Carleton University

Department of Civil and Environmental Engineering

CIVE 3204 Introduction to Structural Design (Fall 2014)

Solution for Assignment #5 [out of 100]

Question 1: [50 marks]

a) Base shear for the earthquake effect in the N-S direction

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

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

Ductility-related force modification factor R_d: (Table 4.1.8.9)
For concrete structures with moderately ductile moment resisting frame $R_d = 2.5$

Overstrength-related force modification factor R_o: (Table 4.1.8.9)
For concrete structures with moderately ductile moment resisting frame $R_o = 1.4$

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

Gravity load W:
W = ΣW_i + 25% snow load on roof
= 5*950*9.81+600*9.81+ 0.25*2200
= 53034 kN

Design spectral response acceleration S(T):
For Ottawa (Table C-2):
$S_a(0.2) = 0.64$
$S_a(0.5) = 0.31$
$S_a(1.0) = 0.14$
$S_a(2.0) = 0.046$

Site class:

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

From 10 to 40m: $N_{60} = 50$

Average $N_{60} = \frac{30}{\frac{10}{20}+\frac{20}{50}} = 33.3$ $\quad\quad 15 \leq$ Average $N_{60} \leq 50$

→ The building is located in site class D.

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

Sa(0.2)=0.64 → Fa = 1.2+[(1.1-1.2)/(0.75-0.50)]*(0.64-0.50) = 1.144

Sa(1.0)=0.14 → Fv = 1.4+[(1.3-1.4)/(0.20-0.10)]*(0.14-0.10) = 1.36

Construct S(T):

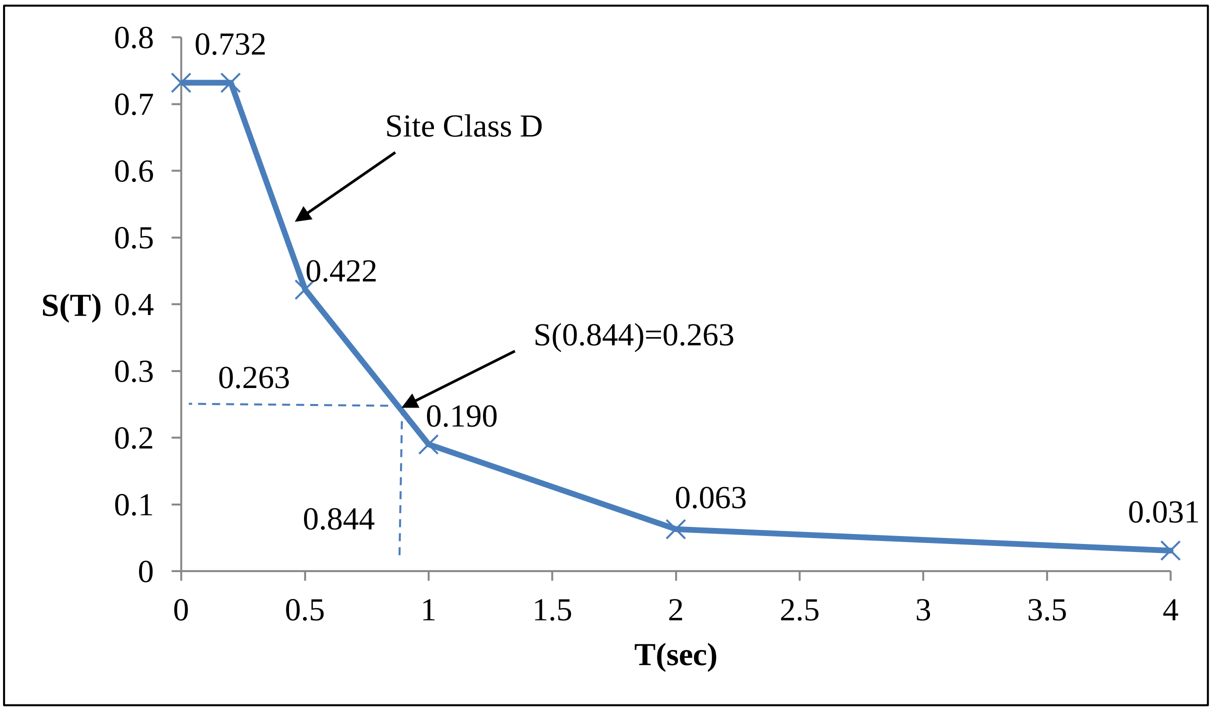
$T \leq 0.2$ s → $S(T) = F_aS_a(0.2) = 1.144*0.64 = 0.73216$

