Overhead Line Designer's Forum 2021 – South Island

Seismic Design

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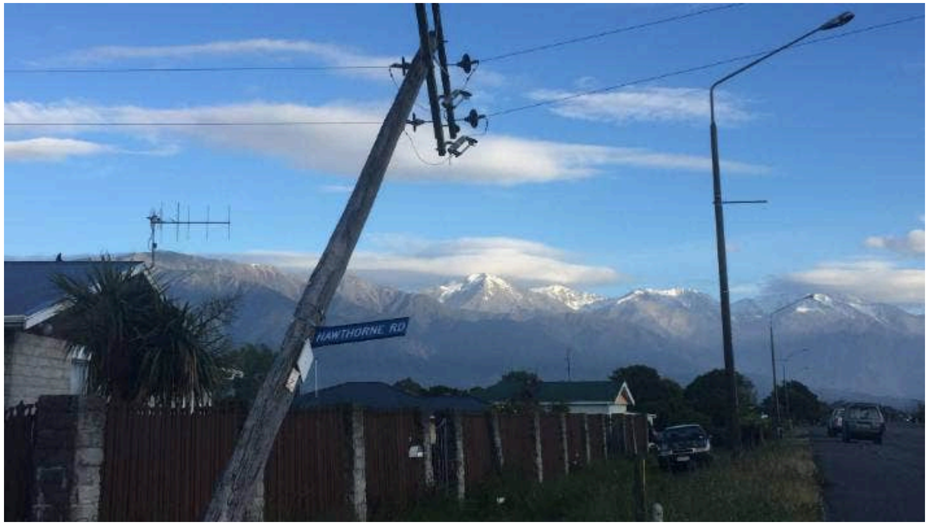
Overview of Presentation

- Real world examples
- Discussion on Seismic portion of Overhead Line Design
- Background to Seismic Code
- Overview of Seismic Code
- Parts and Components
- HB331 - Example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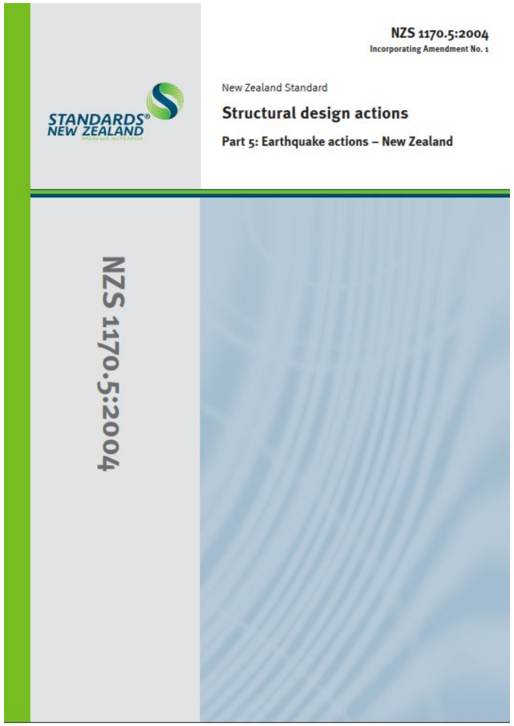
Seismic portion of Overhead Line Design

- AS/NZS 7000 Appendix C: Special Forces has a section on Earthquakes
- “Wind loadings are usually the main determining factor in the design of overhead line towers”
- Conductors essentially don’t influence the design (but include their mass)
- Conductors can be considered a linear spring, not worth it for distribution.
- Number of methods to assess but simple Equivalent Static force method is best.
- Liquification: have to build infrastructure everywhere hard to avoid. Consider serviceability.

New Zealand’s Seismic Code

- NZ loading code AS/NZS 1170
- Part 5 is Seismic and is NZ specific
- Based on research of fault lines and probabilities.
- Separate commentary



NZS 1170.5:2004
Incorporating Amendment No. 1

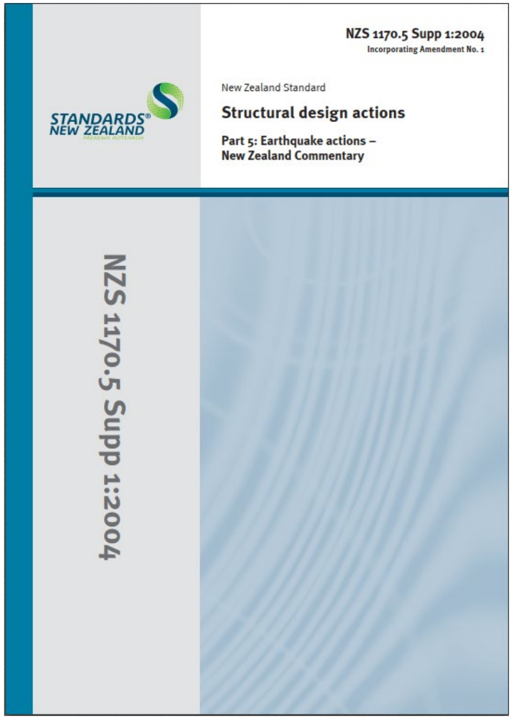
STANDARDS NEW ZEALAND

New Zealand Standard

Structural design actions

Part 5: Earthquake actions – New Zealand

NZS 1170.5:2004



NZS 1170.5 Supp 1:2004
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STANDARDS NEW ZEALAND

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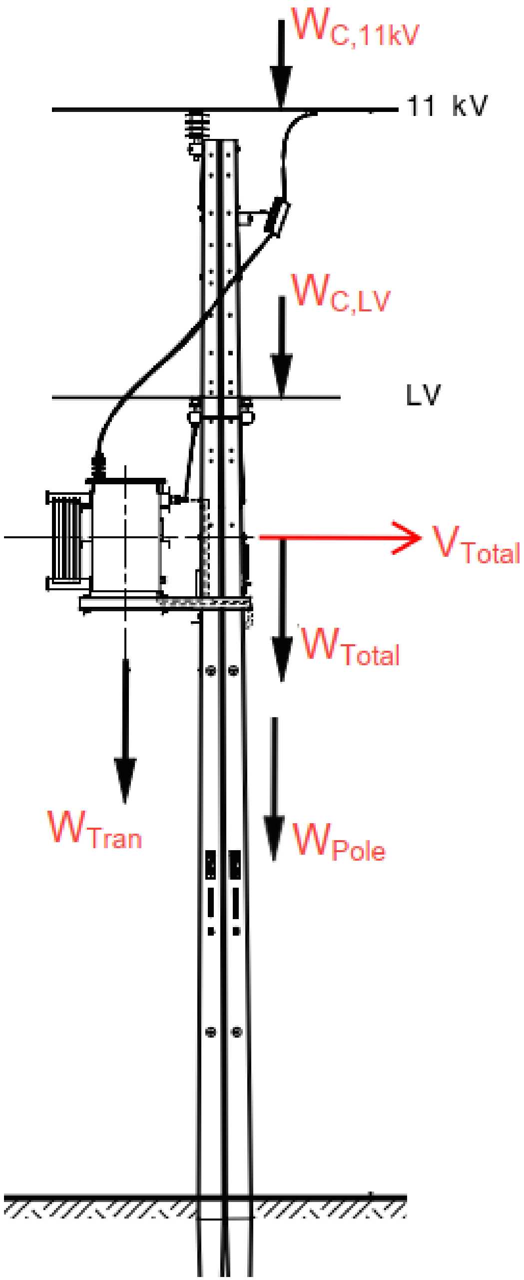
Structural design actions

**Part 5: Earthquake actions –
New Zealand Commentary**

NZS 1170.5 Supp 1:2004


$W_{C,11kV}$
11 kV
$W_{C,LV}$
LV
V_{Total}
W_{Total}
W_{Tran}
W_{Pole}

Development of the Code

- Seismic force proportional to the weight
- Code is a method to develop the co -efficient.
- Period of the structure is important

