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## Structural Design Actions for South Pacific Village Buildings



Kopeng Community Health Building in the Papua New Guinea Western Highlands Province using the Partner Housing Australasia **DANCER** Building System

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## **Partner Housing Australasia (Building) Incorporated**

Partner Housing Australasia is an entirely voluntary organisation, which aims to transform the lives of people living in Asia-Pacific villages by improving the cyclone, earthquake and tsunami resistance of their houses, clinics, schools and community buildings; and by providing clean water supplies and hygienic sanitation.

### **Disclaimer**

This manual has been prepared by Quasar Management Services Pty Limited for use by Partner Housing Australasia and its partner organisations. It is intended for use by qualified and experienced structural design engineers, who must assume responsibility for the exercise of their professional judgement in selecting appropriate probabilities of exceedance, design actions and combinations for the particular applications.

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### **Acknowledgements**

Quasar acknowledges the references and publications cited elsewhere in this document, which form the basis of the information reproduced herein.

### **Scope of this Manual**

This scope of this manual is limited to examination of the structural design actions that may reasonably be expected to act on small village buildings in the following South Pacific countries – American Samoa, Cook Islands, Fiji, French Polynesia, Kiribati, Nauru, New Caledonia, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Wallis and Futuna.

The Manual deals with:

1. Design for Ultimate Limit State
2. Load Combinations
3. Permanent Loads
4. Imposed Loads
5. Wind Loads
6. Earthquake Loads
7. Tsunami Loads
8. Flood Loads
9. Soil properties.

## Background

In cities of the South Pacific region, structural design and construction generally follow established building regulations and design standards. However, remote village housing and infrastructure in these countries often incorporate traditional materials and detailing, which do not necessarily have the structural resilience implicit in modern regulations. This Manual discusses the design principles and details that ensure consistent resistance to applicable cyclonic wind, earthquake and tsunami loads for detached houses and small buildings in located in villages in the South Pacific region. The following parts describe the derivation and application of the relevant design actions.

### Part 1 – Structural Design Principals

#### *(a) Where Building Regulations are Enforced*

Governments have the responsibility to enact and enforce compliance with building regulations. In locations where building regulations are enacted and routinely enforced, design and construction must adhere to those regulations. For example, construction in cities and in developed countries must adhere to local building regulations.

#### *(b) Where Building Regulations are Unclear, Not Enacted or Not Routinely Enforced*

There are some situations in the South Pacific, where small detached village buildings (such as houses and small community health buildings, schools and community buildings), presenting a low degree of hazard to life and other property in case of failure, are not covered by building regulations. This part of the Manual applies only in such circumstances as listed below –

- Location: South Pacific.
- Building use: Small detached village buildings (such as houses, small community health buildings or clinics, school classrooms, and community buildings).
- Maximum design life: 25 years
- Hazard: Low degree of hazard to life and other property in case of failure.
- Building regulations: Exempted or not covered.
- Compliance monitoring: Assume minimal compliance monitoring [with regulations].
- Number of habitable storeys: Single storey
- Building shape and materials: The building may be –
  - Elevated braced timber frame superstructure, on steel posts, with timber or steel cladding and corrugated steel roof; or
  - Braced timber frame superstructure, on concrete slab-on-ground, with timber or steel cladding and corrugated steel roof; or
  - Reinforced concrete masonry superstructure, on concrete slab-on-ground, with corrugated steel roof.
- Maximum dimensions: Building dimensions shall not exceed 16.5 x 8.4 m plan dimensions (exclusive of steps and landings), 2.7 m storey height, 6.0 m maximum eaves height, 8.5 m maximum ridge height, and 35° maximum pitch.

### Part 2 – Country Analysis, Design and Checking Assumptions

This section provides assumptions for the analysis, design and checking of both unregulated and regulated small detached village buildings (such as houses and small community buildings) and in each of the countries covered by this Manual, taking account of the location, proximity to cyclonic wind zones, proximity to high earthquake areas and plate boundaries, typical topography and susceptibility to tsunamis.

# Part 1 – Structural Design Principles

## Background

In cities of the South Pacific region, structural design and construction generally follow established building regulations and design standards. However, village housing and infrastructure in developing countries often incorporate traditional materials and detailing, which do not necessarily have the structural resilience implicit in modern regulations.

## Countries Covered by this Manual

The following countries are covered by this Manual – American Samoa, Cook Islands, Fiji, French Polynesia, Kiribati, Nauru, New Caledonia, Niue, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Wallis and Futuna.

## Assumptions for Structural Design and Structural Design Checking

It is common practice for structural design to be more conservative than that which is mandated by the minimum requirements of building regulations or other design policies. This conservatism is normal and arises through several mechanisms:

- (a) Most structural components are supplied in discreet sizes. For example, structural bolts are available in M12, M16, M20 etc. If analysis based on the assumed design actions dictates that a bolt must be at least (say) 13.7 mm in diameter, the design engineer must adopt the next available size, M16, which implies conservatism.
- (b) In many cases, design for one action will lead to conservatism in another action. For example, the depth of long span flexural members (such as bearers) may be dictated by deflection serviceability, and therefore will be conservative in respect of ultimate load capacity.
- (c) The adoption of conservative design assumptions may minimise disputes arising from differing analysis assumptions of the design checking process.

Recognising this intrinsic conservatism, the following assumptions for “structural design” and “structural design checking” are offered for consideration.

### For regulated buildings –

- (a) the building is of Importance Level 2; and
- (b) relevant building regulations are enforced; and
- (c) a probability of exceedance of 1 in 500 years is specified.

For the **design** of regulated buildings, consider slightly conservative assumptions (in excess of those based on a probability of exceedance of 1 in 500 years).

For the **checking** of regulated buildings, consider precise assumptions (based on a probability of exceedance of 1 in 500 years).

### For unregulated village buildings

- (a) the building is of Importance Level 1 or 2; and
- (b) they offer low risk to occupants; and
- (c) the design life is under 25 years; and
- (d) there is no other practical way of determining the design actions and soil properties, and;
- (e) relevant building regulations are not routinely enforced.

For the **design** of unregulated village buildings subject to wind and earthquake actions, and subject to close consideration of the hazard associated for both the design actions and the building uses, consider slightly conservative assumptions (at least in excess of those based on a probability of exceedance of 1 in 250 years).

For the **checking** of unregulated village buildings subject to wind and earthquake actions, and subject to close consideration of the hazard associated for both the design actions and the building uses, consider precise assumptions (based on a probability of exceedance of 1 in 250 years).

This option is not applicable in Australia or New Zealand.

### Probability of Structural Failure

The following extracts from the “Guide to NCC Volume One 2016”, published by the Australia Building Codes Board provide background to the probabilities of structural failure implicit in the Australian National Construction Code. This approach is reflected in this Manual.

#### *Performance attributes*

*BP1.1(a) uses the term “with appropriate degrees of reliability” which can be judged with due regard to the possible consequences of failure and the expense, level of effort and procedures necessary to reduce the risk of failure. The measures that can be taken to achieve the appropriate degree of reliability include:*

- *choice of a structural system, proper design and analysis;*
- *implementation of a quality policy;*
- *design for durability and maintenance; and*
- *protective measures.*

*Degrees of reliability of structural elements can be quantified in terms of probabilities of failure with the use of probabilistic models for actions and resistances.*

*BP1.1(a)(i) is concerned with the serviceability limit states of buildings in terms of local damage, deformation and vibration. Expected actions are actions with high probabilities of occurrence. The acceptable level of serviceability is subjective. The design for serviceability depends to a large extent on professional judgement. The risk of serviceability failure is, historically, of the order of  $10^{-1}$  to  $10^{-2}$ .*

*BP1.1(a)(ii) is concerned with the ultimate limit states of buildings in terms of strength and stability. Extreme actions are actions with low probability of occurrence. Repeated actions are actions, with high frequencies of occurrence in a given time period, that may cause fatigue or other cumulative failures. The notional probability of failure of structural elements is of the order of  $10^{-3}$  to  $10^{-4}$  for a 50 year reference period. The probability of structural failure is historically of the order of  $10^{-6}$  per year.*

*BP1.1(a)(iii) is concerned with consequences of unspecified actions and is often referred to as "structural robustness". It includes, but is not limited to, progressive collapse. Ways to improve structural robustness include providing redundancies, minimum resistances, protective measures, etc.*

<b>Importance Level</b>	<b>Examples of building types</b>
1	<i>Farm buildings and farm sheds Isolated minor storage facilities Minor temporary facilities.</i>
2	<i>Low rise residential construction Buildings and facilities below the limits set for Importance Level 3.</i>
3	<i>Buildings and facilities where more than 300 people can congregate in one area. Buildings and facilities with a primary school, a secondary school or day care facilities with a capacity greater than 250. Buildings and facilities with a capacity greater than 500 for colleges or adult educational facilities Health care facilities with a capacity of 50 or more residents but not having surgery or emergency treatment facilities Jails and detention facilities Any occupancy with an occupant load greater than 5000 Power generating facilities, water treatment and waste water treatment facilities, any other public utilities not included in Importance Level 4 Buildings and facilities not included in Importance Level 4 containing hazardous materials capable of causing hazardous conditions that do not extend beyond property boundaries.</i>
4	<i>Buildings and facilities designated as essential facilities Buildings and facilities with special post disaster functions Medical emergency or surgery facilities Emergency service facilities: fire, rescue, police station and emergency vehicle garages Utilities required as backup 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 property boundaries.</i>

### **Locations Where Building Regulations are Enforced**

In those locations where building regulations are enacted and routinely enforced, all new construction should adhere to those regulations. For example, construction in cities and in developed countries should adhere to local building regulations.

The following clause appears in the National Building Codes for Cook Islands, Fiji, Niue, Solomon Islands, Tuvalu and Vanuatu.

#### *Schedule of Referenced Documents*

*The Standards and other documents listed in Table 1 are referred to in this Code. In order to reduce possible confusion/conflict, the Standards produced by the Standards Association of Australia or by the Standards Association of New Zealand as seen to be particularly relevant, have been called up. However, Code users are free to use any suitable mix of Australian and New Zealand Standards provided care is taken to follow consistent technical principles and prevalent practices. Where Standards from either Australia or New Zealand do not cover any specific area, the relevant Standards issued by the British Standards Institution or the American Society for Testing Materials may be used.*

## Small Buildings where Building Regulations are Not Enforced

This applies only to small detached village buildings (such as houses and small community buildings), presenting a low degree of hazard to life and other property in case of failure.

It applies only to single storey buildings, with cladding on elevated braced timber frame or to reinforced concrete masonry buildings built on concrete slab-on-ground.

The maximum dimensions of such buildings shall not exceed 16.5 x 8.4 m, 2.7 m storey height, maximum eaves height 6.0 m, maximum ridge height 8.5 m, and maximum pitch 35°.

The intended design life shall not be less than 25 years.

Unless specifically over-ridden by existing in-country building regulations, requirements shall be interpreted in the light of the most recent Australian and Australian/New Zealand Standards listed below.

1. Design for Ultimate Limit State – Annual Probability of Exceedance is 1 in 250. Reference Period (design life) is 25 years, leading to a probability of exceedance during the life of 0.10. Load factors (applied to the representative loads) and capacity reduction factors (applied to a specified “lower 5 percentile” characteristic strengths of components) shall ensure that the probability of failure is “low” (e.g., Target Reliability Index  $\beta = 3.1$ )
2. Load Combinations– As per AS/NZS 1170.0
3. Permanent Loads – As per AS/NZS 1170.1
4. Imposed Loads – As per AS/NZS 1170.1
5. Wind Loads – Analysis as per AS 4055, using wind speeds from the relevant Building Regulations or, if appropriate, HB 212
6. Earthquake Loads – Analysis assumptions set out in AS 1170.4, EDC II, using hazard factors appropriate to the region
7. Tsunami Loads– For structures that are required to be designed for tsunami (except those that should be moved), analysis shall be in accordance with using the method in Australian Building Codes Board Handbook, *Construction of Buildings in Flood Hazard Areas* for a velocity of 1.5 m/s. Structural components shall be designed to withstand the design event, assuming that the cladding is partially destroyed.
8. Flood Loads – For structures that are required to be designed for flood (except those that should be moved), analysis shall be in accordance with using the method in Australian Building Codes Board Handbook, *Construction of Buildings in Flood Hazard Areas* for a velocity of 1.5 m/s. Structural components shall be designed to withstand the design event, assuming that the cladding remains intact.
9. Soil Properties – Site classification, construction and analysis to AS 2870; Soil loads to AS 4678

Similar to the situation where the “Building Regulations are enforced” the following clause (from the National Building Codes for Cook Islands, Fiji, Niue, Solomon Islands, Tuvalu and Vanuatu) is considered applicable.

### *Schedule of Referenced Documents*

*The Standards and other documents listed in Table 1 are referred to in this Code. In order to reduce possible confusion/conflict, the Standards produced by the Standards Association of Australia or by the Standards Association of New Zealand as seen to be particularly relevant, have been called up. However, Code users are free to use any suitable mix of Australian and New Zealand Standards provided care is taken to follow consistent technical principles and prevalent practices. Where Standards from either Australia or New Zealand do not cover any specific area, the relevant Standards issued by the British Standards Institution or the American Society for Testing Materials may be used.*

## Notes on Annual Probability of Exceedance

### Australia

While the Australian National Construction Code is formatted as performance code (thus permitting Performance Solutions) it does not contain quantified structural Performance Requirements.

The Australian National Construction Code (NCC) Verification Methods, NCC 2016 Volume One Parts BV1 and BV2 and NCC 2016 Volume Two Parts V2.1.1 and V2.1.2, apply only to Performance solutions.

Therefore, there are no overarching quantified probabilities of structural reliability that apply to both Performance Solutions and Deemed-to-Satisfy Solutions.

The following approach is considered:

- (a) Design using the referenced DTS Australian and Australian/New Zealand Standards for both design actions and capacities; and
- (b) Check designs and apply acceptance / rejection criteria using the same referenced DTS Australian and Australian/New Zealand Standards.

NCC Volume One Table B1.2a and Table B1.2b are reproduced below. NCC Volume Two Table 3.11.3a and 3.11.3b includes similar information for Importance Levels 1 and 2.

**Table B1.2a IMPORTANCE LEVELS OF BUILDINGS AND STRUCTURES**

Importance Level	Building Types
1	Buildings or structures presenting a low degree of hazard to life and <i>other property</i> in the case of failure.
2	Buildings or structures not included in Importance Levels 1, 3 and 4.
3	Buildings or structures that are designed to contain a large number of people.
4	Buildings or structures that are essential to post-disaster recovery or associated with hazardous facilities.

**Table B1.2b DESIGN EVENTS FOR SAFETY**

Importance Level	Annual probability of exceedance			
	Wind		Snow	Earthquake
	Non-cyclonic	Cyclonic		
1	1:100	1:200	1:100	1:250
2	1:500	1:500	1:150	1:500
3	1:1000	1:1000	1:200	1:1000
4	1:2000	1:2000	1:250	1:1500

In Australia, houses and small buildings with an Importance Level of 2 must be designed for an Annual Probability of Exceedance for wind loads and earthquake loads of 1 : 500.

The Building Regulations require the capacity to be based on the “lower 5 percentile” characteristic strengths of components) but do not regulate the probability of failure.

### New Zealand

The approach in New Zealand is similar to that of Australia, except that the definitions of design events are in the Standards. Cyclonic winds do not apply and there is significantly more emphasis on earthquake loads.

## Other South Pacific Countries

Section 2 of this policy applies only to small detached village buildings (such as houses and small community buildings such as clinics and small school buildings. It is further limited to single storey buildings, with cladding on elevated braced timber frame, or to reinforced concrete masonry buildings built on concrete slab-on-ground. The maximum dimensions of such buildings shall not exceed 16.5 x 8.4 m, 2.7 m storey height, maximum eaves height 6.0 m, maximum ridge height 8.5 m, and maximum pitch 35°.

Such buildings are deemed to “present a low degree of hazard to life and other property in case of failure”.

Based on the above-mentioned limitations, an Annual Probability of Exceedance of 1 in 250 has been selected for design for Ultimate Limit State.

These small, single storey houses are (in general) considerably smaller than most new houses in Australia and New Zealand. Further, the likely design life will also probably much shorter. A design life “not exceeding 25 years” has been selected.

The Reference Period (design life) of 25 years for 1 in 250 leads to a probability of exceedance during the life of 0.10.

This Manual seeks to achieve consistency of approach when dealing with various loads; in particular wind and earthquake loads. To achieve this the basic variables (3 second wind gust speed at a height of 10 m and earthquake hazard) are determined and reported for a Probability of Exceedance of 1 : 500. A factor,  $k_p$ , is then applied to the resulting forces, after (in the case of wind) provision has been made for terrain category, shielding, topography and pressure/suction factors.

Annual Probability of Exceedance	Application	Probability Factor, $k_p$	
		Earthquake Loads AS 1170.4 Table 3.1	AS/NZS 1170.2 and HB 212
1 : 500	Ultimate limit state in Australia, New Zealand and in places where 1 : 500 is regulated	1.0	1.0
1 : 250	Ultimate limit state in villages where 1 : 500 is not regulated	0.75	Zone I 0.90
			Zone II 0.91
			Zone III 0.86
			Zone IV 0.88
			Zone V 0.86
1 : 50	Serviceability in villages where 1 : 500 is not regulated	0.35	Zone I 0.64
			Zone II 0.75
			Zone III 0.60
			Zone IV 0.62
			Zone V 0.66

The following approach is considered:

- (a) Design using the referenced (or otherwise appropriate) Australian and New Zealand Standards; and
- (b) Initially check the design using the referenced (or otherwise appropriate) Australian and New Zealand Standards, but carry out further checks, if necessary, using the applicable Importance, Design Life and corresponding Probability of Exceedance (based on the applicable factor,  $k_p$ ).

## Tonga

The Tonga Building Code 2007 Part B Performance Requirements state:

### **BP1.3 Design criteria**

*The following criteria must be satisfied –*

- (a) *during the designed life of the building the probability of experiencing unacceptable deflections or vibrations must not exceed 5%;*
- (b) *the probability of risk of structural failure must not exceed 0.1% within the designed life of the building.*

For a 50-year building design life, this equates to an annual probability of exceedance of 1 in 500, and a factor  $k_p = 1.0$ .

For a 25-year building design life, this equates to an annual probability of exceedance of 1 in 250, and a factor  $k_p = 0.75$ .

**Table 1.1 – Importance levels of buildings**  
(Based on Table 3.2 of AS/NZS 1170.0 – see 1.1.3)

Importance level	Description
<b>Building types covered by this Standard</b>	
1	Structures of a secondary nature
2	Single family dwellings and structures not in other importance levels
<b>Building types not covered by this Standard</b>	
3	Structures that may contain crowds or contents of a high value to the community
4	Structures with special post-disaster functions
5	Special structures

This infers that single family dwellings (including in villages) are considered to be of Importance Level 2.

The Australian and New Zealand Standards that are referenced as Deemed-to-Satisfy (DTS) provisions in the Tongan Building Code are based on Annual Probability of Exceedance of 1 in 500 ( $k_p = 1.0$ ), which correspond to Importance Level 2 and design life of 50 years. This is similar to the design in Australia and New Zealand using these Standards.

If a shorter design life (say 25 years) were to be considered appropriate for village houses and similar buildings,  $k_p = 0.75$  would be applicable and design actions less than those assumed in the referenced Australian and New Zealand Standards would apply. In other words, the referenced Standards would be a little more conservative than the calculated design actions would indicate.

Therefore, the following approach is considered:

- (c) Design using the referenced (or otherwise appropriate) Australian and New Zealand Standards; and
- (d) Initially check the design using the referenced (or otherwise appropriate) Australian and New Zealand Standards, but carry out further checks, if necessary using the applicable Importance, Design Life and corresponding Probability of Exceedance (based on the applicable factor,  $k_p$ ).

## **Notes on Load Combinations**

### Australia and New Zealand

Australia and New Zealand Building Regulations call up the 2002 version (with amendments) of AS/NZS 1170.0:2002, which includes formulae for load combinations. This includes a combination factor of 1.2 on permanent loads (in combination with imposed loads), rather than the value of 1.25 in the earlier 1989 standard.

### Other Countries

The 2002 version (with amendments) of AS/NZS 1170.0:2002, including the combination factor of 1.2, is used in this “Policy for Small Buildings where Building Regulations are Not Enforced”, although some other countries do not specifically refer to them.

## Notes on Permanent Loads

The 2002 version (with amendments) of AS/NZS 1170.1:2002 is used in this policy to determine permanent loads, although some other countries do not specifically refer to it.

In providing default values for standard calculations, the following permanent loads of particular components (expressed as kN / m<sup>2</sup> of plan footprint area) have been assumed.

### Surface Weight of Components of Timber Framed Houses

Surface weight of roof sheeting	0.080	kN/m <sup>2</sup>
Surface weight of roof battens	0.037	kN/m <sup>2</sup>
Surface weight of roof framing	0.135	kN/m <sup>2</sup>
Surface weight of ceiling battens	0.033	kN/m <sup>2</sup>
Surface weight of ceiling lining	0.076	kN/m <sup>2</sup>
Surface weight of external wall cladding	0.215	kN/m <sup>2</sup>
Surface weight of external wall framing	0.167	kN/m <sup>2</sup>
Surface weight of external wall lining	0.076	kN/m <sup>2</sup>
Surface weight of internal wall framing	0.167	kN/m <sup>2</sup>
Surface weight of internal wall lining	0.260	kN/m <sup>2</sup>
Surface weight of floor sheeting	0.220	kN/m <sup>2</sup>
Surface weight of floor Joists	0.138	kN/m <sup>2</sup>
Surface weight of floor bearers	0.092	kN/m <sup>2</sup>
Surface weight of subfloor posts	0.183	kN/m <sup>2</sup>
Surface weight of sub-floor bracing	0.014	kN/m <sup>2</sup>
Surface weight of steps	0.748	kN/m <sup>2</sup>
Surface weight of windows	0.150	kN/m <sup>2</sup>
Surface weight of doors	0.330	kN/m <sup>2</sup>

### Surface Weight of Components of Reinforced Concrete Masonry Houses

Surface weight of roof sheeting	0.080	kN/m <sup>2</sup>
Surface weight of roof battens	0.037	kN/m <sup>2</sup>
Surface weight of roof framing	0.135	kN/m <sup>2</sup>
Surface weight of ceiling battens	0.033	kN/m <sup>2</sup>
Surface weight of ceiling lining	0.076	kN/m <sup>2</sup>
Surface weight of external wall cladding	2.158	kN/m <sup>2</sup>
Surface weight of internal wall framing	0.167	kN/m <sup>2</sup>
Surface weight of internal wall lining	0.260	kN/m <sup>2</sup>
Surface weight of windows	0.150	kN/m <sup>2</sup>
Surface weight of doors	0.330	kN/m <sup>2</sup>

The permanent loads should be calculated for each building, although, for small detached village buildings, the following default permanent loads acting at floor level may be used.

