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EQ Response Spectra in Direction X, Y, Z

Peak Ground Acceleration (Horizontal), PGA(g) | Spectral Acceleration (Horizontal) S_S(g), S_1(g)

Note that peak ground acceleration, ***PGA(g)*** *and spectral accelerations* ***S_S(g)***, ***S_1(g)*** *define the site seismic hazard level.*

Location: UBC97 Zone 4, World

Alternate return period, T: 475 years — Lubkowski, 20

Ref. PGA, a_{gR}(g) | PGA, PGA(g) | Zone factor, Z(g) | Hazard factor	0.400		10.5.1 SNI1726 | cl.2
Ref. return period, T_R — $\frac{a_g}{a_{gR}} = \left(\frac{T}{T_R}\right)^k$	475	yrs	
Exponent, k	0.30		Lubkowski, 20

475 Year PGA	0.05g	0.10g	0.20g	0.30g	0.40g
k	0.45	0.435	0.40	0.35	0.30

Multiplier for alternate return period, $(T/T_R)^k$: 1.00

Alternate return period, T: 475 years — Lubkowski, 20

Spectral response acceleration at 0.2s, S_S(g)	0.922	g m/s²	CE7 | cl.6.
Ref. return period, T_R — $\frac{a_g}{a_{gR}} = \left(\frac{T}{T_R}\right)^k$ — S_s/PGA = 0.3386 PGA + 2.1696	475	yrs	
Exponent, k	0.35		Lubkowski, 20

475 Year S_S	0.20g	0.55g	0.90g	1.20g	1.50g
k	0.46	0.42	0.39	0.35	0.30

Multiplier for alternate return period, $(T/T_R)^k$: 1.00

Spectral response acceleration at 1.0s, S_1(g)	0.331	g m/s²	CE7 | cl.6.
Ref. return period, T_R — $\frac{a_g}{a_{gR}} = \left(\frac{T}{T_R}\right)^k$ — S_1/PGA = 0.5776 PGA +0.5967	475	yrs	
Exponent, k	0.40		Lubkowski, 20

475 Year S_1	0.01g	0.02g	0.05g	0.10g	0.20g
k	0.40	0.40	0.40	0.40	0.40

Multiplier for alternate return period, $(T/T_R)^k$: 1.00

Ref. PGA, a_{gR}(g) | PGA, PGA(g) | Zone factor, Z(g) | Hazard factor, Z(g)	0.400	g m/s²	10.5.1 SNI
Spectral response acceleration at 0.2s, $(T/T_R)^k.S_S$(g)	0.922	g m/s²	CE7 | cl.6.
Spectral response acceleration at 1.0s, $(T/T_R)^k.S_1$(g)	0.331	g m/s²	CE7 | cl.6.

Note spectral response acceleration can be obtained at https://ascehazardtool.org/. — ASCE7

Note spectral response acceleration can be obtained at SNI1726-2019 Earthquake Code - Response — SNI1726

Design horizontal PGA, $a_g(g) = \gamma_I.a_{gR}(g)$	0.400	g m/s²	2.1(3) EN1
Design horizontal PGA very low, $a_g(g) \leq 0.04g$ | $a_g(g).S \leq 0.05g$	N/A		cl.3.2.1(5) EN1
Design horizontal PGA low, $a_g(g) \leq 0.08g$ | $a_g(g).S \leq 0.10g$	N/A		cl.3.2.1(4) EN1
Design horizontal PGA moderate, $a_g(g) \leq 0.30g$ | $a_g(g).S \leq 0.375g$	N/A		
Design horizontal PGA high, $a_g(g) > 0.30g$ | $a_g(g).S > 0.375g$	High Seismicity		

Peak Ground Acceleration (Vertical), PGA(g)

Vertical peak ground acceleration factor, k_v			0.90	16 | cl.7.4.2.2 SNI17	
Design vertical PGA, $a_{vg}(g) = \gamma_I.k_v.a_{gR}(g)$			0.360	g m/s²	
Inclusion of vertical action ?	0.36g	>	0.250g	Included	cl.4.3.3.5.2 EN1

Fundamental Building Period, $T_{1,X|Y|Z}$

	X-Dir	Y-Dir	Z-Dir		
Fundamental period of building, $T_{1,X\|Y\|Z}$	0.50	2.60	0.15	s	NOT OK

Note for employing the equivalent lateral static force method, check $T_{1,X|Y} \leq 4T_C$ and 2.0s. — cl.4.3.3.2.1 EN1

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Importance Factor | Redundancy Factor | Overstrength Factor

Note that the importance factor, redundancy factor, and overstrength factor, ***linearly multiplies*** *the horizontal peak ground acceleration, PGA(g) and spectral accelerations* $S_S(g)$, $S_1(g)$.

Importance factor, γ_I | I_e | Probability factor, k_p		1.00	*.1.2 SNI1726 | cl.208*
	Imp. class | Risk cat. | Occupancy cat. | Imp. level		*4.1.2 SNI1726 | cl.10*
10	Class II [Ordinary Buildings] [1.00] [T=475 Years]		
Redundancy factor for horizontal spectra, ρ		1.00	*12.3.4 ASCE7 | cl.7.3*
	Structure w/o. Vertical Irregularity [cl.5.2.2.2(3), cl.6.3.2(2)] [1.00]		
Overstrength factor for horizontal spectra, γ_{Rd} | Ω_0		1.40	*| cl.8.3.2.1 SNI1726*
	Foundation ULS Axial, Bending [cl.4.4.2.6(8)] [1.40]		

Response Modification Factor, R

The response modification factor, R ***linearly divides*** *the elastic spectral response to produce the design (inelastic) spectral response.*

