AS 1170.4—2007

Australian Standard®

Structural design actions

Part 4: Earthquake actions in Australia

Originated as AS 2121—1979.
Revised and redesignated as AS 1170.4—1993.
Second edition 2007.

Published by Standards Australia GPO Box 476, Sydney, NSW 2001, Australia

ISBN 0 7337 8349 X

STANDARDS AUSTRALIA

Australian Standard
Structural design actions

Part 4: Earthquake actions in Australia

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard 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.

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

NOTES:

1 For structures in New Zealand, see NZS 1170.5.

2 For earth-retaining structures, see AS 4678.

1.2 NORMATIVE REFERENCES

The following referenced documents are indispensable to the application of this Standard.

AS	
1684	Residential timber-framed construction (all parts)
1720	Timber structures
1720.1	Part 1: Design methods
3600	Concrete structures
3700	Masonry structures
4100	Steel structures
AS/NZS	
1170	Structural design actions
1170.0	Part 0: General principles
1170.1	Part 1: Permanent, imposed and other actions
1170.3	Part 3: Snow and ice actions

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 Standard shall be deemed to comply with 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 (AS/NZS 1170.0 and BCA);

(b) determine the probability factor (k_p) and the hazard 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; and

(f) design the structure in accordance with the requirements for the EDC as set out in Section 5.

Importance level 1 structures are not required to be designed to this Standard, (i.e., for earthquake actions), and domestic structures (housing) that comply with 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: 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 comply with the limits specified in Appendix A shall be designed as importance level 2 structures.

NOTE: Structures (including housing) that are constructed on a site with a hazard 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: Structures, where the structural ductility factor (μ) assumed in design is greater than 3, should be designed in accordance with NZS 1170.5.

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 ensure they remain serviceable for immediate use following the design event for importance level 2 structures.

TABLE 2.1

SELECTION OF EARTHQUAKE DESIGN CATEGORIES

Importance level, type of structure (see Clause 2.2)	**($k_{\mathrm{p}}Z$) for site sub-soil class**				**Structure height, h_{n} (m)**	**Earthquake design category**
	$\mathrm{E_e}$ or $\mathrm{D_e}$	**$\mathrm{C_e}$**	**$\mathrm{B_e}$**	**$\mathrm{A_e}$**		
1	—				—	Not required to be designed for earthquake actions
Domestic structure (housing)	—				Top of roof ≤8.5	Refer to Appendix A
					Top of roof >8.5	Design as importance level 2
2	≤0.05	≤0.08	≤0.11	≤0.14	≤12 >12, <50 ≥50	I II III
	>0.05 to ≤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	—				<12 ≥12	II III

NOTES:

1 Values for k_{p} and Z are given in Section 3. Site sub-soil class are given in Section 4.

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

3 Height (h_{n}) is defined in Clause 1.5. For domestic structures refer to Appendix A.

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

SECTION 3 SITE HAZARD

3.1 ANNUAL PROBABILITY OF EXCEEDANCE (P) AND PROBABILITY FACTOR (k_p)

The probability factor (k_p) for the annual probability of exceedance, appropriate for the limit state under consideration, shall be obtained from Table 3.1.

TABLE 3.1

PROBABILITY FACTOR (k_p)

Annual probability of exceedance P	Probability factor k_p
1/2500	1.8
1/2000	1.7
1/1500	1.5
1/1000	1.3
1/800	1.25
1/500	1.0
1/250	0.75
1/200	0.7
1/100	0.5
1/50	0.35
1/25	0.25
1/20	0.20

NOTE: The annual probability of exceedance in Table 3.1 is taken from the BCA and AS/NZS 1170.0.

3.2 HAZARD FACTOR (Z)

The hazard factor (Z) shall be taken from Table 3.2 or, where the location is not listed, be determined from Figures 3.2(A) to 3.2(F). A general overview of the hazard factor (Z) for Australia is shown in Figure 3.2(G).

TABLE 3.2

HAZARD FACTOR (*Z*) FOR SPECIFIC AUSTRALIAN LOCATIONS

Location	*Z*	Location	*Z*	Location	*Z*
Adelaide	0.10	Geraldton	0.09	Port Augusta	0.11
Albany	0.08	Gladstone	0.09	Port Lincoln	0.10
Albury/Wodonga	0.09	Gold Coast	0.05	Port Hedland	0.12
Alice Springs	0.08	Gosford	0.09	Port Macquarie	0.06
Ballarat	0.08	Grafton	0.05	Port Pirie	0.10
Bathurst	0.08	Gippsland	0.10	Robe	0.10
Bendigo	0.09	Goulburn	0.09	Rockhampton	0.08
Brisbane	0.05	Hobart	0.03	Shepparton	0.09
Broome	0.12	Karratha	0.12	Sydney	0.08
Bundaberg	0.11	Katoomba	0.09	Tamworth	0.07
Burnie	0.07	Latrobe Valley	0.10	Taree	0.08
Cairns	0.06	Launceston	0.04	Tennant Creek	0.13
Camden	0.09	Lismore	0.05	Toowoomba	0.06
Canberra	0.08	Lorne	0.10	Townsville	0.07
Carnarvon	0.09	Mackay	0.07	Tweed Heads	0.05
Coffs Harbour	0.05	Maitland	0.10	Uluru	0.08
Cooma	0.08	Melbourne	0.08	Wagga Wagga	0.09
Dampier	0.12	Mittagong	0.09	Wangaratta	0.09
Darwin	0.09	Morisset	0.10	Whyalla	0.09
Derby	0.09	Newcastle	0.11	Wollongong	0.09
Dubbo	0.08	Noosa	0.08	Woomera	0.08
Esperance	0.09	Orange	0.08	Wyndham	0.09
Geelong	0.10	Perth	0.09	Wyong	0.10
Meckering region				**Islands**	
Ballidu	0.15	Meckering	0.20	Christmas Island	0.15
Corrigin	0.14	Northam	0.14	Cocos Islands	0.08
Cunderdin	0.22	Wongan Hills	0.15	Heard Island	0.10
Dowerin	0.20	Wickepin	0.15	Lord Howe Island	0.06
Goomalling	0.16	York	0.14	Macquarie Island	0.60
Kellerberrin	0.14			Norfolk Island	0.08