- Elevated timber building,  $w = 2.0 \text{ kN/m}^2$  (of plan footprint area),
- Reinforced masonry building  $w = 3.0 \text{ kN/m}^2$  (of plan footprint area)

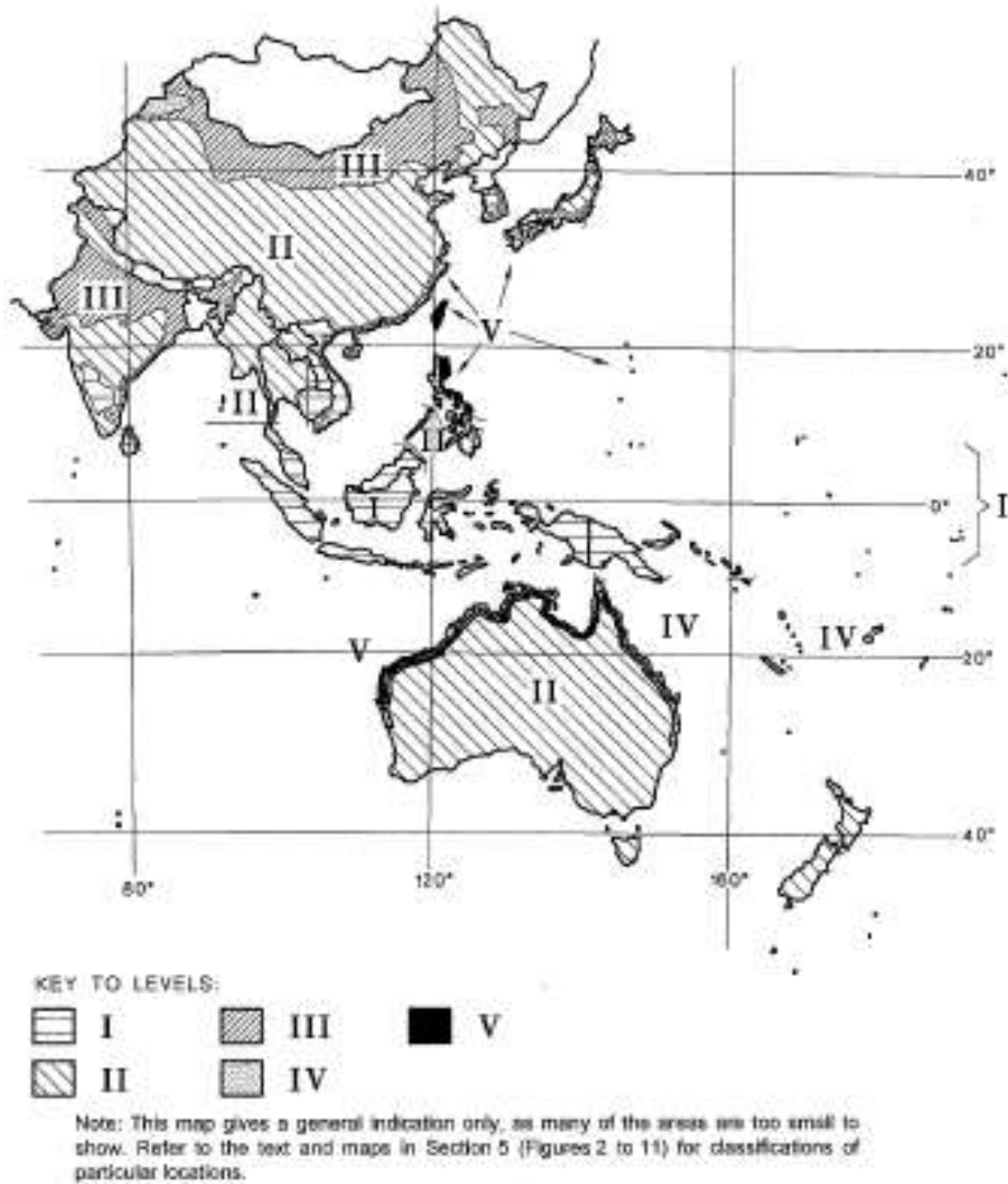
### **Notes on Imposed Loads**

The 2002 version (with amendments) of AS/NZS 1170.1:2002 is used in this policy to determine imposed loads, although some other countries do not specifically refer to them.

In particular, for small detached village buildings, an imposed floor load of 1.5 kPa and an imposed roof load of 0.25 kPa are used.

## Notes on Wind Loads

Basic wind speeds shall be determined in accordance with the following map and table, except where overridden by more recent Australian or New Zealand Standards.



Reference: Standards Australia Handbook HB 212:2002

Wind Categories	Description	Equation	$V_{u 500 (3,10)}$ m/s	$V_{u 250 (3,10)}$ m/s	$k_{p 250}$
Zone I - Pacific islands adjacent to the equator, East Timor, Papua New Guinea, Solomon Islands, Indonesia, Malaysia, Singapore, Inland Karnataka (India),	Strong thunderstorms and monsoon winds	$70 - 56 R^{-0.1}$	40	38	0.90
Zone II (A) - South-west tip of Papua New Guinea, most of southern India, western Indian coastal strip (Mumbai, inland Madhya Pradesh, Orissa), western Mindanao, Australia & New Zealand Zones A1-A7(Southern & inland)	Moderately severe thunderstorms and extra-tropical gales	$67 - 41 R^{-0.1}$	45	43	0.91
Zone III (B) - Coastal strips of Tamil Nadu (including Chennai), Andhra Pradesh, Orissa, Gujarat, West Bengal (including Calcutta), Assam, northern India (including Delhi), central Tamil Nadu, Eastern Mindanao, Palawan(Philippines) Australia Zone B (South-east Queensland)	Severe thunderstorms and moderate or weakening typhoons or tropical cyclones	$106 - 92 R^{-0.1}$	57	53	0.86
Zone IV (C) - Pacific Islands below 6°S, Tripiura & Mizoram, Ladakh (India), remainder of Philippines Australia Zone C (Northern coast)	Strong typhoons or tropical cyclones	$F_C (122 - 104 R^{-0.1})$	66	62	0.88
Zone V (D) - Eastern Luzon (Philippines) Australia Zone D (West coast)	Very strong typhoons or tropical cyclones	$F_D (156 - 142 R^{-0.1})$	80	74	0.86
Zone W New Zealand Wellington Region		$104 - 70 R^{-0.045}$	51	49	0.92
<b>Notes</b> 1. Wind speeds are for a 3 second gust, at 10 m height in open country terrain. 2. For $R < 50$ years, $F_c$ and $F_d = 1.0$ 3. Sources: HB 212 <i>Design wind speeds for the Asia-Pacific Region</i> , 2002 and AS/NZS 1170.2:2011; Standards Australia 4. Pink shaded areas are for 1 : 500 Probability of Exceedance (e.g. Housing in Australia and New Zealand). 5. Blue shaded areas are for 1 : 250 Probability of Exceedance (e.g. Village housing in developing countries). 6. Probability Factor, $k_p = (V_{u 500 (3,10)} / V_{u 500 (3,10)})^2$ , and is applied to resulting pressures, suctions and forces.					

This Manual seeks to achieve consistency of approach when dealing with various loads; in particular wind and earthquake loads.

To achieve this the basic variable (3 second wind gust speed at a height of 10 m) is determined and reported for a Probability of Exceedance of 1 : 500.

A factor,  $k_p$ , is then applied to the resulting forces, after provision has been made for terrain category, shielding topography and pressure/suction factors.

Noncyclonic	Level I	$V_{u 500 (3,10)} = 40$ m/s	$k_{p 500} = 1.0, k_{p 250} = 0.90$
Noncyclonic	Level II (A)	$V_{u 500 (3,10)} = 45$ m/s	$k_{p 500} = 1.0, k_{p 250} = 0.91$
Noncyclonic	Level III (B)	$V_{u 500 (3,10)} = 57$ m/s	$k_{p 500} = 1.0, k_{p 250} = 0.86$
Cyclonic	Level IV (C)	$V_{u 500 (3,10)} = 66$ m/s	$k_{p 500} = 1.0, k_{p 250} = 0.88$
Cyclonic	Level V(D)	$V_{u 500 (3,10)} = 80$ m/s	$k_{p 500} = 1.0, k_{p 250} = 0.86$
Noncyclonic	Level III (W)	$V_{u 500 (3,10)} = 51$ m/s	$k_{p 500} = 1.0, k_{p 250} = 0.92$

The relevant Wind Classifications (N1 to N6 or C1 to C4) are calculated using AS 4055 from the Basic Wind Speeds (for a 3 second gust at a height of 10 m in open terrain [TC 2]), taking account of the terrain category, shielding and topography.

The following table is based on AS 4055 Table 2.2.

Wind Classifications (for Probability of Exceedance 1 in 500)															
Region	Terrain Category	Topographic classification													
		T0			T1			T2			T3		T4	T5	
		FS	PS	NS	FS	PS	NS	FS	PS	NS	PS	NS	NS	NS	
I	3	N1	N1	N1	N1	N1	N1	N1	N1	N1	N2	N2	N2	N2	
	2.5	N1	N1	N1	N1	N1	N1	N1	N2	N2	N2	N2	N3	N3	
	2	N1	<b>N1</b>	N1	N1	N1	N2	N1	N2	N2	N2	N2	N3	N3	
	1.5	N1	N1	N1	N1	N1	N2	N2	N2	N2	N2	N3	N3	N3	
	1	N1	N2	N2	N1	N2	N2	N2	N2	N2	N3	N3	N3	N3	N4
II (A)	3	N1	N1	N1	N1	N2	N2	N2	N2	N2	N3	N3	N3	N3	
	2.5	N1	N1	N2	N1	N2	N2	N2	N3	N3	N3	N3	N4	N4	
	2	N1	<b>N2</b>	N2	N2	N2	N3	N2	N3	N3	N3	N3	N4	N4	
	1.5	N2	N2	N2	N2	N3	N3	N3	N3	N3	N3	N4	N4	N4	
	1	N2	N3	N3	N2	N3	N3	N3	N3	N3	N4	N4	N4	N4	N5
III (B)	3	N2	N2	N3	N2	N3	N3	N3	N3	N4	N4	N4	N5	N5	
	2.5	N2	N3	N3	N3	N3	N3	N3	N4	N4	N4	N4	N5	N5	
	2	N2	<b>N3</b>	N3	N3	N3	N4	N3	N4	N4	N4	N5	N5	N5	
	1.5	N3	N3	N4	N3	N4	N4	N4	N4	N4	N5	N5	N5	N5	N6
	1	N3	N4	N4	N4	N4	N4	N4	N4	N5	N5	N5	N5	N6	N6
IV (C)	3	C1	C1	C2	C1	C2	C2	C2	C2	C3	C3	C3	C3	C4	
	2.5	C1	C2	C2	C2	C2	C2	C2	C3	C3	C3	C3	C4	C4	
	2	C1	<b>C2</b>	C2	C2	C2	C3	C2	C3	C3	C3	C4	C4	C4	
	1.5	C2	C2	C3	C2	C3	C3	C3	C3	C4	C4	C4	C4	C4	
	1	C2	C3	C3	C3	C3	C3	C3	C3	C4	C4	C4	C4	C4	
V (D)	3	C2	C3	C3	C2	C3	C3	C3	C4	C4	C4	C4	C4	C4	
	2.5	C2	C3	C3	C3	C3	C4	C3	C4	C4	C4	C4	C4	C4	
	2	C3	<b>C3</b>	C4	C3	C4	C4	C4	C4	C4	C4	C4	C4	C4	
	1.5	C3	C4	C4	C4	C4	C4	C4	C4	C4	C4	C4	C4	C4	
	1	C3	C4	C4	C4	C4	C4	C4	C4	C4	C4	C4	C4	C4	

Notes:

1. This table is derived from AS 4055 Table 2.2.
2. The wind classifications for Region I have been determined by extrapolation from Region II.
3. Regions are defined as in HB212.
4. AS/NZS 1170.2 and AS 4055 regions (A, B, C and D) have been indicated in brackets.
5. Region W has been omitted for clarity. It may be conservatively taken as the same as Region III.
6. FS = full shielding PS = partial shielding NS = no shielding
7. The classification shown in large bold red lettering are those taken as defaults in the following data

### For Annual Probability of Exceedance 1 in 500

For structures with Importance Level 2 (including most houses, small community buildings, clinics and the like), The design of buildings with Importance Level 2 (including most houses, small community buildings, clinics and the like) in Australia, New Zealand and several other countries shall be based on wind loads with a probability of Exceedance of 1 : 500,  $k_{p\ 500} = 1.0$ .

The corresponding basic wind pressures, derived from AS 4055 for 1 : 500,  $k_{p\ 500} = 1.0$ , (used for Australia and New Zealand) are:

Non-cyclonic	Wind Level N1	$V_{h,u\ 500\ (3,6.5)} = 34\ \text{m/s};$	$k_p = 1.0\ q_u = 0.69\ \text{kPa}$
Non-cyclonic	Wind Level N2	$V_{h,u\ 500\ (3,6.5)} = 40\ \text{m/s};$	$k_p = 1.0\ q_u = 0.96\ \text{kPa}$
Non-cyclonic	Wind Level N3	$V_{h,u\ 500\ (3,6.5)} = 50\ \text{m/s};$	$k_p = 1.0\ q_u = 1.50\ \text{kPa}$
Non-cyclonic	Wind Level N4	$V_{h,u\ 500\ (3,6.5)} = 61\ \text{m/s};$	$k_p = 1.0\ q_u = 2.23\ \text{kPa}$
Non-cyclonic	Wind Level N5	$V_{h,u\ 500\ (3,6.5)} = 74\ \text{m/s};$	$k_p = 1.0\ q_u = 3.29\ \text{kPa}$
Non-cyclonic	Wind Level N6	$V_{h,u\ 500\ (3,6.5)} = 86\ \text{m/s};$	$k_p = 1.0\ q_u = 4.44\ \text{kPa}$
Cyclonic	Wind Level C1	$V_{h,u\ 500\ (3,6.5)} = 50\ \text{m/s};$	$k_p = 1.0\ q_u = 1.50\ \text{kPa}$
Cyclonic	Wind Level C2	$V_{h,u\ 500\ (3,6.5)} = 61\ \text{m/s};$	$k_p = 1.0\ q_u = 2.23\ \text{kPa}$
Cyclonic	Wind Level C3	$V_{h,u\ 500\ (3,6.5)} = 74\ \text{m/s};$	$k_p = 1.0\ q_u = 3.29\ \text{kPa}$
Cyclonic	Wind Level C4	$V_{h,u\ 500\ (3,6.5)} = 86\ \text{m/s};$	$k_p = 1.0\ q_u = 4.44\ \text{kPa}$

### For Annual Probability of Exceedance 1 in 250

If the design life of a structure such as a village house or similar is (say) 25 years, a Basic Wind Speed with an Annual Probability of Exceedance of (say) 1 : 250 (10% in 25 years) may be more appropriate than the published Basic Wind Speeds with an Annual Probability of Exceedance of 1 in 500 (10% in 50 years).

To convert from 1 in 500 to 1 in 250, the published 1 in 500 wind speeds must be multiplied by a factor of  $k_p$  in accordance with AS/NZS 1170.2.

Further to the above general comment, the “Policy for Small Buildings where Building Regulations are Not Enforced” in this Manual applies only to small detached village buildings (such as houses and small community buildings).

It is further limited to single storey buildings, with:

- (a) cladding on elevated braced timber frame; or
- (b) reinforced concrete masonry buildings built on concrete slab-on-ground.

The maximum dimensions of such buildings shall not exceed 16.5 x 8.4 m, 2.7 m storey height, maximum eaves height 6.0 m, maximum ridge height 8.5 m, and maximum pitch 35°.

The corresponding basic wind pressures, extrapolated from AS 4055 for 1 : 250 (used for other countries) are:

Non-cyclonic	Wind Level N1	$V_{h,u 500 (3,6.5)} = 34 \text{ m/s}$ ;	$k_p = 0.90$	$q_u = 0.62 \text{ kPa}$
Non-cyclonic	Wind Level N2	$V_{h,u 500 (3,6.5)} = 40 \text{ m/s}$ ;	$k_p = 0.90$	$q_u = 0.86 \text{ kPa}$
Non-cyclonic	Wind Level N3	$V_{h,u 500 (3,6.5)} = 50 \text{ m/s}$ ;	$k_p = 0.90$	$q_u = 1.35 \text{ kPa}$
Non-cyclonic	Wind Level N4	$V_{h,u 500 (3,6.5)} = 61 \text{ m/s}$ ;	$k_p = 0.90$	$q_u = 2.01 \text{ kPa}$
Non-cyclonic	Wind Level N5	$V_{h,u 500 (3,6.5)} = 74 \text{ m/s}$ ;	$k_p = 0.90$	$q_u = 2.96 \text{ kPa}$
Non-cyclonic	Wind Level N6	$V_{h,u 500 (3,6.5)} = 86 \text{ m/s}$ ;	$k_p = 0.90$	$q_u = 3.99 \text{ kPa}$
Cyclonic	Wind Level C1	$V_{h,u 500 (3,6.5)} = 50 \text{ m/s}$ ;	$k_p = 0.88$	$q_u = 1.32 \text{ kPa}$
Cyclonic	Wind Level C2	$V_{h,u 500 (3,6.5)} = 61 \text{ m/s}$ ;	$k_p = 0.88$	$q_u = 1.96 \text{ kPa}$
Cyclonic	Wind Level C3	$V_{h,u 500 (3,6.5)} = 74 \text{ m/s}$ ;	$k_p = 0.88$	$q_u = 2.89 \text{ kPa}$
Cyclonic	Wind Level C4	$V_{h,u 500 (3,6.5)} = 86 \text{ m/s}$ ;	$k_p = 0.88$	$q_u = 3.91 \text{ kPa}$

Some national building codes call up AS 1170.2:1989, which was in place at the time that the regulations were drafted. They also refer to the permissible stress method of design.

However, this “Policy for Small Buildings where Building Regulations are Not Enforced” provides ultimate limit state loads, based on the following assumptions:

- Analysis shall be consistent with AS 4055, except as follows.
- Basic wind speeds shall be determined from the relevant Building Regulations or, if appropriate, HB 212 factored to achieve a Probability of Exceedance of 1 : 500 or 1 : 250 as appropriate.
- Terrain category, shielding and topography should be assessed for each particular site. Default values, accounting for the location, basic wind speed, most common terrain, typical topography and partial shielding, are provided in Part 3 of this Manual to give guidance.
- AS/NSZ 1170.2 and HB212 require the calculated value of  $V_R$  to be rounded to the nearest 1 m/s.

- HB 212 states, “The basic wind speed,  $V_R$ , ... is 3 s gust at 10 m height in flat open country terrain.
- The Terrain/Height Multiplier,  $M_{z,cat}$ , for a height of 8 m and Terrain Category 2 is 0.985.
- Calculation of Pressures
- Pressure calculation is as follows:
- $p = k_p (0.5 \rho_{air}) [V_h]^2 C_p$

Where

$p$  = Design wind pressure acting normal to a surface (Pascals)

Pressures are taken as positive, indicating pressures above ambient and negative, indicating pressures below ambient.

$k_p$  = Probability factor (to account for changed Probability of Exceedance)

$\rho_{air}$  = Density of air, taken as  $1.2 \text{ kg/m}^3$

$V_h$  = Design 3 second gust wind speed

$C_p$  = Pressure coefficient (External, internal or net, as appropriate)

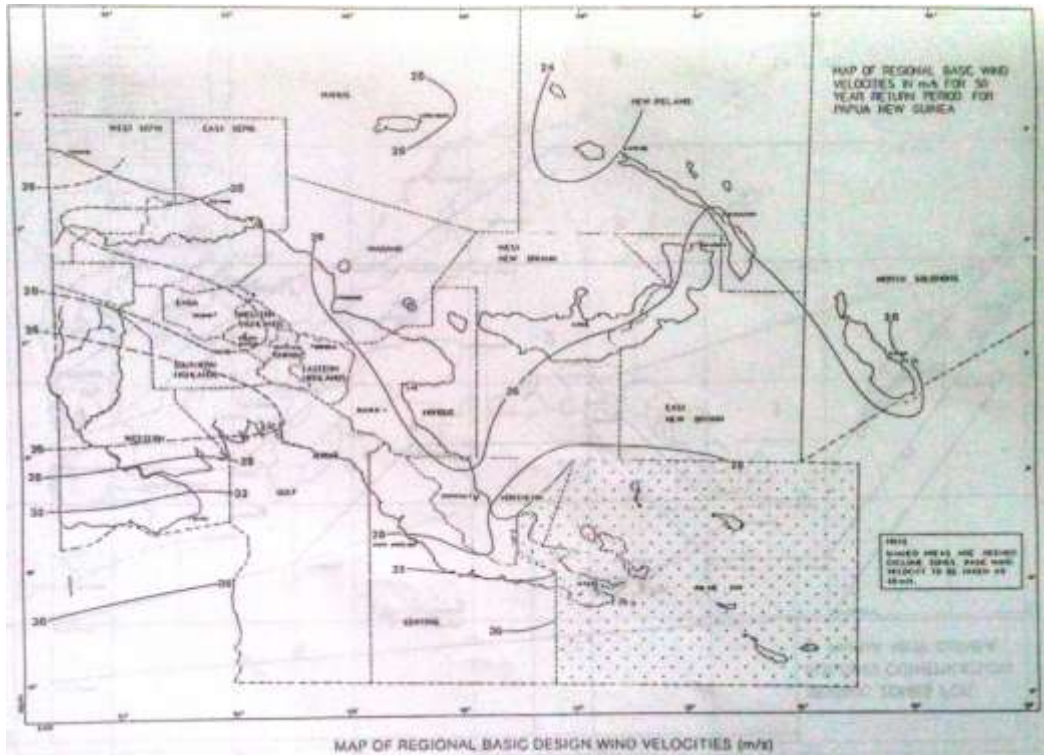
### Basic Wind Speeds for Australia

The Australian National Construction Code BCA Volume Two refers to AS/NZS 1170.2:2011(Including Amendments 1 and 2) and to AS 4055:2012.

### Basic Wind Speeds for New Zealand

The New Zealand building regulations refer to AS/NZS 1170.2:2011(Including Amendments 1 and 2).

### Basic Wind Speeds for Papua New Guinea



Reference: Papua New Guinea Building Regulation 1994

### Basic Wind Speeds for Solomon Islands

As an interim measure, assume values similar to Fiji #

### Basic Wind Speeds for Vanuatu

As an interim measure, assume values similar to Fiji #

## Basic Wind Speeds for Fiji

The Fiji Building Code 1990 states:

### *B1.2 Loads*

*The loading requirements of B1.1 are satisfied if the building or structure can resist loads determined in accordance with the following:*

*(a) Wind loads: AS 1170 – Minimum design loads on structures (known as SAA Loading Code) Part 2 – Wind loads*

*When using Part 2 of the Standard the following provisions apply: a limit state basic wind speed of 70 m/s to all areas. The equivalent basic wind speed for permissible stress methods of design is 57 m/s. When the simplified procedure of AS 1170 part 2 is followed, the value of the factor B, to be applied is 2.3. The map of Australia at Figure 2.5.1 and 3.2.2 in the Standard are to be disregarded.*

Discussion:

In this Manual, design for win actions is in according to the limit state method set out in AS/NZS 1170.2, with a regional wind speed of 70 m/s.