		X-Dir	Y-Dir	Z-Dir	
12					
Response mod. factor, R | Behaviour factor, q = $q_0.k_w$		1.50	1.50	1.50	*7 | cl.7.2.2, cl.6.11.3*
	Moment Frame [cl.5.3.3(1) DCL Moment Frame] [q0=1.50] [Cd=q]			1.50	*7 | cl.7.2.2, cl.6.11.3*
	Moment Frame [cl.5.3.3(1) DCL Moment Frame] [q0=1.50] [Cd=q]			1.50	*7 | cl.7.2.2, cl.6.11.3*
		X-Dir	Y-Dir	Z-Dir	
.2 SNI172(	Prevailing failure mode for walls, k_w	1.00	1.00		*cl.5.2.2.2(11) EN*
	Shear Wall Height/Length ≥ 2.0 [cl.5.2.2.2(11)] [1.00]			1.00	*cl.5.2.2.2(11) EN*
12	Shear Wall Height/Length ≥ 2.0 [cl.5.2.2.2(11)] [1.00]			1.00	*cl.5.2.2.2(11) EN*

1726 | cl.208.4.4.1 NSCP | cl.3.2 AS1170.4
.2 SNI1726
.2 SNI1726

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26-2019 | cl.208.6.1 NSCP | cl.7.2(c) AS1170.4 | cl.1630.1.1 UBC97-1997

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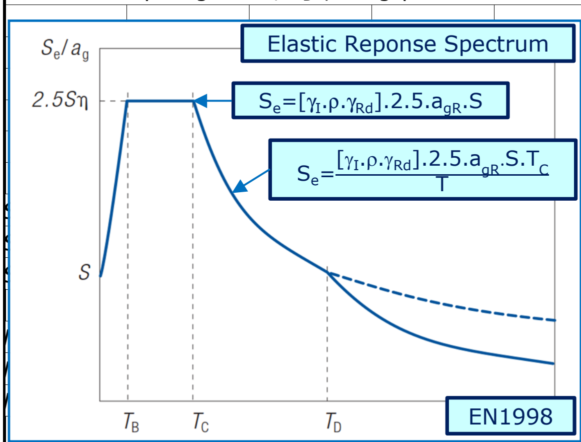
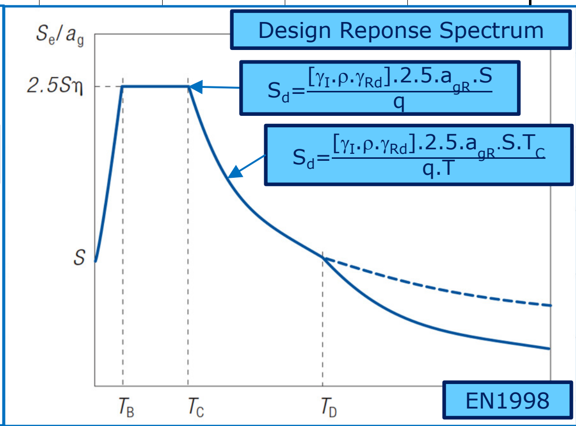
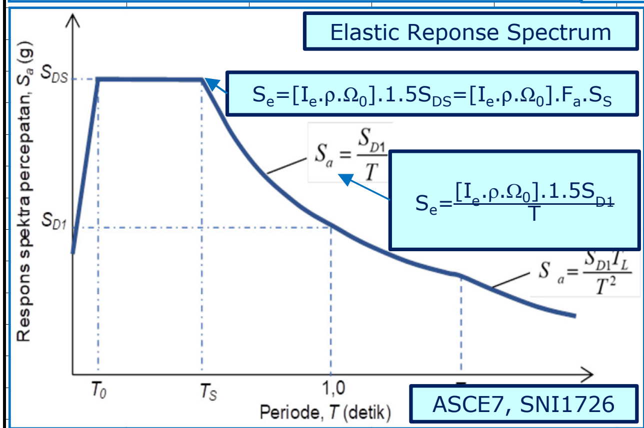
Earthquake Spectra

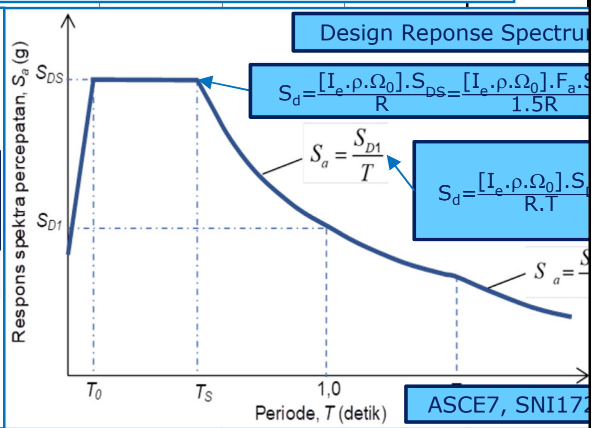
Note that the earthquake spectra define the ***spectral accelerations*** *for all structural periods.*

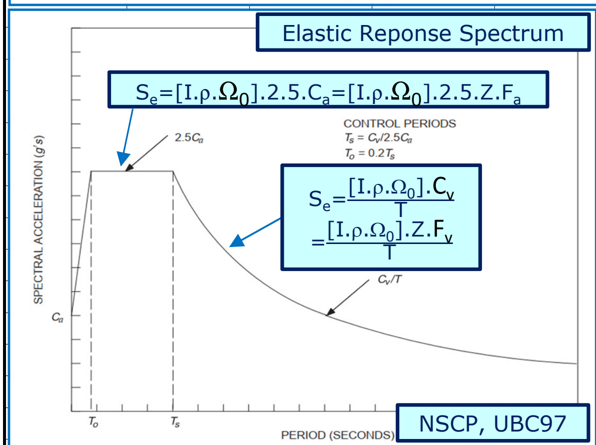
Earthquake spectrum	EN1998 Eurocode Type I [Ms>5.5] [2013]			*cl.6.4 SNI1726 | cl.208*
Ground type | Site class | Soil ty	Ground Type B [Dense Soil, N>50, vs>360m/s, TS<0.30s]			*6.1.3 SNI1726 | cl.208*
Soil response parameter, S | F_{PGA}		**1.20**		*cl.3.2.2.2 EN1*
Short-period seismic coefficient, F_a		**N/A**		*726 | cl.208.4.4.4 NSC*
Long-period seismic coefficient, F_v		**N/A**		*726 | cl.208.4.4.4 NSC*
	X|Y-Dir	**Z-Dir**		
Constant accn. region LL, T_B | T_0	**0.15**	**0.05**	s	*726 | cl.208*
Constant accn. region UL, T_C | Short-period transition period, T_S	**0.50**	**0.15**	s	*726 | cl.208*
Constant disp. region LL, T_D | Long-period transition period, T_L	**2.00**	**1.00**	s	*726 | cl.208*

