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Structural design actions

Part 4: Earthquake actions in Australia



AS 1170.4:2024

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Preface

This document was prepared by the Australian members of Joint Standards Australia/Standards New Zealand Committee BD-006, General Design Requirements and Loading on Structures, to supersede AS 1170.4:2007.

After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian Standard rather than an Australian/New Zealand Standard.

The objective of this Standard is to provide designers of structures with earthquake actions and general detailing requirements for use in the design of structures subject to earthquakes with a primary focus on life safety.

The Standard has been drafted to be applicable to the design of structures constructed of any material or combination thereof. Designers will need to refer to the appropriate material Standard(s) on detailing requirements additional to those contained in this Standard.

This Standard is based on equivalent principles to ISO 3010:2017, *Basis for design of structures—Seismic actions on structures*. ISO 3010 gives guidance on a general format and on detail for the drafting of national Standards on seismic actions. The principles of ISO 3010 have been adopted, including some of the detail, with modifications for the low seismicity in Australia. The most significant points are as follows:

- (a) ISO 3010 is drafted as a guide for committees preparing Standards on seismic actions.
- (b) Method and notation for presenting the mapped earthquake hazard data has not been adopted.

The terms “normative” and “informative” are used in Standards to define the application of the appendices to which they apply. A “normative” appendix is an integral part of a Standard, whereas an “informative” appendix is only for information and guidance.

Statements expressed in mandatory terms in notes to figures and tables are deemed to be requirements of this document. Notes that appear in the main text of this document provide information only.

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Australian Standard®

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Part 4: Earthquake actions in Australia

Section 1 Scope and general

1.1 Scope

This document sets out procedures for determining earthquake actions and detailing requirements for structures and components to be used in the design of structures. It also includes requirements for domestic structures.

Importance level 1 structures are not required to be designed for earthquake actions.

The following structures are outside the scope of this Standard:

- (a) High-risk structures.
- (b) Bridges.
- (c) Tanks containing liquids.
- (d) Civil structures including dams and bunds.
- (e) Offshore structures that are partly or fully immersed.
- (f) Soil-retaining structures.
- (g) Structures with first mode periods greater than 5 s.
- (h) Transmission line towers.

This document does not consider the effect on a structure of related earthquake phenomena such as settlement, slides, subsidence, liquefaction or faulting.

NOTE 1 For structures in New Zealand, see NZS 1170.5.

NOTE 2 For earth-retaining structures, see AS 4678.

NOTE 3 For bridges and related structures, see AS 5100.2.

1.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document.

NOTE Documents referenced for informative purposes are listed in the Bibliography.

AS 1684, *Residential timber-framed construction (all parts)*

AS 1720.1, *Timber structures, Part 1: Design methods*

AS 3600, *Concrete structures*

AS 3700, *Masonry structures*

AS 4100, *Steel structures*

AS/NZS 1170.0, *Structural design actions, Part 0: General principles*

AS/NZS 1170.1, *Structural design actions, Part 1: Permanent, imposed and other actions*

AS/NZS 1170.3, *Structural design actions, Part 3: Snow and ice actions*

AS/NZS 1664, *Aluminium structures (all parts)*

AS/NZS 4600, *Cold formed steel structures*

1.3 Terms and definitions

For the purposes of this document, the definitions given in the National Construction Code (NCC) and the following terms and definitions apply:

1.3.1

base, structural

level that earthquake motions are imparted to the structure, or level that structure as a dynamic vibrator is supported (see [Figure 1.5\(C\)](#))

1.3.2

bearing wall system

structural system in which loadbearing walls provide support for vertical loads while shear walls or braced frames provide horizontal earthquake resistance

1.3.3

braced frame

two-dimensional structural system composed of a vertical truss (or equivalent) whose members are subject to axial forces when resisting earthquake actions

1.3.3.1

braced frame, concentric

braced frame in which bracing members are connected at the column-beam joints (see [Table 6.5](#))

1.3.3.2

braced frame, eccentric

braced frame where at least one end of each brace intersects a beam at a location away from the column-beam joint (see [Table 6.5](#))

1.3.4

connection

mechanical means that provide a load path for actions between structural elements, non-structural elements and structural and non-structural elements

1.3.5

design storey drift

d_{st}
calculated as the difference of the deflections (d_i) at the top and bottom of the storey under consideration (see [Clause 6.7.2](#))

1.3.6

diaphragm

structural system that transmits earthquake actions to the seismic-force-resisting system