## Basic Wind Speeds for Tonga

The Tonga National Building Code 2007 states:

### *B1.2 Loads*

*The loading requirements of B1.1 are satisfied if the building or structure can resist loads determined in accordance with the following:*

*(a) Wind loads: AS/NZS 1170.2 – Structural design actions – Wind actions.*

*When using this Part of the Standard the following provisions apply: A limit state regional wind speed of 70 m/s to all islands of the Kingdom. The equivalent regional wind speed for permissible stress methods of design is 57 m/s. All maps of Australia and New Zealand in the Standard are to be disregarded.*

Discussion:

In this Manual, design for win actions is in according to the limit state method set out in AS/NZS 1170.2, with a regional wind speed of 70 m/s.

## Basic Wind Speeds for Other South Pacific Countries

Discussion:

In this Manual, design for win actions is in according to the limit state method set out in AS/NZS 1170.2, with a regional wind speeds determined in accordance with Standards Australia Handbook HB212. Refer to individual country calculations.

## Notes on Earthquake Loads

### Earthquake Hazard Factors for Australia

The Australian National Construction Code BCA Volume Two refers to AS 1170.4:2018. The design of houses and minor buildings (Importance 2) in Australia shall be based on earthquake loads with a Probability of Exceedance of 1 : 500.

Peak Ground Acceleration, adjusted for Probability of Exceedance		
$k_p z$ (Where $k_p = 1.0$ )		
Country	Location	Probability of Exceedance
		1 : 500
Australia	As per AS 1170.4 Table 3.2 and Fig 3.2	
	Mekering region (Ranges from 0.14 to 0.22)	0.22
	Tennant Creek	0.13
	Newcastle, Bundaberg	0.11
	Adelaide, Wyong	0.10
	Darwin, Geraldton, Gladstone, Wyndham, Wollongong, Whyalla	0.09
	All other locations	0.08

## Earthquake Hazard Factors for New Zealand

The New Zealand building regulations refer to NZS 1170.5:2004. The design of houses and minor buildings (Importance 2) in New Zealand shall be based on earthquake loads with a Probability of Exceedance of 1 : 500.

Peak Ground Acceleration, adjusted for Probability of Exceedance		
$k_p z$ (Where $k_p = 1.0$ )		
Country	Location	Probability of Exceedance
		1 : 500
New Zealand	As per NZS 1170.5 Table 3.3 and Figs 3.3, 3.4, 3.5	
	Auckland, Dunedin, Palmerston	0.13
	Hamilton, Akaroa	0.16
	Christchurch	0.22
	Wellington, Seddon, Hutt Valley, Ward, Cheviot, Otaki	0.40
	Otira, Arthurs Pass (maximum value)	0.60

Discussion:

NZS 1170.5 - Commentary

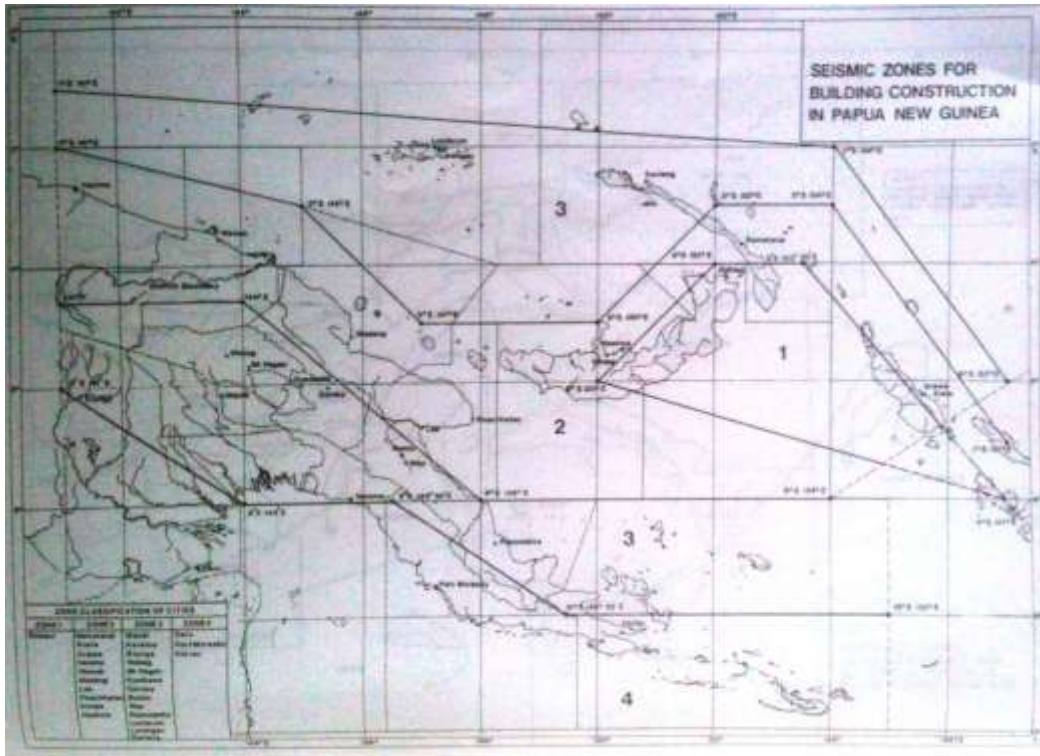
C3.1.4 Hazard factor

*The hazard factor Z has been derived as 0.5 times the magnitude-weighted (Idriss, Ref. 14) 5% damped response spectrum acceleration for 0.5 s period for site class C (shallow soil) that has a return period of 500 years. It corresponds to the value in g of the peak ground acceleration (corresponding to 0.0 s period) for site classes A and B (rock) for R = 1. The range of Z has been limited by a lower bound of 0.13. The Z-values have been spatially smoothed over a distance of 10 from the values resulting directly from the hazard analysis. The selection of the period of 0.5 s to normalize the hazard spectra is a change from New Zealand Standard NZS 4203, which used 0.2 s. The unusual selection of the mid-period value of 0.5 s for the normalization provided sufficiently small variations over the country between the code spectra and the 500-year magnitude-weighted spectra of the hazard study to allow spectra to be defined from the values at only one normalization period, rather than two as in recent U.S. codes (UBC, 1997, Ref. 16, NEHRP, 2000, Ref. 13, and IBC, 2000, Ref. 15)*

## Earthquake Hazard Factors for Papua New Guinea

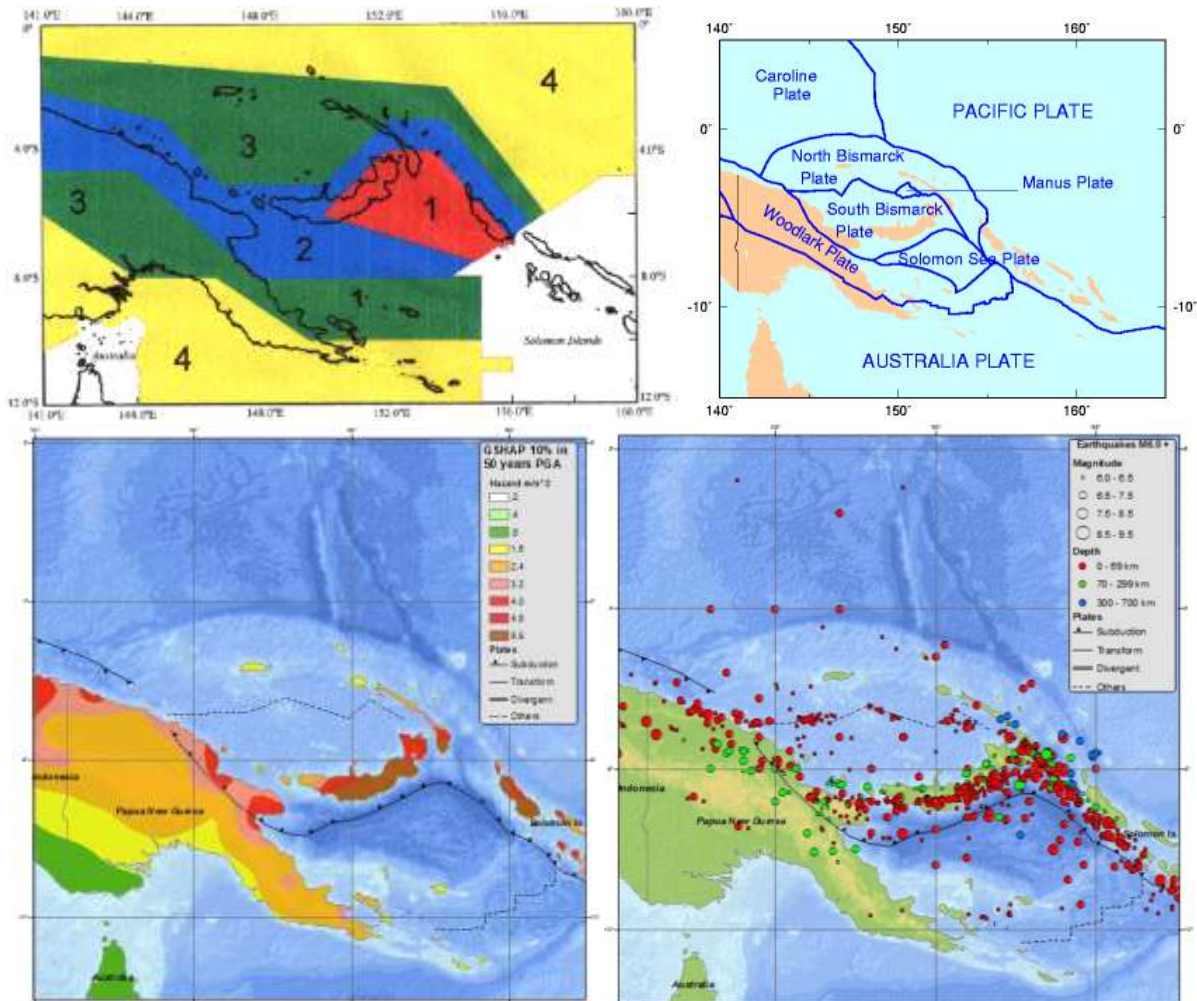
The Papua New Guinea Building Code has the following earthquake design requirements for an Annual Probability of Exceedance of 1 : 500.

Peak Ground Acceleration, adjusted for Probability of Exceedance			
$k_p z$			
Location		Probability of Exceedance	
		1 : 500	1 : 250
Papua New Guinea	Zone 1 (Extremely High Hazard) – Bougainville, Eastern and Central New Britain, Southern New Ireland (Includes Rabaul)	1.00	0.75
	Zone 2 (Moderately High Hazard) – Northern coast of the mainland, Western New Britain, Central New Ireland, Lihir Group (Includes Namatani, Kieta, Arawa, Vanimo, Wewak, Madang, Lae, Finchhafen, Kimbe, Hoskins)	0.40	0.30
	Zone 3 (Moderate Hazard) – Central region of the mainland, Northern Province, D'Entrecasteaux and Trobriand Islands, Northern New Ireland and Admiralty Islands (Includes Mendi, Kerema, Klunga, Wabag, Mt Hagen, Kundiawa, Goroko, Bulolo, Wau, Popondetta, Lombrum, Lorengau, Kayieng)	0.24	0.18
	Zone 4 (Very Low Hazard) – Papuan Peninsula - Louisiade Archipelago and St. Mathias Group (Includes Daru, Port Moresby, Alotau)	0.16	0.12
<p><b>Note:</b></p> <p>1. If the design life of a structure such as a village house or similar is (say) 25 years, a Hazard Factor (Z) corresponding to Peak Ground Acceleration with an Annual Probability of Exceedance of (say) 1 : 250 (10% in 25 years) may be more appropriate than the published Hazard Factors (Z) for Peak Ground Acceleration with an Annual Probability of Exceedance of 1 in 500 (10% in 50 years). To convert from 1 in 500 to 1 in 250, the published 1 in 500 hazard factors must be multiplied by a factor of <math>k_p = 0.75</math> in accordance with AS/NZS 1170.4 Table 3.1.</p>			



Discussion:

The following maps provide context to the PNG Building Code. It is important to note that these maps and the Code requirements predate the 2018 Southern Highlands earthquake of magnitude 7.5.



**Generalised Seismic Hazard Zones of PNG** - (Modified from the PNG National Standards Council, 1983)

Zone 1 (Extremely High Hazard) – Bougainville, Eastern and Central New Britain, Southern New Ireland

Zone 2 (Moderately High Hazard) – Northern coast of the mainland, Western New Britain, Central New Ireland, Lihir Group

Zone 3 (Moderate Hazard) – Central region of the mainland, Northern Province, D’Entrecasteaux and Trobriand Islands, Northern New Ireland and Admiralty Islands

Zone 4 (Very Low Hazard) – Papuan Peninsula - Louisiade Archipelago and St. Mathias Group Hazard map of PNG

References: Geosciences Australia; Anton, L., “Earthquake and Tsunami Hazard Mitigation in Papua New Guinea”; Geological Survey of Papua New Guinea; Papua New Guinea Building Regulation 1994

## Earthquake Hazard Factors for Solomon Islands

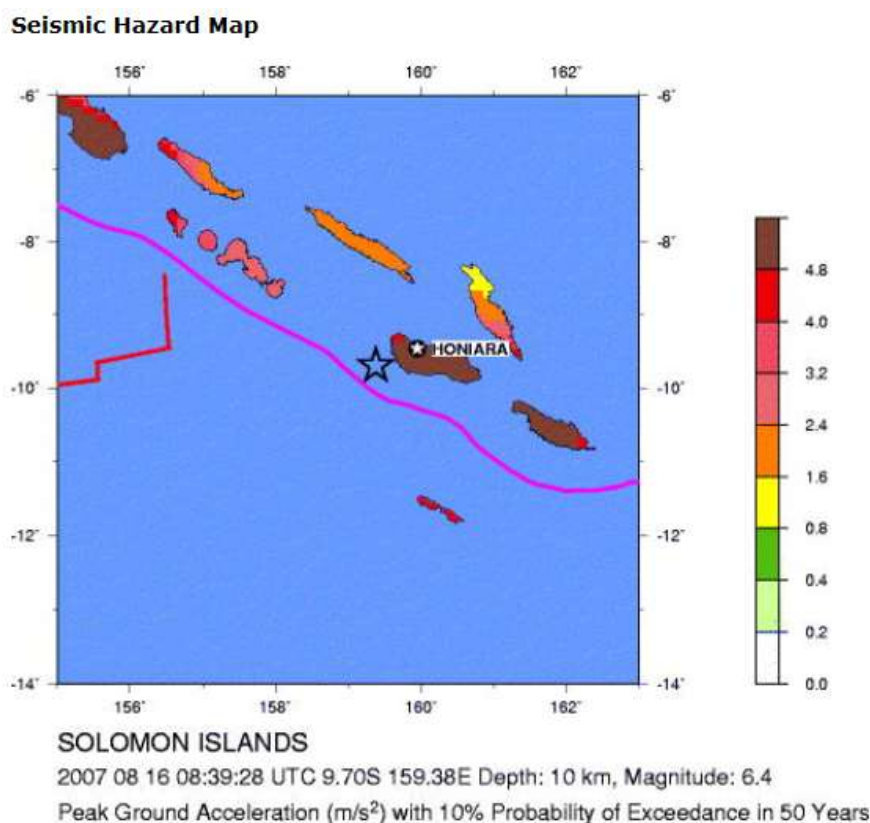
Peak Ground Acceleration, adjusted for Probability of Exceedance			
$k_p z$			
Country	Location	Probability of Exceedance	
		1 : 500	1 : 250
Solomon Islands	Eastern Province	0.80	0.60
	Guadalcanal	0.60	0.45
	Rest of Solomon Islands	0.50	0.37

Notes

1. The values given in this table are for buildings of Importance 1 and 2 only, and are estimates from various sources and maps provided in this Manual, together with the approach taken for Fiji, Tonga and Papua New Guinea.
2. The values for all countries should be checked against the requirements of local building regulations.
3. If the design life of a structure such as a village house or similar is (say) 25 years, a Hazard Factor (Z) corresponding to Peak Ground Acceleration with an Annual Probability of Exceedance of (say) 1 : 250 (10% in 25 years) may be more appropriate than the published Hazard Factors (Z) for Peak Ground Acceleration with an Annual Probability of Exceedance of 1 in 500 (10% in 50 years). To convert from 1 in 500 to 1 in 250, the published 1 in 500 hazard factors must be multiplied by a factor of  $k_p = 0.75$  in accordance with AS/NZS 1170.4 Table 3.1.

### Discussion

The following maps provide context.



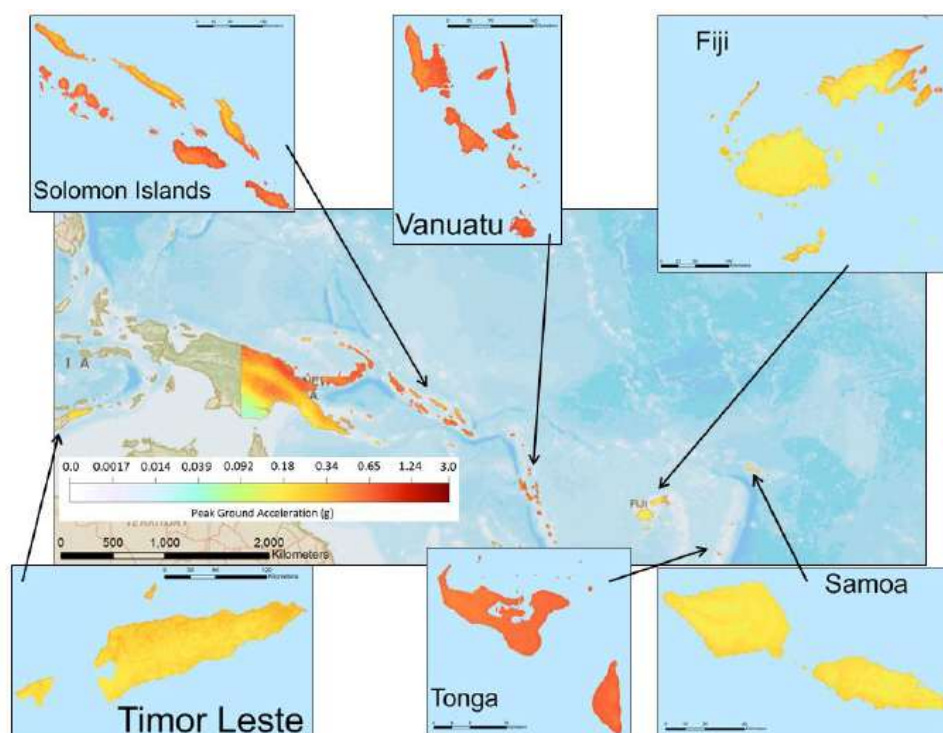
Reference: [http://neic.usgs.gov/neis/eq\\_depot/2007/eq\\_070816\\_gccj/neic\\_gccj\\_w.html](http://neic.usgs.gov/neis/eq_depot/2007/eq_070816_gccj/neic_gccj_w.html)

## Earthquake Hazard Factors for Vanuatu

Peak Ground Acceleration, adjusted for Probability of Exceedance			
$k_p z$			
Location		Probability of Exceedance	
		1 : 500	1 : 250
Vanuatu		0.60	0.45
<p>Notes</p> <ol style="list-style-type: none"> <li>1. The values given in this table are for buildings of Importance 1 and 2 only, and are estimates from various sources and maps provided in this Manual, together with the approach taken for Fiji, Tonga and Papua New Guinea.</li> <li>2. The values for all countries should be checked against the requirements of local building regulations.</li> <li>3. If the design life of a structure such as a village house or similar is (say) 25 years, a Hazard Factor (Z) corresponding to Peak Ground Acceleration with an Annual Probability of Exceedance of (say) 1 : 250 (10% in 25 years) may be more appropriate than the published Hazard Factors (Z) for Peak Ground Acceleration with an Annual Probability of Exceedance of 1 in 500 (10% in 50 years). To convert from 1 in 500 to 1 in 250, the published 1 in 500 hazard factors must be multiplied by a factor of <math>k_p = 0.75</math> in accordance with AS/NZS 1170.4 Table 3.1.</li> </ol>			

### Discussion

The following maps provide context.



**Figure 9.** Map of free surface PGA, including site conditions, with 10% probability of exceedance in 50 years (475-year mean return period) for some of the Pacific Island Countries.

Y. Rong, Y. Park, J. Duggan, D. Mahdyiar, M and Bazzurro, P., *Probabilistic Seismic Hazard Assessment for Pacific Island Countries* 15 WCEE Lisboa, 2012

<http://earthquake.usgs.gov/earthquakes/world/png/gshap.php>

## Earthquake Hazard Factors for Fiji

The Fiji National Building Code -1990 Part B1.2 (b) has the following requirements:

*Dead, Live and earthquake loads: NZS4203 Part 1, 2 and 3 General structural design and design loadings for buildings. The maps of New Zealand shown in the Standard are to be disregarded. The earthquake zones for Fiji are marked in Figure B1.2. For use with NSZ 4203 the zone factors corresponding to the zone numbers given in the figure are:*

ZONE NO.	ZONE FACTOR
4	0.4
6	0.6
7	0.7

*Each zone factor applies uniformly over the whole area of the zone.*

*Note: The zone numbers have been given on the basis of consistent values for Fiji, Vanuatu, Solomon Islands, Cook Islands, Tuvalu and Niue. This means that any particular zone number such as zone 6 and the value of its zone factor, have the same meaning in the codes of all these countries.*



National Building Code -1990 Figure B1.2

Peak Ground Acceleration, adjusted for Probability of Exceedance			
$k_p z$			
Country	Location	Probability of Exceedance	
		1 : 500	1 : 250
Fiji	Refer to Fiji Building Code Map.		
	High Risk - East Vanua Levu, south-western islands	0.70	0.53
	Medium Risk – East & central Viti Levu, north-eastern islands	0.60	0.45
	North-western Viti Levu and south-western Vanua Levu	0.40	0.30
Notes:			
The values for an Annual Probability of Exceedance of 1 in 250 are calculated using AS 1170.4:2007			
The following alternative values have been suggested for Fiji:			
West Vanua Levu		1:500 - 0.60,	1:250 - 0.45
Central and east Vanua Levu and north-eastern islands		1:500 - 0.40,	1:250 - 0.30
Viti Levu and south-eastern islands		1:500 - 0.24,	1:250 - 0.18

Discussion:

Based on the GNS Science Hazard Map and extracts below, it is suggested that the more recent seismic hazard map, published by GNS Science, may be more appropriate in lieu of the preliminary hazard map in the current Fiji Building Code.