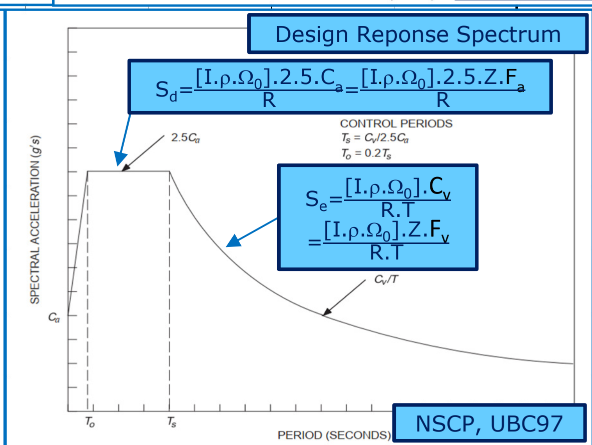












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Displacement Compatibility Factor, C_d (Displacements and Non-Seismic Participating Columns)

The displacement compatibility factor, C_d linearly multiplies the design (inelastic) spectra to determine the ***structural displacements*** *and action effects within* ***non-seismic-participating columns****. Herewith, this figure* ***does not*** *affect the presentation of the spectra and resulting forces.*

.4.3.1 NSCP | cl.4.1 AS1170.4 | cl.1636.2 UBC97

998	X-Dir	Y-Dir	Z-Dir	
Displacement compatibility factor, C_d	1.50	1.50		*.2.5 SNI1726 | cl.208.*
P | cl.6.4 A Moment Frame [cl.5.3.3(1) DCL Moment Frame] [q0=1.50] [Cd=q]			1.50	
Moment Frame [cl.5.3.3(1) DCL Moment Frame] [q0=1.50] [Cd=q]			1.50	
.5.3.2 NSCP | cl.6.4 AS1170.4 | cl.1631.2 UBC97	X-Dir	Y-Dir	Z-Dir	
Displacement drift criteria, $[\lvert\Delta\delta_{X\lvert Y}\rvert/h_s]_{limit}$	1:100	1:100		*.7.12.1 SNI1726 | cl.2*

.5.3.2 NSCP | cl.6.4 AS1170.4 | cl.1631.2 UBC97

Design Ground Displacement

Design ground displacement, $d_{g,X\lvert Y} = 0.025.a_g(g).S.T_C.T_D$	118	mm	*.2.2.4 EN1*

Non-Structural Component (NSC) Seismic Effects

Weight of NSC, W_a | W_p	80	kN	
Height of NSC from foundation, z	25.0	m	
Building height from foundation, h	25.0	m	

	X-Dir	Y-Dir	Z-Dir		
Inelastic (design) force of NSC, $F_a = W_a.S_a(g)$	106	60		kN	*.5.2(2) EN*
$S_a(g)=\frac{a_g(g).S.\gamma_a}{q_a}.\left[\frac{3.(1+z/h)}{1+(1-T_{a,X\lvert Y}/T_{1,X\lvert Y})^2}-0.5\right]$	1.320	0.751		g m/s²	*.5.2(3) EN*
Fundamental period of NSC, $T_{a,X\lvert Y}$	0.50	0.50		s	
Importance factor of NSC, γ_a			1.00		*cl.4.3.5.3 EN1*
Behaviour factor of NSC, q_a			2.00		*cl.4.3.5.4 EN1*
astic (design) force of NSC, $F_p = W_p.S_a(g)$	N/A	N/A	N/A	kN	*13.3.1 ASC*
$S_a(g)=0.4a_p.S_{DS}.[1+2.(z/h)].\Omega_0.I_p/R_p$ $S_{DS}=2/3.F_a.S_S\lvert 0.3S_{DS}.I_p\leq S_a(g)\leq 1.6S_{DS}.I_p$	N/A	N/A	N/A	g m/s²	*13.3.1 ASC*
Amplification factor of NSC, a_p			2.50		*T.13.5-1, T.13.6-1*
Importance factor of NSC, I_p			1.00		*cl.13.1.3 ASC*
Overstrength factor of NSC, Ω_0			2.00		*T.13.5-1, T.13.6-1*
Response mod. factor of NSC, R_p			2.50		*T.13.5-1, T.13.6-1*
Inelastic (design) force of NSC, $F_p = W_p.S_a(g)$	N/A	N/A		kN	*SCP | cl.16*
$0.7C_a.I_p\leq S_a(g)=\frac{a_p.C_a.I_p}{R_p}.[1+3.z/h)]\leq 4C_a.I_p$	N/A	N/A		g m/s²	*SCP | cl.16*
Component amplification factor of NSC, a_p			2.50		*T.208-13 NSCP | T.16*
Importance factor of NSC, I_p			1.00		*T.208-1 NSCP | T.16*
Response mod. factor of NSC, R_p			3.00		*T.208-13 NSCP | T.16*