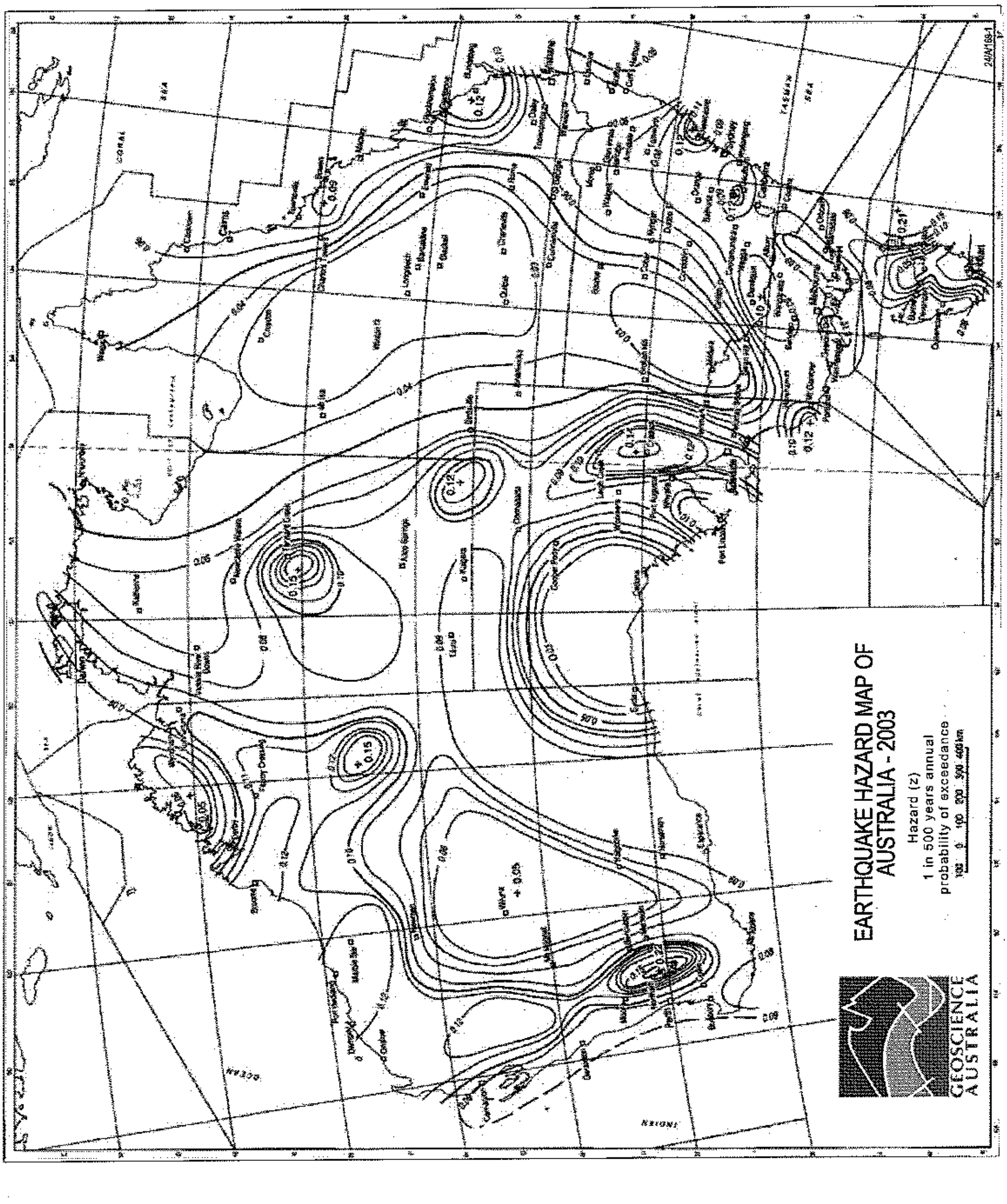

FIGURE 3.2(G) HAZARD FACTOR (Z)

SECTION 4 SITE SUB-SOIL CLASS

4.1 DETERMINATION OF SITE SUB-SOIL CLASS

4.1.1 General

The site shall be assessed and assigned to the site sub-soil class it most closely resembles. The site sub-soil classes shall be as defined in Clause 4.2, that is, Classes A_e to E_e as follows:

(a) Class A_e—Strong rock.

(b) Class B_e—Rock.