The following extract forms the basis of this observation.

Stirling, M.W. , Horspool, N.A., & Gerstenberger, M.C. *Recent Seismic Hazard Studies in SE Asia, Pacific, and USA* , 2015 NZSEE Conference

GNS Science, Lower Hutt, New Zealand P.H. Nguyen Institute of Geophysics, Hanoi, Vietnam

**2 FIJI Z-FACTOR** We have developed a probabilistic seismic hazard (PSH) model for Fiji (Stirling et al.2014), and produced a map of the hazard factor Z (Fig. 1) according to the NZS1170.5 definition of the Z-factor (Standards New Zealand, 2004). The NZS1170.5 Z-factor is defined as half the 0.5 second spectral acceleration ( $0.5 * SA(0.5s)$ ) expected with a 10% probability of exceedance in 50 years (equivalent to a 500 year return period) on shallow soil sites. The use of a Next Generation Attenuation (NGA) model for Fiji has required the Class C site conditions to be approximated by an average shear-wave velocity to 30m depth ( $V_{s30}$ ) of 450m/s. The PSH model is based on a gridded seismicity model that is developed from the 1960-2009 component of the International Seismicity Catalogue of the Global Earthquake Model (ISC-GEM; [globalquakemodel.org](http://globalquakemodel.org)). Prior to developing the Z-factor map we briefly evaluated the suitability of the NZS1170.5 code spectral shape for Fiji by comparing the unsmoothed 500 year Class C spectrum for the city of Suva to the NZS1170.5 spectrum, and also to the Australian AS1170.4 and International Building Code (IBC) spectra (Fig. 2). These code spectra have different spectral shapes and, in the case of IBC, alternative hazard parameters for their construction. We found that neither AS1170.4 or IBC code spectra provide a better match to the unsmoothed spectrum than the NZS1170.5 spectrum (Fig. 2), so the NZS1170.5-based Z-factor definition has been used to construct the Z-factor map and associated spectra. The Z-factor map shows hazard that is lowest in the southeast of Fiji, and progressively increasing to the north and northwest (Fig. 1).

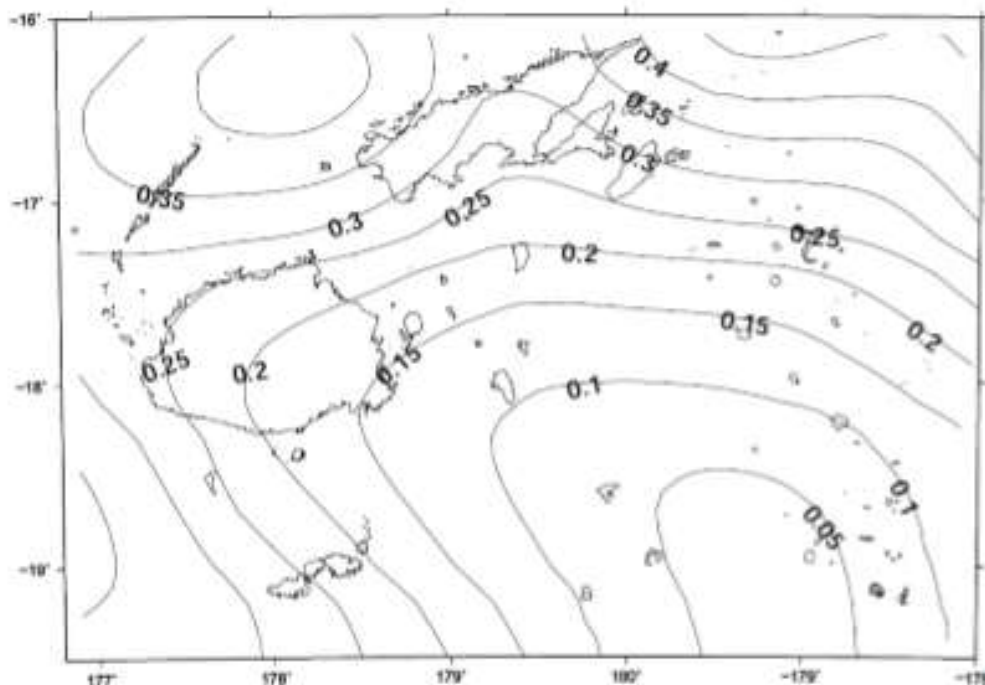


Figure 1. Z-factor map for Fiji. Accelerations are in units of g. See the text for further explanation.

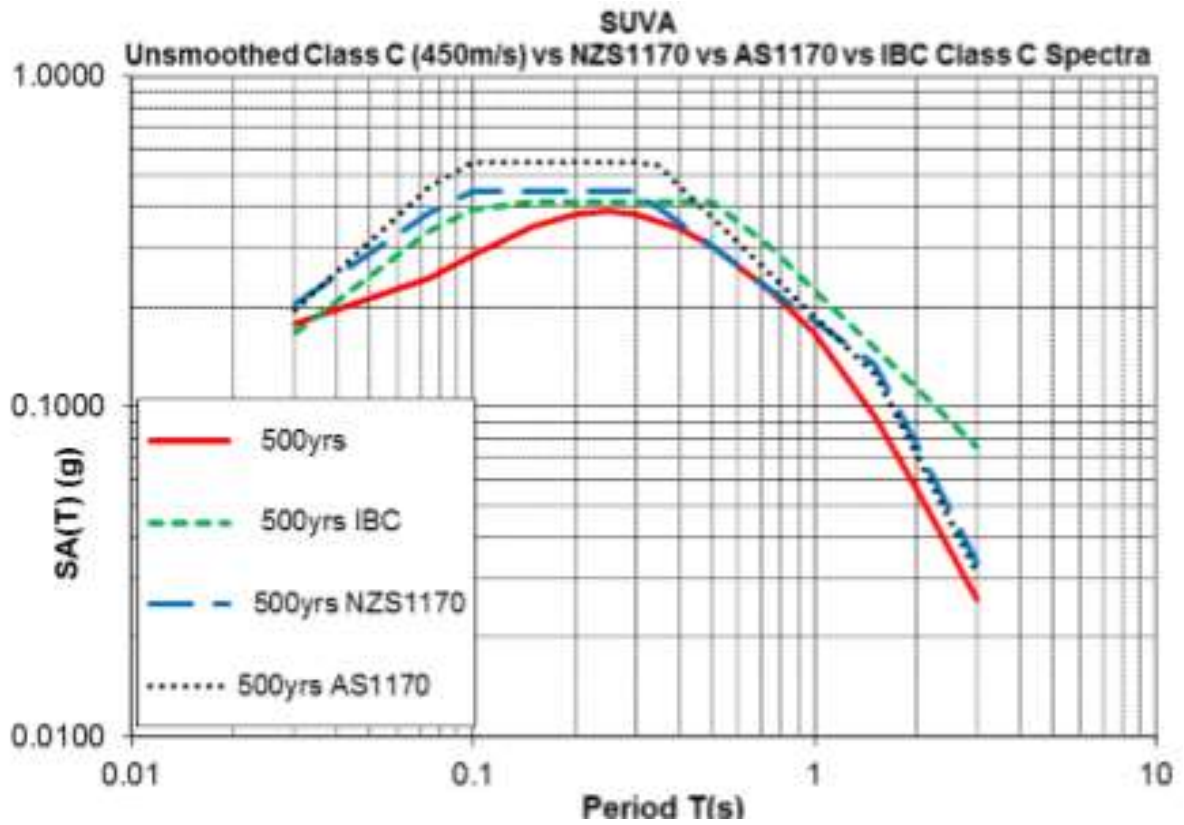


Figure 2. Unsmoothed horizontal Class C spectrum for the 500 year return period for Suva, with modified NZS1170.5, AS1170.4, and IBC code spectra shown for comparison. Note that  $SA(0.0s)$  is plotted at 0.03s as the plot is log-log.

## Earthquake Hazard Factors for Tonga

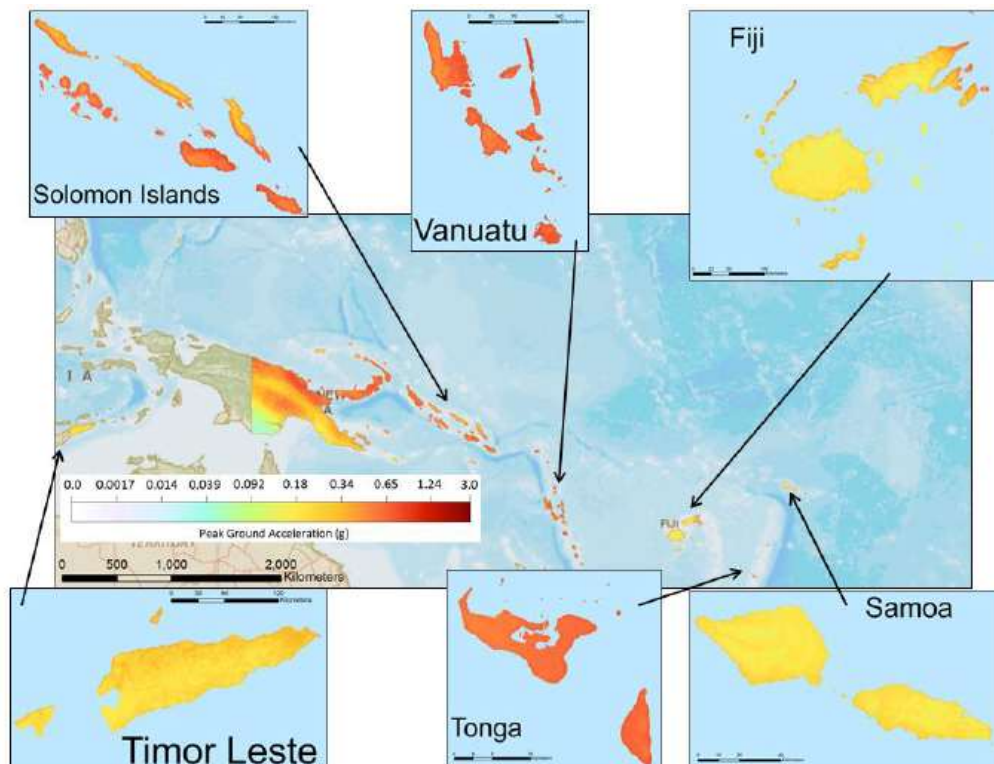
The Tonga National Building Code 2007 states:

*The seismic provisions of the California Building Code – 1998. Ignore all other provisions of the Code. The seismic zone factor Z is 0.4 (same as for San Francisco).*

*As an alternative, AS 1170.4 – 1993 – Minimum design loads on structures – Earthquake loads, may be used using an “a” value of 0.4 (equivalent to California Building Code Z = 0.4)*

Discussion:

Based on the maps below, one would expect the ground acceleration with a 10% probability of exceedance in 50 years (Z), to be of the order of 0.8. However the Tonga National Building Code 2007 requires design to be based on Z = 0.4, inferring an acceptance of risk higher than 10% in 50 years.



**Figure 9.** Map of free surface PGA, including site conditions, with 10% probability of exceedance in 50 years (475-year mean return period) for some of the Pacific Island Countries.

Y. Rong, Y. Park, J. Duggan, D. Mahdyiar, M and Bazzurro, P., *Probabilistic Seismic Hazard Assessment for Pacific Island Countries* 15 WCEE Lisboa, 2012

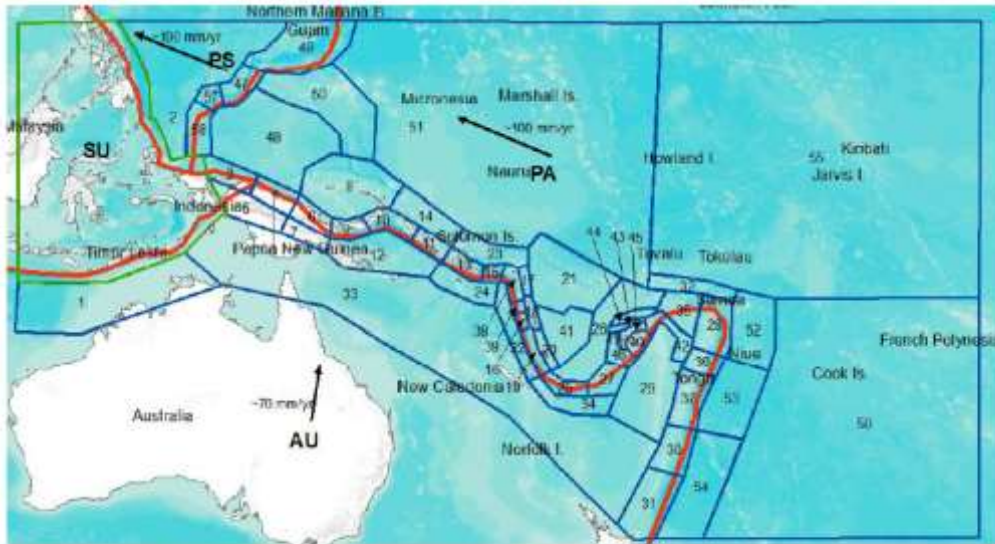
<http://earthquake.usgs.gov/earthquakes/world/png/gshap.php>

## Earthquake Hazard Factors for Other South Pacific Countries

Peak Ground Acceleration, adjusted for Probability of Exceedance			
$k_p z$			
Country	Location	Probability of Exceedance	
		1 : 500	1 : 250
Cook Islands		0.10	0.075
French Polynesia		0.10	0.075
Kiribati		0.10	0.075
Nauru		0.10	0.075
New Caledonia	North-eastern islands	0.40	0.30
	Main island	0.16	0.12
Niue		0.10	0.075
Samoa		0.16	0.12
American Samoa		0.24	0.18
Tuvalu		0.10	0.075
Wallis and Futuna	Wallis	0.60	0.45
	Futuna	0.20	0.15
<p>Notes</p> <ol style="list-style-type: none"> <li>The values given in this table are for buildings of Importance 1 and 2 only, and are estimates from various sources and maps provided in this Manual, together with the approach taken for Fiji, Tonga and Papua New Guinea.</li> <li>The values for all countries should be checked against the requirements of local building regulations.</li> <li>For islands that are at least 200 km from the plate boundaries, and for which there is little data available. As an interim measure, a default value of 0.08 is assumed for the Peak Ground Acceleration for Probability of Exceedance or 1 : 500. These values are shown in red.</li> <li>If the design life of a structure such as a village house or similar is (say) 25 years, a Hazard Factor (Z) corresponding to Peak Ground Acceleration with an Annual Probability of Exceedance of (say) 1 : 250 (10% in 25 years) may be more appropriate than the published Hazard Factors (Z) for Peak Ground Acceleration with an Annual Probability of Exceedance of 1 in 500 (10% in 50 years). To convert from 1 in 500 to 1 in 250, the published 1 in 500 hazard factors must be multiplied by a factor of <math>k_p = 0.75</math> in accordance with AS/NZS 1170.4 Table 3.1.</li> </ol>			

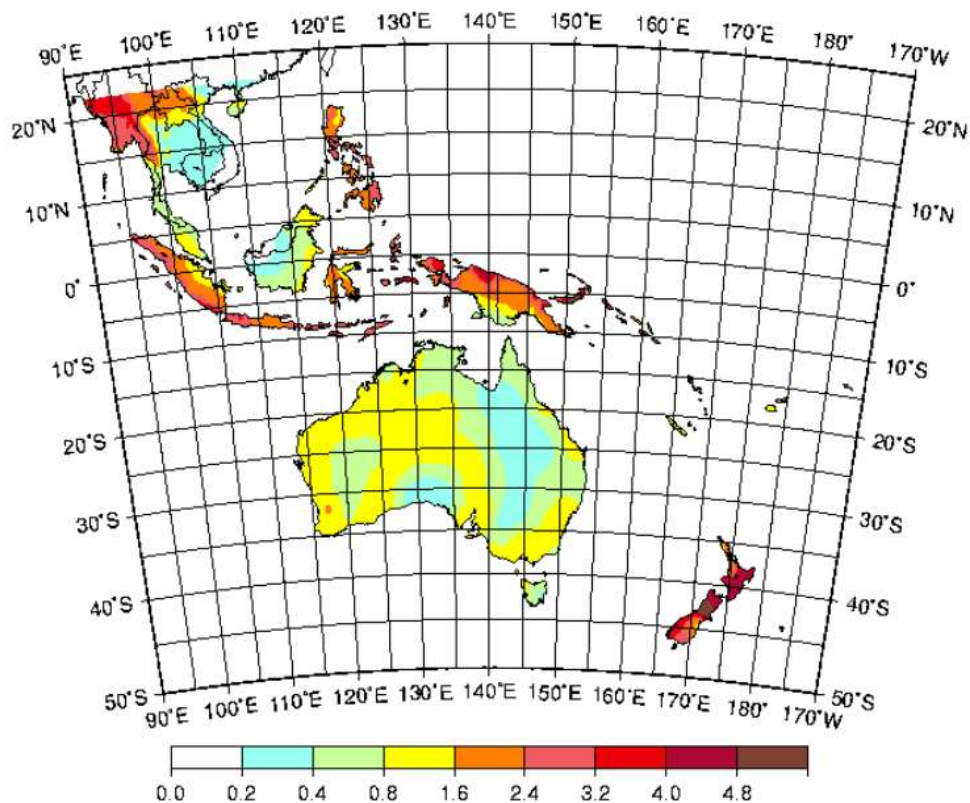
This policy provides ultimate limit state loads, based on the following assumptions:

- Analysis shall be consistent with AS 1170.4, except as follows.
- Hazard factors shall be determined from the relevant Building Regulations or, if appropriate estimated from published data, some of which is shown below.
- The values shown in the maps below correspond to the Peak Ground Acceleration with a Probability of Exceedance of 10% in 50 years (i.e. 1 : 500).



**Figure 1.** Regional tectonic setting and seismic source zones in the South Pacific region. Thick red lines indicate the major plate boundaries between the four major plates: Pacific (PA), Philippine Sea (PS), Sunda (SU), and Australia (AU) plates. Thick black arrows illustrate the movement of the PA, PS, and AU plates relative to the SU plate (Bird, 2003). The source zones are illustrated by blue polygons, and the numbers are the zone IDs. The area in the green polygon was covered by the AIR Southeast Asia earthquake model.

Reference: Y. Rong, Y. Park, J. Duggan, D. Mahdyar, M and Bazzurro, P., *Probabilistic Seismic Hazard Assessment for Pacific Island Countries* 15 WCEE Lisboa, 2012

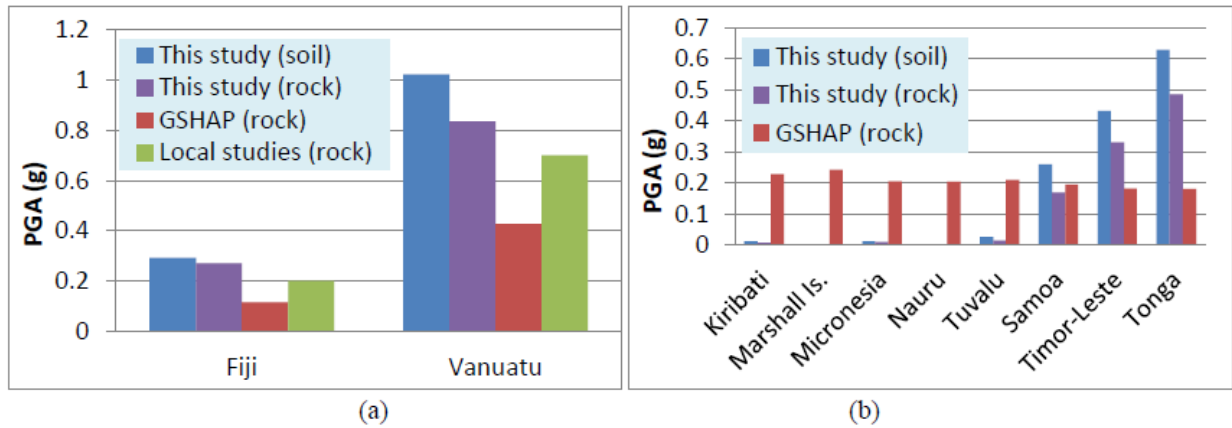


Peak Ground Acceleration with a Probability of Exceedance of 10% in 50 years (i.e. 1 : 500)

References:

McCue, K., "Seismic hazard mapping in Australia, the South-west Pacific and South-east Asia" Global Seismic Hazard Assessment Program, Geoscience Australia

<http://www.seismo.ethz.ch/static/GSHAP/swpacific/swpac.gif>



**Figure 10.** Expected PGA (g), with a 10% probability of exceedance in 50 years (475-year mean return period), at the capitals of some of the PICs. The blue and purple bars are PGA values from this study with and without site conditions accounted for, respectively. The red bars are PGA values by GSHAP. The green bars in (a) are the results of local studies (Jones 1998 for Fiji; Suckale and Grünthal 2009 for Vanuatu).

