Carleton University

Department of Civil and Environmental Engineering

CIVE 3204 Introduction to Structural Design (Fall 2013)

Solution for Assignment #5 [out of 100]

Question 1: [50 marks]

a) <u>Base shear for the earthquake effect in the N-S direction</u> [35 marks]

base shear $V = [S(T_a)M_vI_EW]/(R_dR_o)$

1 **Earthquake Importance Factor I_E :** for normal facility, $I_E = 1.0$

1 **Ductility-related force modification factor R_d:** (Table 4.1.8.9)

For concrete structures with moderately ductile moment resisting frame $R_d = 2.5$

1 **Overstrength-related force modification factor R_o:** (Table 4.1.8.9)

For concrete structures with moderately ductile moment resisting frame $R_o = 1.4$

3 **Fundamental lateral period T_a:**

For Concrete moment frame, $T_a = 0.075\,(h_n)^{0.75} = 0.075\,(25.2)^{0.75} = 0.844$ s

$h_n = 6*4.2 = 25.2$ m

3 **Gravity load W:**

$W = \Sigma W_i$ + 25% snow load on roof

$= 5*800*9.81+600*9.81+ 0.25*2200$

$= 45676$ kN

Design spectral response acceleration S(T):

2 For Cornwall (Table C-2):

$S_a(0.2) = 0.62$

$S_a(0.5) = 0.31$

$S_a(1.0) = 0.14$

$S_a(2.0) = 0.046$

2

Site class:

Top 10m: $N_{60} = 20$

From 10 to 50m: $N_{60} = 50$

Average $N_{60} = \frac{30}{\frac{5}{20}+\frac{25}{50}} = 40$ $\qquad 15 \leq \text{Average } N_{60} \leq 50$

→ The building is located in site class D.

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Modifying spectral response acceleration, $S_a(T)$ for site class D (Table 4.1.8.4 B and C):

$S_a(0.2)=0.62$ → $F_a = 1.2+[(1.1-1.2)/(0.75-0.50)]*(0.62-0.50) = 1.152$

$S_a(1.0)=0.14$ → $F_v = 1.4+[(1.3-1.4)/(0.20-0.10)]*(0.14-0.10) = 1.36$

Construct S(T):

$T \leq 0.2$ s → $S(T) = F_aS_a(0.2) = 1.152*0.62 = 0.7142$

$T = 0.5$ s → $S(T) = \min[F_vS_a(0.5)\ ,\ F_aS_a(0.2)] = \min[1.36*0.31\ ,\ 1.152*0.62] = 0.4216$