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$_{D1}T_L/T^2$

26

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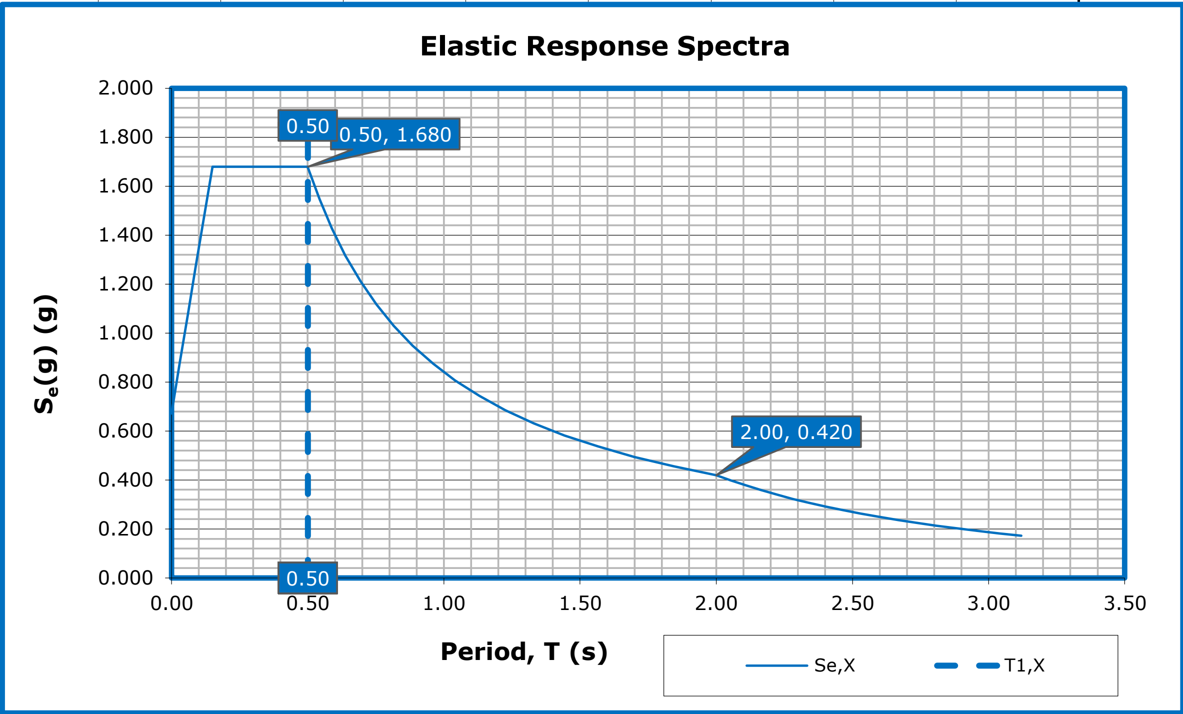
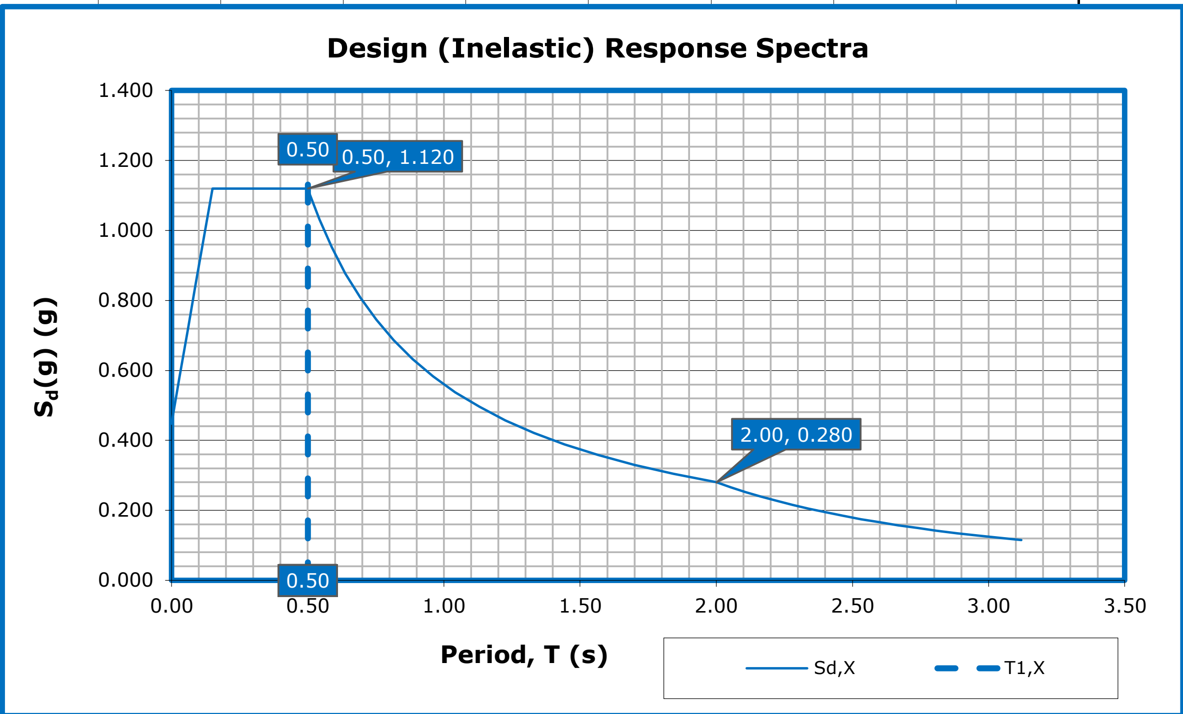
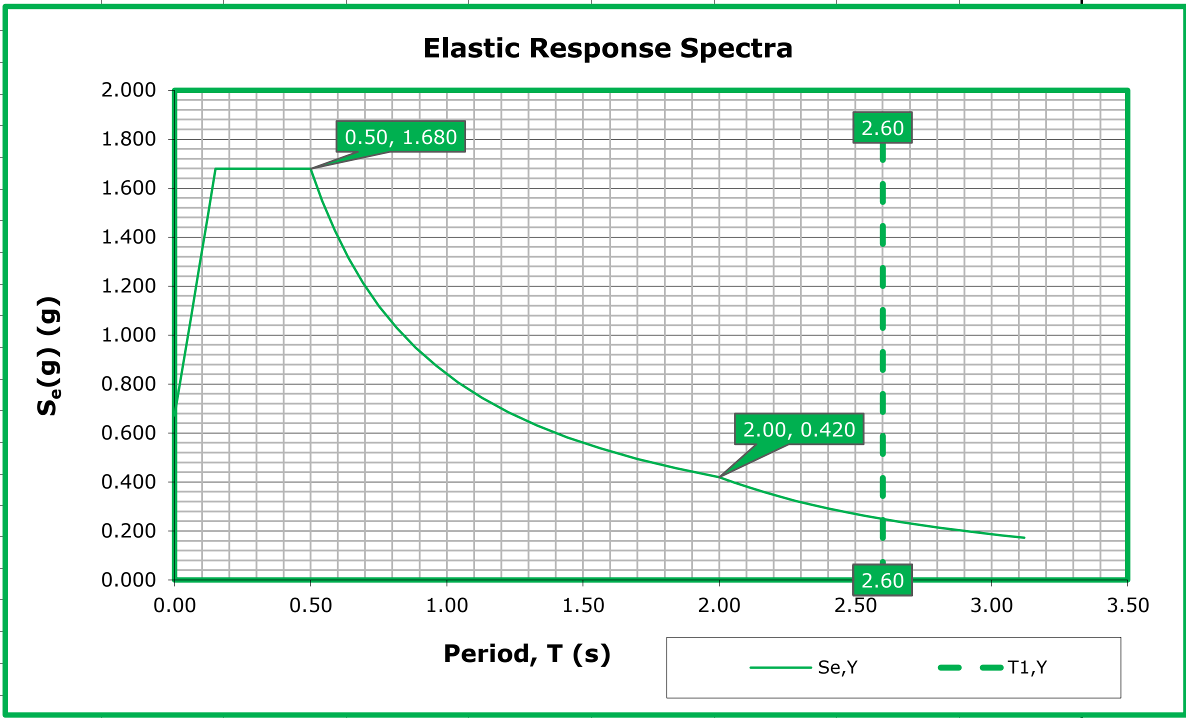