Y. Rong, Y. Park, J. Duggan, D. Mahdyiar, M and Bazzurro, P., *Probabilistic Seismic Hazard Assessment for Pacific Island Countries* 15 WCEE Lisboa, 2012

<http://earthquake.usgs.gov/earthquakes/world/png/gshap.php>

## 6. DISCUSSION

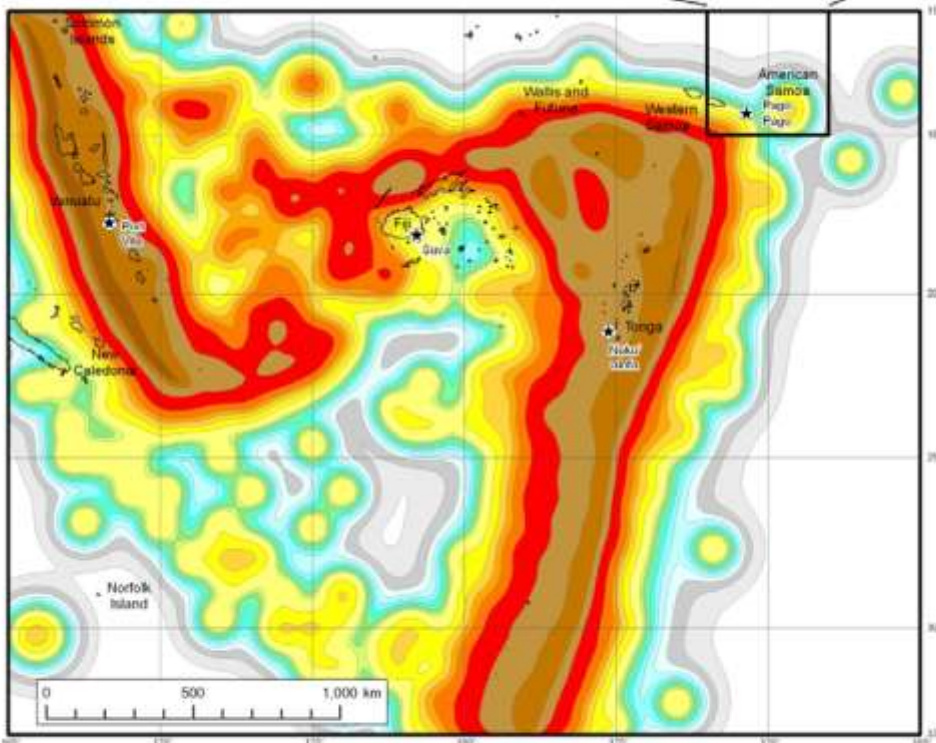
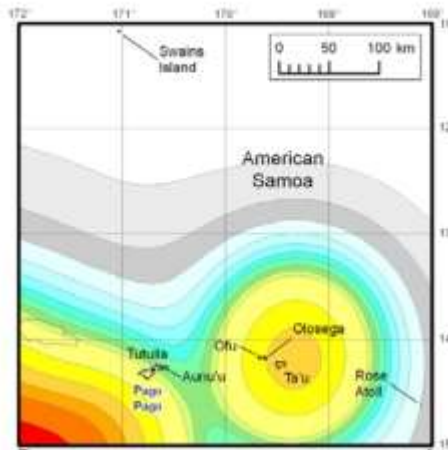
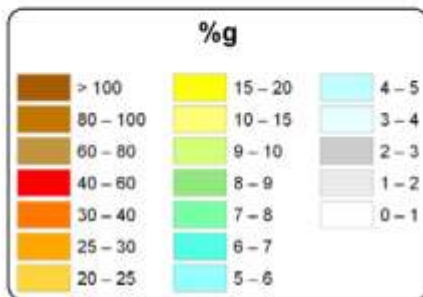
Figure 10 compares the hazard results from this study and the corresponding results from earlier studies. It shows that:

- In general, our estimates of the 475-year mean return period rock PGA values are closer to the results from the detailed local studies than to those from the GSHAP study.
- Historical seismicity in the neighborhood of the PICs does not explain the very similar 475-year rock PGA estimates for Kiribati, Marshall Islands, Micronesia, Nauru, Tuvalu, Samoa, Timor-Leste, and Tonga in the GSHAP study (Figure 10b) because: (1) Tonga is on the seismically active Tonga subduction zone, while Tuvalu, Kiribati, Marshall Islands, and Nauru are not only far from the regional subduction zones but are also located in seismically inactive areas; (2) Samoa is located at about 130 km north of the northern tip of the Tonga subduction zone; and (3) Timor-Leste is in the middle of the seismically active Timor and Banda Sea trenches. The relative difference in the seismic hazard is correctly reflected in the PGA estimates from this study.
- It is important to account for site conditions in seismic hazard analysis. Based on the results from this study, the hazard with site conditions considered is about 20-30% higher than the rock hazard at the capitals of Vanuatu, Tonga, Timor-Leste and Micronesia, about 50% higher at the capital of Samoa, and more than 80% higher at the capitals of Tuvalu and Kiribati.

The seismic hazard maps presented here have sufficient details to be used in local seismic risk studies and were developed using the current state of practice in probabilistic seismic hazard assessment. The large differences between this study and GSHAP can be attributed to the combined impact of differences in earthquake source models, GMPEs, site conditions, and the details of the hazard calculations.

## Seismic-Hazard Maps For American Samoa

Peak Horizontal Acceleration  
With 10% Probability of Exceedance in 50 Years



Reference: Petersen, M.D., Harmsen, S.C., Rukstales, K.S., Mueller, C.S., McNamara, D.E., Luco, Nicolas, and Walling, Melanie, 2012, Seismic hazard of American Samoa and Neighboring South Pacific Islands—Methods, data, parameters, and results: U.S. Geological Survey Open-File Report 2012–1087, 98 p.

## Notes on Tsunami Loads

Sites shall be analysed to determine whether they are prone to tsunamis, giving consideration to the following logic, extracted from the MS Excel workbook developed by Quasar for this purpose:

Distance from high water mark,  $T_{dhw}$  (km)

Height of finished floor above mean sea level,  $T_{ffi}$  (m)

Distance from high earthquake area ( $Z > 0.4$ ),  $T_{equ}$  (km)

Site specific exposure,  $T_{exp}$  (2 is maximum risk; 1 is normal risk, 0 is no risk)

Tsunami risk factor (10 is maximum risk; 0 is no risk)

$$R_t = IF(T_{dhw} > 2, 0, IF(T_{ffi} > 20, 0, IF(T_{equ} > 1000, 0, T_{exp} * 5 / (MAX(T_{dhw}, 0.2) * MAX(T_{ffi}, 1) * MAX(T_{equ} / 100, 5))))))$$

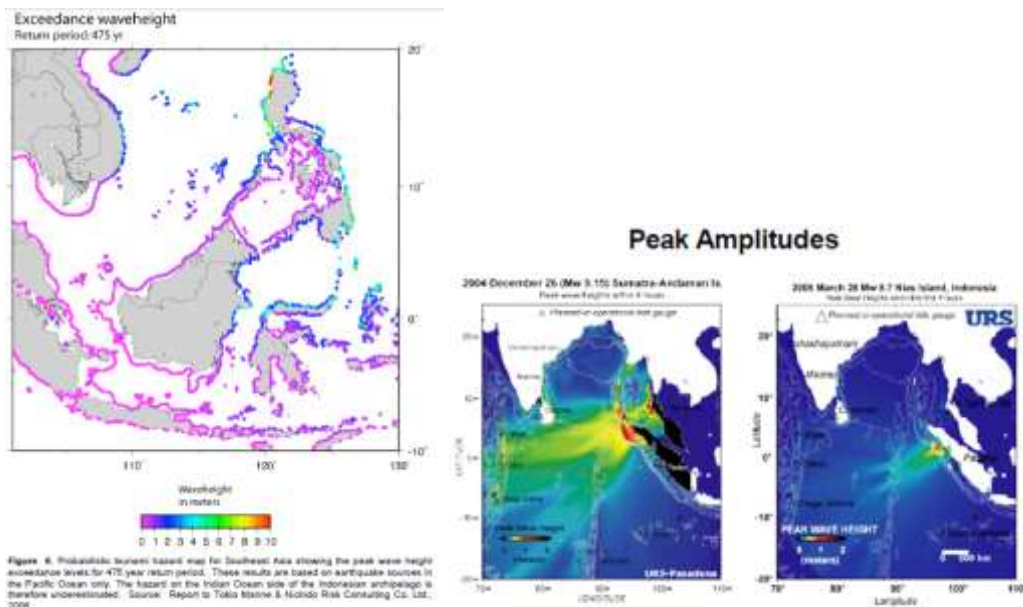
Design strategy

$$IF(R_t < 1, "No design required", IF(R_t < 5, "Design structure", "Move structure"))$$

For structures that are required to be designed for tsunami (except those that should be moved), analysis shall be in accordance with the method in Australian Building Codes Board Handbook, *Construction of Buildings in Flood Hazard Areas* for velocity equal to the maximum of the calculated risk factor (m/s) or 1.5 m/s.

Structural components shall be designed to withstand the design event, assuming that the cladding is destroyed. Remaining cladding and other water-borne material, of a combined area equal to 20% of the building elevation area facing the tsunami shall be assumed for determination of the tsunami forces. It is also assumed that the water flows at depth numerically equal to the risk factor (m).

The following map for South-east Asia tsunamis is included to give a typical indication for the wave heights for a Probability of Exceedance of 1 in 500. While this information is not transferrable to the South Pacific, it does give a feel for the possible magnitude of tsunamis.



## Notes on Flood Loads

Sites shall be analysed to determine whether they are prone to flooding, giving consideration to the following:

Distance to closest water course,  $F_{dwc}$  (m)

Height of finished floor above normal level of water course,  $F_{ffi}$  (m)

Catchment area,  $F_{cat}$  (km<sup>2</sup>)

Concentration of catchment runoff past structure,  $F_{con}$  (2 is maximum; 1 is normal, 0 is no risk)

Flooding risk factor (10 is maximum risk; 0 is no risk)

$R_f = IF(F_{dwc} > 200, 0, IF(F_{ffi} > 10, 0, IF(F_{cat} < 1, 0, F_{con} * MIN(F_{dwc}, 100) / (MAX(F_{dwc}, 10) * MAX(F_{ffi}, 2))))))$

Design strategy

$IF(R_f < 1, "No design required", IF(R_f < 5, "Design structure", "Move structure"))$

For structures that are required to be designed for flood (except those that should be moved), analysis shall be in accordance with the method in Australian Building Codes Board Handbook, *Construction of Buildings in Flood Hazard Areas* for a velocity equal to the maximum of the calculated risk factor (m/s) or 1.5 m/s.

Structural components shall be designed to withstand the design event, assuming that 100% of the cladding remains intact and the water flows at depth calculated from the topography.

## Notes on Soil Properties

For purposes of designing concrete slab-on-ground, concrete pad footings or concrete strip footings, sites shall be classified in accordance with AS 2870. Design of concrete slab-on-ground, concrete pad footings or concrete strip footings shall be in accordance with AS 2870. Determination of soil pressures and capacity reduction factors for earth retaining structures, or similar, shall in accordance with AS 4678. Design of earth retaining structures shall in accordance with AS 4678. AS 4768 Table D4 gives the following typical soil properties.

Soil Description	Characteristic Cohesion $c'$ kPa	Characteristic internal friction angle $\phi'$ (degrees)
Soft and firm clay of medium to high plasticity, silty clays, loose variable clayey fill, loose sandy silts	0 to 5	17 to 25
Stiff sandy clays, gravelly clays, compact clayey sands and sandy silts, compacted clay fill (Class II)	0 to 10	26 to 32
Gravelly sands, compacted sands, controlled crushed sandstone and gravel fills (Class I), dense well-graded sands	0 to 5	32 to 37
Weak weathered rock, controlled fills (Class I) of road base, gravel and recycled concrete	0 to 25	36 to 43
Notes: Characteristic values are conservative estimates of the mean.		

### Derivation of Characteristic Ultimate Bearing Capacity

Effective width of bearing pad,  $B'$

Terzaghi Factors

$$N_q = e^{\pi \tan \phi^* f} \tan^2 \left[ \pi/4 + \phi^* f / 2 \right]$$

$$N_c = (N_q - 1) \cot \phi^* f$$

$$N_\gamma = 2 (N_q + 1) \tan \phi^* f$$

Shape factors

$$\xi_c = 1.0$$

$$\xi_q = 1.0$$

$$\xi_\gamma = 1.0$$

Factors for inclined load

$$\xi_{qi} = \left[ 1 - P_H / (P_v + B' c^* f \cot \phi^* f) \right]^2$$

$$\xi_{ci} = \xi_{qi} - (1 - \xi_{qi}) / (N_c \tan \phi^* f)$$

$$\xi_{\gamma i} = \left[ 1 - P_H / (P_v + B' c \cot \phi^* f) \right]^3$$

Factors for sloping bases

$$\xi_{qt} = (1 - \alpha \tan \phi^* f)^2 = 1.0 \text{ for level base}$$

$$\xi_{ct} = \xi_{qt} - (1 - \xi_{qt}) / (N_c \tan \phi^* f) = 1.0 \text{ for level base}$$

$$\xi_{\gamma t} = (1 - \alpha \tan \phi^* f)^2 = 1.0 \text{ for level base}$$

Average bearing capacity based on factored soil properties

$$q_{av} = c N_c \xi_c \xi_{ci} \xi_{ct} + \gamma (H_{emb} + H_{bp}) N_q \xi_q \xi_{qi} \xi_{qt} + 0.5 \gamma B N_\gamma \xi_\gamma \xi_{\gamma i} \xi_{\gamma t}$$

Bearing capacity of the foundation

$$P_{v \text{ cap}} = q_{av} B'$$

Based on this information, the following properties are assumed for various soils classified in accordance with AS2870. The following assumptions have been used.

1. Characteristic internal friction angles and characteristic cohesions are conservative estimates of the mean values for the particular soil type, without capacity reduction factors.
2. Characteristic bearing capacities are determined using values for internal friction angle that have been factored in accordance with AS 4678 for in-situ soil.
3. Characteristic bearing capacities have been calculated by the Terzaghi method, for vertical concentric load on 450 mm wide strip footings buried not less than 300 mm deep on undisturbed in-situ soil.

#### Australia, New Zealand and Papua New Guinea

It is assumed that, due to the geological diversity of these countries, all of the following soil types are possible.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa
Slightly reactive clay	S	30°	3 kPa	670 kPa
Moderately reactive clay	M	27°	6 kPa	640 kPa
Highly reactive clay	H1	24°	9 kPa	609 kPa
Highly reactive clay	H2	24°	9 kPa	609 kPa
Extremely reactive clay	E	20°	9 kPa	150 kPa

#### Volcanic Islands

Sites on volcanic islands, will be assumed to have the following properties .

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

#### Coral Atolls

Sites on islands consisting principally of coral atolls, will be assumed to have the following properties.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa

## References for Building Acts and Building Regulations – South Pacific

Partner Housing Australasia and Quasar Management Services recognise the on-going work in Building Code development and adaptation, currently being undertaken by the Pacific Regional Infrastructure Facility (PRIF). The following extracts and reference documents are available from the PRIF. Additional PRIF-referenced documents are included with the following country lists.

[www.theprif.org/building-codes](http://www.theprif.org/building-codes).

*In 2021, PRIF launched a regional Technical Assistance “Improving National Building Codes and Standards in the Pacific”. The TA has two key tasks:*

- 1. Assist coordination across PRIF member countries and partners to support the sharing of NBC best practice, leverage lessons-learned and support related initiatives.*
- 2. Support national efforts to improve NBCs, strengthen legislation and regulatory frameworks and build capacity for the application and enforcement of codes.*

*In the short term, we expect this page to become a repository for codes, guidelines and other key documents.*

*For further information, contact the consultant team leader, Rhys Gwilliam [rhysg@outlook.com.au](mailto:rhysg@outlook.com.au)*

*[Regional Guidance from the PRIF](#)*

*<https://www.theprif.org/document/regional-guidance-prif/building-codes-guidance>*

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*[Building Codes Guidance](#)*

*<https://www.theprif.org/document/regional-guidance-prif/building-codes-guidance>*

*<https://www.theprif.org/document/regional-guidance-prif/building-codes-and-standards/improving-national-building-codes-and-standards>*

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*[Improving National Building Codes and Standards in the Pacific - Coordination and Harmonization Report](#)*

*[PRIF Building Code Bibliography | Pacific Regional Infrastructure Facility \(PRIF\) \(theprif.org\)](#)*

*<https://www.theprif.org/document/regional-guidance-prif/building-codes-and-standards/prif-building-code-bibliography>*

## Australia

National Construction Code 2022 Volume Two

<https://ncc.abcb.gov.au/editions-national-construction-code>

## Cook Islands

National Building Code for Cook Islands

<https://www.theprif.org/document/cook-islands/building-codes-and-standards/cook-islands-building-code-0>

Home Building Manual Cook Islands

<https://www.theprif.org/document/cook-islands/building-codes-and-standards/cook-islands-building-manual>

Partial Commentary of the National Building Code Cook Islands

Cook Islands 1991 Building Controls and Standards

Cook Islands Building Controls and Standards (National Building Code) (Amendment) (No.2) Order 2005

[Building Controls and Standard \(National Building Code\) \(Amendment\) \(No.2\) Order 2005](#)  
[32%]

(From [Cook Islands Sessional Legislation](#); 1 January 2005

[Building Controls and Standards Act 1991](#)

(From [Cook Islands Sessional Legislation](#);

## Fiji

National Building Code for Fiji

<https://www.theprif.org/document/fiji/fiji-building-code>

Partial Commentary of the National Building Code Fiji

<https://www.theprif.org/document/fiji/building-codes-and-standards/partial-commentary-national-building-code-fiji-1990>

Home Building Manual

<https://www.theprif.org/document/fiji/building-codes-and-standards/home-building-manual-fiji-1990>

## French Polynesia

## Kiribati

[Building Act 2006](#)

(From [Kiribati Sessional Legislation](#); 1 January 2006

<https://www.theprif.org/document/kiribati/building-codes-and-standards/national-building-code-kiribati>

## Nauru

<https://www.theprif.org/document/nauru/nauru-building-code-2023-draft>

## New Caledonia

## New Zealand

Building Regulations

<https://www.building.govt.nz/building-code-compliance/annual-building-code-updates/2022-building-code-update/>

Building Code Compliance

<https://www.building.govt.nz/building-code-compliance/>

Building Code Handbook

<https://www.building.govt.nz/assets/Uploads/building-code-compliance/handbooks/building-code-handbook/building-code-handbook-3rd-edition-amendment-13.pdf>

## Niue

National Building Code for Niue

Partial Commentary of the National Building Code Niue

Home Building Manual Niue

[Building Code Act 1992](#)

(From [Niue Consolidated Legislation](#); 1 January 1992)

<https://www.theprif.org/document/niue/building-codes-and-standards/niue-national-building-code-1990>

## Papua New Guinea

[http://www.paclii.org/pg/legis/consol\\_act/br1994182](http://www.paclii.org/pg/legis/consol_act/br1994182)

[Building Regulation 1994](#) [100%]

(From [Papua New Guinea Consolidated Legislation](#); 1 January 1994)

[Building Act 1971](#) [51%]

(From [Papua New Guinea Consolidated Legislation](#); 1 January 1971)

[Public Health Ordinance 1932-1938 - Building Regulations](#)

(From [Laws of the Territory of New Guinea 1921-1945 \(Annotated\)](#))

[Building Ordinance, 1929](#)

(From [Laws of the Territory of Papua 1888-1945 \(Annotated\)](#))

## Samoa

[Ministry of Works Act 2002](#) [18%]

(From [Consolidated Acts of Samoa 2011](#); 1 January 2002)

## American Samoa

## Solomon Islands

National Building Code for Solomon Islands

<https://www.theprif.org/document/solomon-islands/building-codes-and-standards/solomon-islands-national-building-code-2022>

Partial Commentary of the National Building Code Solomon Islands

[Building Standards Ordinance 1991](#)

(From [Solomon Islands Western Province Consolidated Legislation 1999](#); 1 January 1991

[Local Government Act - Subsidiary](#)

(From [Solomon Islands Consolidated Legislation](#)

## Tonga

[Building Control and Standards Act 2002](#)

(From [Tonga Sessional Legislation](#); 1 January 2002

[Building Code Regulations 2007](#) [31%]

(From [Tonga Subsidiary Legislation](#); 1 January 2007

National Building Code of Tonga, 2001

<https://www.theprif.org/document/tonga/national-building-code-tonga-2001-english>

National Building Code of Tonga, 2007 - Tongan

<https://www.theprif.org/document/tonga/building-codes-and-standards/national-building-code-tonga-2007-tongan>

Commentary on the National Building Code, Tonga, 2001

<https://www.theprif.org/document/tonga/building-codes-and-standards/commentary-national-building-code-tonga-2001>

<https://www.theprif.org/document/tonga/building-codes-and-standards/commentary-national-building-code-tonga-2001Tonga>

## Tuvalu

National Building Code for Tuvalu

<https://www.theprif.org/document/tuvalu/building-codes-and-standards/tuvalu-national-building-code-1990>

Partial Commentary of the National Building Code Tuvalu

<https://www.theprif.org/document/tuvalu/building-codes-and-standards/tuvalu-national-building-code-1990-partial-commentary>

Home Building Manual Tuvalu

## Vanuatu

National Building Code for Vanuatu

<https://www.theprif.org/document/vanuatu/vanuatu-national-building-code-2000>

Partial Commentary of the National Building Code Vanuatu

<https://www.theprif.org/document/vanuatu/partial-commentary-national-building-code-vanuatu-1990>

Home Building Manual Vanuatu

<https://www.theprif.org/document/vanuatu/home-building-manual-vanuatu-1990>

## Wallis and Futuna

## References for Load Combinations, Permanent Loads, Imposed Loads

Unless specifically stated otherwise in the relevant Building Regulations, the latest published version (including any published amendments) of the Standards specified in this policy shall be used.

Australian & New Zealand Standard AS/NZS 1170.0:2002 (Including Amendments 1, 2, 3, 4, and 5)

Australian & New Zealand Standard AS/NZS 1170.1:2002 (Including Amendments 1 and 2)

## References for Wind

Australian & New Zealand Standard AS/NZS 1170.2:2011 (Including Amendments 1 and 2)

Australian Standard AS 4055:2012

Standards Australia Handbook HB212:2002

## References for Earthquakes

Australian Standard AS 1170.4:2007

New Zealand Standard NZS 1170.5:2004

Anon, *Science Plan on Hazards and Disasters – Earthquakes Floods and Landslides*, ICSU Regional Office for Asia and the Pacific, 2008

Anon, *Suva Earthquake Risk Management Scenario Pilot Project (Sermp) Part I Summary Report* January 2002 South Pacific Disaster Reduction Program (Spdrp) Report

Anon, *Earthquake Intensity Risk Zones & Presence of UN/ISDR in Asia Pacific*, UN/ISDR 10 April 2008

Anton, L., *Earthquake and Tsunami Hazard Mitigation in Papua New Guinea*, Geological Survey Of Papua New Guinea, P.O. Box 323, Port Moresby, National Capital District, Papua New Guinea (p: +(675) 321 4500, f: +(675) 321 3976, e: [Pmgo@Daltron.Com.Pg](mailto:Pmgo@Daltron.Com.Pg))

McCue, K., *Seismic hazard mapping in Australia, the South-west Pacific and South-east Asia*, ANNALI DI GEOFISICA, Vol 42, No 6, December 1999

Petersen, M.D., Harmsen, S.C., Rukstales, K.S., Mueller, C.S., McNamara, D.E., Luco, Nicolas, and Walling, M., *Seismic hazard of American Samoa and neighboring South Pacific Islands—Methods, data, parameters, and results: 2012*, U.S. Geological Survey Open-File Report 2012–1087, 98 p.

Rong, Y., Park, J., Duggan, D., Mahdyar, M. & Bazzurro, P. *Probabilistic Seismic Hazard Assessment for Pacific Island Countries*, 15 WCEE, Lisboa 2012

Wilson, J & Lam, N., *A recommended earthquake response spectrum model for Australia*, Australian Journal of Structural Engineering, Vol 5, No 1, Institution of Engineers, Australia, 2003

Wijanto, S., *World Housing Encyclopedia Report Country: Indonesia Housing Type: Unreinforced clay brick masonry house*, 6/5/2002( Modified 7/2/2003)

### **References for Tsunamis and Floods**

Australian Building Codes Board Handbook, *Construction of Buildings in Flood Hazard Areas*, Version 2012.2.