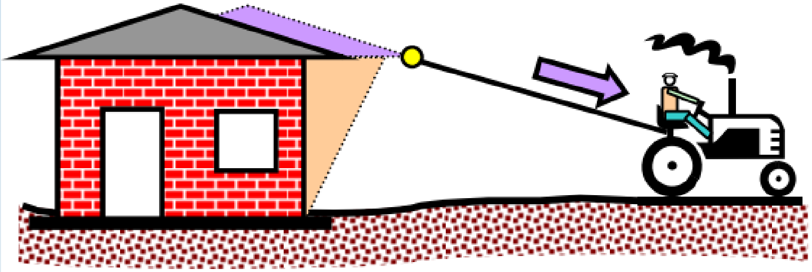
$$V = C_{\mathrm{d}}(T_1)W_{\mathrm{t}}$$

$$C(T) = C_{\mathrm{h}}(T)\ Z\ R\ N(T,D)$$

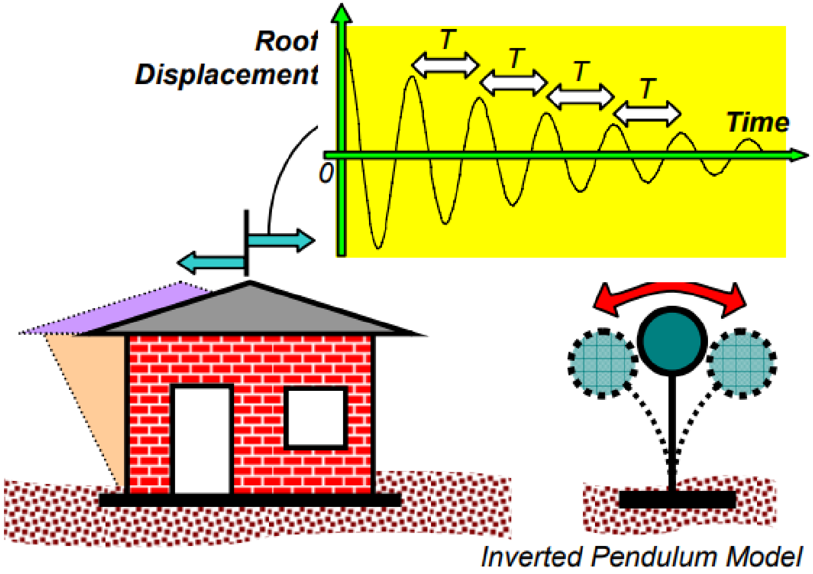
$$C_{\mathrm{d}}(T_1) = \frac{C(T_1)S_p}{k_\mu}$$

$$C(T) = C_h(T)\, Z\, R\, N(T,D)$$

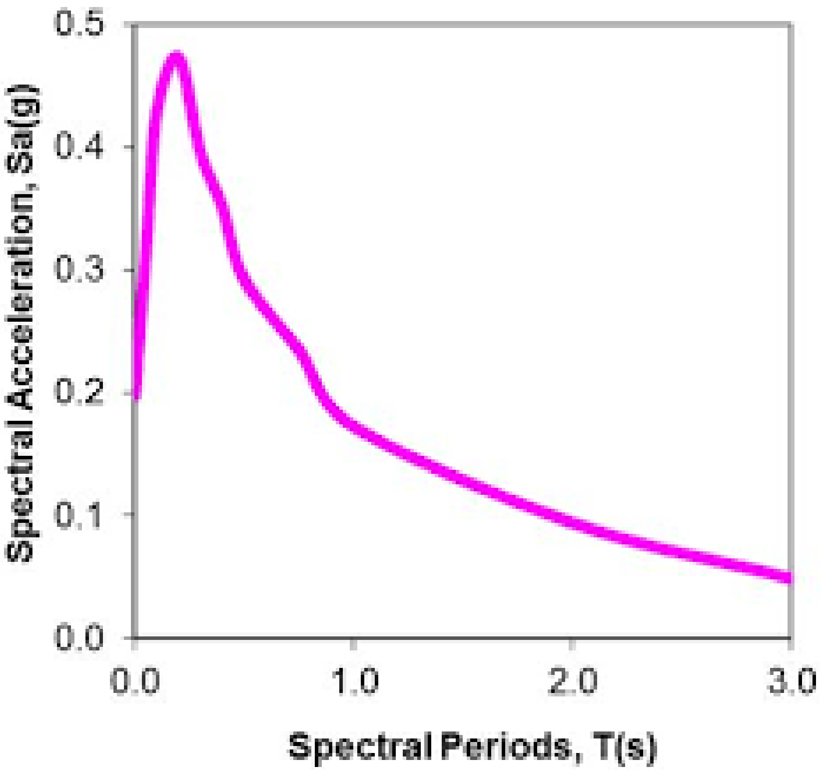
- $C_h(T)$ – Spectral Shape
- Dependent on the soil type and period



(a) Building pulled with a rope tied at its roof



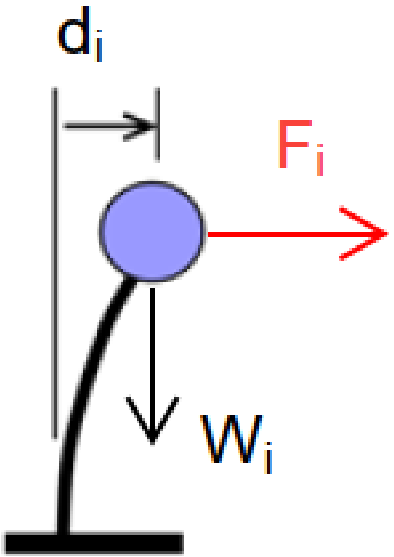
(b) Oscillation of building on cutting the rope



$$C(T) = C_h(T)\, Z\, R\, N(T,D)$$

- $C_h(T)$ – Spectral Shape
- Dependent on the soil type and period

$$T_1 = 2\pi \sqrt{\frac{\sum_{i=1}^{n} \left(W_i d_i^{\,2}\right)}{g \sum_{i=1}^{n} \left(F_i d_i\right)}}$$



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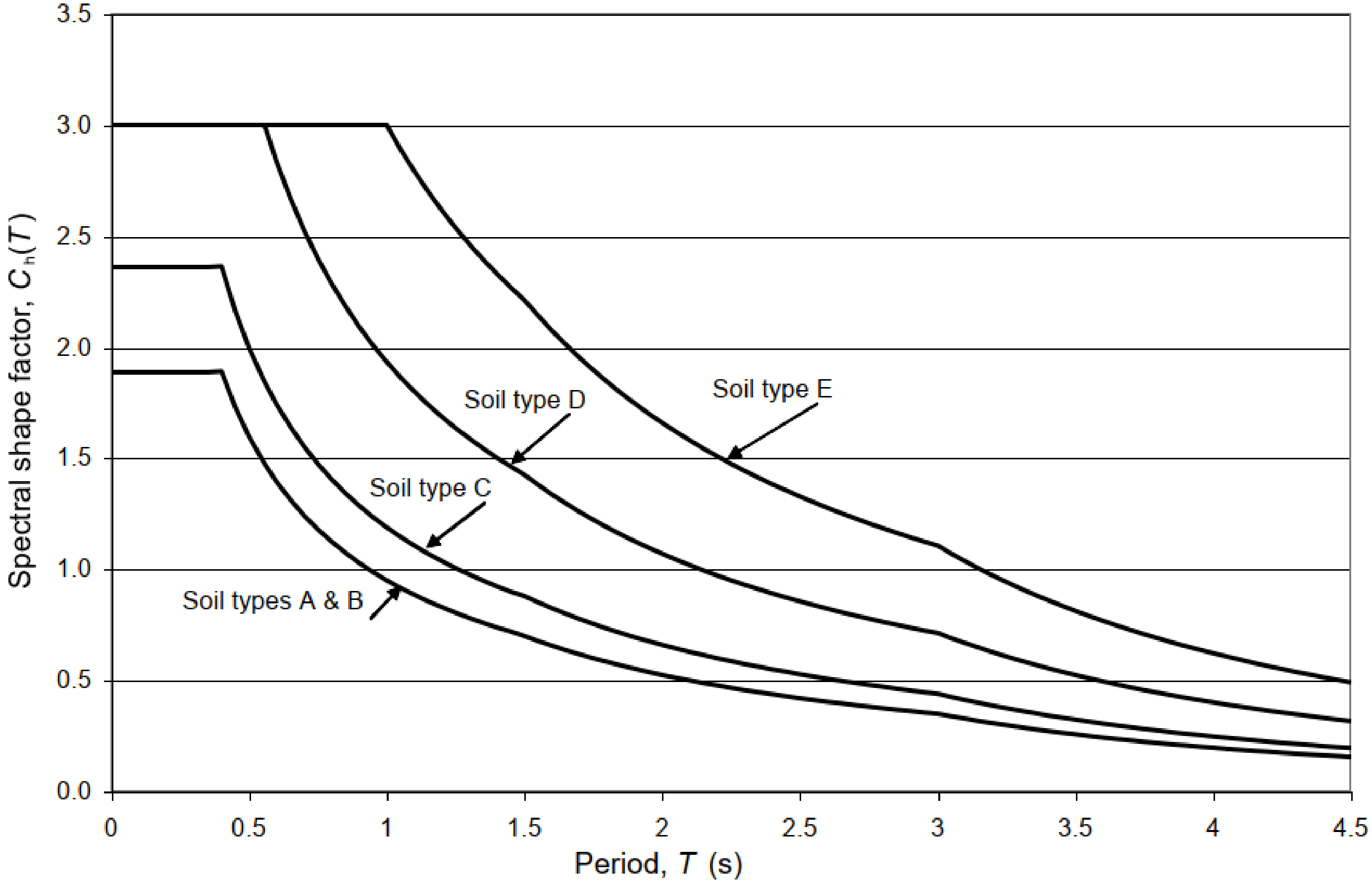