(c) Class C_e—Shallow soil.

(d) Class D_e—Deep or soft soil.

(e) Class E_e—Very soft soil.

4.1.2 Hierarchy for site classification methods

Site classification shall be determined using the methods in the following list, in order of most preferred to least preferred:

(a) Site periods based on four times the shear-wave travel-time through material from the surface to underlying rock.

(b) Bore logs, including measurement of geotechnical properties.

(c) Evaluation of site periods from Nakamura ratios or from recorded earthquake motions.

(d) Bore logs with descriptors but no geotechnical measurements.

(e) Surface geology and estimates of the depth to underlying rock.

Where more than one method has been carried out, the site classification determined by the most preferred method shall be used.

4.1.3 Evaluation of periods for layered sites

For sites consisting of layers of several types of material, the low-amplitude natural period of the site may be estimated by summing the contributions to the natural period of each layer. The contribution of each layer may be estimated by determining the soil type of each layer, and multiplying the ratio of each layer's thickness to the maximum depth of soil for that soil type (given in Table 4.1) by 0.6 s. In evaluating site periods, material above rock shall be included in the summation.

SECTION 5 EARTHQUAKE DESIGN

5.1 GENERAL

Structures required by Section 2 to be designed for earthquake actions shall be designed in accordance with the general principles of Clause 5.2, the provisions of the appropriate earthquake design category (see Clauses 5.3, 5.4 or 5.5) and the requirements of the applicable material design Standards.

5.2 BASIC DESIGN PRINCIPLES

5.2.1 Seismic-force-resisting system

All structures shall be configured with a seismic-force-resisting system that has a clearly defined load path, or paths, that will transfer the earthquake actions (both horizontal and vertical) generated in an earthquake, together with gravity loads, to the supporting foundation soil.

5.2.2 Tying structure together

All parts of the structure shall be tied together both in the horizontal and the vertical planes so that forces generated by an earthquake from all parts of the structure, including structural and other parts and components, are carried to the foundation.

Footings supported on piles, or caissons, or spread footings that are located in or on soils with a maximum vertical ultimate bearing value of less than 250 kPa shall be restrained in any horizontal direction by ties or other means, to limit differential horizontal movement during an earthquake.

5.2.3 Performance under earthquake deformations

Stiff components (such as concrete, masonry, brick, precast concrete walls or panels or stair walls, stairs and ramps) shall be—

(a) considered to be part of the seismic-force-resisting system and designed accordingly; or

(b) separated from all structural elements such that no interaction takes place as the structure undergoes deflections due to the earthquake effects determined in accordance with this Standard.

All components, including those deliberately designed to be independent of the seismic-force-resisting system, shall be designed to perform their required function while sustaining the deformation of the structure resulting from the application of the earthquake forces determined for each limit state.

Floors shall be—

(i) continuous over a series of internal walls at right angles or near right angles; or

(ii) tied to supporting walls at all supported edges.

Provision shall be made for floors to span without collapse if they become dislodged from edges to which they are not tied.

5.2.4 Walls

Walls shall be anchored to the roof and restrained at all floors that provide horizontal support for the wall. Walls shall be designed for in-plane and out-of-plane forces.

Out-of-plane forces on walls shall be designed in accordance with Section 8.

5.2.5 Diaphragms

The deflection in the plane of the diaphragm, as determined by analysis, shall not exceed the permissible deflection of the attached elements. Permissible deflection shall be that deflection that will permit the attached element to maintain its structural integrity and continue to support the prescribed forces.

5.3 EARTHQUAKE DESIGN CATEGORY I (EDC I)

This Clause shall not apply to structures of height (h_n) over 12 m.

All structures subject to earthquake design category I (EDC I) shall comply with the requirements of Clause 5.2 and the requirements of this Clause.

The structure and all parts and components shall be designed for the following equivalent static forces applied laterally to the centre of mass of the part or component being considered, or to the centres of mass of the levels of the structure (see Figure 5.2), in combination with gravity loads (see combination [G, E_u, $\psi_c Q$] in AS/NZS 1170.0):

$$F_i = 0.1 W_i \qquad \ldots 5.3$$

where

W_i = seismic weight of the structure or component at level i as given in Clause 6.2.2

Each of the major axes of the structure shall be considered separately.

Vertical earthquake actions and pounding need not be considered, except where vertical actions apply to parts and components.

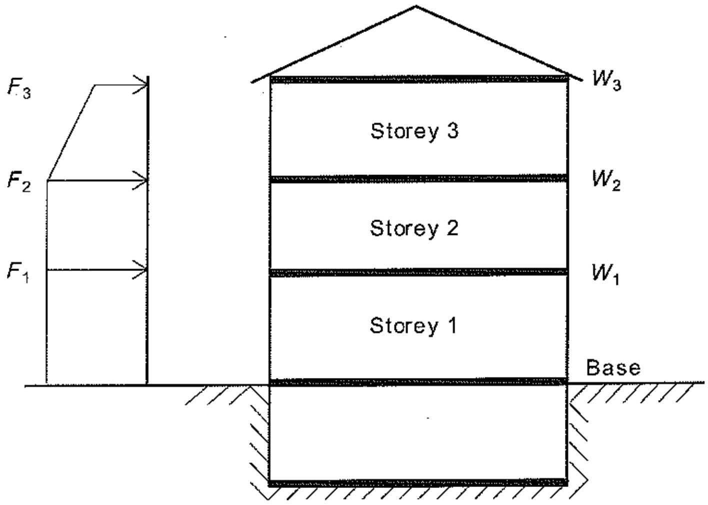

FIGURE 5.2 ILLUSTRATION OF EARTHQUAKE DESIGN CATEGORY I

5.4 EARTHQUAKE DESIGN CATEGORY II (EDC II)

5.4.1 General

All structures subject to earthquake design category II (EDC II) shall comply with the requirements of Clause 5.2 and Clauses 5.4.2 to 5.4.6.