$T = 1$ s → $S(T) = F_vS_a(1) = 1.36*0.14 = 0.1904$

$T = 2$ s → $S(T) = F_vS_a(2) = 1.36*0.046 = 0.06256$

$T \geq 4$ s → $S(T) = F_vS_a(2)/2 = 1.36*0.046/2 = 0.03128$

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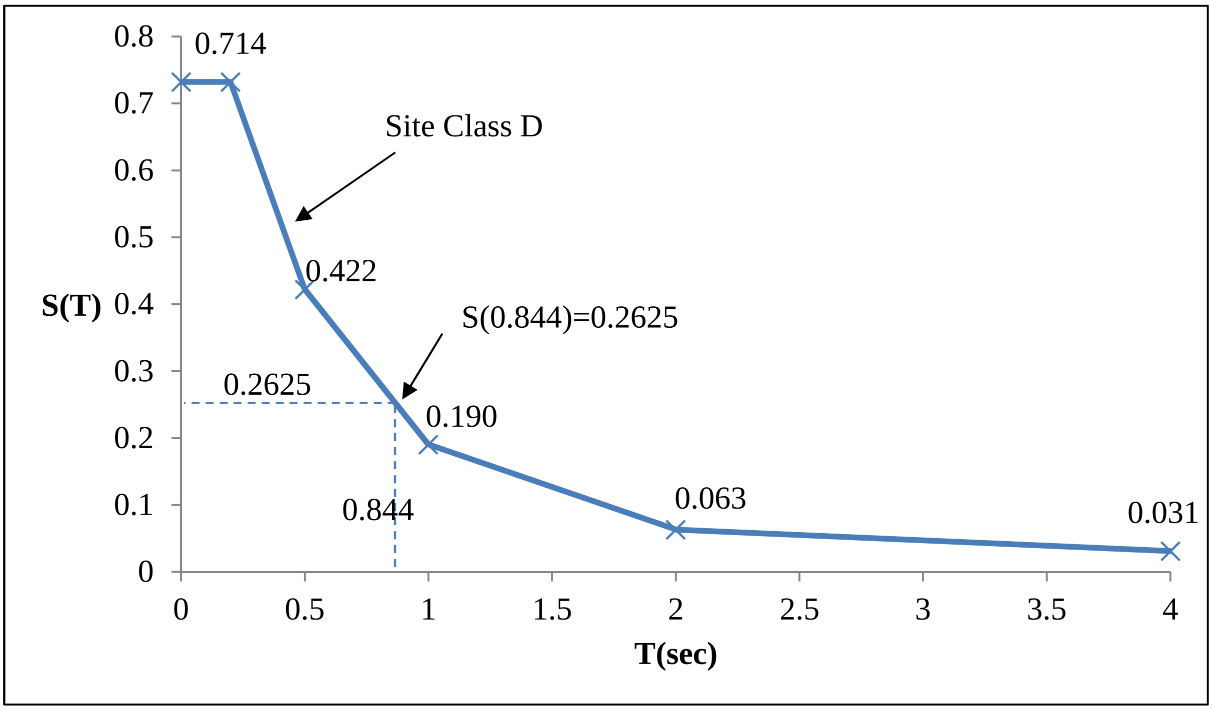

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$T_a = 0.844$ s → $S(0.844) = 0.1904+[(0.4216-0.1904)/(0.5-1)]*(0.844-1) = 0.2625$

2

Higher mode effect factor M_v: (use Table 4.1.8.11)

[$S_a(0.2)$/ $S_a(2.0)$ = 0.62/0.046 = 13.5 ≥ 8] and [moment-resisting frame] →

[T_a = 0.844] ≤ 1.0 ^{s} → M_v (T_a) = 1.0

Base shear V:

V = [S(T_a)$M_v I_E$W]/($R_d R_o$) = (0.2625*1.0*1.0*45676)/(2.5*1.4) = 3426 kN

V= 3.43 MN

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For moment-resisting frame,

V_{min} = [S(2)$M_v I_E$W]/($R_d R_o$) = (0.06256*1.0*1.0*45676)/(2.5*1.4) = 816 kN

For SFRS with R_d ≥ 1.5,

V_{max} = (2/3)[S(0.2) I_EW]/($R_d R_o$) =(2/3) (0.7142*1.0*45676)/(2.5*1.4) = 6.21 MN

[V_{min} =816 kN] ≤ [V= 3.43 MN] ≤ [V_{max} =6.21 MN] →

V= 3.43 MN

b) **<u>Lateral force applied at each storey</u>** [15 marks]

2

T= 0.844 s > 0.7 s → $F_t = 0.07\, T_a V = 0.07*0.844*3426 = 202.4$ kN

$F_t \leq 0.25\, V$ O.K.

$$F_x = (V - F_t)\frac{W_x h_x}{\sum_{i=1}^{n} W_i h_i} = (3426 - 202.4) * \left[\frac{W_x h_x}{\sum_{i=1}^{n} W_i h_i}\right] = 3223.6 * \left[\frac{W_x h_x}{\sum_{i=1}^{n} W_i h_i}\right]$$

$$= 3223.6 * \left[\frac{W_x h_x}{656611}\right]$$ (see table below)

8

Level	h_x (m)	W_x (kN)	$W_x h_x$ (kN.m)	F_x (kN)	F_t (kN)	F_{Story} (kN)
roof	25.2	6436	162187	**796.2**	**202.4**	**998.6**
5	21	7848	164808	**809.1**	**0**	**809.1**
4	16.8	7848	131846	**647.3**	**0**	**647.3**
3	12.6	7848	98884.8	**485.5**	**0**	**485.5**
2	8.4	7848	65923.2	**323.6**	**0**	**323.6**
1	4.2	7848	32961.6	**161.8**	**0**	**161.8**
	Σ=	45676	656611	3223.6	202.4	**3426.0**