$T = 0.5$ s → $S(T) = \min[F_vS_a(0.5) , F_aS_a(0.2)] = \min[1.36*0.31 , 1.144*0.64]$
$= 0.4216$

$T = 1$ 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 → $S(T) = F_vS_a(2)/2 = 1.36*0.046/2 = 0.03128$



$T_a = 0.844$ s → $S(0.844) = 0.4216+[(0.1904-0.4216)/(1-0.5)]*(0.844-0.5) = 0.263$

Higher mode effect factor M_v: (use Table 4.1.8.11)

[$S_a(0.2)/ S_a(2.0) = 0.64/0.046 = 13.9 \geq 8$] and [moment-resisting frame] →

[$T_a = 0.844$] ≤ 1.0 → $M_v (T_a) = 1.0$

Base shear V:

$V = [S(T_a)M_vI_EW]/(R_dR_o) = (0.263*1.0*1.0*53034)/(2.5*1.4) = 3985$ kN

V= 3.99 MN

For moment-resisting frame,

$V_{min} = [S(2)M_vI_EW]/(R_dR_o) = (0.06256*1.0*1.0*53034)/(2.5*1.4) = 948$ kN

For SFRS with $R_d \geq 1.5$,

$V_{max} = (2/3)[S(0.2)\ I_EW]/(R_dR_o) =(2/3)\ (0.73216*1.0*53034)/(2.5*1.4) = 7.4$ MN

[V_{min} =948 kN] ≤ [V= 3.99 MN] ≤ [V_{max} =7.4 MN] →

V= 3.99 MN

b) <u>Lateral force applied at each storey</u>

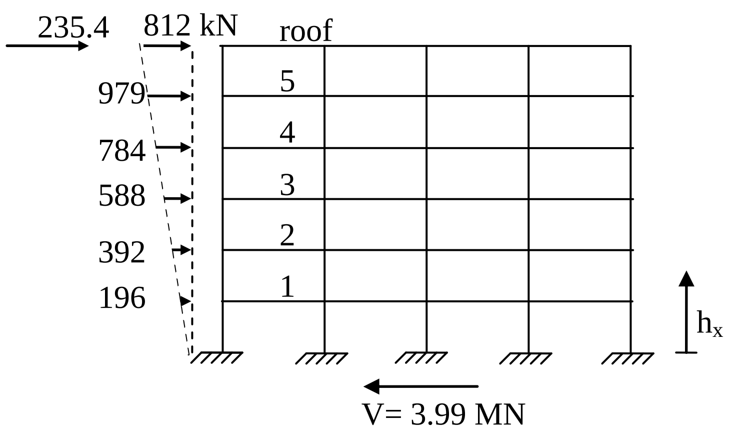
T= 0.844 s > 0.7 s → $F_t = 0.07\ T_a V$ = 0.07*0.844*3985 = 235.4 kN

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

$F_x = (V - F_t)\frac{W_x h_x}{\sum_{i=1}^{n} W_i h_i}$ = (3985 – 235.4) * $[\frac{W_x h_x}{\sum_{i=1}^{n} W_i h_i}]$ = 3749.6 * $[\frac{W_x h_x}{\sum_{i=1}^{n} W_i h_i}]$

= 3749.6 * $[\frac{W_x h_x}{749316}]$ (see table below)

Level	h_x	W_x	$W_x\ h_x$	F_x	F_t	F_x
	(m)	(kN)	(kN.m)	(kN)	(kN)	(kN)
	25.2	6436	162187	**811.6**	**235.4**	**1047.0**
5	21	9320	195710	**979.3**	**0**	**979.3**
4	16.8	9320	156568	**783.5**	**0**	**783.5**
3	12.6	9320	117426	**587.6**	**0**	**587.6**
2	8.4	9320	78283.8	**391.7**	**0**	**391.7**
1	4.2	9320	39141.9	**195.9**	**0**	**195.9**
	Σ=	53034	749316	3749.6	235.4	**3985.0**