$$C(T) = C_h(T)\,Z\,R\,N(T,D)$$

- $C_h(T)$ – Spectral Shape
- A and B rock
- C, D and E soft

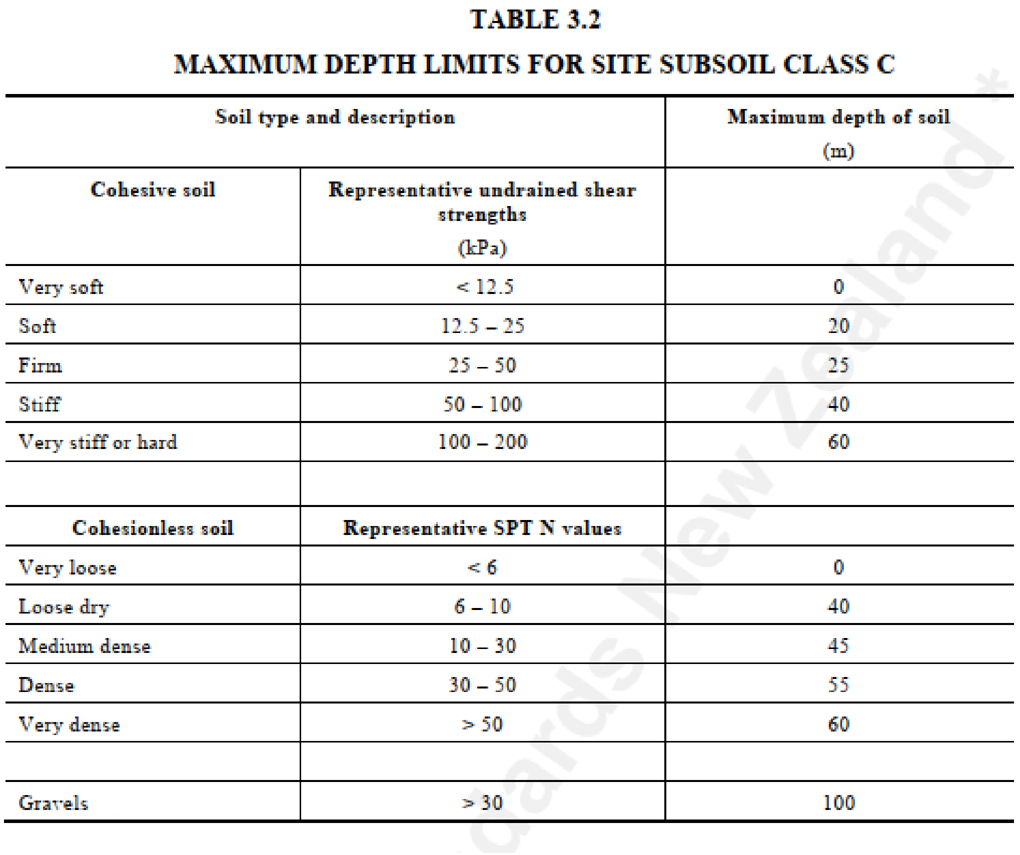


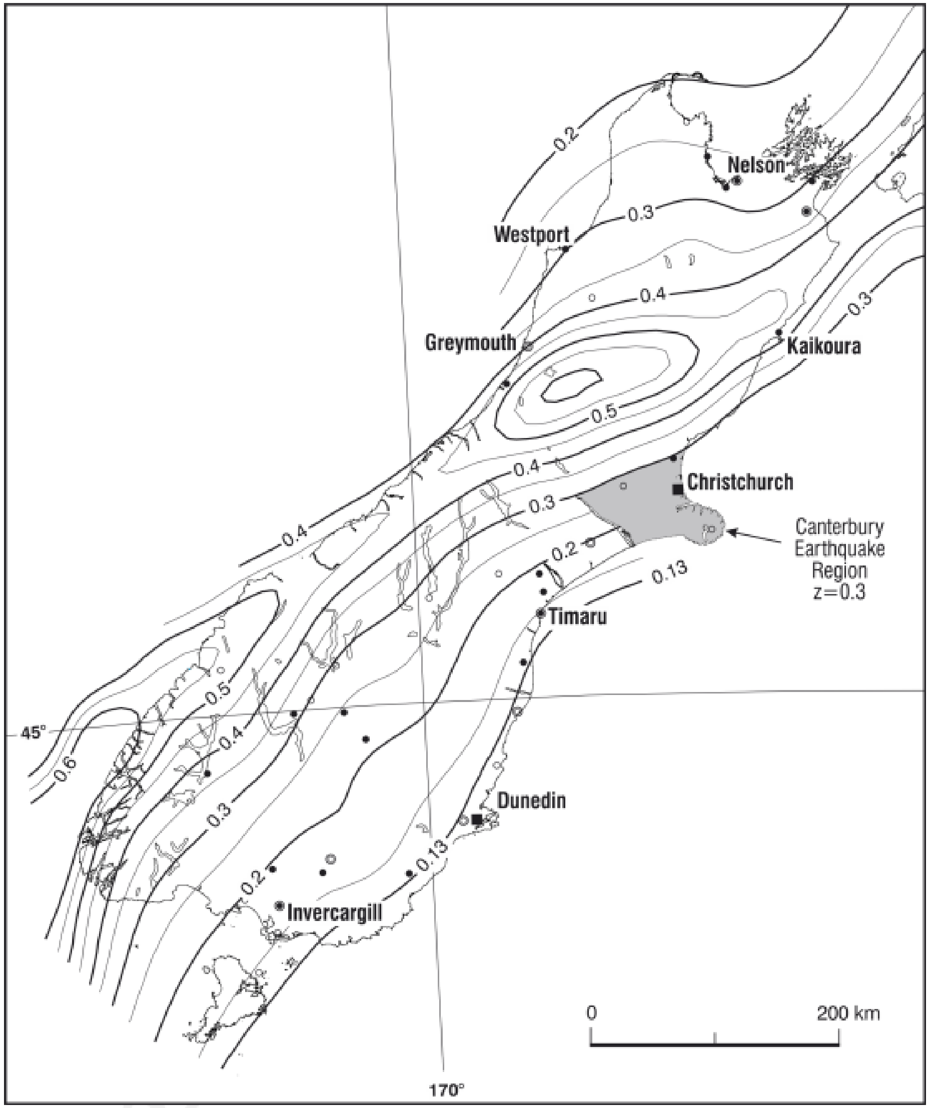
TABLE 3.2

MAXIMUM DEPTH LIMITS FOR SITE SUBSOIL CLASS C

Soil type and description		**Maximum depth of soil** (m)
Cohesive soil	**Representative undrained shear strengths** (kPa)	
Very soft	< 12.5	0
Soft	12.5 – 25	20
Firm	25 – 50	25
Stiff	50 – 100	40
Very stiff or hard	100 – 200	60
Cohesionless soil	**Representative SPT N values**	
Very loose	< 6	0
Loose dry	6 – 10	40
Medium dense	10 – 30	45
Dense	30 – 50	55
Very dense	> 50	60
Gravels	> 30	100

$$C(T) = C_h(T)\ Z\ R\ N(T,D)$$

- Z – Hazard Factor
- Location, how close to a fault line and likelihood of the fault rupturing and severity of rupture



$$C(T) \quad = \quad C_h(T)\, Z\, R\, N(T,D)$$

- R – Return period
- Importance level and design life
- Given in AS/NZS 7000 Table 6.1