5.4.2 Strength and stability provisions

5.4.2.1 *General*

The structural system shall be designed to resist the most critical action effect arising from the application of the earthquake actions in any direction.

Except for structure components and footings that participate in resisting horizontal earthquake forces in both major axes of the structure, this provision shall be deemed to be satisfied by applying the horizontal force in the direction of each of the major axes of the structure and considering the effect for each direction separately.

For structure components and footings that participate in resisting horizontal earthquake forces in both major axes of the structure, the effects of the two directions determined separately shall be added by taking 100% of the horizontal earthquake forces for one direction and 30% in the perpendicular direction.

Forces shall be applied at the centre of mass of each floor except where offset from the centre of mass is required for the consideration of torsion effects (see Clause 6.6).

Connections between components of the structure shall be capable of transmitting an internal ultimate limit state horizontal action equal to the values calculated using this section but not less than 5% of the vertical reaction arising from the seismic weight or 5% of the seismic weight of the component which ever is the greater.

5.4.2.2 *Earthquake forces—Equivalent static method*

Earthquake forces shall be calculated using the equivalent static method, in accordance with Section 6 except where covered by Clause 5.4.2.3.

NOTE: Dynamic analysis, in accordance with Section 7, may be used if desired (see Clause 2.2).

5.4.2.3 *Simplified design for structures not exceeding 15 m*

Structures not exceeding 15 m tall and structural components within those structures shall be deemed to meet the requirements of Clause 5.4.2.2 when they have been designed to resist at the ultimate limit state a minimum horizontal static force given by the following, applied simultaneously at each level for the given direction in combination with other actions as specified in AS/NZS 1170.0:

$$F_i = K_s[k_p Z S_p/\mu] W_i \qquad \ldots 5.4$$

where k_p and Z are as given in Section 3 and S_p and μ are given in Clause 6.5

K_s = factor to account for floor, as given in Table 5.4

W_i = seismic weight of the structure or component at level i

TABLE 5.4

VALUES OF K_s FOR STRUCTURES NOT EXCEEDING 15 m

Total number of stories	Sub-soil class	K_s factor				
		Storey under consideration				
		5th	4th	3rd	2nd	1st
5	A_e	2.5	1.9	1.4	1.0	0.5
	B_e	3.1	2.5	1.8	1.2	0.6
	C_e	4.4	3.5	2.6	1.7	0.9
	D_e, E_e	6.1	4.9	3.6	2.5	1.2
4	A_e	—	2.7	2.0	1.4	0.6
	B_e	—	3.5	2.6	1.7	0.9
	C_e	—	4.9	3.6	2.5	1.2
	D_e, E_e	—	5.8	4.4	3.0	1.4
3	A_e	—	—	3.1	2.0	1.0
	B_e	—	—	3.9	2.6	1.3
	C_e, D_e, E_e	—	—	5.5	3.6	1.8
2	A_e	—	—	—	3.1	1.6
	B_e	—	—	—	3.9	1.9
	C_e, D_e, E_e	—	—	—	4.9	2.5
1	A_e	—	—	—	—	2.3
	B_e	—	—	—	—	3.0
	C_e, D_e, E_e	—	—	—	—	3.6

5.4.3 Vertical earthquake actions

Vertical earthquake actions need not be considered.

NOTE: For parts and components, see Clauses 5.4.6 and 8.1.3.

5.4.4 Drift

The inter-storey drift at the ultimate limit state calculated from the forces determined in Clause 5.4.2 shall not exceed 1.5% of the storey height for each level (see Clause 6.7.2).

Attachment of cladding and facade panels to the seismic-force-resisting system shall have sufficient deformation and rotational capacity to accommodate the design storey drift (d_{st}).

This Clause is deemed to be satisfied if the primary seismic force-resisting elements are structural walls that extend to the base.

5.4.5 Pounding

Structures over 15 m shall be separated from adjacent structures or set back from a building boundary by a distance sufficient to avoid damaging contact.

This Clause is deemed to be satisfied if the primary seismic force-resisting elements are structural walls that extend to the base, or the setback from a boundary is more than 1% of the structure height.

5.4.6 Parts and components

Non-structural parts and components shall be designed in accordance with Section 8 except that for importance level 2 and 3 structures not exceeding 15 m, parts and components of non-brittle construction may be attached using connectors designed for horizontal capacity of 10% of the seismic weight of the part.

5.5 EARTHQUAKE DESIGN CATEGORY III (EDC III)

5.5.1 General

All structures subject to earthquake design category III (EDC III) shall comply with the requirements of Clause 5.2 and Clauses 5.5.2 to 5.5.6.

5.5.2 Strength and stability provisions

5.5.2.1 *General*

The seismic-force-resisting system shall be designed to resist the most critical action effect arising from the application of the earthquake actions in any direction.