1.3.7

domestic structure

single dwelling or one or more attached dwellings (single occupancy units) conforming to Class 1a or 1b as defined in the National Construction Code

1.3.8

ductility (of a structure)

ability of a structure to sustain its load-carrying capacity and dissipate energy when responding to cyclic displacements in the inelastic range during an earthquake

1.3.9**earthquake actions**

inertia-induced actions arising from the response to earthquake of the structure

1.3.10**engineering bedrock**

horizon at which the shear wave velocity is greater than 600 m/s and below which it continuously increases with depth (for sites with hard rock outcrops underlain by soft soils, the upper hard rock outcrop should not be taken as the engineering bedrock)

1.3.11**moment-resisting frame**

essentially complete space frame that supports the vertical and horizontal actions by both flexural and axial resistance of its members and connections

1.3.11.1**moment-resisting frame, intermediate**

concrete or steel moment-resisting frame designed and detailed to achieve moderate structural ductility (see [Table 6.5](#))

1.3.11.2**moment-resisting frame, ordinary**

moment-resisting frame with no particular earthquake detailing specified in the relevant material standard (see [Table 6.5](#))

1.3.11.3**moment-resisting frame, special**

concrete or steel moment-resisting frame designed and detailed to achieve high structural ductility and where plastic deformation is planned under ultimate actions (see [Table 6.5](#))

1.3.12**partition**

permanent or relocatable internal dividing wall between floor spaces

1.3.13**parts and components**

elements that are —

- (a) structural or non-structural elements attached to and supported by the structure but are not part of the seismic-force-resisting system; or
- (b) structural elements of the seismic-force-resisting system, which can be loaded by an earthquake in a direction not usually considered in the design of that element

1.3.14**P-delta effect**

additional induced structural forces caused by gravity loads being displaced horizontally

1.3.15**seismic-force-resisting system**

part of the structural system that provides resistance to the earthquake forces and effects

1.3.16**shear wall**

wall designed to resist horizontal earthquake forces acting in the plane of the wall

1.3.17**space frame**

three-dimensional structural system composed of interconnected members (other than loadbearing walls) able to support vertical loads and may provide horizontal resistance to earthquake forces

1.3.18**storey**

space between levels including the space between the structural base and the level above (storey i is the storey below the i th level)

1.3.19**structural performance factor**

S_p
numerical assessment of the additional ability of the total building to survive earthquake motion

1.3.20**structural ductility factor**

μ
numerical assessment of a structure's ability to sustain cyclic displacements in the inelastic range, ductility value depends on structural form, ductility of materials and structural damping characteristics

1.3.21**top (of a structure)**

level of the uppermost principal seismic weight (see [Clause 1.5](#))

1.4 Notation and units

Except where specifically noted, this Standard uses SI units of kilograms, metres, seconds, pascals and newtons (kg, m, s, Pa, N). Unless stated otherwise, the notation used in this Standard shall have the following meanings:

a_c	=	component amplification factor
a_{floor}	=	effective floor acceleration at the height of the component centre of mass
a_x	=	height amplification factor at height h_x of the component centre of mass
b	=	plan dimension of the structure at right angles to the direction of the action, in metres
$C(T)$	=	elastic site hazard spectrum for horizontal loading as a function of period (T)
$C(T_1)$	=	value of the elastic site hazard spectrum for the fundamental natural period of the structure
$C_d(T)$	=	horizontal design response spectrum as a function of period (T)
$C_d(T_1)$	=	horizontal design action coefficient (value of the horizontal design response spectrum for the fundamental natural period of the structure)
$C_h(T)$	=	spectral shape factor as a function of period (T) (dimensionless coefficient)
$C_h(T_1)$	=	value of the spectral shape factor for the fundamental natural period of the structure
$C_v(T_v)$	=	elastic site hazard spectrum for vertical loading, which may be taken as half of the elastic site hazard spectrum for horizontal loading ($C(T)$)
$C_{vd}(T)$	=	vertical design response spectrum as a function of period (T)
$C_h(0)$	=	bracketed value of the spectral shape factor for the period of zero seconds
d_i	=	horizontal deflection of the centre of mass at level ' i '
d_{ie}	=	deflection at level ' i ' determined by an elastic analysis
d_{st}	=	design storey drift (see Clause 6.7.2)