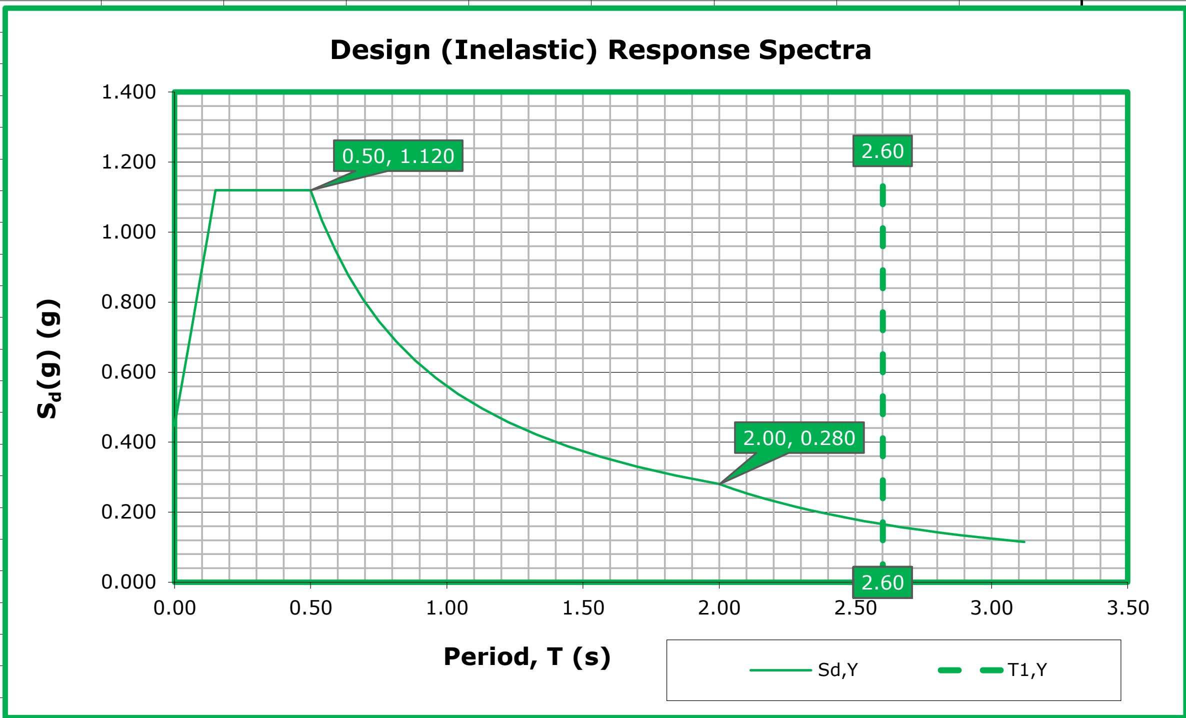
	X-Dir	
Elastic spectral acceleration, $S_e(g)(T_1)$	1.680	g m/s^2
Elastic base shear force, $F_{be}(W) = W.S_e(g)(T_1).\lambda$	1.680	W kN
Correction factor, λ — Otherwise	1.00	*cl.4.3.3.2.2 EN1998*



Inelastic (design) spectral acceleration, $S_d(g)(T_1)$	1.120	g m/s^2
Note spectra level {low inelastic 0.050g – 0.070g, high inelastic 0.150g – 0.200g, high elastic 0.250g – 0.300g};		
Inelastic base shear force, $F_{bd}(W) = W.S_d(g)(T_1).\lambda$	1.120	W kN
Correction factor, λ — Otherwise	1.00	*cl.4.3.3.2.2 EN1998*



