BRANZ FACTS

SEISMICALLY RESILIENT NON-STRUCTURAL ELEMENTS #2

Design criteria

NZS 4219:2009 *Seismic performance of engineering systems in buildings* requires the arrangement and layout of engineering systems within a building to allow for earthquake actions.

NZS 4219:2009 STATES that the location, design, construction and installation of engineering systems should reduce life and injury hazards and protect property and systems from damage or loss of function. To achieve this, the standard requires engineering systems to be designed, constructed and installed so that the following criteria are met:

- Components representing a hazard (classification P1, P2 and P3) will not collapse, rupture or lose support after an ultimate limit state (ULS) earthquake.
- Components required for emergency evacuation (classification P4) will not collapse, rupture or lose support after a ULS earthquake.
- Components required for operational continuity (classification P5) within buildings of importance level 4 are restrained in a manner so that the system is able to continue to perform its functions after a serviceability limit state 2 (SLS2) earthquake.
- All components are restrained in a manner so that the system retains its structural and operational integrity without requiring repairs after a serviceability limit state 1 (SLS1) earthquake.
- The definitions of ULS and SLS earthquake events are given in AS/NZS 1170.0:2002 *Structural design actions – Part 0: General principles*. Component categories are described below.

Determination of earthquake demand

When following the NZS 4219:2009 non-specific design pathway to meet these criteria, the first step is to determine the earthquake demand on all of the components that make up the engineering systems within the building. The procedure to determine earthquake demand is as follows:

1. Classify the building importance level and component categories.
2. Determine the earthquake load demand (static forces).
3. Obtain the relative displacement from the building designer.

Building importance level

The importance level of the building containing the engineering system can be established from Table 2.1.

Component categories

NZS 4219:2009 sets out general objectives and performance requirements for each component of an engineering system. This requires the designer to classify all components on the basis of their expected performance under earthquake actions.

Components should be classified into the categories shown in Table 2.2.

Table 2.1 Description and examples of building importance levels (from NZS 4219:2009 Appendix A).		
Importance level	**Type of building**	**Examples**
1	Structures presenting a low degree of hazard to life and other property	Structures with a total floor area less than 30 m². Farm buildings, isolated structures, towers in rural situations. Fences, masts, walls, in-ground swimming pools.
2	Normal structures and structures not in other importance levels	Buildings not included in importance levels 1, 3 or 4. Single family dwellings. Car parking buildings.
3	Structures that, as a whole, may contain people in crowds or contents of high value to the community or pose risks to people in crowds	Buildings and facilities as follows: • Where more than 300 people can congregate in one area. • Daycare facilities with a capacity greater than 150 people. • Primary school or secondary school facilities with a capacity greater than 250 people. • Colleges or adult education facilities with a capacity greater than 500 people. • Healthcare facilities with a capacity of 50 or more resident patients, without surgery or emergency treatment facilities. • Airport terminals and principal railway stations with a capacity greater than 250 people. • Correctional institutions. • Multi-occupancy residential, commercial (including shops), industrial, office and retail buildings designed to accommodate more than 5,000 people and with an area greater than 10,000 m². • Public assembly buildings, theatres and cinemas with an area greater than 1,000 m². Emergency medical and other emergency facilities not designated as post-disaster. Power-generating facilities, water treatment and wastewater treatment facilities and other public utilities not designated as post-disaster. Buildings and facilities not designated as post-disaster containing hazardous materials capable of causing hazardous conditions that do not extend beyond the property boundaries.
4	Structures with special post-disaster functions	Buildings and facilities designated as essential facilities. Buildings and facilities with a special post-disaster function. Medical emergency or surgical facilities. Emergency service facilities such as fire and Police stations and emergency vehicle garages. Utilities or emergency supplies or installations required as back-up for buildings and facilities of importance level 4. Designated emergency shelters, designated emergency centres and ancillary facilities. Buildings and facilities containing hazardous materials capable of causing hazardous conditions that extend beyond the property boundaries.
5	Special structures (outside the scope of NZS 4219:2009)	Structures that have special functions or whose failure poses catastrophic risk to a large area (such as 100 km²) or a large number of people (such as 100,000). Major dams, extreme hazard facilities.

Table 2.2 Engineering system component categories (from NZS 4219:2009 Table 2).		
Criteria	**Component category**	**Limit state**
Component represents a hazard to life outside the building	P1	ULS
Component represents a hazard to a crowd of greater than 100 people within the building	P2	ULS
Component represents a hazard to individual life within the building	P3	ULS
Component necessary for the continuing function of the evacuation and life safety systems within the building	P4	ULS
Component of a system required for operational continuity of the building	P5	SLS2
Component for which the consequential damage caused by its failure is disproportionately great	P6	SLS1
All other components	P7	SLS1

Note that category P5 only applies to importance level 4 buildings as this is a requirement of NZS 1170.5:2004 Structural design actions – Part 5: Earthquake actions – New Zealand. The design loads derived for components in lower importance level buildings may be increased unnecessarily if category P5 is applied instead of P6 or P7 to other components in importance level 1, 2 and 3 buildings.