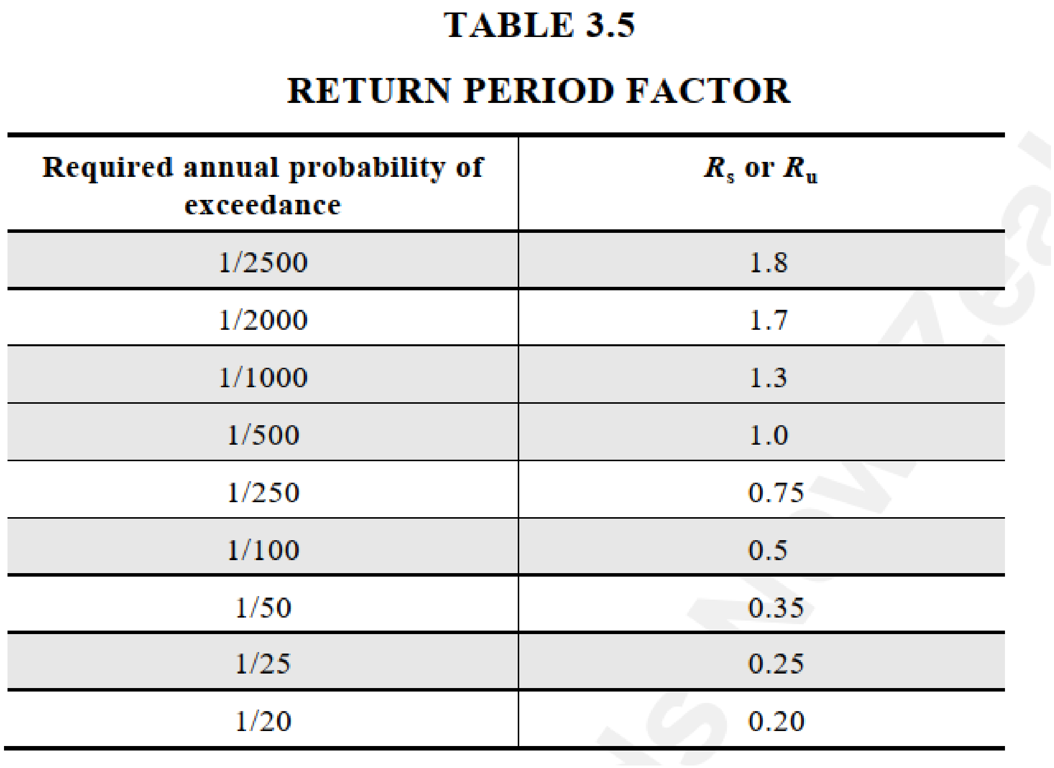


TABLE 3.5

RETURN PERIOD FACTOR

Required annual probability of exceedance	R_s or R_u
1/2500	1.8
1/2000	1.7
1/1000	1.3
1/500	1.0
1/250	0.75
1/100	0.5
1/50	0.35
1/25	0.25
1/20	0.20

$$C(T) = C_h(T)\, Z\, R\, N(T,D)$$

- R – Return period
- ULS vs SLS

$$C(T) = C_h(T)\ Z\ R\ N(T,D)$$

- R – Return period

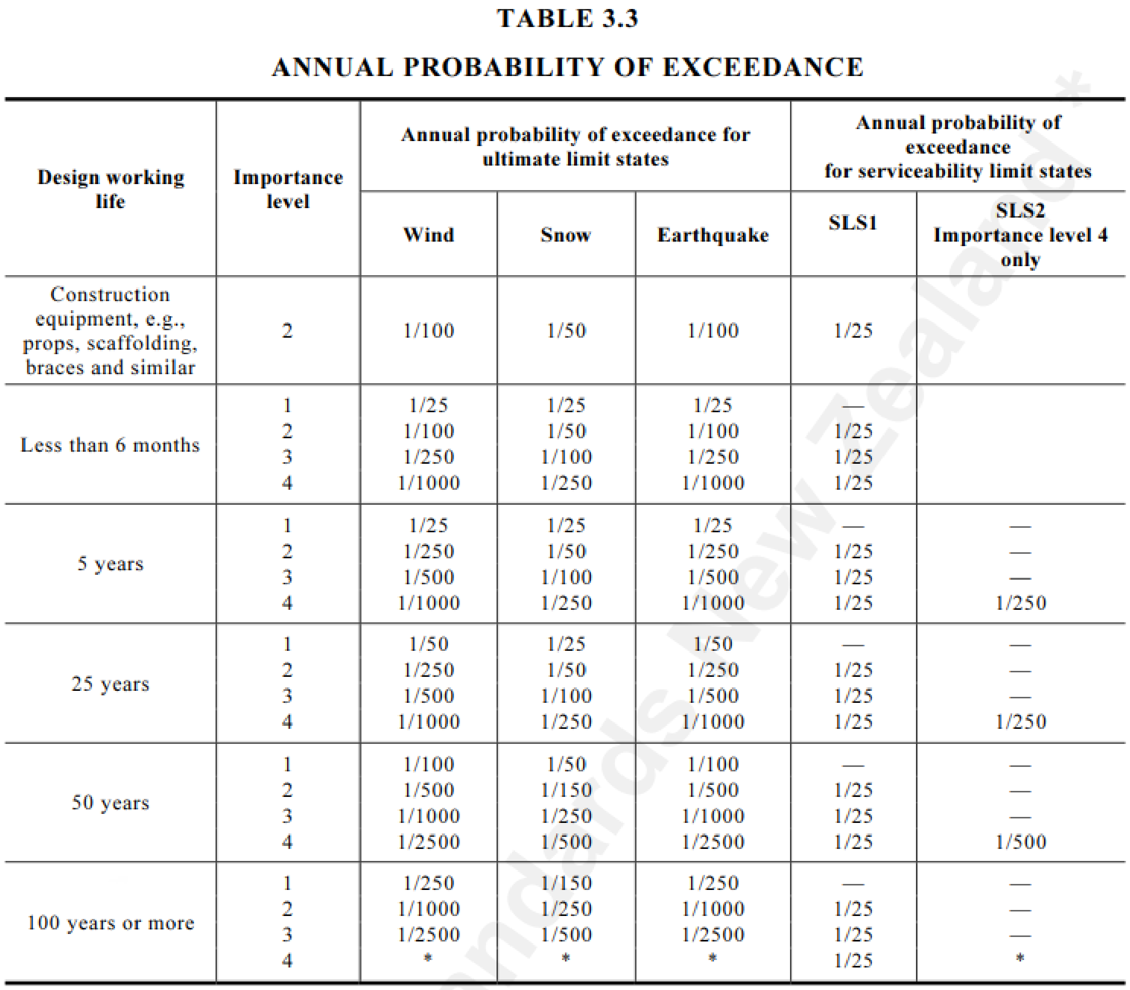


TABLE 3.3

ANNUAL PROBABILITY OF EXCEEDANCE

Design working life	Importance level	Annual probability of exceedance for ultimate limit states			Annual probability of exceedance for serviceability limit states	
		Wind	**Snow**	**Earthquake**	**SLS1**	**SLS2 Importance level 4 only**
Construction equipment, e.g., props, scaffolding, braces and similar	2	1/100	1/50	1/100	1/25	
Less than 6 months	1	1/25	1/25	1/25	—	
	2	1/100	1/50	1/100	1/25	
	3	1/250	1/100	1/250	1/25	
	4	1/1000	1/250	1/1000	1/25	
5 years	1	1/25	1/25	1/25	—	—
	2	1/250	1/50	1/250	1/25	—
	3	1/500	1/100	1/500	1/25	—
	4	1/1000	1/250	1/1000	1/25	1/250
25 years	1	1/50	1/25	1/50	—	—
	2	1/250	1/50	1/250	1/25	—
	3	1/500	1/100	1/500	1/25	—
	4	1/1000	1/250	1/1000	1/25	1/250
50 years	1	1/100	1/50	1/100	—	—
	2	1/500	1/150	1/500	1/25	—
	3	1/1000	1/250	1/1000	1/25	—
	4	1/2500	1/500	1/2500	1/25	1/500
100 years or more	1	1/250	1/150	1/250	—	—
	2	1/1000	1/250	1/1000	1/25	—
	3	1/2500	1/500	1/2500	1/25	—
	4	*	*	*	1/25	*