The design shall consider the earthquake loading applied, as specified in Clause 5.4.2.1.

Connections between elements of the structure shall be capable of transmitting an internal ultimate limit state horizontal action equal to the values calculated using the dynamic analysis but not less than 5% of the vertical reaction arising from the seismic weight or 5% of the seismic weight of the component, whichever is the greater.

5.5.2.2 *Earthquake forces—Dynamic analysis*

Earthquake forces shall be calculated using the dynamic analysis method given in Section 7.

5.5.3 Vertical earthquake actions

Vertical earthquake actions need not be considered.

NOTE: For parts and components, see Clause 8.1.3.

5.5.4 Drift

The inter-storey drift at the ultimate limit state, calculated from the forces determined in Clause 5.5.2, shall not exceed 1.5% of the storey height for each level (see Clause 6.7.2).

Attachment of cladding and facade panels to the seismic-force-resisting system shall have sufficient deformation and rotational capacity to accommodate the design storey drift (d_{st}).

5.5.5 Pounding

Structures shall be separated from adjacent structures or set back from a building boundary by a distance sufficient to avoid damaging contact.

This Clause is deemed to be satisfied when the setback from a boundary is more than 1% of the structure height.

5.5.6 Parts and components

Non-structural parts and components shall be designed in accordance with Section 8.

SECTION 6 EQUIVALENT STATIC ANALYSIS

6.1 GENERAL

Equivalent static analysis, when used, shall be carried out in accordance with this Section.

The procedure for equivalent static analysis is as follows:

(a) Decide on the form and material of the structure.

(b) Calculate $k_p Z$ using Section 3.

(c) Determine T_1, $C_h(T_1)$, μ, and other structural properties.

(d) Determine the design action coefficients.

(e) Determine the seismic weight at each level (W_i).

(f) Calculate V using Clause 6.2.

(g) Calculate F_i using Clause 6.3.

(h) Apply the forces to the structure at the eccentricities specified in Clause 6.6.

(i) Take P-delta effects into account as specified in Clause 6.7.

6.2 HORIZONTAL EQUIVALENT STATIC FORCES

6.2.1 Earthquake base shear

The set of equivalent static forces in the direction being considered shall be assumed to act simultaneously at each level of the structure and shall be applied taking into account the torsion effects as given in Clause 6.6 in combination with other actions as specified in AS/NZS 1170.0.

The horizontal equivalent static shear force (V) acting at the base of the structure (base shear) in the direction being considered shall be calculated from the following equations:

$$V = C_d(T_1)W_t \qquad \ldots 6.2(1)$$

$$= [C(T_1)S_p/\mu]W_t \qquad \ldots 6.2(2)$$

$$= [k_p Z C_h(T_1)S_p/\mu]W_t \qquad \ldots 6.2(3)$$

where

$C_d(T_1)$ = horizontal design action coefficient (value of the horizontal design response spectrum at the fundamental natural period of the structure)

$$= C(T_1)S_p/\mu \qquad \ldots 6.2(4)$$

$C(T_1)$ = value of the elastic site hazard spectrum, determined from Clause 6.4 using k_p appropriate for the structure, Z for the location and the fundamental natural period of the structure

$$= k_p Z C_h(T_1) \qquad \ldots 6.2(5)$$

$C_h(T_1)$ = value of the spectral shape factor for the fundamental natural period of the structure, as given in Clause 6.4

W_t = seismic weight of the structure taken as the sum of W_i for all levels, as given in Clause 6.2.2

S_p = structural performance factor, as given in Clause 6.5

μ = structural ductility factor, as given in Clause 6.5

T_1 = fundamental natural period of the structure, as given in Clause 6.2.3

6.2.2 Gravity load

The seismic weight (W_i) at each level shall be as given by the following equation:

$$W_i = \sum G_i + \sum \psi_c Q_i \qquad \text{. . . 6.2(6)}$$

where

G_i and $\psi_c Q_i$ are summed between the mid-heights of adjacent storeys

G_i = permanent action (self-weight or 'dead load') at level *i*, including an allowance of 0.3 kPa for ice on roofs in alpine regions as given in AS/NZS 1170.3

ψ_c = earthquake-imposed action combination factor

= 0.6 for storage applications

= 0.3 for all other applications

Q_i = imposed action for each occupancy class on level *i* (see AS/NZS 1170.1)

NOTE: Seismic mass is the weight divided by acceleration due to gravity ($m_i = W_i/g$).

6.2.3 Natural period of the structure

The fundamental period of the structure as a whole (T_1, fundamental natural translational period of the structure) in seconds, including all the materials incorporated in the whole construction, may be determined by a rigorous structural analysis or from the following equation:

$$T_1 = 1.25 k_t h_n^{0.75} \quad \text{for the ultimate limit state} \qquad \text{. . . 6.2(7)}$$

where

k_t = 0.11 for moment-resisting steel frames

= 0.075 for moment-resisting concrete frames

= 0.06 for eccentrically-braced steel frames

= 0.05 for all other structures

h_n = height from the base of the structure to the uppermost seismic weight or mass, in metres

The base shear obtained using the fundamental structure period (T_1) determined by a rigorous structural analysis shall be not less than 80% of the value obtained with T_1 calculated using the above equation.