Earthquake load demand

The earthquake load demand (F) on a component for each design criterion should be assessed using the lateral force coefficient (C) and the operating weight of the component (W) in the equation:

$$F = C \times W$$

The lateral force coefficient can be found by using the component's height (CH), the building's earthquake zone factor (Z), the component performance factor (CP) and the component risk factor (RC) in the equation:

$$C = 2.7 \times CH \times Z \times CP \times RC$$

where CH is 3.0 for components above ground floor or 1.0 at or below ground floor. C should be no greater than 3.6.

Earthquake zone factor

The earthquake zone factor (Z) represents the relative level of seismicity for the building's location in New Zealand. It can be determined from Figure 2.1 below or from Table 3 of NZS 4219:2009, subject to Building Code Verification Method B1/VM1 clause 13.0 modifications for the Canterbury earthquake region (the area contained within the boundaries of the Christchurch City Council, the Selwyn District Council and the Waimakariri District Council).

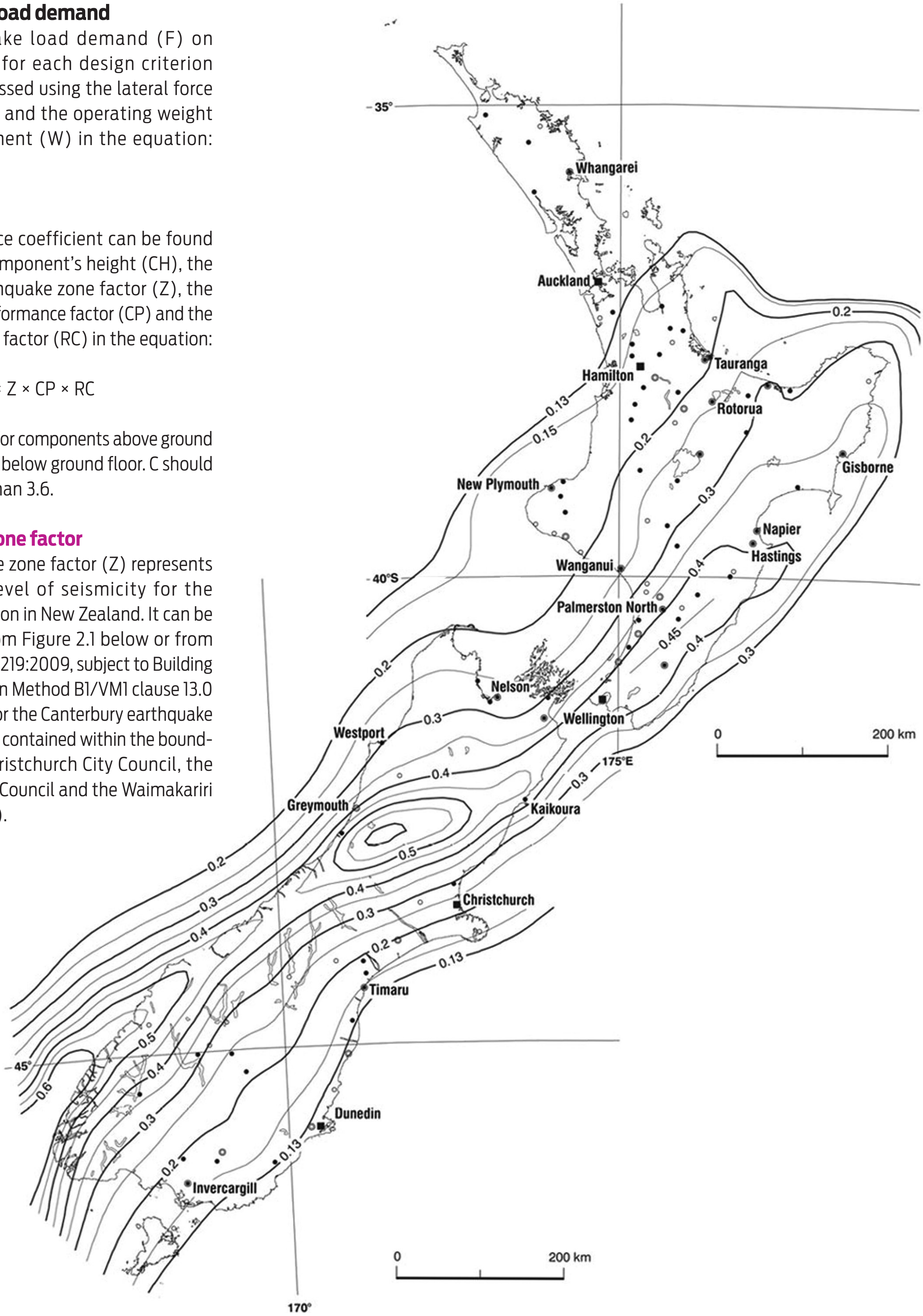

Figure 2.1 Map of relative seismicity in New Zealand showing earthquake zone factors (from NZS 4219:2009 Figure 2). Provided by Standards New Zealand under licence 001138.

Note that, following the 2010/11 earthquakes, for buildings in the Canterbury earthquake region with a building structure period less than 1.5 seconds, the zone factor should not be less than 0.3.

Component performance factor

The component performance factor (C_P) should be used to determine the load in each part of the seismic restraint system rather than taking the most severe applicable value and applying it to the whole system. Table 2.3 lists relevant performance factors for components of engineering systems.

Component risk factor

The component risk factor (R_c) can be determined from Table 2.4 using the importance level and component category.

Relative displacement

Components connected to the building structure at more than one level must be designed to sustain the relative seismic displacement (D) between the levels for the appropriate design criterion.

The displacement can be determined from the building's calculated design displacement, where known. If the displacement is not known, it may be calculated using the component risk factor (R_c), the height between fixing points (H_z) and the following equation:

$$D = 0.025 \times R_c \times H_z$$

Note that, when using this equation, R_c should be no greater than 1.0.

The NZS 4219:2009 non-specific design pathway allows relative displacement to be accommodated using flexible joints. The joints must have been demonstrated, by test or other means, that they are able to accommodate the relative displacements between fixing points.

Where a component is attached to the structure using rigid joints that are not designed to allow for the relative displacement, the component must follow the NZS 4219:2009 specific design pathway.