$$C(T) = C_h(T)\,Z\,R\,N(T,D)$$

- R – Return period

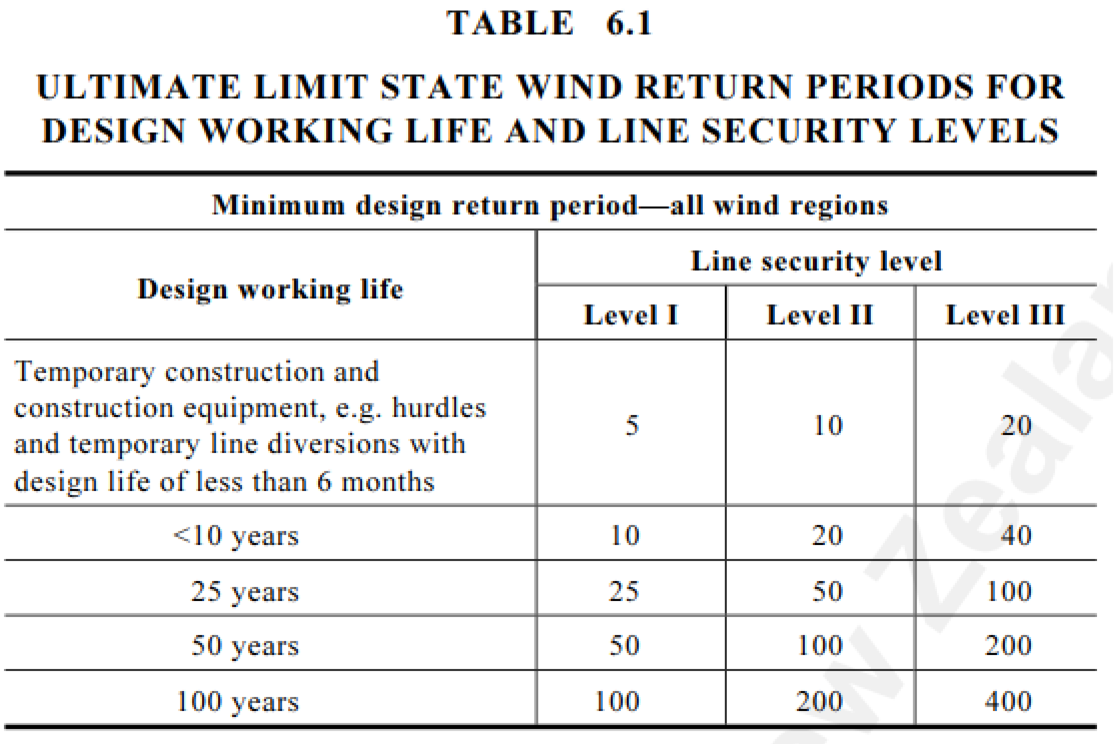


TABLE 6.1

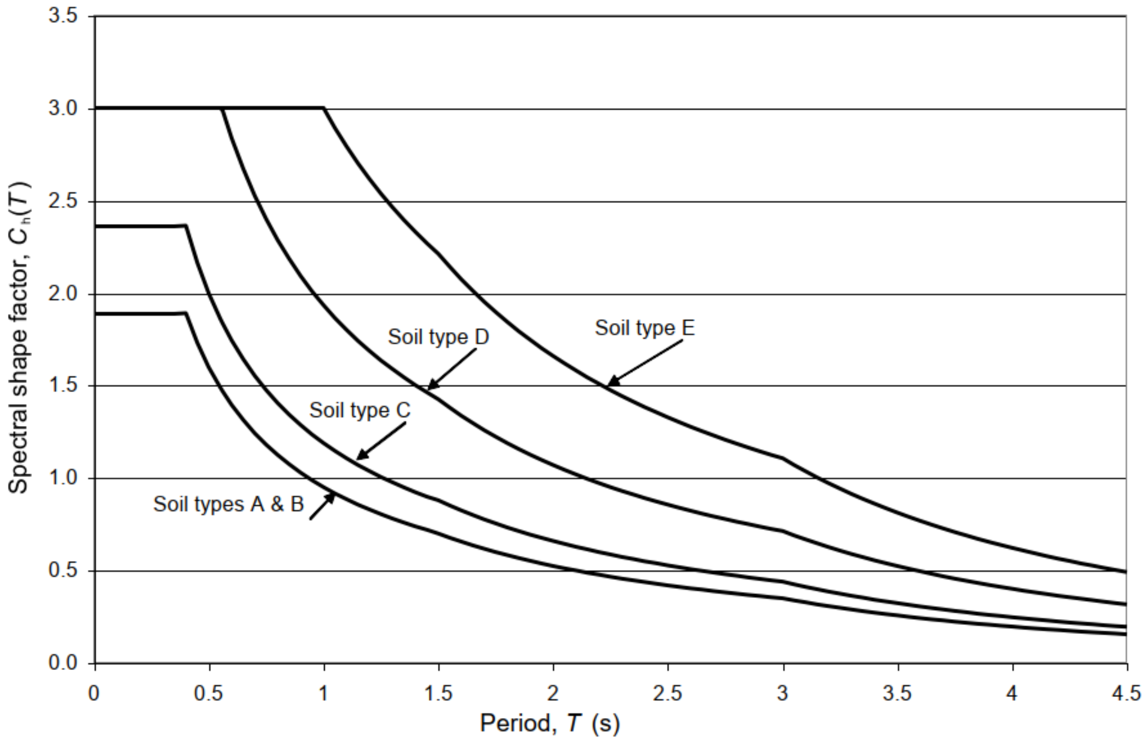
ULTIMATE LIMIT STATE WIND RETURN PERIODS FOR DESIGN WORKING LIFE AND LINE SECURITY LEVELS

Minimum design return period—all wind regions

Design working life	Line security level		
	Level I	Level II	Level III
Temporary construction and construction equipment, e.g. hurdles and temporary line diversions with design life of less than 6 months	5	10	20
<10 years	10	20	40
25 years	25	50	100
50 years	50	100	200
100 years	100	200	400