6.3 VERTICAL DISTRIBUTION OF HORIZONTAL FORCES

The horizontal equivalent static design force (F_i) at each level (*i*) shall be obtained as follows:

$$F_i = k_{F,i} V \qquad \text{. . . 6.3(1)}$$

$$= \frac{W_i h_i^k}{\sum_{j=1}^{n} \left(W_j h_j^k\right)} \left[k_p Z C_h (T_1) \frac{S_p}{\mu} \right] W_t \qquad \text{. . . 6.3(2)}$$

where

$k_{F,i}$ = seismic distribution factor for the *i*th level

W_i = seismic weight of the structure at the *i*th level, in kilonewtons

h_i = height of level *i* above the base of the structure, in metres

k = exponent, dependent on the fundamental natural period of the structure (T_1), which is taken as—

1.0 when $T_1 \leq 0.5$;

2.0 when $T_1 \geq 2.5$; or

linearly interpolated between 1.0 and 2.0 for $0.5 < T_1 < 2.5$

n = number of levels in a structure

The horizontal equivalent static earthquake shear force (V_i) at storey i is the sum of all the horizontal forces at and above the ith level (F_i to F_n).

6.4 SPECTRAL SHAPE FACTOR ($C_h(T)$)

The spectral shape factor ($C_h(T)$) shall be as given in Table 6.4 (illustrated in Figure 6.4) for the appropriate site sub-soil class defined in Section 4.

TABLE 6.4

SPECTRAL SHAPE FACTOR ($C_h(T)$)

	Site sub-soil class				
Period (seconds)	**A_e Strong rock**	**B_e Rock**	**C_e Shallow soil**	**D_e Deep or soft soil**	**E_e Very soft soil**
0.0	2.35 (0.8)*	2.94 (1.0)*	3.68 (1.3)*	3.68 (1.1)*	3.68 (1.1)*
0.1	2.35	2.94	3.68	3.68	3.68
0.2	2.35	2.94	3.68	3.68	3.68
0.3	2.35	2.94	3.68	3.68	3.68
0.4	1.76	2.20	3.12	3.68	3.68
0.5	1.41	1.76	2.50	3.68	3.68
0.6	1.17	1.47	2.08	3.30	3.68
0.7	1.01	1.26	1.79	2.83	3.68
0.8	0.88	1.10	1.56	2.48	3.68
0.9	0.78	0.98	1.39	2.20	3.42
1.0	0.70	0.88	1.25	1.98	3.08
1.2	0.59	0.73	1.04	1.65	2.57
1.5	0.47	0.59	0.83	1.32	2.05
1.7	0.37	0.46	0.65	1.03	1.60
2.0	0.26	0.33	0.47	0.74	1.16
2.5	0.17	0.21	0.30	0.48	0.74
3.0	0.12	0.15	0.21	0.33	0.51
3.5	0.086	0.11	0.15	0.24	0.38
4.0	0.066	0.083	0.12	0.19	0.29
4.5	0.052	0.065	0.093	0.15	0.23
5.0	0.042	0.053	0.075	0.12	0.18
Equations for spectra					
$0 < T \leq 0.1$	$0.8 + 15.5T$	$1.0 + 19.4T$	$1.3 + 23.8T$	$1.1 + 25.8T$	$1.1 + 25.8T$
$0.1 < T \leq 1.5$	$0.704/T$ but ≤ 2.35	$0.88/T$ but ≤ 2.94	$1.25/T$ but ≤ 3.68	$1.98/T$ but ≤ 3.68	$3.08/T$ but ≤ 3.68
$T > 1.5$	$1.056/T^2$	$1.32/T^2$	$1.874/T^2$	$2.97/T^2$	$4.62/T^2$

* Values in brackets correspond to values of spectral shape factor for the modal response spectrum and the numerical integration time history methods and for use in the method of calculation of forces on parts and components (see Section 8)