E	=	earthquake actions (see Clause 1.3 and AS/NZS 1170.0)
E_u	=	earthquake actions for ultimate limit state
	=	represented by a set of equivalent static forces F_i at each level (i) or by resultant action effects determined using a dynamic analysis
F_c	=	horizontal design earthquake force on the part or component, in kilonewtons
F_i	=	horizontal equivalent static design force at the i th level, in kilonewtons
F_j	=	horizontal equivalent static design force at the j th level, in kilonewtons
F_n	=	horizontal equivalent static design force at the uppermost seismic mass, in kilonewtons
g	=	acceleration due to gravity (9.8 m/s^2)
G	=	permanent action (self-weight or 'dead load'), in kilonewtons
G_i	=	permanent action (self-weight or 'dead load') at level i , in kilonewtons
h_i	=	height of level i above the base of the structure, in metres
h_n	=	height from the base of the structure to the uppermost seismic weight or mass, in metres (see Clause 1.5)
h_{si}	=	inter-storey height of level i , measured from centre-line to centre-line of floor, in metres
h_x	=	height at which the component is attached above the structural base of the structure, in metres
I_c	=	component importance factor
i, j	=	levels of the structure under consideration
k	=	exponent, dependent on the fundamental natural period of the structure (T_1)
k_c	=	factor for determining height amplification factor (a_x)
$k_{F,i}$	=	seismic force distribution factor for the i th level
k_p	=	probability factor appropriate for the limit state under consideration
k_t	=	factor for determining building period
m_i	=	seismic mass at each level
N -values	=	number of blows for standard penetration (Standard Penetration Test)
n	=	number of levels in a structure
P	=	annual probability of exceedance
P -delta	=	second order effects due to amplification of axial loads
Q	=	imposed action for each occupancy class, in kilonewtons
Q_i	=	imposed action for each occupancy class on the i th level
R_c	=	component ductility factor

S_p	=	structural performance factor
T	=	period of vibration, which varies according to the mode of vibration being considered
T_1	=	fundamental natural period of the structure as a whole (translational first mode natural period)
T_v	=	period of vibration appropriate to vertical mode of vibration of the structure
V	=	horizontal equivalent static shear force acting at the base (base shear)
V_i	=	horizontal equivalent static shear force at the i th level
W	=	sum of the seismic weight of the building ($G + \psi_c Q$) at the level where bracing is to be determined and above this level, in kilonewtons
W_c	=	seismic weight of the part or component, in kilonewtons
W_i	=	seismic weight of the structure or component at the i th level, in kilonewtons
W_j	=	seismic weight of the structure or component at level j , in kilonewtons
W_n	=	seismic weight of the structure or component at the n th level (upper level) in kilonewtons
W_t	=	total seismic weight of the building, in kilonewtons
Z	=	earthquake hazard design factor modified from an acceleration coefficient with an annual probability of exceedance of 1/500
μ	=	structural ductility factor ($\mu = \mu_u$)
θ	=	stability coefficient
ψ_c	=	earthquake imposed action combination factor
ψ_a	=	area reduction factor, as defined in Clause 3.4 of AS/NZS 1170.1

1.5 Levels, weights and forces of the structure

For the purposes of analysis, the masses of the structure, parts and components are taken as acting at the levels of the structure (see [Figure 1.5\(A\)](#)).

The seismic weight at a level is determined by summing the weights that would act at that level, including the weight of the floor plus any items spanning from one level to the next, e.g. walls, half way to the level above and half way to the level below and adding the factored imposed actions on that level. This mass is then assumed to act at the height of the centre of the floor slab (excluding consideration of any beams).

The centre of mass of the uppermost (top) weight (including roofing, structure and any additional parts and components above and down to half way to the floor below) shall be considered to act at the centre of the combined mass (see [Figure 1.5\(B\)](#)). For more complicated situations, the uppermost seismic weight shall be assessed depending on the effect on the distribution of forces. Where a concentrated weight exists above the ceiling level that contributes more than 1/3 of W_n , it shall be treated as the top seismic weight and W_n and W_{n-1} recalculated.

The building height (h_n) is taken as the height of the centre of mass of W_n above the base. [Figure 1.5\(C\)](#) illustrates the structural base for various situations.