	Y-Dir	
Elastic spectral acceleration, $S_e(g)(T_1)$	**0.249**	g m/s^2
Elastic base shear force, $F_{be}(W) = W.S_e(g)(T_1).\lambda$	**0.249**	W kN N1998 | cl.
998 Correction factor, λ — Otherwise	**1.00**	cl.4.3.3.2.2 EN1



Inelastic (design) spectral acceleration, $S_d(g)(T_1)$	**0.166**	g m/s^2

Note spectra level {low inelastic 0.050g – 0.070g, high inelastic 0.150g – 0.200g, high elastic 0.250g – 0.300g};

Inelastic base shear force, $F_{bd}(W) = W.S_d(g)(T_1).\lambda$	**0.166**	W kN N1998 | cl.
998 Correction factor, λ — Otherwise	**1.00**	cl.4.3.3.2.2 EN1

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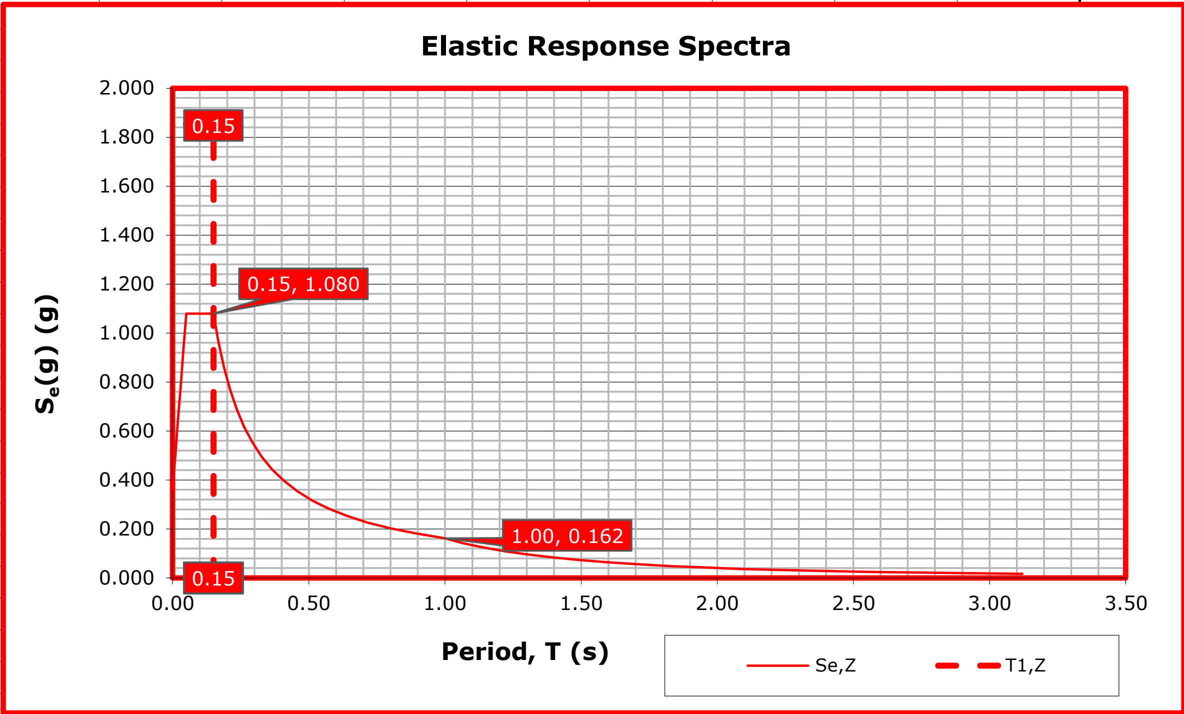
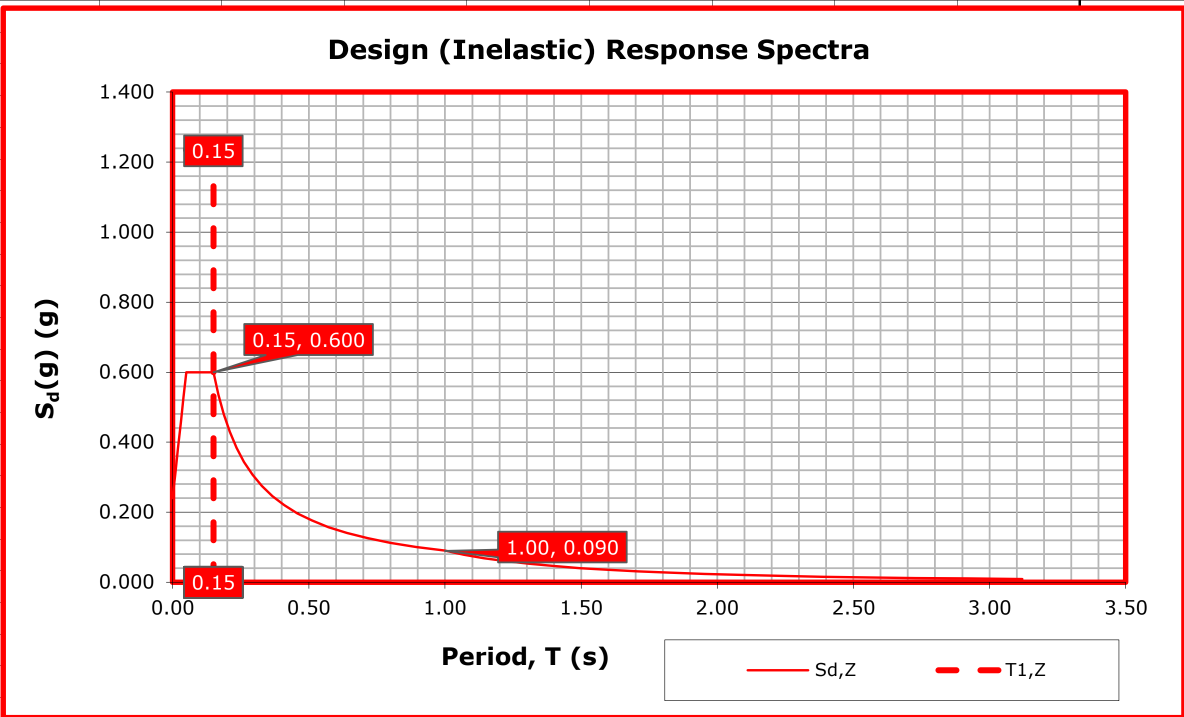