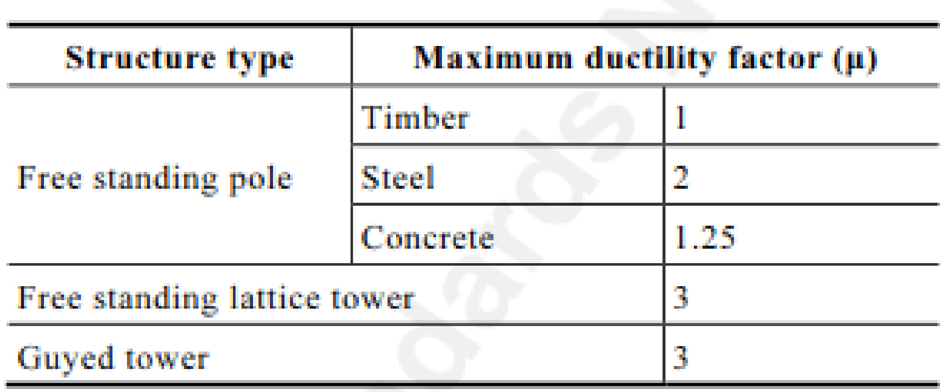
$$C(T) = C_h(T)\, Z\, R\, N(T,D)$$

- N(T,D) – Near fault factor
- Extra loading if close to a stated fault line
- Unlikely to contribute as kicks in for long period structures



$$C_d(T_1) = \frac{C(T_1)S_p}{k_\mu}$$

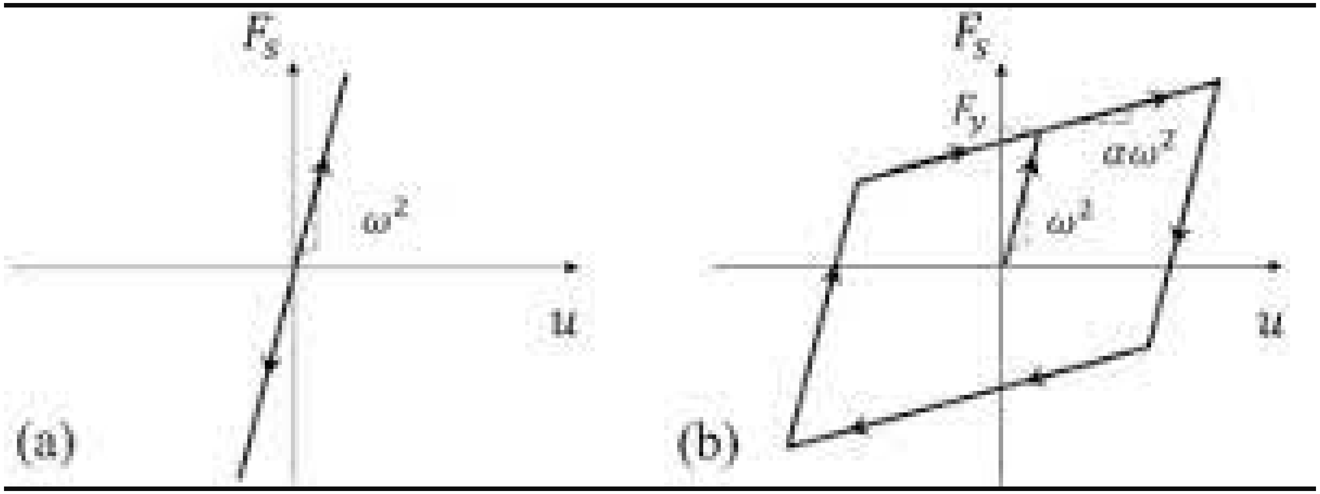
- S_p – Structural Performance Factor
- K_μ – Ductility Factor
- Based on the ductility and non-linearity
- Can reduce the demand if the system has ductility
- Determine if you want the system to remain linear or non-linear
- Damage after an event



Structure type	Maximum ductility factor (μ)	
Free standing pole	Timber	1
	Steel	2
	Concrete	1.25
Free standing lattice tower		3
Guyed tower		3

$$C_d(T_1) = \frac{C(T_1)S_p}{k_\mu}$$

- S_p – Structural Performance Factor
- K_μ – Ductility Factor

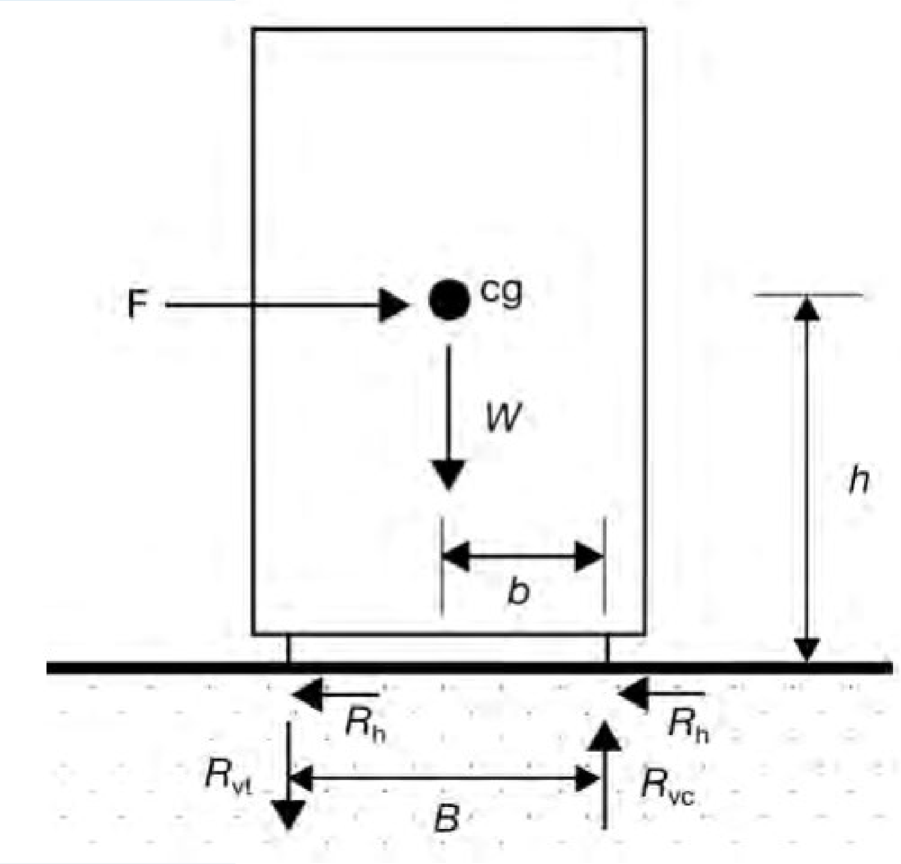


Linear

Non-linear

- Force displacement curves

Parts and Components



- Something in the code which is not well understood
- Secondary structure supported by the primary structure
- Description from commentary: Items of plant, machinery and services
- Example: Transformer connected to a pole
- For the design of the connection to the structure

$$F_{ph} = C_p(T_p)\, C_{ph}\, R_p\, W_p \leq 3.6\, W_p$$

$$C_p(T_p) = C(0)\, C_{Hi}\, C_i(T_p)$$

- $C(0)$ – Site Hazard Co -efficient
- As previously shown but for a period of 0

- C_{Hi} – Floor Height Co -efficient
- How high the part is attached to the structure

- $C_i(T_p)$ – Part Spectral Shape Co -efficient
- Uses the period of the part and how it will move

- C_{ph} – Part Response Factor
- Takes into account the level of ductility that the part can sustain
- Note need to show that part under the seismic force can achieve the ductility stated.
- Usually taken as 1

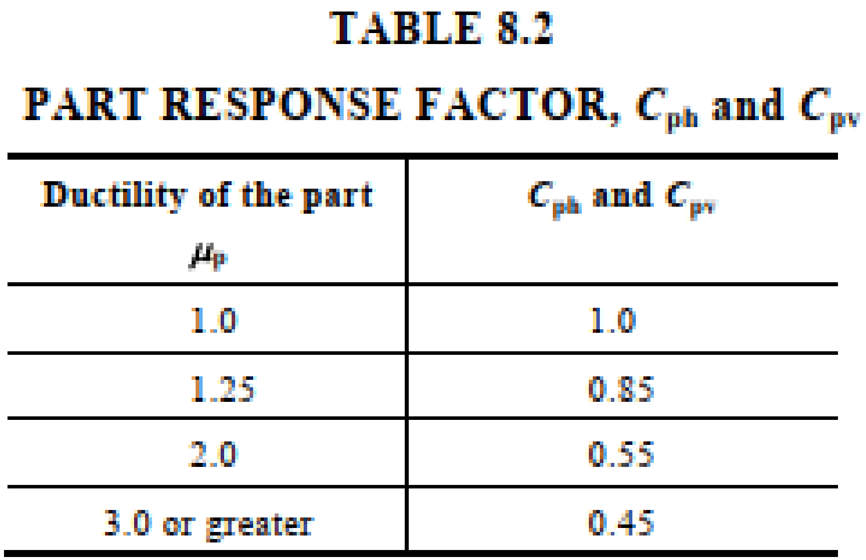


TABLE 8.2

PART RESPONSE FACTOR, C_{ph} and C_{pv}

Ductility of the part μ_p	C_{ph} and C_{pv}
1.0	1.0
1.25	0.85
2.0	0.55
3.0 or greater	0.45

- R_p – Part Risk Factor
- The risk of the part if it were to fail.

