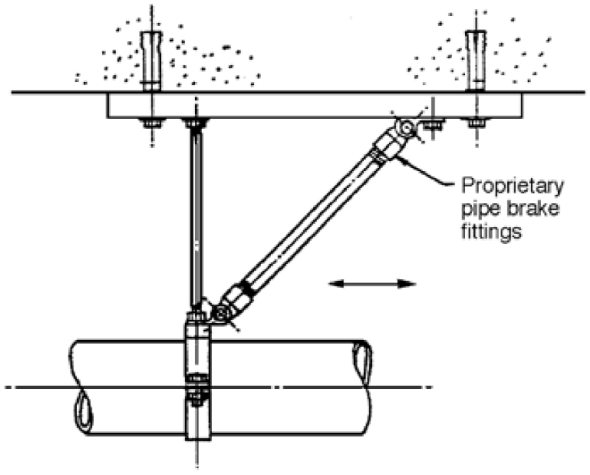

Figure 3.5 Example of longitudinal pipework restraint (from NZS 4219:2009 Figure 17).

Piping systems

All piping systems must be seismically restrained, unless:

- the pipes have a diameter less than 50 mm
- the pipework is suspended by individual hangers less than 150 mm long from the top of the pipe to the supporting structure.

Pipes should be restrained:

- at the point of connection of branch pipes
- at the point of connection to equipment.
- on at least one side of flexible couplings
- where the free swaying of the pipe may damage other building elements.

Water supply piping shall be considered as at least category P5. Steam piping and gas piping shall be classified as category P1, P2 or P3. (See Fact Sheet 2 Design Criteria for a description of these categories.)

All piping systems with pipes greater than 200 mm in diameter require specifically designed restraints.

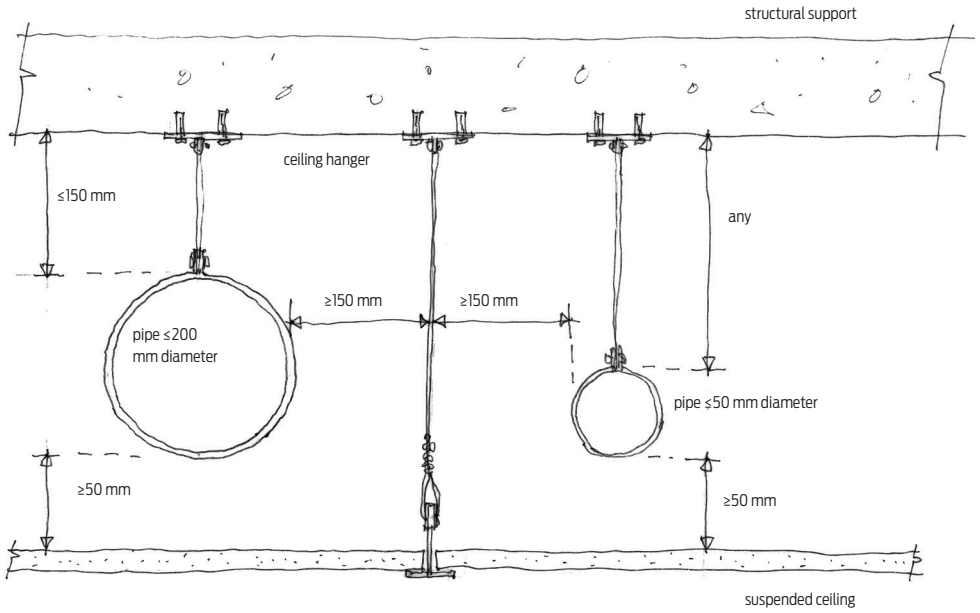

Figure 3.6 Where pipe restraints are not required.

Horizontal pipes

Each straight length of horizontal pipe shall have at least two transverse restraints and one longitudinal restraint. Continuous lengths of pipe with an offset along the length that is less than the corresponding maximum spacing given by NZS 4219:2009 may be considered as a single length of pipe for the purposes of longitudinal restraint.

Longitudinal restraint of a pipe length can be provided by transverse restraint of connected perpendicular pipes at elbows, bends or tees as long as the connected pipes are of the same size or no more than one nominal size smaller and the transverse restraint of the connected pipe is located within 600 mm of the elbow, bend or tee.

Vertical pipes

Each length of vertical pipe shall have at least two transverse restraints in each orthogonal direction.