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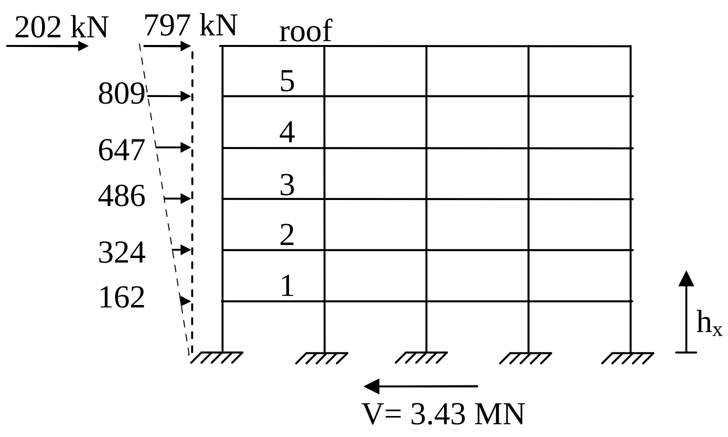


Lateral Earthquake force distribution along the height

Question 2: [50 marks]

External Pressure: P = $I_w q C_e C_g C_p$

Internal Pressure: $P_i = I_w q C_e C_{gi} C_{pi}$

1 **Reference wind pressure q:** In Ottawa, the 1/50 years wind pressure, q = 0.41 kPa

1 **Importance factor I_w:** Assume normal importance structure, I_w=1.0

4 **Exposure factor C_e:**

For structures exposed to rough terrain: $C_e = 0.7 \times \left(\frac{h}{12}\right)^{0.3} \geq 0.7$

Where,

h = reference height above grade (m)

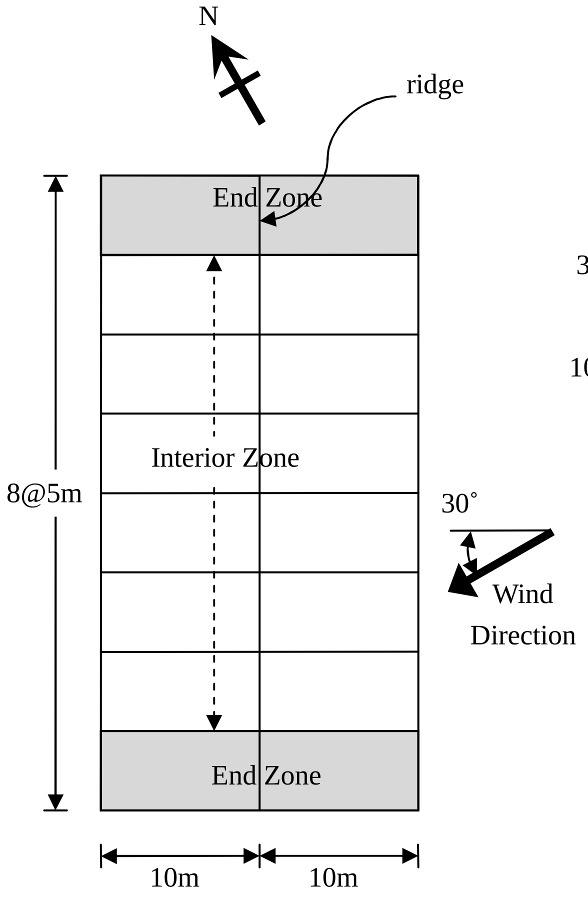
D_s = shorter plan dimension = 20 m

H = mean height of the roof from the ground level = 10+3/2=11.5 m

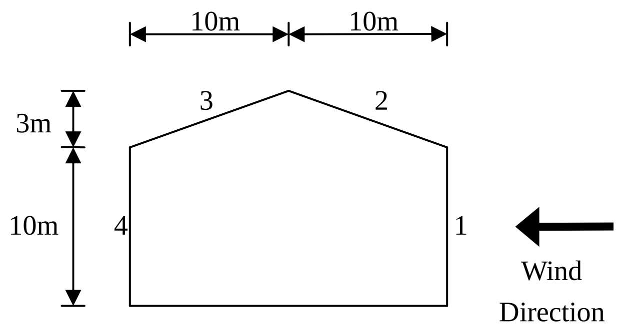
Since H = 11.5 m < 20 m, and H/D_s = 11.5/20 ≤ 1.0, the building should be considered as low-rise.