### **References for Soil Load and Movement**

Australian Standard AS 2870:2011

Australian Standard AS 4678:2002 (Including Amendment 1 and 2)

### **General References**

Johnston, R.K. (July 2001), *Australian Involvement in Constructing Affordable Housing in Developing Countries*, Deakin University, AID719

Schilderman, T. & Lowe, L., *Regulatory Issues Affecting Shelter Development by The Urban Poor*, ITDG

## Part 2. Country Design and Analysis Assumptions

### Background

The engineering design of structures should be based on professionally determined design life, annual probability of exceedance and the probability of exceedance during life of each design action. In locations where building regulations apply, this information is either specified in the building regulation, or in the relevant design standards.

Engineering design should also be based on professionally determined soil properties, permanent actions, imposed action, wind actions (including cyclonic wind), earthquake actions, tsunami actions and flood actions. When so regulated, or when the structure is of significance or importance, these properties must be determined by suitably qualified and experienced engineers.

However, many remote villages in the South Pacific are beyond regulatory coverage, the structure (houses, clinics and small school buildings) are small and present low risk to life in the case of exposure to extreme events. Due to remoteness, there may be little practical means of accurately determining from local inspection some of the listed properties.

This part provides some default design and analysis assumptions for each of the countries covered by this Manual, taking account of the location, proximity to cyclonic wind zones, proximity to high earthquake areas and plate boundaries, typical topography and susceptibility to tsunamis.

### 1. Design of Regulated Buildings

Slightly conservative assumptions (in excess of those based on a probability of exceedance of 1 in 500 years) are considered for the design of structures for wind and earthquake actions, where:

- (a) relevant building regulations are enforced; and
- (b) a probability of exceedance of 1 in 500 years is specified.

### 2. Checking Regulated Buildings

Precise assumptions (based on a probability of exceedance of 1 in 500 years) are recommended for the checking of structures for wind and earthquake actions, where:

- (a) relevant building regulations are enforced; and
- (b) a probability of exceedance of 1 in 500 years is specified.

### 3. Design of Village Buildings

Slightly conservative assumptions (in excess of those based on a probability of exceedance of 1 in 250 years) are recommended for the design of structures for wind and earthquake actions, where:

- (a) they offer low risk to occupants; and
- (b) the design life is under 25 years; and
- (c) there is no other practical way of determining the design actions and soil properties, and;
- (d) relevant building regulations are not enacted and routinely enforced.

This is not applicable in Australia or New Zealand.

### 4. Checking of Village Buildings

Precise assumptions (based on a probability of exceedance of 1 in 250 years) are considered for the checking of structures for wind and earthquake actions, where:

- (a) they offer low risk to occupants; and
- (b) the design life is under 25 years; and
- (c) there is no other practical way of determining the design actions and soil properties, and;
- (d) relevant building regulations are not routinely enforced.

This is not applicable in Australia or New Zealand.

## Australia

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Australia Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure; Single storey; Cladding on elevated braced timber frame OR reinforced concrete masonry on concrete slab-on-ground; Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 50 years; Annual probability of exceedance 1 in 500; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa
Slightly reactive clay	S	30°	3 kPa	670 kPa
Moderately reactive clay	M	27°	6 kPa	640 kPa
Highly reactive clay	H1	24°	9 kPa	609 kPa
Highly reactive clay	H2	24°	9 kPa	609 kPa
Extremely reactive clay	E	20°	9 kPa	436 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Based on AS/NZS 1170.2:2011

Noncyclonic	Region A	$V_{u\ 500\ (3,10)} = 45 \text{ m/s}$	$k_p\ 500 = 1.0$
Noncyclonic	Region B	$V_{u\ 500\ (3,10)} = 57 \text{ m/s}$	$k_p\ 500 = 1.0$
Cyclonic	Region C	$V_{u\ 500\ (3,10)} = 66 \text{ F}_c = 73 \text{ m/s}$	$k_p\ 500 = 1.0$
Cyclonic	Region D	$V_{u\ 500\ (3,10)} = 80 \text{ F}_b = 88 \text{ m/s}$	$k_p\ 500 = 1.0$

## Earthquake:

Probability  $k = 1.0$ ; Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Location	Peak Ground Acceleration, adjusted for Probability of Exceedance $k_p z$ (Where $K_p = 1.0$ ) 1 : 500
As per AS 1170.4 Table 3.2 and Fig 3.2	
Mekering region (Ranges from 0.14 to 0.22)	0.22
Tennant Creek	0.13
Newcastle, Bundaberg	0.11
Adelaide, Wyong	0.10
Darwin, Geraldton, Gladstone, Wyndham, Wollongong, Whyalla	0.09
All other locations	0.08

Tsunami: Should be determined for each site. Provided the distance from high water mark > 2 km; OR height of finished floor above mean sea level >20 m; OR distance from high earthquake area (Z > 0.4) >1,000 km; the Tsunami Risk Factor = 0 (Site specific exposure = Value to be determined)

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km<sup>2</sup>; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## Cook Islands

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Cook Islands Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure; Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground; Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic      Level IV (C)       $V_{u500(3,10)} = 66 \text{ m/s}$        $k_{p500} = 1.0$ ,  $k_{p250} = 0.88$

The *National Building Code for Cook Islands 1990* calls up the version AS 1170.2 that was in place at the time. It also provides further information for the permissible stress method. However, this policy provides ultimate limit state loads, which may be derived using the following passages from the *National Building Code for Cook Islands 1990*. “When using Part 2 of the standard the following provisions apply: a limit state basic wind speed of 60 m/s to all areas..... The bulk of the developing areas in the Cook Islands are such that simple buildings up to 6 m height, ..... [and] category 2 terrain and an upwind slope of 1 : 10 for escarpments ...”

Earthquake: Probability  $k_{p500} = 1.0$ ,  $k_p = 0.75$ ; Hazard  $Z_{500} = 0.08$ ; Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Tsunami: Should be determined for each site. Provided the distance from high water mark > 2 km; OR height of finished floor above mean sea level >20 m; OR distance from high earthquake area ( $Z > 0.4$ ) >1,000 km; the Tsunami Risk Factor = 0 (Site specific exposure = Value to be determined)

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km<sup>2</sup>; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## Fiji

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Fiji Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C)  $V_{u500(3,10)} = 66 \text{ m/s}$   $k_{p500} = 1.0$ ,  $k_{p250} = 0.88$

The *National Building Code for Fiji* 1990 calls up the version AS 1170.2 that was in place at the time. It also provides further information for the permissible stress method. However, this policy provides ultimate limit state loads, which may be derived using the following passages from the *National Building Code for Fiji* 1990. “When using Part 2 of the standard the following provisions apply: *a limit state basic wind speed of 70 m/s to all areas*”

Earthquake: Probability  $k_p = 0.75$ ; Hazard  $Z_{500} = 0.60$  (West Vanua Levu),  $0.40$  (Central and east Vanua Levu and north-eastern islands),  $0.24$  (Viti Levu and south-eastern islands); Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Tsunami: Should be determined for each site. Distance from high water mark = ..... km; Height of finished floor above mean sea level = .....m; Distance from high earthquake area ( $Z > 0.4$ ) >..... km; Site specific exposure = ..... Tsunami Risk Factor = .....

Flood: Should be determined for each site. Provided the distance to closest water course  $> 200 \text{ m}$ ; OR height of finished floor above normal level of water course  $> 10.0 \text{ m}$ ; or catchment area  $< 5 \text{ km}^2$ ; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## French Polynesia

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: French Polynesia Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C)  $V_{u50(3,10)} = 66 \text{ m/s}$   $k_{p500} = 1.0$ ,  $k_{p250} = 0.88$

Earthquake: Probability  $k_{p500} = 1.0$ ,  $k_{p250} = 0.75$ ; Hazard  $Z_{500} = 0.08$ ; Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Tsunami: Should be determined for each site. Provided the distance from high water mark  $> 2 \text{ km}$ ; OR height of finished floor above mean sea level  $> 20 \text{ m}$ ; OR distance from high earthquake area ( $Z > 0.4$ )  $> 1,000 \text{ km}$ ; the Tsunami Risk Factor = 0 (Site specific exposure = Value to be determined)

Flood: Should be determined for each site. Provided the distance to closest water course  $> 200 \text{ m}$ ; OR height of finished floor above normal level of water course  $> 10.0 \text{ m}$ ; or catchment area  $< 5 \text{ km}^2$ ; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## Kiribati

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Kiribati Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Noncyclonic Level I  $V_{u\ 500\ (3,10)} = 40 \text{ m/s}$   $k_{p\ 500} = 1.0$ ,  $k_{p\ 250} = 0.90$

Earthquake: Probability  $k_{p\ 500} = 1.0$ ,  $k_{p\ 250} = 0.75$ ; Hazard  $Z_{500} = 0.08$ ; Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Tsunami: Should be determined for each site. Provided the distance from high water mark  $> 2 \text{ km}$ ; OR height of finished floor above mean sea level  $> 20 \text{ m}$ ; OR distance from high earthquake area ( $Z > 0.4$ )  $> 1,000 \text{ km}$ ; the Tsunami Risk Factor = 0 (Site specific exposure = Value to be determined)

Flood: Should be determined for each site. Provided the distance to closest water course  $> 200 \text{ m}$ ; OR height of finished floor above normal level of water course  $> 10.0 \text{ m}$ ; or catchment area  $< 5 \text{ km}^2$ ; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## Nauru

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Nauru Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Noncyclonic Level I  $V_{u\ 500\ (3,10)} = 40 \text{ m/s}$   $k_{p\ 500} = 1.0$ ,  $k_{p\ 250} = 0.90$

Earthquake: Probability  $k_{p\ 500} = 1.0$ ,  $k_{p\ 250} = 0.75$ ; Hazard  $Z_{500} = 0.08$ ; Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Tsunami: Should be determined for each site. Provided the distance from high water mark  $> 2 \text{ km}$ ; OR height of finished floor above mean sea level  $> 20 \text{ m}$ ; OR distance from high earthquake area ( $Z > 0.4$ )  $> 1,000 \text{ km}$ ; the Tsunami Risk Factor = 0 (Site specific exposure = Value to be determined)

Flood: Should be determined for each site. Provided the distance to closest water course  $> 200 \text{ m}$ ; OR height of finished floor above normal level of water course  $> 10.0 \text{ m}$ ; or catchment area  $< 5 \text{ km}^2$ ; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## New Caledonia

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: New Caledonia Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C)  $V_{u500(3,10)} = 66 \text{ m/s}$   $k_{p500} = 1.0$ ,  $k_{p250} = 0.88$

Earthquake: Probability  $k_{p500} = 1.0$ ,  $k_{p250} = 0.75$ ; Hazard  $Z_{500} = 0.40$  (North-eastern islands), 0.16 (Main island); Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Tsunami: Should be determined for each site. Distance from high water mark = ..... km; Height of finished floor above mean sea level = .....m; Distance from high earthquake area ( $Z > 0.4$ ) >..... km; Site specific exposure = ..... Tsunami Risk Factor = .....

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km<sup>2</sup>; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## New Zealand

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: New Zealand Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa
Slightly reactive clay	S	30°	3 kPa	670 kPa
Moderately reactive clay	M	27°	6 kPa	640 kPa
Highly reactive clay	H1	24°	9 kPa	609 kPa
Highly reactive clay	H2	24°	9 kPa	609 kPa
Extremely reactive clay	E	20°	9 kPa	150 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind:

Noncyclonic	Level II (A)	$V_{u\ 500(3,10)} = 45 \text{ m/s}$	$k_{p\ 500} = 1.0, k_{p\ 250} = 0.91$
Noncyclonic	Level III (W)	$V_{u\ 500(3,10)} = 51 \text{ m/s}$	$k_{p\ 500} = 1.0, k_{p\ 250} = 0.92$

Earthquake:

Probability  $k_{p\ 500} = 1.0, k_{p\ 250} = 0.75$ ; Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Location	Peak Ground Acceleration, adjusted for Probability of Exceedance $k_p$ $z = 1 : 500$ (Where $K_p = 1.0$ )
As per NZS 1170.5 Table 3.3 and Figs 3.3, 3.4, 3.5	
Auckland, Dunedin, Palmerston	0.13
Hamilton, Akaroa	0.16
Christchurch	0.22
Wellington, Seddon, Hutt Valley, Ward, Cheviot, Otaki	0.40
Otira, Arthurs Pass (maximum value)	0.60

Tsunami: Should be determined for each site. Distance from high water mark = ..... km; Height of finished floor above mean sea level =.....m; Distance from high earthquake area ( $Z > 0.4$ ) >..... km; Site specific exposure = ..... Tsunami Risk Factor = .....

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km<sup>2</sup>; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

**Niue**

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Niue Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C)  $V_{u,500(3,10)} = 66 \text{ m/s}$   $k_{p,500} = 1.0$ ,  $k_{p,250} = 0.88$

Earthquake: Probability  $k_{p,500} = 1.0$ ,  $k_{p,250} = 0.75$ ; Hazard  $Z_{500} = 0.08$ ; Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Tsunami: Should be determined for each site. Distance from high water mark = ..... km; Height of finished floor above mean sea level =.....m; Distance from high earthquake area ( $Z > 0.4$ ) >..... km; Site specific exposure = ..... Tsunami Risk Factor = .....

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km<sup>2</sup>; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## Papua New Guinea

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Papua New Guinea Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa
Slightly reactive clay	S	30°	3 kPa	670 kPa
Moderately reactive clay	M	27°	6 kPa	640 kPa
Highly reactive clay	H1	24°	9 kPa	609 kPa
Highly reactive clay	H2	24°	9 kPa	609 kPa
Extremely reactive clay	E	20°	9 kPa	150 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Most of the country except south-east. (refer also to map for reduced velocities)

Noncyclonic	Level I	$V_{u\ 500(3,10)} = 40 \text{ m/s}$	$k_{p\ 500} = 1.0, k_{p\ 250} = 0.90$
South-eastern peninsular (Including Milne Bay)			
Cyclonic	Level IV (C)	$V_{u\ 500(3,10)} = 66 \text{ m/s}$	$k_{p\ 500} = 1.0, k_{p\ 250} = 0.88$

Earthquake: Probability  $k_{p\ 500} = 1.0, k_{p\ 250} = 0.75$ ; Hazard  $Z_{500} = \text{As per table below}$ ; Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Location	Hazard $Z_{500}$
Zone 1 (Extremely High Hazard) – Bougainville, Eastern and Central New Britain, Southern New Ireland (Includes Rabaul)	<b>1.00</b>
Zone 2 (Moderately High Hazard) – Northern coast of the mainland, Western New Britain, Central New Ireland, Lihir Group (Includes Namatani, Kieta, Arawa, Vanimo, Wewak, Madang, Lae, Finnhafen, Kimbe, Hoskins)	<b>0.40</b>
Zone 3 (Moderate Hazard) – Central region of the mainland, Northern Province, D’Entrecasteaux and Trobriand Islands, Northern New Ireland and Admiralty Islands (Includes Mendi, Kerema, Klunga, Wabag, Mt Hagen, Kundiawa, Goroko, Bulolo, Wau, Popondetta, Lombrum, Lorengau, Kayieng)	<b>0.24</b>
Zone 4 (Very Low Hazard) – Papuan Peninsula - Louisiade Archipelago and St. Mathias Group (Includes Daru, Port Moresby, Alotau)	<b>0.16</b>

Tsunami: Should be determined for each site. Distance from high water mark = ..... km; Height of finished floor above mean sea level =.....m; Distance from high earthquake area ( $Z > 0.4$ ) >..... km; Site specific exposure = ..... Tsunami Risk Factor = .....

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km<sup>2</sup>; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## Samoa

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Samoa Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C)  $V_{u 500(3,10)} = 66 \text{ m/s}$   $k_{p 500} = 1.0$ ,  $k_{p 250} = 0.88$

Earthquake: Probability  $k_{p 500} = 1.0$ ,  $k_{p 250} = 0.75$ ; Hazard  $Z_{500} = 0.16$ ; Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Tsunami: Should be determined for each site. Distance from high water mark = ..... km; Height of finished floor above mean sea level = .....m; Distance from high earthquake area ( $Z > 0.4$ ) >..... km; Site specific exposure = ..... Tsunami Risk Factor = .....

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km<sup>2</sup>; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## American Samoa

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: American Samoa Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C)  $V_{u 500(3,10)} = 66 \text{ m/s}$   $k_{p 500} = 1.0$ ,  $k_{p 250} = 0.88$

Earthquake: Probability  $k_{p 500} = 1.0$ ,  $k_{p 250} = 0.75$ ; Hazard  $Z_{500} = 0.24$ ; Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Tsunami: Should be determined for each site. Distance from high water mark = ..... km; Height of finished floor above mean sea level = .....m; Distance from high earthquake area ( $Z > 0.4$ ) >..... km; Site specific exposure = ..... Tsunami Risk Factor = .....

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km<sup>2</sup>; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## Solomon Islands

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Solomon Islands Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Noncyclonic Level I  $V_{u\ 500\ (3,10)} = 40 \text{ m/s}$   $k_{p\ 500} = 1.0$ ,  $k_{p\ 250} = 0.90$

Earthquake: Probability  $k_{p\ 500} = 1.0$ ,  $k_{p\ 250} = 0.75$ ; Hazard  $Z_{500} = 0.60$  (Eastern Province),  $0.60$  Guadalcanal,  $0.50$  (Rest of Solomon Islands); Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Tsunami: Should be determined for each site. Distance from high water mark = ..... km; Height of finished floor above mean sea level = .....m; Distance from high earthquake area ( $Z > 0.4$ ) >..... km; Site specific exposure = ..... Tsunami Risk Factor = .....

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km<sup>2</sup>; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## Tonga

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Tonga Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C)  $V_{u 500(3,10)} = 70 \text{ m/s}$   $k_{p 500} = 1.0$ ,  $k_{p 250} = 0.88$

Earthquake: Probability  $k_{p 500} = 1.0$ ,  $k_{p 250} = 0.75$ ; Hazard  $Z_{500} = 0.40$ ; Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Tsunami: Should be determined for each site. Distance from high water mark = ..... km; Height of finished floor above mean sea level = .....m; Distance from high earthquake area ( $Z > 0.4$ ) >..... km; Site specific exposure = ..... Tsunami Risk Factor = .....

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km<sup>2</sup>; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## Tuvalu

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Tuvalu Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C)  $V_{u500(3,10)} = 66 \text{ m/s}$   $k_{p500} = 1.0$ ,  $k_{p250} = 0.88$

The *National Building Code for Tuvalu* 1990 calls up the version AS 1170.2 that was in place at the time. It also provides further information for the permissible stress method. However, this policy provides ultimate limit state loads, which may be derived using the following passages from the *National Building Code for Tuvalu* 1990. “When using Part 2 of the standard the following provisions apply: a limit state basic wind speed of **60 m/s** to all areas”

Earthquake: Given the very low earthquake hazard, design for cyclonic wind will effectively cater for any earthquake loads. (Probability  $k_{p500} = 1.0$ ,  $k_{p250} = 0.75$ ; Hazard  $Z_{500} = 0.01$ ; Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$ )

Tsunami: Should be determined for each site. Distance from high water mark = ..... km; Height of finished floor above mean sea level = .....m; Distance from high earthquake area ( $Z > 0.4$ ) >..... km; Site specific exposure = ..... Tsunami Risk Factor = .....

Flood: Design for flood can be ignored, given the flat nature of the atolls that comprise Tuvalu.

## Vanuatu

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Vanuatu Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Close to beach - sand or rock	A	36°	0 kPa	1060 kPa
Away from beach - moderately reactive clay	M	27°	6 kPa	640 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C)  $V_{u\ 500(3,10)} = 66 \text{ m/s}$   $k_{p\ 500} = 1.0, k_{p\ 250} = 0.88$

The *National Building Code for Vanuatu 1990* calls up the version AS 1170.2 that was in place at the time. It also provides further information for the permissible stress method. However, this policy provides ultimate limit state loads, which may be derived using the following passages from the *National Building Code for Vanuatu 1990*. “When using Part 2 of the standard the following provisions apply: a limit state basic wind speed of **70 m/s** to all areas”

Earthquake: Probability  $k_{p\ 500} = 1.0, k_{p\ 250} = 0.75$ ; Hazard  $Z_{500} = 0.60$ ; Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Tsunami: Should be determined for each site. Distance from high water mark = ..... km; Height of finished floor above mean sea level = ... m; Distance from high earthquake area ( $Z > 0.4$ ) >... km; Site specific exposure = ... Tsunami Risk Factor = ...

Flood: Should be determined for each site. Provided the distance to closest water course > 200 m; OR height of finished floor above normal level of water course > 10.0 m; or catchment area < 5 km<sup>2</sup>; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## Wallis and Futuna

These design assumptions may not be used for applications that do not comply with the “Building” and “Design” conditions listed below.

Location: Wallis and Futuna Generic

Building: Small detached village building; Presenting a low degree of hazard to life and other property in case of failure;

Single storey; Cladding on elevated braced timber frame OR Reinforced concrete masonry on concrete slab-on-ground;

Maximum dimensions: 16.5 x 8.4 m, 2.7 m storey, Maximum eaves height 6.0 m, Maximum ridge height 8.5 m, Maximum pitch 35°

Design: Design life 25 years; Annual probability of exceedance 1 in 250; Probability of exceedance during life: 0.10

Soil: Based on a rectangular footing 450 mm wide founded 300 mm deep in compacted soil.

Soil Type	AS 2870 Site Classification	Characteristic internal friction angle, degrees	Characteristic cohesion, kPa	Characteristic ultimate bearing capacity, kPa
Sand or rock	A	36°	0 kPa	1060 kPa

Permanent Loads: Elevated timber building,  $w = 2.5 \text{ kN/m}^2$  (floor area), Reinforced masonry building  $w = 3.5 \text{ kN/m}^2$  (floor area)

Imposed Loads: Floor load 1.5 kPa; Roof load 0.25 kPa

Wind: Cyclonic Level IV (C)  $V_{u500(3,10)} = 66 \text{ m/s}$   $k_{p500} = 1.0$ ,  $k_{p250} = 0.88$

Earthquake: Probability  $k_{p500} = 1.0$ ,  $k_{p250} = 0.75$ ; Hazard  $Z_{500} = 0.60$  (Wallis), 0.20 (Futuna); Subsoil = C; Ordinate  $C_{h(T1)} = 3.68$ ; Ductility,  $\mu = 2.00$ ; Performance,  $S_p = 0.77$

Tsunami: Should be determined for each site. Distance from high water mark = ..... km; Height of finished floor above mean sea level = .....m; Distance from high earthquake area ( $Z > 0.4$ ) >..... km; Site specific exposure = ..... Tsunami Risk Factor = .....

Flood: Should be determined for each site. Provided the distance to closest water course  $> 200 \text{ m}$ ; OR height of finished floor above normal level of water course  $> 10.0 \text{ m}$ ; or catchment area  $< 5 \text{ km}^2$ ; the Flooding Risk Factor = 0. (Funnelling of catchment runoff past structure = Value to be determined)

## Appendix 1 – Cyclone Categories

The information below on tropical cyclones is reproduced from the following Bureau of Metrology web site: <http://www.bom.gov.au/cyclone/about/intensity.shtml>

### Tropical Cyclone Intensity

Tropical cyclone intensity is defined by the maximum mean wind speed over open flat land or water. This is sometimes referred to as the maximum sustained wind and will be experienced around the eye-wall of the cyclone.