	Z-Dir	
Elastic spectral acceleration, $S_e(g)(T_1)$	1.080	g m/s^2
Elastic base shear force, $F_{be}(W) = W.S_e(g)(T_1).\lambda$	1.080	W kN

1998 | cl.1
998



Inelastic (design) spectral acceleration, $S_d(g)(T_1)$	0.600	g m/s^2

Note spectra level {low inelastic 0.050g – 0.070g, high inelastic 0.150g – 0.200g, high elastic 0.250g – 0.300g};

Inelastic base shear force, $F_{bd}(W) = W.S_d(g)(T_1).\lambda$	0.600	W kN

1998 | cl.1
998

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EQ Load in Direction X, Y, Z

Note certain cells within this section where indicated are intrinsically linked to the SD - EQ Spectra {X, Y, Z} sl

Note for the employment of the equivalent lateral static force method, $T_{1,X/Y} \leq 4T_C$ and 2.0s (cl.4.3.3.2.1 EN1

	X-Dir	Y-Dir	Z-Dir	Unit	Ref.
Building dimension in X, w			30.000	m	
Building dimension in Y, L			30.000	m	
Floor area, A_F = w.L			**900**	m^2	
Elastic base shear force, $F_{be}(W)$	**1.680**	**0.249**	**1.080**	W kN	3.3.2.2 EN
Inelastic base shear force, $F_{bd}(W)$	**1.120**	**0.166**	**0.600**	W kN	3.3.2.2 EN
P-delta factor, m	1.00	1.00	N/A		*cl.4.4.2.2 EN1*
Coefficients, φ and ψ_{2i}		0.30	1.00		*T.4.2, T.A1.1 EN*

Storey	Storey Height (m)	[DL +SDL]$_i$ (kPa)	LL_i (kPa)	z_i (m)	$\varphi\psi_{2i}LL_i$ (kPa)	X (m)	Y (m)	W_i (kN)	$z_i.W_i$ (kNm)
L1	3.000	16.7	5.0	3.000	1.5	30.000	30.000	16380	49140
L2	3.000	16.7	5.0	6.000	1.5	30.000	30.000	16380	98280
L3	3.000	16.7	5.0	9.000	1.5	30.000	30.000	16380	147420
L4	3.000	16.7	5.0	12.000	1.5	30.000	30.000	16380	196560
L5	3.000	16.7	5.0	15.000	1.5	30.000	30.000	16380	245700
L6	3.000	16.7	5.0	18.000	1.5	30.000	30.000	16380	294840
L7	3.000	16.7	5.0	21.000	1.5	30.000	30.000	16380	343980
L8	3.000	16.7	5.0	24.000	1.5	30.000	30.000	16380	393120
L9	3.000	16.7	5.0	27.000	1.5	30.000	30.000	16380	442260
L10	3.000	16.7	5.0	30.000	1.5	30.000	30.000	16380	491400
10	**30.0 (m)**	**167.0 (kPa)**	**50.0 (kPa)**		**15.0 (kPa)**	**30.0 (m)**	**30.0 (m)**	**164 (MN)**	**2703 (MNm)**

Note that dynamic weight, W_i = ([DL+SDL]$_i$ + $\varphi\psi_{2i}LL_i$).A; *cl.3.2.4, cl.4.2.4 E*

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eet;

	X-Dir	Y-Dir	Z-Dir	
Total dynamic weight of building, $W = \Sigma W_i$			**164**	MN

Base floor inclusion in W: Include (pad, strip, pile cap foundation) — *cl.4.3.3.2.2 EN1*

	X-Dir	Y-Dir	Z-Dir	
Total weight of building, $\Sigma W_{DL+SDL+LL} = \Sigma([DL+SDL]_i+LL_i).A_F$			**195**	MN
Elastic base shear force, $F_{be} = F_{be}(W).W$	**275184**	**40708**	**176904**	kN
Elastic base moment, $M_{be} = \Sigma[z_i.F_{ie}]$	**5779**	**855**	**N/A**	MNm
Inelastic base shear force, $F_{bd} = F_{bd}(W).W$	**183456**	**27138**	**98280**	kN
Inelastic base moment, $M_{bd} = \Sigma[z_i.F_{id}]$	**3853**	**570**	**N/A**	MNm

998

1998

$F_{ie,X}$ (kN)	$F_{ie,Y}$ (kN)	$m_X.F_{ie,X}$ (kN)	$m_Y.F_{ie,Y}$ (kN)	$z_i.m_X.F_{ie,X}$ (kNm)	$z_i.m_Y.F_{ie,Y}$ (kNm)	$m_X.F_{ie,X}$ / W_i (%)	$m_Y.F_{ie,Y}$ / W_i (%)	
5003	740	**5003**	**740**	15010	2220	30.5%	4.5%	
10007	1480	**10007**	**1480**	60040	8882	61.1%	9.0%	
15010	2220	**15010**	**2220**	135090	19984	91.6%	13.6%	
20013	2961	**20013**	**2961**	240161	35527	122.2%	18.1%	
25017	3701	**25017**	**3701**	375251	55510	152.7%	22.6%	
30020	4441	**30020**	**4441**	540361	79935	183.3%	27.1%	
35023	5181	**35023**	**5181**	735492	108801	213.8%	31.6%	
40027	5921	**40027**	**5921**	960642	142107	244.4%	36.1%	
45030	6661	**45030**	**6661**	1215813	179854	274.9%	40.7%	
50033	7401	**50033**	**7401**	1501004	222042	305.5%	45.2%	
275184 (kN)	**40708** (kN)	**275184** (kN)	**40708** (kN)	**5779** (MNm)	**855** (MNm)	**168.0%** (%)	**24.9%** (%)	Σ