h= max (mean height of the roof, 6^m) = 11.5 m

$C_e = 0.7 \times \left(\frac{11.5}{12}\right)^{0.3} < 0.7$ → C_e = 0.7



Plan View



Elevation View

<u>Internal Pressure</u>:

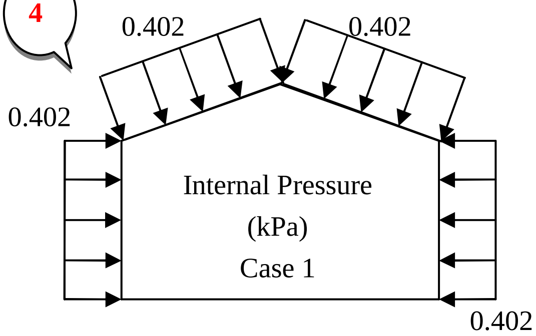
Internal Gust Effect Factor C_{gi} : use default value, C_{gi} =2.0

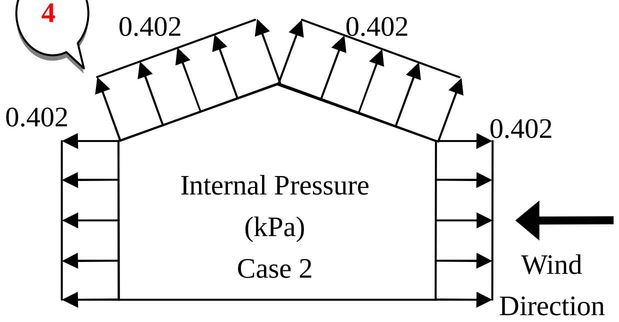
Internal pressure coefficient C_{pi} : For industrial buildings with shipping doors, it is considered as category 3; C_{pi} = -0.7 to 0.7

surface 1: Case 1: $P_i = I_w q C_e C_{gi} C_{pi} = 1*0.41*0.7*2.0*(-0.7) = -0.402$ kPa

Case 2: $P_i = I_w q C_e C_{gi} C_{pi} = 1*0.41*0.7*2.0*(+0.7) = +0.402$ kPa

Following figures show internal pressure on all surfaces.





a) **<u>Net wind pressure profile for the</u>** ***interior zone***

<u>External Pressure</u>:

External peak composite pressure-gust coefficient C_pC_g:

Wind blows generally perpendicular to the ridge → use load case A in Figure I-7

α=roof slope = $\tan^{-1}(3/10)$ = 16.7˚

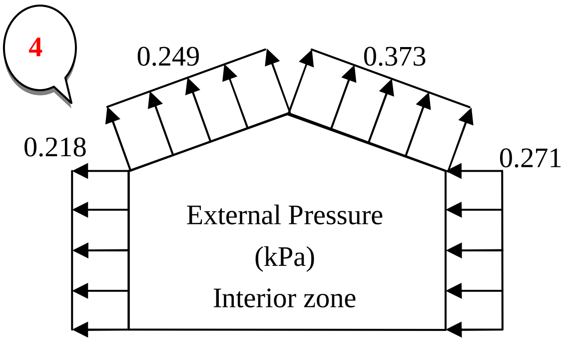
α=5˚ → surface 1: C_pC_g =0.75

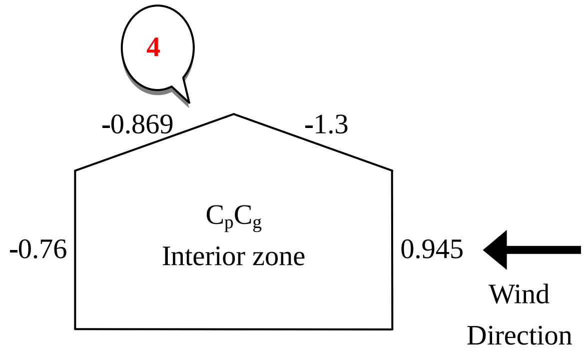
α=20˚ → surface 1: C_pC_g =1.0

α=16.7˚ → surface 1: C_pC_g =0.75+[(1-.75)/(20-5)](16.7-5)=0.945

surface 1: $P = I_w q C_e C_g C_p$ = 1*0.41*0.7*0.945 = 0.271 kPa

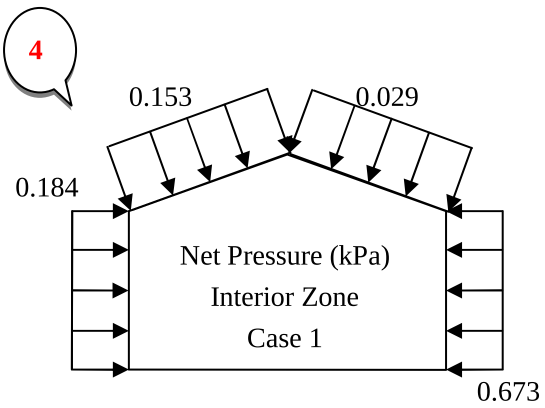
Following figures show C_pC_g values and external pressure on all interior surfaces.

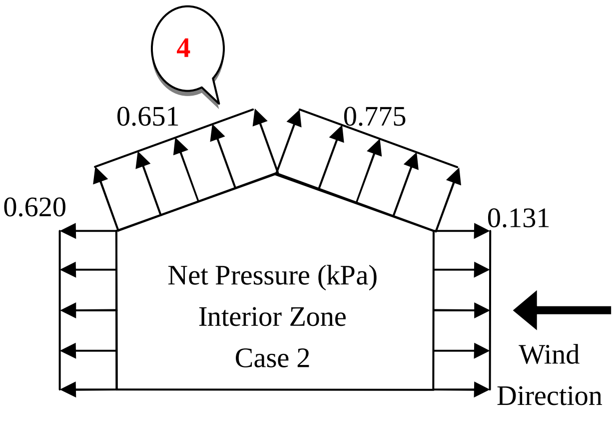




<u>Net Pressure</u>:

To get the net pressure acting on each surface, external and internal pressure should be combined for cases 1 and 2, separately. Following figures show the net pressure profile for the interior zone for cases 1 and 2.





b) Net wind pressure profile for the *End zone*

External Pressure:

External peak composite pressure-gust coefficient C_pC_g:

Wind blows generally perpendicular to the ridge → use load case A in Figure I-7

α=roof slope = $\tan^{-1}(3/10)$ = 16.7°

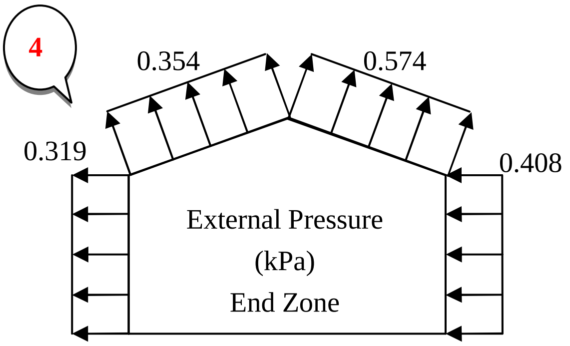
α=5° → surface 1E: C_pC_g =1.15

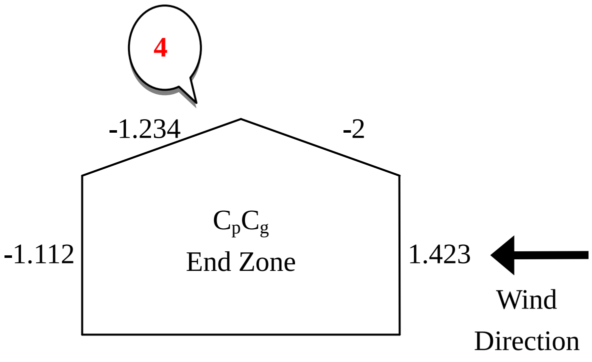
α=20° → surface 1E: C_pC_g =1.5

α=16.7° → surface 1E: C_pC_g =1.15+[(1.5-1.15)/(20-5)](16.7-5)=1.423

surface 1E: $P = I_w q C_e C_g C_p$ = 1*0.41*0.7*1.423 = 0.408 kPa

Following figures show C_pC_g values and external pressure on all surfaces at end zones.





Net Pressure:

To get the net pressure acting on each surface, external and internal pressure should be combined for cases 1 and 2, separately. Following figures show the net pressure profile for end zones for cases 1 and 2.