All restraints on vertical pipes shall be installed within two pipe diameters of a vertical support. Transverse restraints shall be installed perpendicular to the pipe axis, with the centre line of the restraint as close as possible to intersecting the pipe axis. Longitudinal restraints shall be aligned with the axis of the pipe.

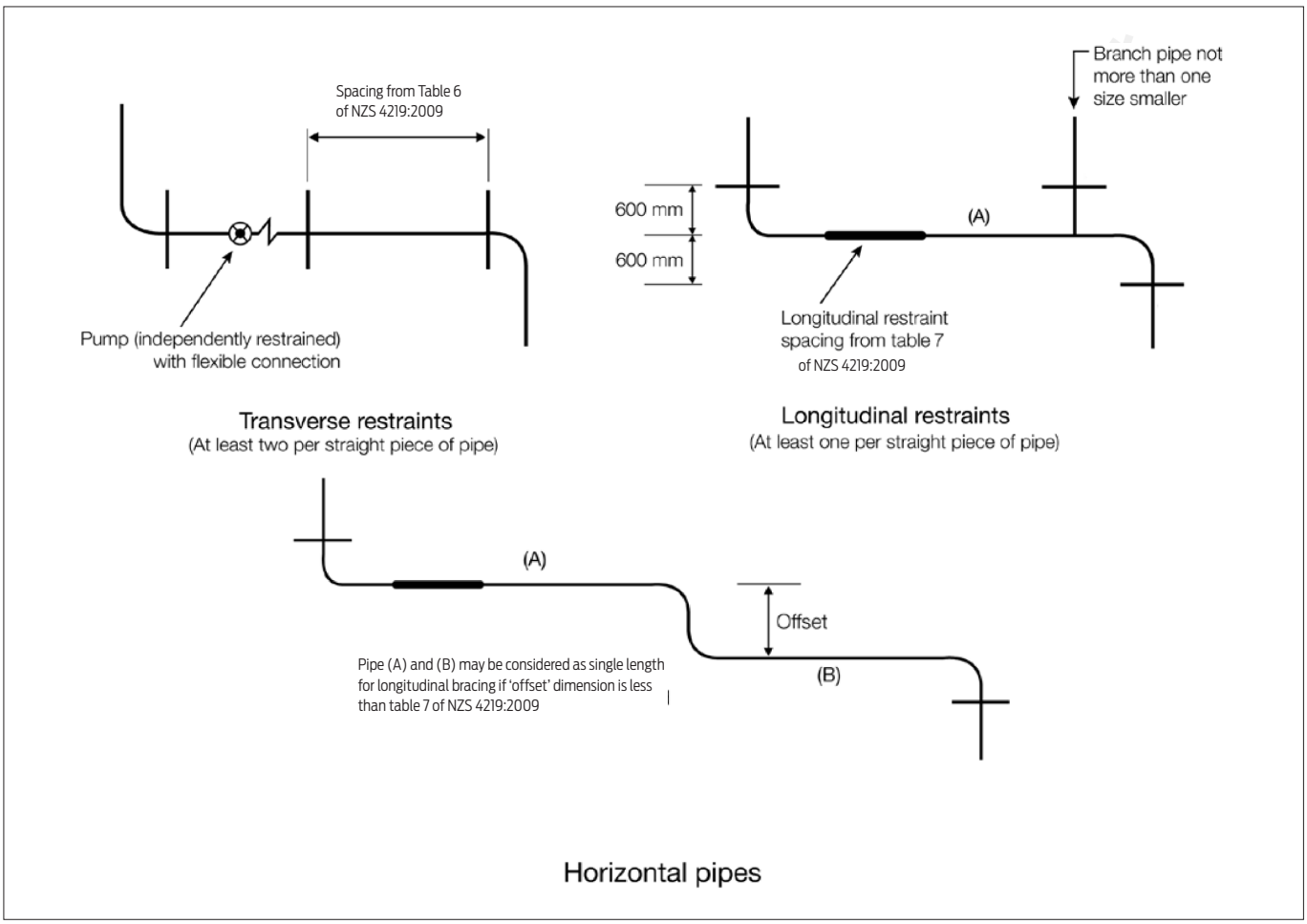

Figure 3.7 Horizontal pipework restraints (from NZS 4219:2009 Figure 16).
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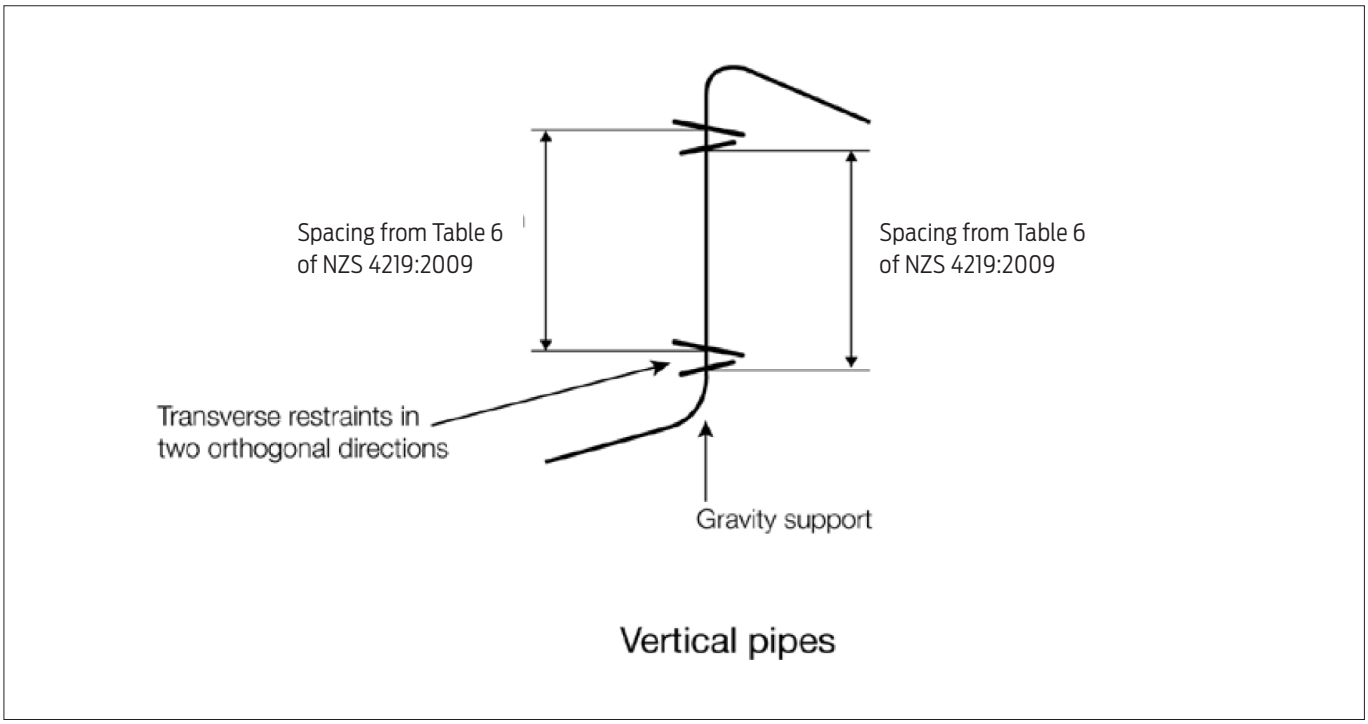

Figure 3.8 Vertical pipework restraints (from NZS 4219:2009 Figure 16).
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Ducting

All ducting systems must be seismically restrained, unless:

- it is a rigid ductwork suspended by hangers that are less than 200 mm long from the duct support position to the structural support
- it is a flexible ducting system that is less than 1.5 m long.

Where a restraint system is required and the ductwork is suspended with cables, the restraints must restrict movement of the ducting in all directions. Cable bracing is recommended for vibration-isolated equipment.

Suspended components that are installed in line with the duct system and have an operating weight greater than 10 kg, such as fans, heat exchangers and humidifiers, should be supported and laterally braced independently of the duct system.