N1998 — *Note that elastic seismic force, $F_{ie} = F_{be} . (z_i.m_i) / \Sigma(z_j.m_j)$;*

998

$F_{id,X}$ (kN)	$F_{id,Y}$ (kN)	$m_X.F_{id,X}$ (kN)	$m_Y.F_{id,Y}$ (kN)	$z_i.m_X.F_{id,X}$ (kNm)	$z_i.m_Y.F_{id,Y}$ (kNm)	$m_X.F_{id,X}$ / W_i (%)	$m_Y.F_{id,Y}$ / W_i (%)	
3336	493	3336	493	10007	1480	20.4%	3.0%	
6671	987	6671	987	40027	5921	40.7%	6.0%	
10007	1480	10007	1480	90060	13323	61.1%	9.0%	
13342	1974	13342	1974	160107	23684	81.5%	12.0%	
16678	2467	16678	2467	250167	37007	101.8%	15.1%	
20013	2961	20013	2961	360241	53290	122.2%	18.1%	
23349	3454	23349	3454	490328	72534	142.5%	21.1%	
26685	3947	26685	3947	640428	94738	162.9%	24.1%	
30020	4441	30020	4441	810542	119903	183.3%	27.1%	
33356	4934	33356	4934	1000669	148028	203.6%	30.1%	
183456 (kN)	27138 (kN)	183456 (kN)	27138 (kN)	3853 (MNm)	570 (MNm)	112.0% (%)	16.6% (%)	Σ

Note that inelastic seismic force, $F_{id} = F_{bd} \cdot (z_i.m_i) / \Sigma(z_j.m_j)$;

CONSULTING ENGINEERS	Engineering Calculation Sheet Consulting Engineers	Job No.	Sheet No.	Rev.
		jXXX	1	
		Member/Location		
Job Title	Structure Design - EQ Load Definition and EQ Effects v2	Drg. Ref.		
Structure Design - EQ Load Definition and EQ Effects		Made by **XX**	Date **18/11/2024**	Chd.

EQ Load Displacements in Direction X

Note storey references and cumulative building heights within this section are intrinsically linked to the SD - E(

Criteria for δ_X / h	1	:	**100**	=	**0.010**
Criteria for $\lvert\Delta\delta_X\rvert$ / h_s	1	:	**100**	=	**0.010**

Storey	Total Disp in X, δ_X mm	Total Building Height, h m	Total Disp Ratio δ_X / h	Total Disp Ratio Check	Relative Disp in X, q.$\Delta\delta_X$ mm	Inter Storey Height, h_s m	Relative Disp Ratio $\lvert\Delta\delta_X\rvert$ / h_s	Relative Disp Ratio Check
L1	0.00	3.000	0.000	**OK**		3.000	0.000	**OK**
L2	0.00	6.000	0.000	**OK**		3.000	0.000	**OK**
L3	0.00	9.000	0.000	**OK**		3.000	0.000	**OK**
L4	0.00	12.000	0.000	**OK**		3.000	0.000	**OK**
L5	0.00	15.000	0.000	**OK**		3.000	0.000	**OK**
L6	0.00	18.000	0.000	**OK**		3.000	0.000	**OK**
L7	0.00	21.000	0.000	**OK**		3.000	0.000	**OK**
L8	0.00	24.000	0.000	**OK**		3.000	0.000	**OK**
L9	0.00	27.000	0.000	**OK**		3.000	0.000	**OK**
L10	0.00	30.000	0.000	**OK**		3.000	0.000	**OK**

CONSULTING ENGINEERS	Engineering Calculation Sheet Consulting Engineers	Job No.	Sheet No.	Rev.
		jXXX	2	
		Member/Location		
Job Title	Structure Design - EQ Load Definition and EQ Effects v2	Drg. Ref.		
Structure Design - EQ Load Definition and EQ Effects		Made by XX	Date 18/11/2024	Chd.

EQ Load Displacements in Direction Y

) Load {X, Y, Z} sheet;

Criteria for δ_Y / h	1	:	100	=	0.010	
Criteria for $\lvert\Delta\delta_Y\rvert$ / h_s	1	:	100	=	0.010	

Storey	Total Disp in Y, δ_Y mm	Total Building Height, h m	Total Disp Ratio δ_Y / h	Total Disp Ratio Check	Relative Disp in Y, q.$\Delta\delta_Y$ mm	Inter Storey Height, h_s m	Relative Disp Ratio $\lvert\Delta\delta_Y\rvert$ / h_s	Relative Disp Ratio Check
L1	0.00	3.000	0.000	OK		3.000	0.000	OK
L2	0.00	6.000	0.000	OK		3.000	0.000	OK
L3	0.00	9.000	0.000	OK		3.000	0.000	OK
L4	0.00	12.000	0.000	OK		3.000	0.000	OK
L5	0.00	15.000	0.000	OK		3.000	0.000	OK
L6	0.00	18.000	0.000	OK		3.000	0.000	OK
L7	0.00	21.000	0.000	OK		3.000	0.000	OK
L8	0.00	24.000	0.000	OK		3.000	0.000	OK
L9	0.00	27.000	0.000	OK		3.000	0.000	OK
L10	0.00	30.000	0.000	OK		3.000	0.000	OK