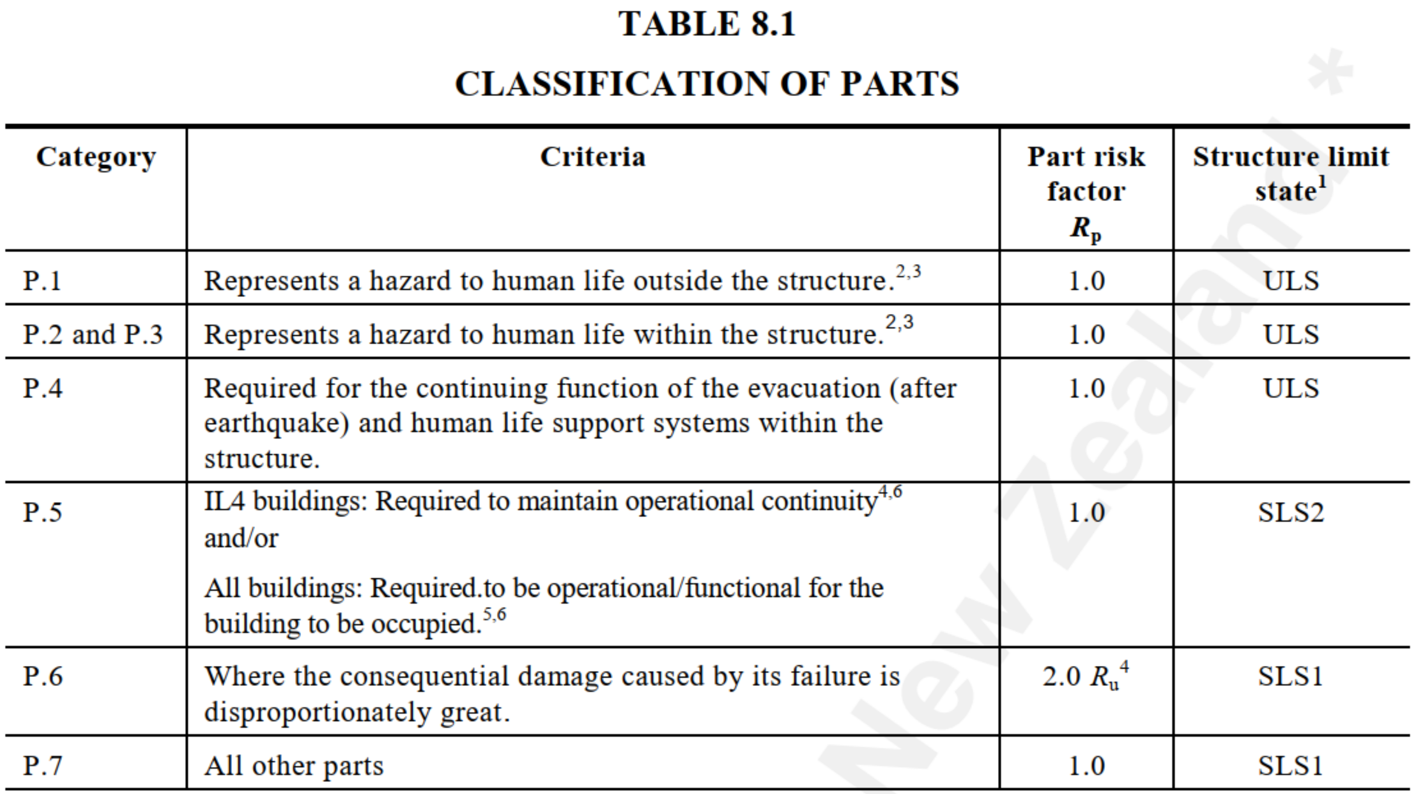


TABLE 8.1

CLASSIFICATION OF PARTS

Category	Criteria	Part risk factor R_p	Structure limit state[1]
P.1	Represents a hazard to human life outside the structure.[2,3]	1.0	ULS
P.2 and P.3	Represents a hazard to human life within the structure.[2,3]	1.0	ULS
P.4	Required for the continuing function of the evacuation (after earthquake) and human life support systems within the structure.	1.0	ULS
P.5	IL4 buildings: Required to maintain operational continuity[4,6] and/or All buildings: Required.to be operational/functional for the building to be occupied.[5,6]	1.0	SLS2
P.6	Where the consequential damage caused by its failure is disproportionately great.	2.0 R_u[4]	SLS1
P.7	All other parts	1.0	SLS1

Vertical Actions

- NZS 1170.5 Vertical action. Generally less that weight of the structure so not an issue.
- Similar method as for horizontal.
- But for Parts and Components (transformers) need to consider the vertical action for the connections.