### Mean Wind

In most of the world the mean wind speed is defined as the wind speed averaged over a period of 10 minutes. It should be measured at 10 m above the surface. *The major exception is the USA where they use a 1-minute average.*

### Wind Gust

In most of the world the wind gust speed is defined as the wind speed averaged over 2 or 3 seconds (in Australia we use 3 seconds).

Typically gusts over open land will be about 40% greater than the mean wind and gusts over the ocean will be 25 - 30% greater than the mean wind. It is often the stronger gusts that cause the most significant damage to buildings

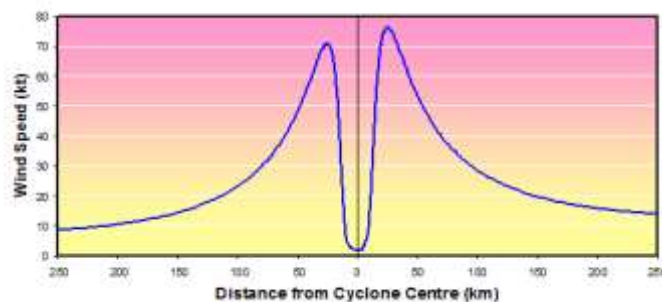
While a cyclone advice may refer to a certain maximum sustained wind or gust, there will be localised points where the winds will exceed this value, particularly in gullies, about ridges and between buildings where winds can be funnelled by the landscape.

### Extent of Significant Winds

The extent of damaging winds will vary between cyclones. More importantly, the most severe winds will be confined to a small area around the outside of the eye. Often people will experience the winds in the outer part of a Category 4 or 5 cyclone. They will believe that they have experienced a major cyclone, yet the winds may have only been Cat 1 or 2 strength.

It is important to recognise the structure of a cyclone when assessing past experience. This will make a future direct hit less of a surprise.

Mean Wind Strengths for a Typical Tropical Cyclone



## Tropical Cyclone Category System

**CATEGORY 1 (*tropical cyclone*)** – Negligible house damage. Damage to some crops, trees and caravans. Craft may drag moorings. A Category 1 cyclone's strongest winds are GALES with typical gusts over open flat land of 90 - 125 km/h. These winds correspond to Beaufort 8 and 9 (Gales and strong gales).

**CATEGORY 2 (*tropical cyclone*)** – Minor house damage. Significant damage to signs, trees and caravans. Heavy damage to some crops. Risk of power failure. Small craft may break moorings. A Category 2 cyclone's strongest winds are DESTRUCTIVE winds with typical gusts over open flat land of 125 - 164 km/h. These winds correspond to Beaufort 10 and 11 (Storm and violent storm).

**CATEGORY 3 (*severe tropical cyclone*)** – Some roof and structural damage. Some caravans destroyed. Power failures likely. A Category 3 cyclone's strongest winds are VERY DESTRUCTIVE winds with typical gusts over open flat land of 165 - 224 km/h. These winds correspond to the highest category on the Beaufort scale, Beaufort 12 (Hurricane).

**CATEGORY 4 (*severe tropical cyclone*)** – Significant roofing loss and structural damage. Many caravans destroyed and blown away. Dangerous airborne debris. Widespread power failures. A Category 4 cyclone's strongest winds are VERY DESTRUCTIVE winds with typical gusts over open flat land of 225 - 279 km/h. These winds correspond to the highest category on the Beaufort scale, Beaufort 12 (Hurricane).

**CATEGORY 5 (*severe tropical cyclone*)** – Extremely dangerous with widespread destruction. A Category 5 cyclone's strongest winds are VERY DESTRUCTIVE winds with typical gusts over open flat land of more than 280 km/h. These winds correspond to the highest category on the Beaufort scale, Beaufort 12 (Hurricane).

## Beaufort Scale

Beaufort scale	Cyclone category	Average wind speed (knots)	Average wind speed (km/h)	Estimating speed over land	Estimating speed over water	
0	Calm	Less than 1	less than 1	Calm, smoke rises vertically.	Sea like mirror	
1	Light Air	1 - 3	1 - 5	Direction of wind shown by smoke drift, but not by wind vanes.	Ripples with the appearance of scales are formed, but without foam crests	
2	Light breeze	4 - 6	6 - 11	Wind felt on face; leaves rustle; ordinary wind vane moved by wind.	Small wavelets, still short, but more pronounced; crests have a glassy appearance and do not break	
3	Gentle breeze	7 - 10	12 - 19	Leaves and small twigs in constant motion; wind extends light flag.	Large wavelets; crests begin to break; foam of glassy appearance; perhaps scattered white horses	
4	Moderate breeze	11 - 16	20 - 28	Raises dust and loose paper; small branches moved.	Small waves, becoming longer; fairly frequent white horses	
5	Fresh breeze	17 - 21	29 - 38	Small trees in leaf begin to sway; crested wavelets form on inland waters.	Moderate waves, taking a more pronounced long form; many white horses are formed (chance of some spray)	
6	Strong breeze	22 - 27	39 - 49	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.	Large waves begin to form; the white foam crests are more extensive everywhere (probably some spray)	
7	Near gale	28 - 33	50 - 61	Whole trees in motion; inconvenience felt when walking against the wind.	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind	
8	Gale	1	34 - 40	62 - 74	Breaks twigs off trees; generally impedes progress.	Moderately high waves of greater length; edges of crests begin to break into the spindrift; the foam is blown in well-marked streaks along the direction of the wind
9	Strong gale	1	41 - 47	75 - 88	Slight structural damage occurs (chimney pots and slates removed).	High waves; dense streaks of foam along the direction of the wind; crests

Beaufort scale	Cyclone category	Average wind speed (knots)	Average wind speed (km/h)	Estimating speed over land	Estimating speed over water
10 Storm	2	48 - 55	89 - 102	Seldom experienced inland; trees uprooted; considerable structural damage occurs.	of waves begin to topple, tumble and roll over; spray may affect visibility  Very high waves with long overhanging crests; the resulting foam, in great patches, is blown in dense white streaks along the direction of the wind; on the whole, the surface of the sea takes a white appearance; the tumbling of the sea becomes heavy and shock-like; visibility affected
11 Violent storm	2	56 - 63	103 - 117	Very rarely experienced; accompanied by widespread damage.	Exceptionally high waves (small and medium sized ships might be for a time lost to view behind the waves); the sea is completely covered with long white patches of foam lying along the direction of the wind; everywhere the edges of the wave crests are blown into froth; visibility affected
12 Hurricane	3,4,5	64 and over	118 and over	Severe and extensive damage.	The air is filled with foam and spray; sea completely white with driving spray; visibility very seriously affected

## Global Tropical Cyclone Terminology

Tropical cyclones can be defined in different ways elsewhere in the world. Often news reports from the United States or Asia will refer to hurricanes or typhoons. These are all tropical cyclones, but with different names. While the category definitions are not identical, the following provides an approximate guide for comparison.

Australian name	Australian category	US*	US Saffir-Simpson category scale*	NW Pacific	Arabian Sea Bay of Bengal	SW Indian Ocean	South Pacific (East of 160E)
Tropical low	-	Tropical depression	-	Tropical depression	Depression or severe depression	Tropical depression	Tropical depression
Tropical cyclone	1	Tropical storm	-	Tropical storm	Cyclonic storm	Moderate tropical storm	Tropical cyclone (Gale)
Tropical cyclone	2	Tropical storm	-	Severe tropical storm	Severe cyclonic storm	Severe tropical storm	Tropical cyclone (Storm)
Severe tropical Cyclone	3	Hurricane	1	Typhoon	Very severe cyclonic storm	Tropical cyclone	Tropical cyclone (Hurricane)
Severe tropical cyclone	4	Hurricane	2 - 3	Typhoon	Very severe cyclonic storm	Intense tropical cyclone	Tropical cyclone (Hurricane)
Severe tropical cyclone	5	Hurricane	4 - 5	Typhoon	Super cyclonic storm	Very intense tropical cyclone	Tropical cyclone (Hurricane)

*\* Note that the USA uses 1-minute wind averages, which are generally greater than 10-minute wind averages used elsewhere in the world – hence their intensity definitions (wind strengths) will differ by about 10%.*

## Appendix 2 – Earthquake Definitions

### Earthquake Scales

Source: [https://en.wikipedia.org/wiki/Richter\\_magnitude\\_scale](https://en.wikipedia.org/wiki/Richter_magnitude_scale)

The Richter scale was defined in 1935 for particular circumstances and instruments; the particular circumstances refer to it being defined for Southern California and "implicitly incorporates the attenuative properties of Southern California crust and mantle."<sup>[17]</sup> The particular instrument used would become saturated by strong earthquakes and unable to record high values.

The scale was replaced in the 1970s by the moment magnitude scale (MMS, symbol  $M_w$ ); for earthquakes adequately measured by the Richter scale, numerical values are approximately the same.

Although values measured for earthquakes now are (MMS), they are frequently reported by the press as Richter values, even for earthquakes of magnitude over 8, when the Richter scale becomes meaningless. Anything above 5 is classified as a risk by the USGS.

The Richter and MMS scales measure the energy released by an earthquake; another scale, the Mercalli intensity scale, classifies earthquakes by their *effects*, from detectable by instruments but not noticeable, to catastrophic. The energy and effects are not necessarily strongly correlated; a shallow earthquake in a populated area with soil of certain types can be far more intense in effects than a much more energetic deep earthquake in an isolated area.

Several scales have historically been described as the "Richter scale", especially the *local magnitude* and the surface wave scale. In addition, the *body wave magnitude*, and the *moment magnitude*, abbreviated MMS, have been widely used for decades. A couple of new techniques to measure magnitude are in the development stage by seismologists.....

The Richter magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs (adjustments are included to compensate for the variation in the distance between the various seismographs and the epicentre of the earthquake).

The following describes the typical effects of earthquakes of various magnitudes near the epicentre. The values are typical only. They should be taken with extreme caution, since intensity and thus ground effects depend not only on the magnitude, but also on the distance to the epicentre, the depth of the earthquake's focus beneath the epicentre, the location of the epicentre and geological conditions (certain terrains can amplify seismic signals).

Magnitude	Description	<u>Mercalli intensity</u>	Average earthquake effects	Average frequency of occurrence (estimated)
1.0–1.9	<u>Micro</u>	I	Microearthquakes, not felt, or felt rarely. Recorded by seismographs	Continual/several million per year
2.0–2.9	Minor	I to II	Felt slightly by some people. No damage to buildings.	Over one million per year
3.0–3.9		III to IV	Often felt by people, but very rarely causes damage. Shaking of indoor objects can be noticeable.	Over 100,000 per year
4.0–4.9	Light	IV to VI	Noticeable shaking of indoor objects and rattling noises. Felt by most people in the affected area. Slightly felt outside. Generally causes none to minimal damage. Moderate to significant damage very unlikely. Some objects may fall off shelves or be knocked over.	10,000 to 15,000 per year
5.0–5.9	Moderate	VI to VII	Can cause damage of varying severity to poorly constructed buildings. At most, none to slight damage to all other buildings. Felt by everyone.	1,000 to 1,500 per year
6.0–6.9	Strong	VIII to X	Damage to a moderate number of well-built structures in populated areas. Earthquake-resistant structures survive with slight to moderate damage. Poorly designed structures receive moderate to severe damage. Felt in wider areas; up to hundreds of miles/kilometers from the epicentre. Strong to violent shaking in epicentral area.	100 to 150 per year
7.0–7.9	Major	X or greater	Causes damage to most buildings, some to partially or completely collapse or receive severe damage. Well-designed structures are likely to receive damage. Felt across great distances with major damage mostly limited to 250 km from epicentre.	10 to 20 per year
8.0–8.9	Great		Major damage to buildings, structures likely to be destroyed. Will cause moderate to heavy damage to sturdy or earthquake-resistant buildings. Damaging in large areas. Felt in extremely large regions.	One per year
9.0 and greater			At or near total destruction – severe damage or collapse to all buildings. Heavy damage and shaking extends to distant locations. Permanent changes in ground topography.	One per 10 to 50 years

(Based on U.S. Geological Survey documents.)

## Ground Acceleration

Source: [https://en.wikipedia.org/wiki/Peak\\_ground\\_acceleration](https://en.wikipedia.org/wiki/Peak_ground_acceleration)

Earthquake energy is dispersed in waves from the [hypocentre](#), causing ground movement omnidirectionally but typically modelled horizontally (in two directions) and vertically. PGA records the [acceleration](#) (rate of change of speed) of these movements, while peak ground velocity is the greatest speed (rate of movement) reached by the ground, and peak displacement is the distance moved. These values vary in different earthquakes, and in differing sites within one earthquake event, depending on a number of factors. These include the length of the fault, magnitude, the depth of the quake, the distance from the epicentre, the duration (length of the shake cycle), and the geology of the ground (subsurface). Shallow-focused earthquakes generate stronger shaking (acceleration) than intermediate and deep quakes, since the energy is released closer to the surface.

Peak ground acceleration can be expressed in  $g$  (the acceleration due to [Earth's gravity](#), equivalent to [g-force](#)) as either a decimal or percentage; in  $m/s^2$  ( $1 g = 9.81 m/s^2$ ); or in [Gal](#), where 1 Gal is equal to  $0.01 m/s^2$  ( $1 g = 981 Gal$ ).

The ground type can significantly influence ground acceleration, so PGA values can display extreme variability over distances of a few kilometers, particularly with moderate to large earthquakes. The varying PGA results from an earthquake can be displayed on a [shake map](#). Due to the complex conditions affecting PGA, earthquakes of similar magnitude can offer disparate results, with many moderate magnitude earthquakes generating significantly larger PGA values than larger magnitude quakes.

During an earthquake, ground acceleration is measured in three directions: vertically (V or UD, for up-down) and two perpendicular horizontal directions (H1 and H2), often north-south (NS) and east-west (EW). The peak acceleration in each of these directions is recorded, with the highest individual value often reported. Alternatively, a combined value for a given station can be noted. The peak horizontal ground acceleration (PHA or PHGA) can be reached by selecting the higher individual recording, taking the [mean](#) of the two values, or calculating a [vector sum](#) of the two components. A three-component value can also be reached, by taking the vertical component into consideration also.

In seismic engineering, the effective peak acceleration (EPA, the maximum ground acceleration to which a building responds) is often used, which tends to be  $\frac{2}{3}$  –  $\frac{3}{4}$  the PGA.

Study of geographic areas combined with an assessment of historical earthquakes allows geologists to determine [seismic risk](#) and to create [seismic hazard maps](#), which show the likely PGA values to be experienced in a region during an earthquake, with a [probability of exceedance](#) (PE). [Seismic engineers](#) and government planning departments use these values to determine the appropriate [earthquake loading](#) for buildings in each zone, with key identified structures (such as hospitals, bridges, power plants) needing to survive the [maximum considered earthquake](#) (MCE).

Damage to buildings is related to both [peak ground velocity](#) (PGA) and the duration of the earthquake – the longer high-level shaking persists, the greater the likelihood of damage.

Peak ground acceleration provides a measurement of *instrumental intensity*, that is, ground shaking recorded by [seismic instruments](#). Other intensity scales measure *felt intensity*, based on eyewitness reports, felt shaking, and observed damage. There is correlation between these scales, but not always absolute agreement since experiences and damage can be affected by many other factors, including the quality of earthquake engineering.

Generally speaking,

- 0.001 g (0.01 m/s<sup>2</sup>) – perceptible by people
- 0.02 g (0.2 m/s<sup>2</sup>) – people lose their balance
- 0.50 g – very high; well-designed buildings can survive if the duration is short.

### Correlation with the Mercalli scale

The [United States Geological Survey](#) developed an Instrumental Intensity scale, which maps peak ground acceleration and peak ground velocity on an intensity scale similar to the felt [Mercalli scale](#). These values are used to create shake maps by seismologists around the world.

Instrumental Intensity	Acceleration (g)	Velocity (cm/s)	Perceived shaking	Potential damage
I	< 0.0017	< 0.1	Not felt	None
II–III	0.0017 – 0.014	0.1 – 1.1	Weak	None
IV	0.014 – 0.039	1.1 – 3.4	Light	None
V	0.039 – 0.092	3.4 – 8.1	Moderate	Very light
VI	0.092 – 0.18	8.1 – 16	Strong	Light
VII	0.18 – 0.34	16 – 31	Very strong	Moderate
VIII	0.34 – 0.65	31 – 60	Severe	Moderate to heavy
IX	0.65 – 1.24	60 – 116	Violent	Heavy
X+	> 1.24	> 116	Extreme	Very heavy

## Appendix 3 – Probability of Failure for Small Village Buildings

### Background

In the absence of quantified structural performance requirements for most South Pacific countries, the following approach is taken to the determination of an acceptable probability of failure for village buildings, within the following parameters.

### Disclaimer

Much of this content of this appendix includes reference to the current (2022) version of the Australian National Construction Code (NCC). However, it is neither suggested nor inferred that the proposed method outlined herein represents future changes to the NCC.

### Scope

Most regulated design is carried out in accordance with Standards (e.g., Australian Standards) that are referenced as deemed-to-satisfy in the relevant Building Code (e.g., Australian NCC (National Construction Code)).

New and innovative methods and designs incorporating materials, systems or forms of construction that are not covered by Building Code referenced Standards must be designed as Performance Solutions, assessed against as-yet unquantified Performance Requirements.

This Appendix provides considerations of reasonable public expectations regarding structural safety of village buildings and structures, thus providing a basis for building and structure design.

### Building Parameters

- Location: South Pacific.
- Building use: Small detached village buildings (such as houses, small community health buildings or clinics, school classrooms, and community buildings).
- Maximum design life: 25 years
- Hazard: Low degree of hazard to life and other property in case of failure.
- Building regulations: Exempted or not covered.
- Compliance monitoring: Assume minimal compliance monitoring [with regulations].
- Number of habitable storeys: Single storey
- Building shape and materials: The building may be –
  - Elevated braced timber frame superstructure, on steel posts, with timber or steel cladding and corrugated steel roof; or
  - Braced timber frame superstructure, on concrete slab-on-ground, with timber or steel cladding and corrugated steel roof; or
  - Reinforced concrete masonry superstructure, on concrete slab-on-ground, with corrugated steel roof.
- Maximum dimensions: Building dimensions shall not exceed 16.5 x 8.4 m plan dimensions (exclusive of steps and landings), 2.7 m storey height, 6.0 m maximum eaves height, 8.5 m maximum ridge height, and 35° maximum pitch.

## Principles

The following principles have been adopted in preparing this Appendix.

1. Governments set public policy regarding buildings, and minimum technical standards deemed necessary and cost effective to achieve public policy and communicates it via the relevant Building Code.
2. Buildings, structures and their components with a higher consequence of failure should present a lower risk of structural failure than other buildings, structures and components.
3. The regulated risk of structural failure of buildings, structures and their components should be material-neutral.
4. The quantified performance requirements, used herein, reflect stringency consistent with the majority of current referenced deemed-to-satisfy Standards (to the extent that is possible, given the variability from Standard to Standard).

## Minimum Performance Requirements and Related Verification Methods

There is an importance distinction to be made between quantified minimum performance requirements and the related verification methods that are used to predict compliance with those stated minimum performance requirements.

- a) If precisely expressed, quantified minimum performance requirements (e.g., probabilities of structural failure) can be absolute stated values, independent of the assumptions used for their prediction.

For example, building regulations may require buildings with particular consequence of failure to be designed and constructed such that their probability of structural failure is less than (say) 1 in 10,000 when subjected to specified permanent, imposed, wind, earthquake and/or snow actions.

However, this does not mean (or require) that the various methods available to predict compliance will necessarily yield the same level of precision.

- b) The prediction of compliance with quantified minimum performance requirements (for example, the methods of estimating the probability of structural failure) are dependent on a number of assumptions, including the assumed distribution of the design actions, assumed distribution of the resistances, the assumed variabilities of both, the assumed relationships between means and nominal values of both, the assumed analysis models and so on.

It means that quantified minimum performance requirements can be stated in mandatory terms in building regulations or non-mandatory terms in performance solutions.

Corresponding verification methods are non-mandatory deemed-to-satisfy options, each calibrated (within the range of current knowledge) to yield approximately similar levels of precision.

## Possible Metrics

### a) Maximum Acceptable Annual Probability of Structural Failure

Maximum Acceptable Annual Probability of Structural Failure of Buildings, Structures, Members and Connections is the metric used herein.

- (i) Probability of ultimate structural failure of the building or structure and its components during any year is recognizable by most technical and non-technical people as representing the risk of a building or structure collapse or partial collapse.
- (ii) Probability of ultimate structural failure is directly related to structural reliability index ( $\beta$ ), which can be determined reasonably easily by experts, regulators and Standards writers.
- (iii) Probability expressed in the format of 1 in ... is more easily understood by most people than probability expressed as a decimal or in scientific format.

For example, "... not greater than 1 in 10,000 ..." is more easily understood by most people than "... not greater than 0.0001 ..." or "... not greater than  $10^{-4}$  ..."

- (iv) Other (non-structural) NCC performance requirements, which are likely to be quantified (e.g., fire resistance, egress, weatherproofing, scalding, sound attenuation etc.) can also be expressed as a "probability of ... failure".

### b) Minimum Structural Reliability Index ( $\beta$ )

Although structural reliability index ( $\beta$ ) is understood well by structural experts, it is not well understood by other designers, who may have difficulty in associating it quantitatively with either the probability of failure or probability of fatalities.

### c) Maximum Acceptable Probability of Serviceability Failure

The referenced structural ACMs (Acceptable Construction Manuals), including AS/NZS 1170, AS 4100, AS 3600, AS 3700, AS/NZS 4600, AS 1720.1, AS 1684 etc., provide for both the ultimate limit state and serviceability limit states (commonly based on deflection limits).

Thus, designs based on these Standards are in some circumstances controlled by deflection limits rather than strength limits. For example, suspended concrete slab thickness may be dictated by deflection limits. Although the deemed-to-satisfy Standards deal with serviceability, it has not been specifically identified in building regulations as a performance requirement.

### d) Maximum Acceptable Probability of Fatalities

Probability of fatalities is clearly a health and safety issue, and it is therefore a logical candidate as the metric.

The stringency implicit in the referenced Standards is a product of several considerations, including such as property damage and serviceability.

The adoption of probability of fatalities (based on historical data) as the sole building code structural performance metric would therefore represent a significant reduction in stringency.

Notwithstanding, the probability of fatalities is used as the metric for Tolerable Risk analyses, which may be used to check the reasonableness of the relevant Building Code

#### e) Maximum Acceptable Probability of Injury (or Harm)

Probability of injury (or harm) is not a criterion upon which the building codes are based.