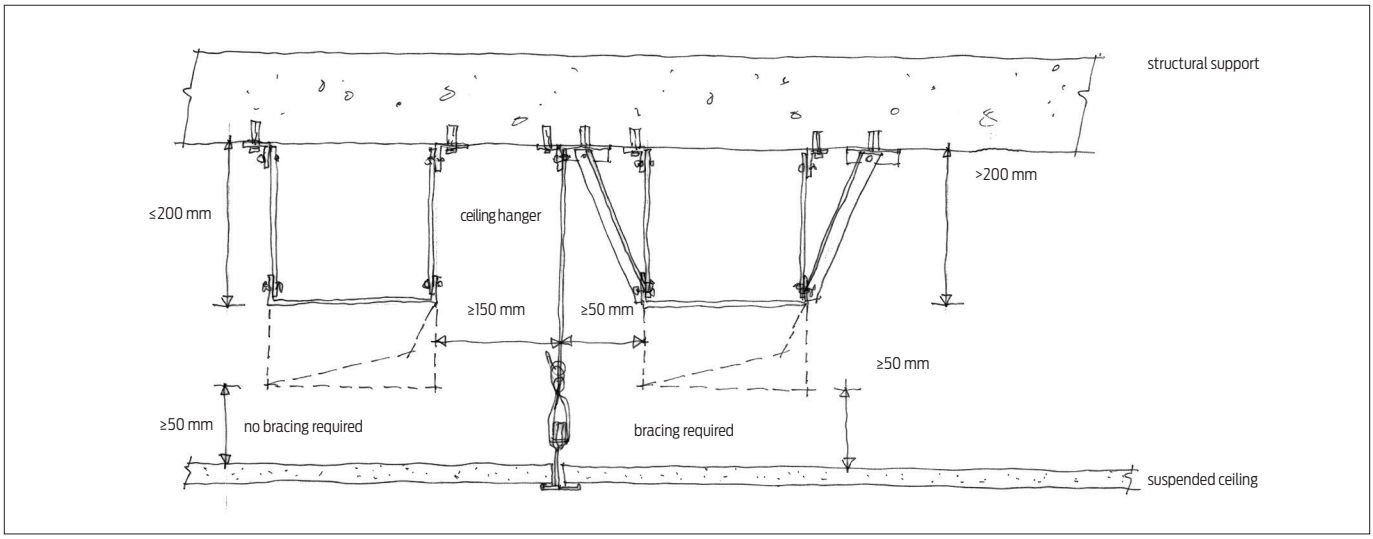

Figure 3.9 Where ducting restraint is and is not needed.

Electrical services

All electrical components installed within a cabinet should be positively restrained with straps, bars, bolts or similar devices. Cabinets should have hinged or sliding doors fitted with top and bottom catches. All free-standing cabinets must be sufficiently restrained to the structure.

All cable tray systems must be seismically restrained, unless the cable tray supports only non-essential electrical services and is suspended less than 400 mm below the structural support.

All components and cabling of non-essential electrical systems should be classified category P7. All components and cabling of emergency electrical systems should be classified category P4. The P4 classification extends to systems that support emergency components, such as emergency egress lighting mounted in a suspended ceiling.

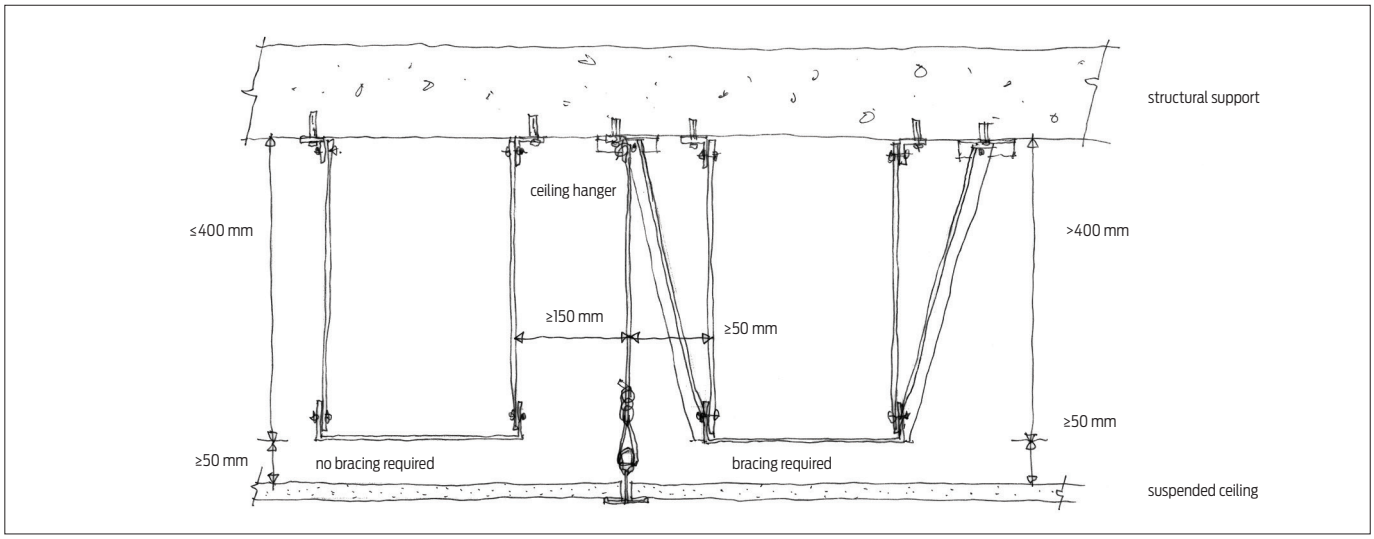

Figure 3.10 Where electrical services support system (cable tray) restraint is and is not needed.