Table 2.3 Performance factors (from NZS 4219:2009 Table 4).

Component	Importance level	Component category	Performance factor (C_P)
Anchors, fixings and fasteners	1, 2, 3, 4	All	0.85
Braces and supports	1, 2, 3, 4	P1, P2, P3, P4 (ULS)	0.85 or from NZS 4219:2009 Appendix C (whichever is lower)
Braces and supports	1, 2, 3	P6, P7 (SLS1)	0.85
Braces and supports	4	P5 (SLS2)	0.85

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Table 2.4 Component risk factors (from NZS 4219:2009 Table 5).

Component category	Risk factor (R_c)		
	Importance level		
	1 and 2	3	4
P1, P2, P4	1.00	1.30	1.80
P3	0.90	1.20	1.60
P5	NA	NA	1.00
P6	0.50	0.50	0.50
P7	0.25	0.25	0.25

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Note that, following the 2010/11 earthquakes, the component risk factor for buildings in the Canterbury earthquake region should not be less than 0.33.

Other design considerations

When designing a building, consider the role of engineering systems in protecting life and property and providing safe egress from the building as well as the seismic resistance of the services and their components. The basic concepts of a building layout should be examined against the likely effect of earthquakes on the particular building.

The effect of heavy equipment on the structure and other building components should be considered. Heavy equipment-breaking loose is a potential source of injury and building damage. Locating heavy plant at a high level within the building not only adds to the earthquake loading, but it may require pipes and electric power to run the full height of the building.

The seismic resilience of connections to public utility services should be assessed. The design should aim to reduce the probability of damage and to provide for connection to temporary alternative services when required. Vehicle access, mains pipe connections and the position of shut-off valves, meters, risers and main reticulation are all important.

The consequences of leakage from pipes and vessels should be assessed. Where gas or other hazardous substances may leak, consider installing seismically operated shut-off valves. There could also be a risk of flooding to electric power supply substations, main switchboards and emergency standby power plant located below ground floor level.

The design should consider how an engineering system's seismic bracing will affect, accommodate and integrate with the system's non-seismic requirements, such as thermal expansion in piping systems and wind forces on roof-mounted equipment.

Restraint forces

The second step in the NZS 4219:2009 non-specific design pathway is to determine the required restraint forces on all components. The procedure to do this (and where more information can be found in NZS 4219:2009) is as follows:

- Determine the required restraint forces for linear components (section 3.6).
- Determine the required restraint forces for floor-mounted components (section 3.7).
- Determine the required restraint forces for suspended components, excluding suspended ceilings (section 3.8)

ISSN 2463-672X