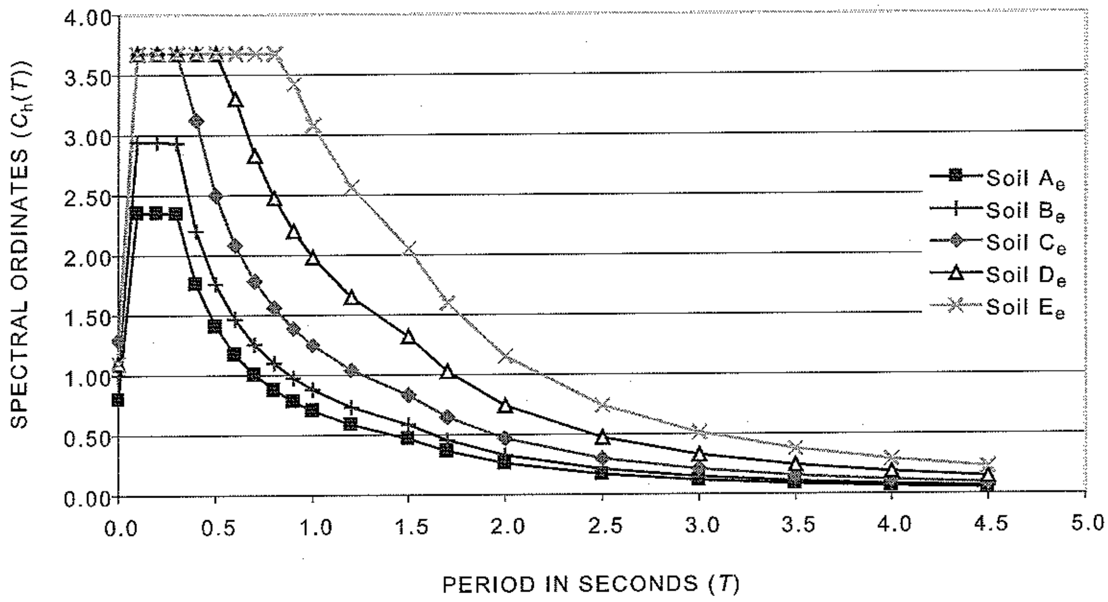

FIGURE 6.4 NORMALIZED RESPONSE SPECTRA FOR SITE SUB-SOIL CLASS

6.5 DETERMINATION OF STRUCTURAL DUCTILITY (μ) AND STRUCTURAL PERFORMANCE FACTOR (S_p)

The ductility of the structure (μ) and the structural performance factor (S_p) shall be determined either—

(a) in accordance with the appropriate material standard where the data is provided; or

(b) as given in Table 6.5(A) or 6.5(B) for the structure type and material where the data is not provided,

except that, for a specific structure, it shall be permissible to determine μ and S_p by using a non-linear static pushover analysis.

NOTES:

1 Where the design is carried out using other than recognized Australian material design Standards, then the values given in the last row for each material type in Table 6.5A should be used.

2 Where the design is carried out in accordance with NZS 1170.5, μ and S_p should be determined as set out therein.

A lower μ value that is specified in this Clause or the relevant material standard may be used. In all cases, the structure shall be detailed to achieve the level of ductility assumed in the design, in accordance with the applicable material design Standard.

TABLE 6.5(A)

STRUCTURAL DUCTILITY FACTOR (μ) AND STRUCTURAL PERFORMANCE FACTOR (S_p)—BASIC STRUCTURES

Structural system	Description	μ	S_p	S_p/μ	μ/S_p
Steel structures					
	Special moment-resisting frames (fully ductile)*	4	0.67	0.17	6
	Intermediate moment-resisting frames (moderately ductile)	3	0.67	0.22	4.5
	Ordinary moment-resisting frames (limited ductile)	2	0.77	0.38	2.6
	Moderately ductile concentrically braced frames	3	0.67	0.22	4.5
	Limited ductile concentrically braced frames	2	0.77	0.38	2.6
	Fully ductile eccentrically braced frames*	4	0.67	0.17	6
	Other steel structures not defined above	2	0.77	0.38	2.6
Concrete structures					
	Special moment-resisting frames (fully ductile)*	4	0.67	0.17	6
	Intermediate moment-resisting frames (moderately ductile)	3	0.67	0.22	4.5
	Ordinary moment-resisting frames	2	0.77	0.38	2.6
	Ductile coupled walls (fully ductile)*	4	0.67	0.17	6
	Ductile partially coupled walls*	4	0.67	0.17	6
	Ductile shear walls	3	0.67	0.22	4.5
	Limited ductile shear walls	2	0.77	0.38	2.6
	Ordinary moment-resisting frames in combination with a limited ductile shear walls	2	0.77	0.38	2.6
	Other concrete structures not listed above	2	0.77	0.38	2.6
Timber structures					
	Shear walls	3	0.67	0.22	4.5
	Braced frames (with ductile connections)	2	0.77	0.38	2.6
	Moment-resisting frames	2	0.77	0.38	2.6
	Other wood or gypsum based seismic-force-resisting systems not listed above	2	0.77	0.38	2.6
Masonry structures					
	Close-spaced reinforced masonry†	2	0.77	0.38	2.6
	Wide-spaced reinforced masonry†	1.5	0.77	0.5	2
	Unreinforced masonry†	1.25	0.77	0.62	1.6
	Other masonry structures not complying with AS 3700	1.00	0.77	0.77	1.3

* The design of structures with $\mu > 3$ is outside the scope of this Standard (see Clause 2.2)

† These values are taken from AS 3700

SECTION 7 DYNAMIC ANALYSIS

7.1 GENERAL

Dynamic analysis, when used, shall be carried out in accordance with this Section. The analysis shall be based on an appropriate ground-motion representation in accordance with Clause 7.2. The mathematical model used shall be in accordance with Clause 7.3.

The analysis procedure may be either a modal-response-spectrum analysis in accordance with Clause 7.4 or a time-history analysis in accordance with Clause 7.2(c).

Drift and P-delta effects shall be determined in accordance with Clause 7.5.

7.2 EARTHQUAKE ACTIONS

The earthquake ground motion shall be accounted for by using one of the following:

(a) Horizontal design response spectrum ($C_d(T)$), including the site hazard spectrum and the effects of the structural response as follows:

$$C_d(T) = C(T)S_p/\mu \qquad \ldots 7.2(1)$$

$$= k_p Z C_h(T) S_p/\mu \qquad \ldots 7.2(2)$$

where values are as given in Section 6, except that—

T = period of vibration appropriate to the mode of vibration of the structure being considered

(b) Site-specific design response spectra developed for the specific site, which shall be based on analyses that consider the soil profile and apply a bedrock ground motion compatible with the rock spectra given in Clause 6.4.