Furthermore, the ABCB “Tolerable Risk Handbook” states: “..... *this introduces problems associated with the degree of injury and comparability between different types of injury (e.g., long-term exposure to a health hazard compared to injuries sustained from an event such as a fall).*”

Probability of injury (or harm) is not considered further in this Appendix.

#### Actions that must be considered

The following is based substantially on the Australian National Construction Code:

*The actions to be considered to satisfy (a) include but are not limited to—*

- a) permanent actions (dead loads) including, for a Class 7b building an additional notional permanent roof load of not less than 0.15 kPa to support solar voltaic panels; and*
- b) imposed actions (live loads arising from occupancy and use); and*
- c) wind action; and*
- d) earthquake action; and*
- e) snow action; and*
- f) liquid pressure action; and*
- g) ground water action; and*
- h) rainwater action (including ponding action); and*
- i) earth pressure action; and*
- j) differential movement; and*
- k) time dependent effects (including creep and shrinkage); and*
- l) thermal effects; and*
- m) ground movement caused by—*
  - a. swelling, shrinkage or freezing of the subsoil; and*
  - b. landslip or subsidence; and*
  - c. siteworks associated with the building or structure; and*
- n) construction activity actions;*
- o) termite actions;*
- p) fire (The requirement to resist the structural actions of fire are elsewhere in the NCC).*

## Features of structures that affect the risk to life

There are several different considerations that affect the quantified structural performance requirements.

- 1) The risk to life is affected by different structure uses (e.g., farm shed Vs multi-storey buildings .... catered for by Importance Level)
- 2) The risk to life is affected by different component types (e.g., whole buildings Vs loadbearing columns Vs roofing screws)
- 3) The risk to life is affected by the ability of the structure and its components to deform in a ductile manner allowing loads and moments to redistribute (e.g., plastic design)
- 4) The risk to life is affected by the ability of the structure and its components to share load amongst various load paths (e.g., multiple posts Vs a single column)
- 5) The risk to life is affected by the ability of the structure to deflect and/or crack such as to provide a timely clear warning of impending catastrophic collapse and provide there is insufficient time to evacuate. It is influenced by “load paths” and “ductility”, but is different from them.

## Differing structure uses

Do structures with uses exhibiting differing risk to life (differing Importance Levels e.g., farm sheds Vs multi-story buildings) warrant different performance requirements?

### Australian Building Code Importance Levels

Four Importance Levels are defined in NCC 2025 for use with structural design and construction that is deemed -to-satisfy in accordance with referenced Standards. These are used to define differing structural performance requirements.

**NCC 2025 Table B1P1d – Importance Levels of buildings and structures**

Importance Level	Building Types
1	Buildings or structures presenting a low degree of hazard to life and <i>other property</i> in the case of failure.
2	Buildings or structures not included in Importance Levels 1, 3 and 4.
3	Buildings or structures that are designed to contain a large number of people.
4	Buildings or structures that are essential to post-disaster recovery or associated with hazardous facilities.

### AS 5104:2017 Consequence Classes

Consequence Classes for structures are defined in AS 5104:2017 – Appendix F, Table F1. <sup>1</sup> Although there is no direct correlation between NCC 2019 Importance Levels and AS 5104:2017 Consequence Classes, the following relationship is considered to be closest to the intent of both.

NCC 2019 Importance Level	AS 5104:2017 Consequence Classes
1	1
1	2
2	3
3	4
4	5

<sup>1</sup> Refer to Appendix 5, Importance Levels.

Some comparison values are available in AS 5104:2017 – Appendix G. There is a general level of consistency with the top row, except for a reduced value used for Importance Level 4.

Relative cost of safety measure	Consequences of failure (classes from Table E1)		
	Class 2	Class 3	Class 4
Large	$\beta = 3,1 (P_f \approx 10^{-3})$	$\beta = 3,3 (P_f \approx 5 \times 10^{-4})$	$\beta = 3,7 (P_f \approx 10^{-4})$
Medium	$\beta = 3,7 (P_f \approx 10^{-4})$	$\beta = 4,2 (P_f \approx 10^{-5})$	$\beta = 4,4 (P_f \approx 5 \times 10^{-6})$
Small	$\beta = 4,2 (P_f \approx 10^{-5})$	$\beta = 4,4 (P_f \approx 5 \times 10^{-6})$	$\beta = 4,7 (P_f \approx 10^{-6})$

### Differing resistance to collapse

Do structures offering differing resistance to collapse (e.g., load-bearing columns Vs roofing screws) warrant different performance requirements?

A building may consist of loadbearing elements (such as columns upon which the stability of the whole building depends) and non-loadbearing elements (such as cladding panels that has minimal effect on the stability of the building or the safety of its occupants).

It is considered that structural performance requirements should differentiate between the performance requirements of:

- Substantive parts of a building or structure;
- Members and connections that provide primary building support; and
- Members and connections that do not provide primary building support.

### Differing modes of failure

Do structures exhibiting differing mode of failure (e.g. sudden failure Vs gradual failure) warrant different performance requirements?

The risk to life by building or structure collapse (or partial collapse) increases if the collapse occurs suddenly and without warning. Such sudden collapse could occur due to the use of brittle materials, buckling due to compression or combined bending and compression, fatigue failure and bearing failure of supporting foundations.

Conversely, if ultimate failure is gradual and predictable, people have increased change to evacuate affected buildings and structures. Such gradual failure occurs when there is significant and noticeable deformation of a member without loss of strength to resist design actions, including (but not limited to) ductile failure, soil settlement and creep failure.

It is considered that structural performance requirements should differentiate between sudden and gradual collapse.

### Differing load sharing and resistance paths

Do structures with multiple resistance paths to resist forces that could cause collapse warrant different performance requirements?

The terms “single resistance paths” and “multiple resistance paths” have been introduced to reflect two alternative design strategies; viz.

- Single Resistance Paths occur in designs where a single member or connection (acting alone) is intended to support a significant part of the building or structure.

- Multiple Resistance Paths occur in designs where multiple members or connections (acting together) are intended to support a significant part of the building or structure, such that the failure of any member or connection will result in the transfer of loads to the other members and connections with sufficient combined capacity to resist the total applied loads.

For purposes of this Appendix, it is important to understand that these are design strategies. For example:

- a) A single column designed to support a square slab (as shown) would require the stringency associated with a single resistance path.
- b) Each of four columns designed to support a square slab (as shown) would require the stringency associated with a single resistance path. Notwithstanding, if one failed, the other three might have sufficient combined capacity prevent collapse.
- c) Each of nine columns designed to a square slab (as shown) would only require the stringency associated with multiple resistance paths, provided eight acting together have sufficient combined capacity and plasticity to prevent collapse.



It is considered that structural performance requirements should differentiate between single and multiple resistance load paths.

### Gradual Vs Sudden

Do structures that provide “timely warning of impending catastrophic collapse and time to evacuate” warrant different performance requirements?

Risk to life increases if a structure exhibits no timely clear warning of impending catastrophic collapse and if there is insufficient time to evacuate. Warnings of impending collapse may include the appearance of cracks and/or excessive movement.

While structural engineers (particularly those involved in the design of steel and reinforced concrete structures) are very familiar with the concept of ductility and ductile structures, the term may not be broad enough to encompass all of the failure mechanisms that delay and provide warning of catastrophic collapse.

Quantified NCC Structural Performance Requirements must cover all structures that are within the scope of the NCC, including Class 10b structures “.....*fence, mast, antenna, retaining wall or freestanding wall, or swimming pool or the like.*”

While metal structures (e.g., steel, aluminium etc.) and structures incorporating steel (e.g., reinforced concrete reinforced masonry etc.) are commonly classified as either ductile or brittle (for reasons of load and moment redistribution), that notion is not immediately obvious for some critical parts of structures, such as the foundations.

Most structures (including Class 10b) rely on footings supported on, or anchors fixed in, soil (or rock) foundations. Such foundations may fail either gradually or suddenly, although geotech engineers would not use the words “ductile” or “brittle” to describe such soil failures. “Ductility” is a term most common to metals (or products such as concrete with metal reinforcement). However, in geology it has a quite different meaning, and does not adequately describe the slow settlement of retaining wall foundations that may precede collapse, or gradual pull-out of mast anchors. Both (if applicable) could delay and warn of catastrophic collapse.

Although it is not a requirement of the NCC, it is considered appropriate for structural performance analysis to differentiate between ductile and brittle structures.

## Do different design actions warrant different performance requirements?

This question arises from the notion that the public would be more accepting of injury or death resulting from one type action than from another. (e.g., Injury or death resulting from permanent and imposed loads may be less acceptable than injury or death occurring due to wind, cyclonic wind or earthquake).

However, the question of number of people at risk is covered by “importance”, the nature of any failure is covered by “sudden / gradual” and the number of structural redundancies is covered by “load paths”.

The fact the wind, cyclone, earthquake and snow are transient (while permanent and imposed actions are not) is a question for the verification methods and deemed-to-satisfy Standards, not for the statement of performance requirements.

It is considered that structural performance requirements should not differentiate between different loads, although transient and non-transient actions must both be accommodated in any verification method and in any deemed-to-satisfy solution.

## Limits on Probability of Ultimate Structural Failure

The following Limits on Probability of Ultimate Structural Failure are adopted in this manual.

*A building or structure, during construction and use, with appropriate degrees of reliability as specified in the following table, must—*

- (i) perform adequately under all reasonably expected design actions; and*
- (ii) withstand extreme or frequently repeated design actions; and*
- (iii) be designed to sustain local damage, with the structural system as a whole remaining stable and not being damaged to an extent disproportionate to the original local damage; and*
- (iv) avoid causing damage to other properties, by resisting the actions to which it may reasonably expect to be subjected.*

## Structural Performance Requirements specified in NCC 2025

Minimum Acceptable Structural Reliability Index, $\beta$ ,						
	Action	Ancillary Components	Structure Importance Level			
			1	2	3	4
Table B1P1a	Gravity loads only	4.30	4.30	4.30	4.30	4.30
Table B1P1b	Gravity loads combined with other loads	3.45	3.45	3.70	3.85	4.00
Table B1P1c	Action reversal and stability for gravity loads combined with other loads	3.00	3.00	3.35	3.55	3.65

## Corresponding Notional Probabilities of Failure in NCC 2025

Maximum Acceptable Annual Probability of Structural Failure 1 in ....						
	Action	Ancillary Components	Structure Importance Level			
			1	2	3	4
Table B1P1d	Gravity loads only	117,000	117,000	117,000	117,000	117,000
	Gravity loads combined with other loads	3,500	3,500	9,200	16,900	31,500
	Action reversal and stability for gravity loads combined with other loads	700	700	2,400	5,100	7,600

Comments:

- (a) The values in NCC 2025 Tables B1P1a, B1P1b and B1P1c are reliability-based, accounting for uncertainties in design parameters (actions [from loads] and material properties), but excluding accidents and gross human errors.
- (b) The values in NCC 2025 Tables B1P1a, B1P1b and B1P1c are minimum acceptable structural reliability indices ( $\beta$ ).
- (c) The values in NCC 2025 Table B1P1d are the corresponding maximum acceptable notional annual probabilities of failure (expressed as '1 in ....').
- (d) In both cases, the tabulated values are not target values. Because materials, structural behaviour and design actions are variable, practical designs must aim for target values of reliability, which should be more conservative (safer) than these values.
- (e) Larger structural reliability indices ( $\beta$ ) represent more conservative (safer) designs than smaller numbers. For example, an Importance Level 4 building with a minimum acceptable  $\beta = 4.00$  (annual probability of failure of 1 in 31,500) is more conservative (safer) than an Importance Level 2 building with a minimum acceptable  $\beta = 3.70$  (annual probability of failure of 1 in 9,200).
- (f) Designers must also consider other design criteria (such as general serviceability, deflection, cracking etc.). These criteria should override the specified structural reliability criteria if they dictate a more conservative design. That is, serviceability considerations may dictate stringency greater than the requirements of Tables B1P1.
- (g) The values in Table B1P1b represent the most common design situation, where gravity actions (resulting from permanent loads with or without imposed loads) act together with wind, cyclonic wind, earthquake and/or snow loads. Other actions, such as might result from tsunamis, are not specifically excluded, although guidance is not given regarding the characteristic and variability to be used.
- (h) The values in Table B1P1a are more conservative than Table B1P1b, reflecting the fact the failures due to gravity actions (from permanent loads with or without imposed loads) acting alone are generally more unpredictable, sudden and more catastrophic than when transient loads are also involved and failure is generally (but not always) preceded with some indication of imminent failure.
- (i) The values in Table B1P1c than Table B1P1b are less conservative, reflecting the fact that failures due to load reversals (such as wind uplift) are generally less catastrophic. Stability failures are also included in this table, reflecting the fact that stability failure (collapse) generally (but not always) involves the progressive failure of several components (i.e. overcoming structural redundancies). Caution using these assumptions and values is suggested.
- (j) The notes included with Tables B1P1a, B1P1b and B1P1c provide for lower minimum acceptable structure reliability indices ( $\beta$ ) for ancillary components (i.e. those items that are not part of the building structure), irrespective of the building in which they are located. For example, the failure of the fixings of a wall mounted air conditioner (perhaps) represents a similar risk to life irrespective of whether it is located in a farm shed, a house or a hospital. Caution using these assumptions and values is suggested in this case.
- (k) If the structural failure of buildings, structures, members or connections is sudden, without providing timely clear warning of impending catastrophic collapse and without sufficient time to evacuate, failure should be treated as brittle and more conservatism should be applied to the design.

## Definitions

For purposes of this document, the following definitions are suggested.

**Maximum Acceptable Annual Probability of Structural Failure of Structures, Buildings, Members and Connections** – The probability that, in any year, there could be a structural failure leading to collapse of either the whole of the structure or building, or significant members and/or their connections. It is expressed as 1 in .... (e.g. 1 in 1,000 meaning a probability of 1 in 1,000 that the failure could occur).

**Minimum Acceptable Annual Structural Reliability Index of Structures, Buildings, Members and Connections** – The Structural Reliability Index ( $\beta$ ), determined in accordance with the ABCB Structural Reliability Handbook (Version 2022.1) that corresponds to the Maximum Acceptable Annual Probability of Structural Failure.

**Substantive parts of a building or structure** – Those parts of a building or other structure that serve the purpose for which the building or structure has been constructed. They include (but are not limited to) –

- (i) The whole of a building or structure; and
- (ii) Any significant portion of a building or structure (such as habitable or non-habitable storey, a roof system, a floor system, a system of loadbearing walls and the like) which could result in loss of life or injury should it fail.

**Members and connections that provide primary building support** – Those components of a building or other structure that provide the structural system resisting collapse of other members, parts of the building or the whole building under the design actions. They include (but are not limited to) –

- (i) Beams, columns, trusses, portal frames, posts, loadbearing walls, floor systems, footings, foundations and earth retaining structures; and
- (ii) Connections and fixings that transfer loads between members that provide primary building support.

**Members and connections that do not provide primary building support** – Those components of a building or other structure that are not necessary to resist collapse of other members, parts of the building or the whole building. They include (but are not limited to) –

- (i) Non-loadbearing walls including framing, wall cladding, roof cladding, roof purlins and battens, mezzanine floors; and
- (ii) Connections and fixings that fix in position only those members that do not provide primary building support.

**Members** – The parts of a structure or component that provide resistance to structural actions.

**Connections** – The parts that fix the members into the structure, through which the loads pass.

**Non-transient actions** – The combination of structural actions in which the combined magnitude of the permanent gravity action and imposed gravity action is equal to or greater than 50% of the magnitude of the total combined actions.

**Transient actions** – The combination of structural actions in which the combined magnitude of the permanent gravity action and imposed gravity action is less than 50% of the magnitude of the total combined actions.

**Importance Level** – A number which ranks the relative importance of structures and buildings, based on the potential risk to life resulting from their scale and/or use.

<b>Importance level</b>	<b>Comment</b>	<b>Examples</b>
1	Structures presenting a low degree of hazard to life and other property	<ul style="list-style-type: none"> <li>a) Structures with a total floor area &lt; 30 m<sup>2</sup></li> <li>b) Farm buildings, isolated structures, towers in rural situations</li> <li>c) Fences, masts, walls, in-ground swimming pools</li> </ul>
2	Normal structures and structures not in other importance levels	<ul style="list-style-type: none"> <li>a) Buildings not included in Importance Levels 1, 3 or 4</li> <li>b) Single family dwellings</li> <li>c) Car parking buildings</li> </ul>
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	<p>Buildings and facilities as follow:</p> <ul style="list-style-type: none"> <li>a) Where more than 300 people can congregate in one area</li> <li>b) Day care facilities with a capacity greater than 150</li> <li>c) Primary school or secondary school facilities with a capacity greater than 250</li> <li>d) Colleges or adult education facilities with a capacity greater than 500</li> <li>e) Health care facilities with a capacity of 50 or more residents</li> <li>f) Airport terminals, principal railway stations with a capacity greater than 250</li> <li>g) Correctional institutions</li> <li>h) Multi-occupancy residential, commercial (including shops), industrial, office and retailing buildings designed to accommodate more than 5000 people and with a gross area greater than 10,000 m<sup>2</sup></li> <li>i) Public assembly buildings, theatres and cinemas of greater than 1,000 m<sup>2</sup></li> <li>j) Emergency medical and other emergency facilities not</li> <li>k) designated as post-disaster.</li> <li>l) Power-generating facilities, water treatment and waste-water treatment facilities and other public utilities not designated as post-disaster.</li> <li>m) Buildings and facilities not designated as post-disaster containing hazardous materials capable of causing hazardous conditions that do not extend beyond the property boundaries.</li> </ul>
4	Structures with special post- disaster functions	<ul style="list-style-type: none"> <li>a) Buildings and facilities designated as essential facilities. Buildings and facilities with special post-disaster functions. Medical emergency or surgical facilities.</li> <li>b) Emergency service facilities such as fire, police stations and emergency vehicle garages.</li> <li>c) Utilities or emergency supplies or installations required as backup for buildings and facilities of Importance Level 4.</li> <li>d) Designated emergency shelters, designated emergency centres and ancillary facilities.</li> <li>e) Buildings and facilities containing hazardous materials capable of causing hazardous conditions that extend beyond the property boundaries.</li> </ul>

**Brittle Failure** – Loss of strength to resist design actions without first undergoing significant deformation. For purposes of the Performance Requirements, this may be taken to include (but not limited to) buckling, fatigue failure and soil bearing failure.

**Ductile Failure** – Significant deformation of a member without loss of strength to resist design actions. For purposes of the Performance Requirements, this may be taken to include (but not limited to) soil settlement and creep failure.

**Fatigue failure** – Fracture of a material through progressive brittle cracking under repeated alternating or cyclic stresses of an intensity considerably less than strength under static load.

**Sudden failure** – Relatively rapid collapse of a structure that occurs with little warning with little plastic deformation and/or moment redistribution.

**Gradual failure** – Relatively slow collapse of a structure that occurs through significant plastic deformation and/or moment redistribution.

**Single Resistance Paths** – Situations where the failure of a part of a building or structure is resisted by only one member or connection, such that the failure of that member or connection will result in the collapse of a significant part of the building or structure.

**Multiple Resistance Paths** – Situations where the failure of a part of a building or structure is resisted collectively by more than one member or connection, such that the failure of any member or connection will result in the transfer of loads to the other members and connections with sufficient combined capacity to resist the total applied loads.

#### **Verification Method for Structural Reliability**

The following Verification Method for Structural Reliability is based on the draft Australian National Construction Code, NCC 2022 (scheduled for introduction 1 May 2026). There are some modifications to the format of the formulae, but the outcome remains unchanged.

#### B1V1 Structural reliability

- 1) This Verification Method is applicable to components with a resistance coefficient of variation of not more than 40%.
- 2) When the calculated resistance coefficient of variation is less than 10%, then a minimum value of 10% must be used.
- 3) Annual action models must be determined for all reasonably expected actions and combinations in accordance with Table B1V1a.
- 4) Compliance with B1P1(2) is verified for the design of component when—
  - a) the calculated reliability index  $\beta$  is not less than the applicable required values.
  - b) the reliability index  $\beta$  is calculated in accordance with the equation:

$$\beta = \ln \left[ \left( R_m / S_m \right) \cdot \left( C_S / C_R \right)^{0.5} \right] / \left[ \ln \left( C_S / C_R \right) \right]^{0.5}$$

where –

(i)  $C_R = 1 + V_R^2$

(ii)  $C_S = 1 + V_S^2$

(A)  $R_m$  = mean resistance

(B)  $S_m$  = mean action

(C)  $V_S$  = coefficient of variation of the action

(D)  $V_R$  = coefficient of variation of the resistance

(iii) Where to load action  $s$  is due to the combination of multiple structural actions –

(A)  $S = S_1 + S_2 + \dots + S_n$

(B) the mean of the combined load action is calculated in accordance with the equation:

$$S_m = S_{1m} + S_{2m} + \dots + S_{nm}, \text{ where } S_{im} \text{ is the mean of the } i^{\text{th}} \text{ action } S_i; \text{ and}$$

(C) the standard deviation of the combined load action is calculated in accordance with the equation:

$$\sigma_s^2 = \sigma_{s1}^2 + \sigma_{s2}^2 + \dots + \sigma_{sn}^2, \text{ where } \sigma_{si} \text{ is the mean of the } i^{\text{th}} \text{ action } S_i; \text{ and}$$

(D) the coefficient of variation of the combined action  $S$  is calculated in accordance with the equation  $V_s = \sigma_s / S_m$

Table B1V1 – Annual Action Models

Design action	Ratio of mean action to nominal	Coefficient of variation of the action
Permanent action	1.05	0.10
Annual maximum imposed action	0.35	0.45
Arbitrary-point-in-time imposed action	0.25	0.78
Wind (non-cyclonic regions, Importance Level 1)	0.37	0.47
Wind (non-cyclonic regions, Importance Level 2)	0.31	0.47
Wind (non-cyclonic regions, Importance Level 3)	0.29	0.47
Wind (non-cyclonic regions, Importance Level 4)	0.27	0.47
Wind (cyclonic regions, Importance Level 1)	0.19	0.76
Wind (cyclonic regions, Importance Level 2)	0.16	0.76
Wind (cyclonic regions, Importance Level 3)	0.14	0.76
Wind (cyclonic regions, Importance Level 4)	0.13	0.76
Earthquake (Importance Level 1)	0.28	0.90
Earthquake (Importance Level 2)	0.15	0.90
Earthquake (Importance Level 3)	0.12	0.90
Earthquake (Importance Level 4)	0.084	0.90
Snow	0.29	0.57

### Recommended approach to determining resistance model and coefficients of variation

The resistance model and coefficients of variation for building components must be established by taking into account variability due to material properties, fabrication and construction process and structural modelling. This should be determined by a comprehensive testing program whenever practical.

The coefficients of variation used to determine the structural reliability index should be the greater of–

- (i) values determined by comprehensive testing; and
- (ii) 0.2 for members and connections subject to gradual failure (including ductile failure) or 0.3 for members and connections subject to sudden failure (including brittle failure).