HB331 Example

- Section 15.7

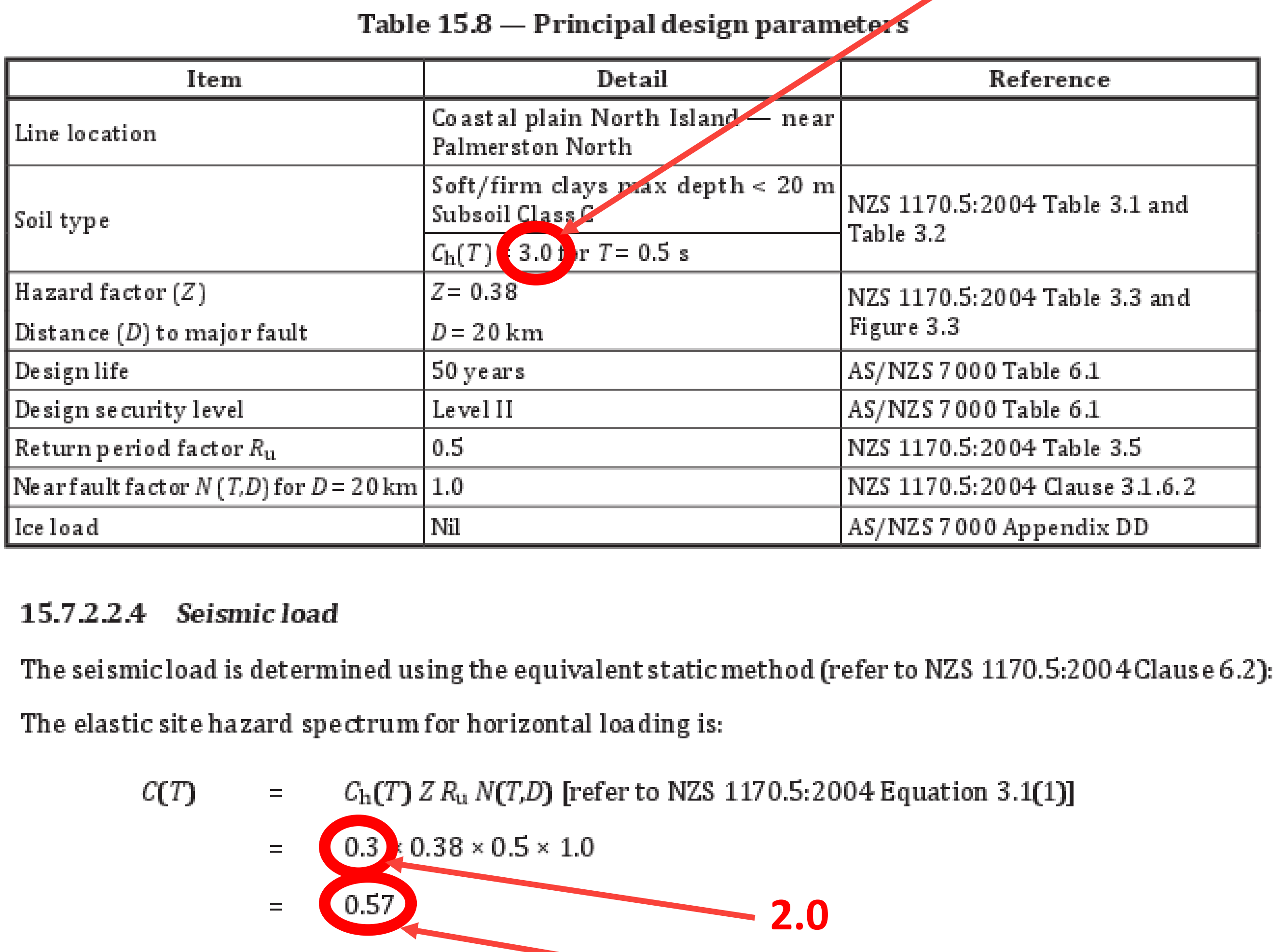


Table 15.8 — Principal design parameters

Item	Detail	Reference
Line location	Coastal plain North Island — near Palmerston North	
Soil type	Soft/firm clays max depth < 20 m Subsoil Class C	NZS 1170.5:2004 Table 3.1 and Table 3.2
	$C_h(T) = 3.0$ for $T = 0.5$ s	
Hazard factor (Z) Distance (D) to major fault	$Z = 0.38$ $D = 20$ km	NZS 1170.5:2004 Table 3.3 and Figure 3.3
Design life	50 years	AS/NZS 7000 Table 6.1
Design security level	Level II	AS/NZS 7000 Table 6.1
Return period factor R_u	0.5	NZS 1170.5:2004 Table 3.5
Near fault factor $N(T,D)$ for $D = 20$ km	1.0	NZS 1170.5:2004 Clause 3.1.6.2
Ice load	Nil	AS/NZS 7000 Appendix DD

15.7.2.2.4 *Seismic load*

The seismic load is determined using the equivalent static method (refer to NZS 1170.5:2004 Clause 6.2):

The elastic site hazard spectrum for horizontal loading is:

$$C(T) = C_h(T)\, Z\, R_u\, N(T,D) \text{ [refer to NZS 1170.5:2004 Equation 3.1(1)]}$$

$$= 0.3 \times 0.38 \times 0.5 \times 1.0$$

$$= 0.57$$

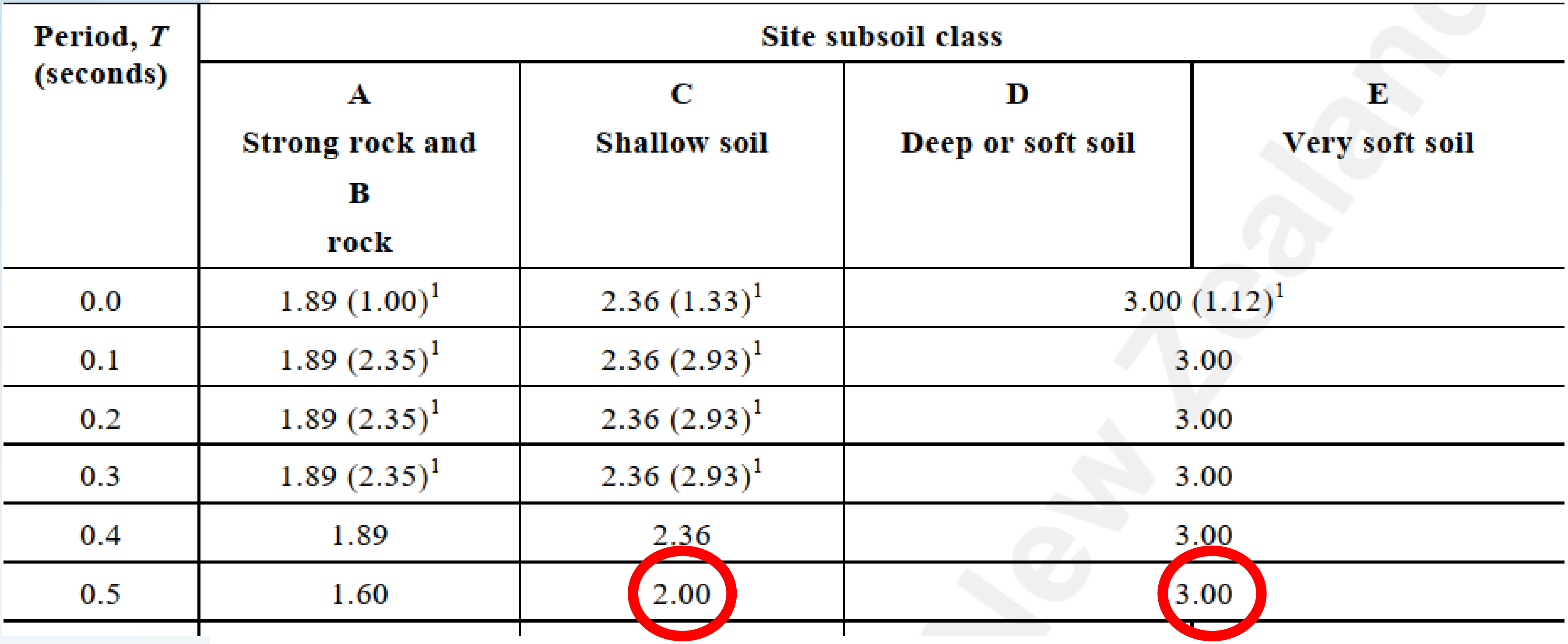
2.0

2.0

0.38

HB331 Example

- Section 15.7



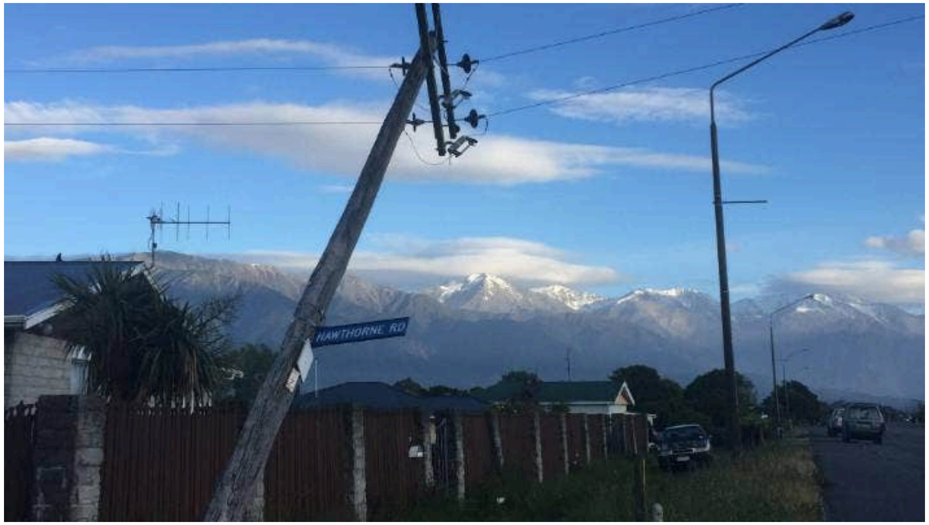
Period, *T* (seconds)	Site subsoil class			
	A **Strong rock and** **B** **rock**	**C** **Shallow soil**	**D** **Deep or soft soil**	**E** **Very soft soil**
0.0	1.89 (1.00)[1]	2.36 (1.33)[1]	3.00 (1.12)[1]	
0.1	1.89 (2.35)[1]	2.36 (2.93)[1]	3.00	
0.2	1.89 (2.35)[1]	2.36 (2.93)[1]	3.00	
0.3	1.89 (2.35)[1]	2.36 (2.93)[1]	3.00	
0.4	1.89	2.36	3.00	
0.5	1.60	2.00	3.00	

Conclusions

- Earthquakes don’t follow the code, based on probabilities
- Need to understand the return period being considered as AS/NZS 7000 is different to AS/NZS 1170
- ULS and SLS and what damage they equate to
- When to consider something as a part.

When to consider Seismic Design

- Transformers mounted on poles.
- Ground that is liquefiable or susceptible to lateral spread
- Most cases s eismic doesn’t actually govern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Questions

Thank you

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