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

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

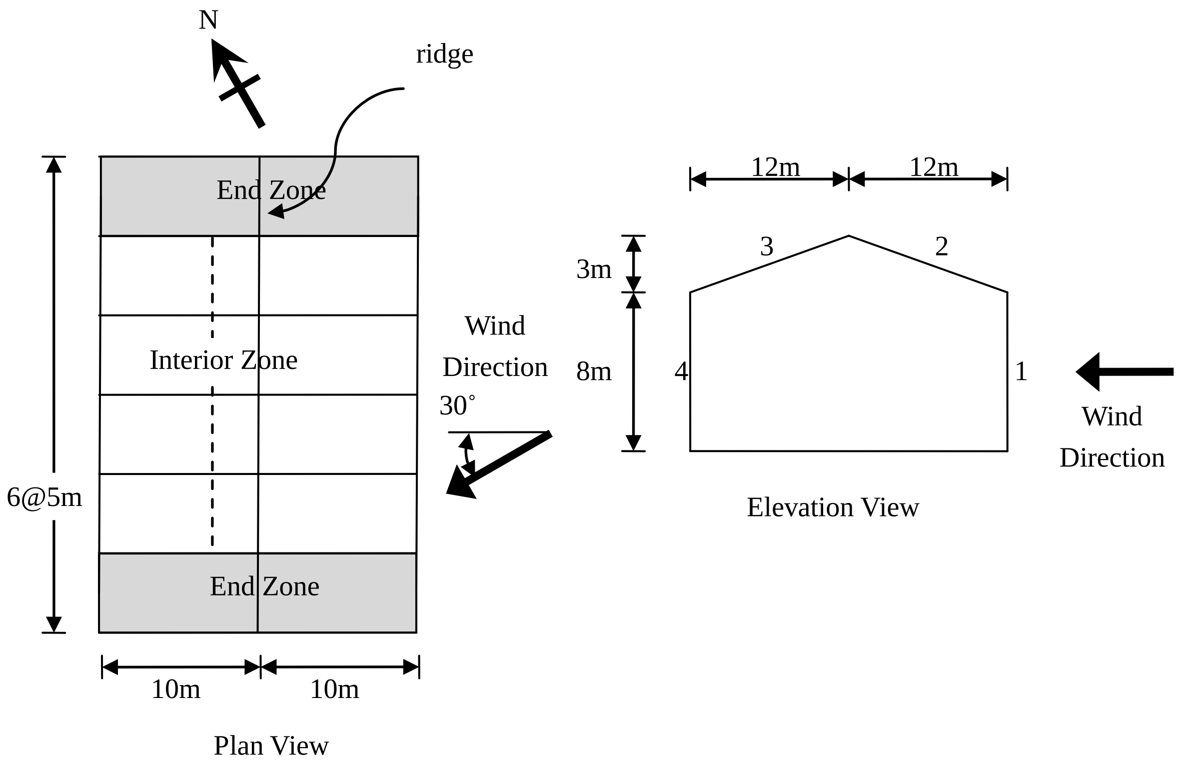
Importance factor I_w: Assume normal importance structure, I_w=1.0

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 = 24 m
H = mean height of the roof from the ground level = 8+3/2=9.5 m
Since H = 9.5 m < 20 m, and H/D_s = 9.5/20 ≤ 1.0, the building should be considered as low-rise.
h= max (mean height of the roof, 6^m) = 9.5 m

$C_e = 0.7 \times \left(\frac{9.5}{12}\right)^{0.3} < 0.7$ → C_e = 0.7



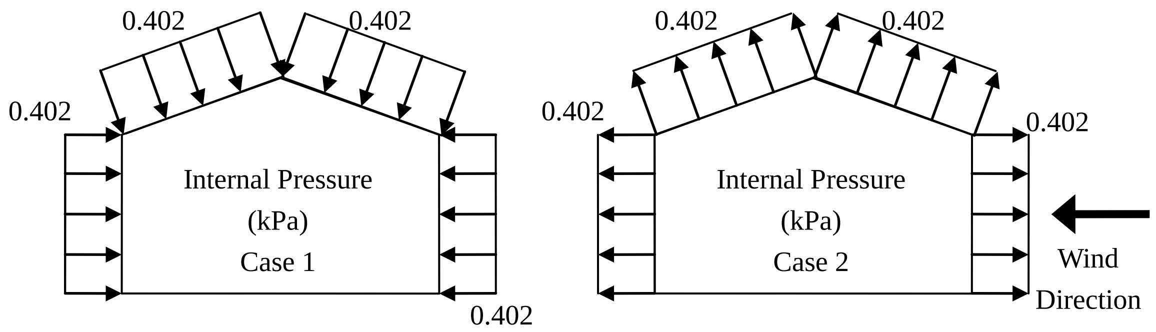
Internal Pressure:

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) **Net wind pressure profile for the *interior zone***