Lighting

All fixings, including those for detachable accessories (such as diffusers and light controllers), should use a positive locking mechanism to prevent them disengaging during an earthquake.

Plinths

Where a component is mounted on a raised concrete plinth, the plinth shall be reinforced and anchored to the main floor slab. The plinth shall be designed to resist earthquake actions prescribed by NZS 4219:2009, including overturning. A seismic specialist must check the plinth design to ensure plant is adequately fixed to the plinth.

Vibration mounts

Components mounted on vibration isolators should have a bumper or snubber installed in each orthogonal horizontal direction. Where required by NZS 4219:2009, vertical restraints should also be installed to resist overturning forces.

Tanks

Tanks should be designed and restrained to prevent damage or loss of contents, depending on the design criterion being considered. Tanks should be restrained to prevent sliding and overturning failure without relying on friction between the tank and support pads.

Suspended components

Where a suspended ceiling system is used to support equipment, it must not weigh more than 10 kg. It should be positively fixed to the ceiling suspension system but not supported by the ceiling panels or tiles. Equipment weighing more than 10 kg must be fixed directly to the structure. Equipment weighing more than 25 kg must use a specific design. Flexible connections should be used between ceiling-supported equipment and ducts, pipes or cables that are supported by the structure.

Clearances

Unless specified elsewhere in NZS 4219:2009, all building services must maintain the clearances between adjacent components shown in Table 3.7.

Ceiling hangers and braces are considered to be restrained components for the purposes of Table 3.7.

Table 3.7 Required clearances (from NZS 4219:2009 Table 15).

Condition being considered	Minimum clearance (mm)	
	Horizontal	Vertical
Unrestrained component to unrestrained component	250[1]	50
Unrestrained component to restrained component	150	50
Restrained component to restrained component	50	50
Penetration through structure (such as walls and floors)	50	50

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[1] Unrestrained linear components only require 150 mm clearance.

Piping systems, ducting and electrical services

Pipes, ducting and cable trays that do not need to be restrained should be installed with a clearance of 150 mm from hangers and braces for suspended ceiling systems or other adjacent suspended components.

Suspended ceilings

Equipment that is not supported by a suspended ceiling should have a clearance of at least 25 mm all round to allow independent movement between the component and ceiling. Suspended ceiling hangers and braces should not be used to support electrical cables or fixtures.

Flexibility

Where components are connected to supports that allow them to move independently under seismic action, the design of the restraint systems must accommodate relative displacement between the components. This can be achieved by using flexible connections or, in the case of pipe and ductwork, configuring the system to accommodate movement without fracture.

Piping systems

Vertical pipes must be have sufficient flexibility to allow for the relative horizontal movement between floors or fixing points. Where vertical pipes pass through more than one floor and are located more than 1 m from a column or shear wall, the fixings or pipework configuration must have enough flexibility to allow for differential vertical movement between the floors.

Piping across seismic gaps

Where pipes cross structural separations, the design should allow for the relative horizontal movement in two orthogonal directions. The allowance should be 160 mm for every 4 m rise in height of the structural separation or the building design movement where known.

Where a connection is necessary between two structural systems, it should have adequate flexibility and be as close to the ground as possible. Bellows type expansion joints are usually unsuitable. Offsets, bends and loops provide the best means of crossing seismic joints. Flexibility may be achieved through piping flexibility or by the use of flexible grooved joints, providing axial and lateral pipe connection equivalent to the pipe strength. In all cases, piping that crosses a seismic gap requires a specific design.

Ducting

Registers and grilles should have positive fixings to the ducting. Ducting between ceiling-mounted grilles and rigidly mounted ducting should be flexible or allow for movement. Dampers, louvres and diffusers should also be positively attached to the duct with mechanical fasteners. Duct tape is not acceptable.

Electrical services

Electrical cables, conduit and cable trays that cross a structural separation or seismic gap should have sufficient flexibility to accomodate the expected horizontal and vertical movements determined during the design.

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