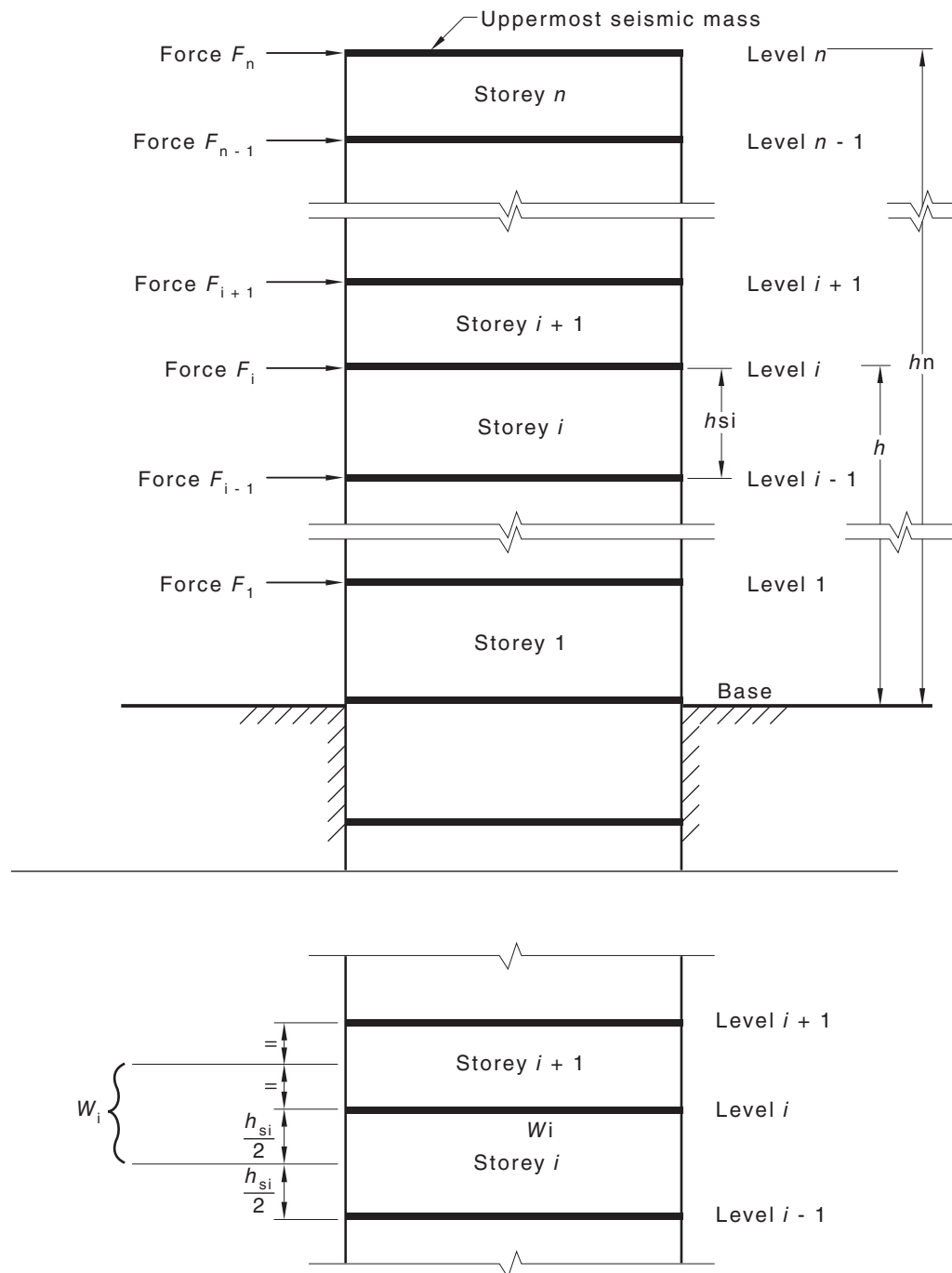


Figure 1.5(A) — Illustration of level, storey, weight and force

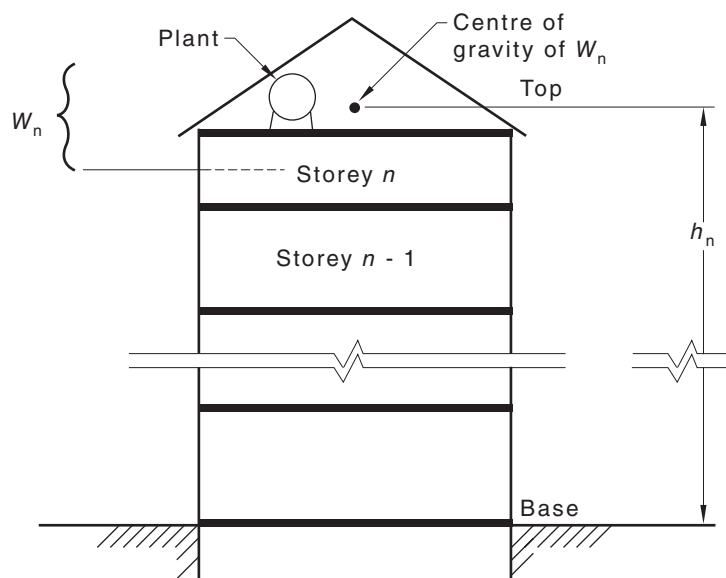