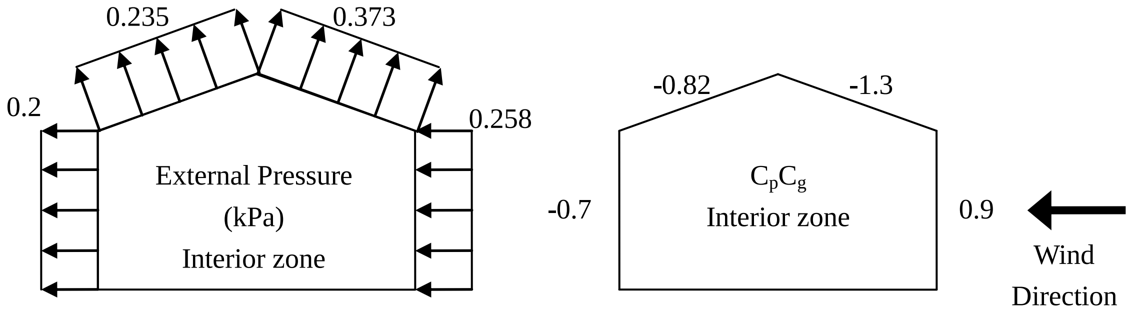
External Pressure:

External peak composite pressure-gust coefficient C_pC_g:

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

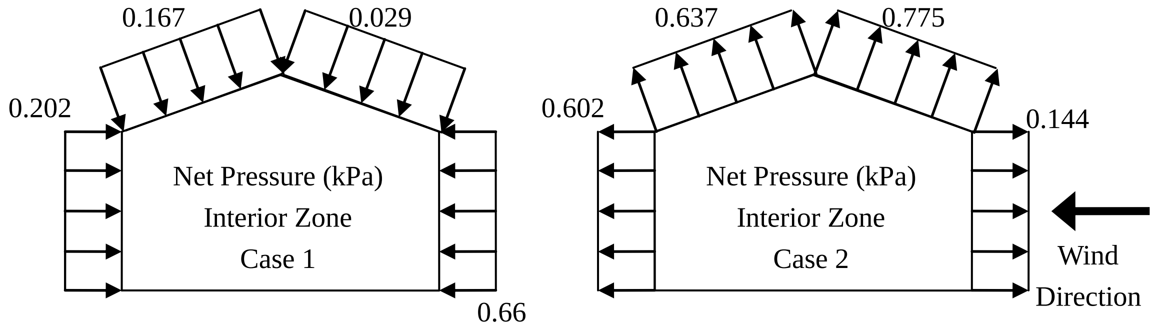
α=roof slope = $\tan^{-1}(3/12)$ = 14.0°
α=5° → surface 1: C_pC_g =0.75
α=20° → surface 1: C_pC_g =1.0
α=14.0° → surface 1: C_pC_g =0.75+[(1-.75)/(20-5)](14.0-5)=0.9
surface 1: $P = I_w q C_e C_g C_p$ = 1*0.41*0.7*0.9 = 0.258 kPa

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



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 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 = $\tan^{-1}(3/12) = 14°$

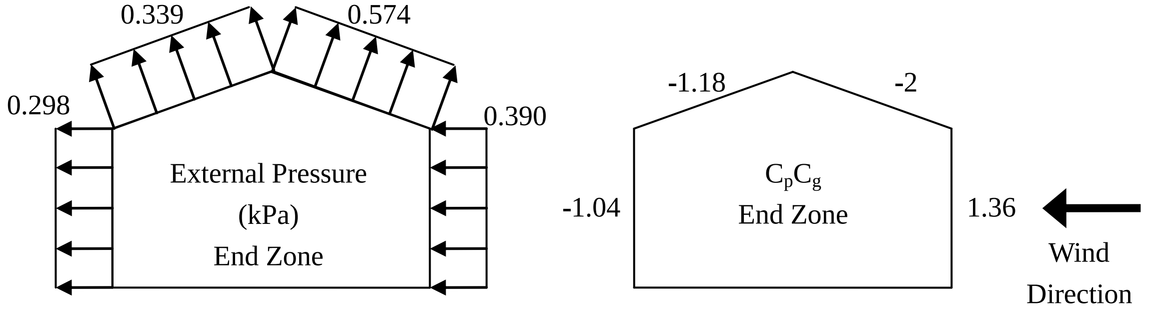
α=5° → surface 1E: C_pC_g =1.15

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)](14-5)=1.36

surface 1E: $P = I_wqC_eC_gC_p$ = 1*0.41*0.7*1.36 = 0.39 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.