(c) Ground-motion time histories chosen for the specific site, which shall be representative of actual earthquake motions. Response spectra from these time histories, either individually or in combination, shall approximate the site design spectrum conforming to Item (a) or (b). A dynamic analysis of a structure by the time-history method involves calculating the response of a structure at each increment of time when the base is subjected to a specific ground-motion time-history. The analysis should be based on well-established principles of mechanics using ground-motion records compatible with the site-specific design response spectra.

Where design includes consideration of vertical earthquake actions, both upwards and downwards directions shall be considered and the vertical design response spectrum shall be as follows:

$$C_{vd}(T) = C_v(T_v)S_p \qquad \ldots 7.2(3)$$

$$= 0.5C(T_v)S_p$$

$$= 0.5k_p Z C_h(T_v) S_p$$

where

$C_v(T_v)$ = elastic site hazard spectrum for vertical loading for the vertical period of vibration

7.3 MATHEMATICAL MODEL

A mathematical model of the physical structure shall represent the spatial distribution of the mass and stiffness of the structure to an extent that is adequate for the calculation of the significant features of its dynamic response.

SECTION 8 DESIGN OF PARTS AND COMPONENTS

8.1 GENERAL REQUIREMENTS

8.1.1 General

Non-structural parts and components and their fastenings, as listed in Clause 8.1.4, shall be designed for horizontal and vertical earthquake forces as defined in Clauses 8.1.2 and 8.1.3.

Base isolation may be used to reduce the forces on a component. Where flexible mounting devices (such as spring mountings) are used, they shall be fitted with restraining devices to limit the horizontal and vertical motions, to inhibit the development of resonance in the flexible mounting system, and to prevent overturning.

8.1.2 Earthquake actions

Design of parts and components shall be carried out for earthquake actions by one of the following methods:

(a) Using established principles of structural dynamics.

(b) Using the general method given in Clause 8.2.

(c) Using the forces determined by the simplified method given in Clause 8.3.

8.1.3 Forces on components

The horizontal earthquake force on any component shall be applied at the centre of gravity of the component and shall be assumed to act in any horizontal direction. Vertical earthquake forces on mechanical and electrical components shall be taken as 50% of the horizontal earthquake force.

Mechanical connectors from the following shall be designed for 1.5 times the design force for the supported element:

(a) Curtain walls.

(b) External walls.

(c) Walls enclosing stairs, stair shafts, lifts and required exit paths.

8.1.4 Parts and components

The following parts and components and their connections shall be designed in accordance with this Section:

(a) *Architectural components*:

  (i) Walls that are not part of the seismic-force-resisting system.

  (ii) Appendages, including parapets, gables, verandas, awnings, canopies, chimneys, roofing components (tiles, metal panels) containers and miscellaneous components.

  (iii) Connections (fasteners) for wall attachments, curtain walls, exterior non-loadbearing walls.

  (iv) Partitions.

  (v) Floors (including access floor systems, where the weight of the floor system shall be determined in accordance with Clause 6.2.2).

  (vi) Ceilings.

8.2 METHOD USING DESIGN ACCELERATIONS

Architectural, mechanical and electrical components and their fixings shall be designed for earthquake actions from the accelerations determined using the design methods given in Sections 6 and 7, as appropriate for the particular structure in which the component or fixing is incorporated.

The forces generated on the part or component in the specific structure being considered are given as follows, based on the principles given in this Standard for design of the structure:

$$F_c = a_{floor}[I_c a_c / R_c] W_c \leq 0.5 W_c \qquad \ldots 8.2(1)$$

where

a_{floor} = effective floor acceleration at the level where the component is situated, calculated from the earthquake actions determined for the structure using Sections 5, 6 and 7 divided by the seismic weight, but not less than $k_p Z C_h(0)$, where the values of $C_h(0)$ are the bracketed values given in Table 6.1

NOTE: The fundamental natural period of vibration of a completed structure may be determined by measurement.

I_c = component importance factor, taken as:

= 1.5 for components critical for life safety, which includes parts and components required to function immediately following an earthquake, those critical to containment of hazardous materials, storage racks in public areas and all parts and components in importance level 4 structures

= 1.0 for all other components

a_c = component amplification factor

= 2.5 for flexible spring-type mounting systems for mechanical equipment (unless detailed dynamic analysis is used to justify lower values)

= 1.0 for all other mounting systems

R_c = component ductility factor

= 1.0 for rigid components with non-ductile or brittle materials or connections

= 2.5 for all other components and parts

W_c = seismic weight of the component, in kilonewtons

For objects mounted on the ground, the acceleration should be taken as follows:

$$a_{floor} = k_p Z C_h(0) \qquad \ldots 8.2(2)$$

where

$C_h(0)$ = bracketed value of the spectral shape factor for the period of zero seconds, as given in Clause 6.4

8.3 SIMPLE METHOD

Non-structural parts or components and their attachments shall be designed to resist the horizontal earthquake force determined as follows and applied to the component at its centre of mass in combination with the gravity load of the element:

$$F_c = [k_p Z C_h(0)] a_x [I_c a_c / R_c] W_c \quad \text{but} > 0.05 W_c \qquad \ldots 8.3$$

where I_c, a_c, R_c, W_c are as given in Clause 8.2; and

k_p = probability factor (see Section 3)

Z = hazard factor (see Section 3)