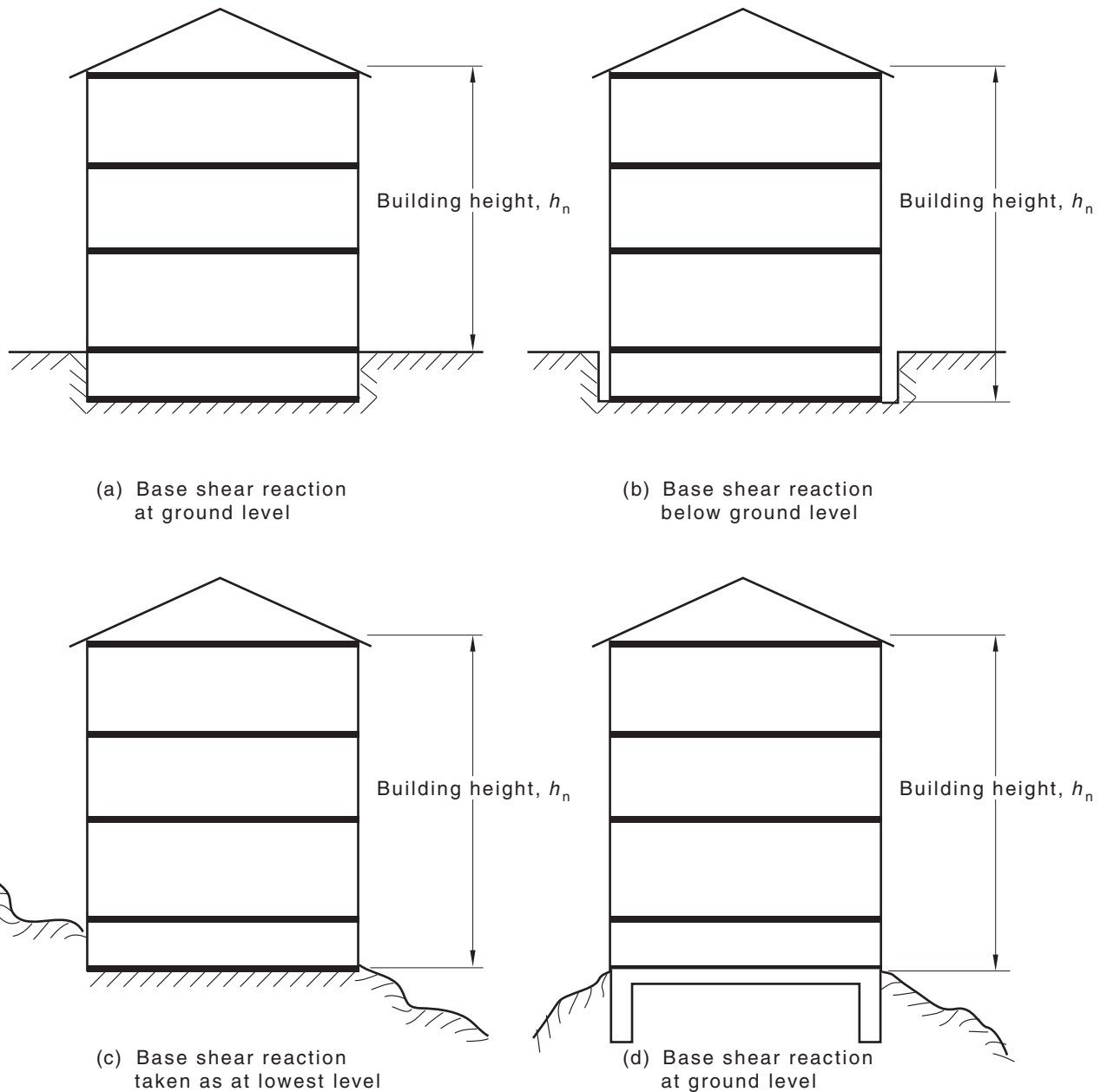


Figure 1.5(B) — Example of determination of the top of the structure



NOTE Building height measured from top of slab at relevant level.

Figure 1.5(C) — Examples of definition of building base where earthquake motions are transmitted to the structure

Section 2 Design procedure

2.1 General

Earthquake actions for use in design (E) shall be appropriate for the type of structure or element, its intended use, design working life and exposure to earthquake shaking. The earthquake actions (E_u) determined in accordance with this document shall be deemed to conform to this provision.

2.2 Design procedure

The design procedure (see [Figure 2.2](#)) to be adopted for the design of a structure subject to this Standard shall —

- (a) determine the importance level for the structure (NCC or AS/NZS 1170.0 Appendix F for structures not defined in the NCC);
- (b) determine the probability factor (k_p) and the hazard design factor (Z) (see [Section 3](#));
- (c) determine if the structure complies with the definition for domestic structures (housing) given in [Appendix A](#) and whether it complies with the requirements therein;
- (d) determine the site sub-soil class (see [Section 4](#));
- (e) determine the earthquake design category (EDC) from [Table 2.1](#);
- (f) design the structure in accordance with the requirements for the EDC as set out in [Section 5](#); and
- (g) design parts and components in accordance with the requirements set out in [Section 8](#).

Importance level 1 structures are not required to be designed to this Standard, (i.e. for earthquake actions), and domestic structures (housing) that conform to the definition given in [Appendix A](#) and with the provisions of [Appendix A](#) are deemed to satisfy this Standard. All other structures, including parts and components, are required to be designed for earthquake actions.

NOTE 1 During an earthquake, motion will be imposed on all parts of any construction. Therefore, parts of a structure (including non-loadbearing walls, etc.) should be designed for lateral earthquake forces such as out-of-plane forces.

A higher level of analysis than that specified in [Table 2.1](#) for a particular EDC may be used. Domestic structures that do not conform to the limits specified in [Appendix A](#) shall be designed as importance level 2 structures.

NOTE 2 Structures (including housing) that are constructed on a site with a hazard design factor Z of 0.3 or greater should be designed in accordance with NZS 1170.5 (see Macquarie Islands, [Table 3.2](#)).

For structures sited on sub-soil Class E (except houses in accordance with [Appendix A](#)), the design shall consider the effects of subsidence or differential settlement of the foundation material under the earthquake actions determined for the structure.

NOTE 3 Structures, where the structural ductility factor (μ) assumed in design is greater than 3, should be designed in accordance with NZS 1170.5 and associated New Zealand Standards.

Serviceability limit states are deemed to be satisfied under earthquake actions for importance levels 1, 2 and 3 structures that are designed in accordance with this Standard and the appropriate materials design Standards. A special study shall be carried out for importance level 4 structures to demonstrate that they will remain operational for immediate use following the design event associated with importance level 2 structures.

NOTE 4 The operational requirements will vary from facility to facility depending on its nature and functionality. Case-by-case assessment is essential.

Table 2.1 — Selection of earthquake design categories

Importance level, type of structure (see Clause 2.2)	$(k_p Z)$ for site sub-soil class				Structure height, h_n (m)	Earthquake design category
	E_e or D_e	C_e	B_e	A_e		
1	—				—	Not required to be designed for earthquake actions
Domestic structure (housing)	—				Top of roof ≤ 8.5	See Appendix A
					Top of roof > 8.5	Design as importance level 2
2	0.08	0.08	≤ 0.11	≤ 0.14	≤ 12 $> 12, < 50$ ≥ 50	I II III
	0.08	> 0.08 to ≤ 0.12	> 0.11 to ≤ 0.17	> 0.14 to ≤ 0.21	< 50 ≥ 50	II III
	> 0.08	> 0.12	> 0.17	> 0.21	< 25 ≥ 25	II III
3	0.08	≤ 0.12	≤ 0.17	≤ 0.21	< 50 ≥ 50	II III
	> 0.08	> 0.12	> 0.17	> 0.21	< 25 ≥ 25	II III
4	—				< 25 ≥ 25	II III

NOTE 1 Values for k_p and Z are given in [Section 3](#). Site sub-soil class are given in [Section 4](#).

NOTE 2 A higher earthquake design category or procedure may be used in place of that specified.

NOTE 3 Height (h_n) is defined in [Clause 1.5](#). For domestic structures see to [Appendix A](#).

NOTE 4 In addition to the above, a special study is required for importance level 4 structures to demonstrate that they will remain operational for immediate use following the design event for importance level 2 structures.