Structural Analysis and Design 1

WIND LOAD CALCULATION
BNBC-2020

Structural Analysis and Design 1

Problem

- **Calculate the design load of the following building. Rectangular (72X48m). Hospital building (6 storied). Storey height = 3m. City Dhaka, Exposure = A Calculate as per BNBC-2020.**

Follow Method-2: Analytical Procedure

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Wind Load Calculation Methods

Three procedures for calculating wind loads for the design of buildings, main wind-force-resisting systems (MWFRS), and components and cladding.

Method 1: Simplified Method: It was first published in the 2000 IBC. It was developed from research done for Metal Building Manufactures Association, MBMA, in the 1980s using wind-tunnel tests. Method 1 is restricted to regular-shaped "simple diaphragm buildings," has many constraints, and is restricted to a maximum height of 60 ft (18.3m).

Method 2: Analytical Procedure: May be used for buildings of any heightthat are regular in shape, provided they are not sensitive to across-wind loading, vortex shedding, or instability due to galloping or flutter; or do not have a site for which channeling effects warrant special consideration.

Method 3: Wind-Tunnel Procedure: To be used in lieu of Methods 1 and 2 for any building. Method 3 is recommended for buildings that exhibit the following characteristics:

- Non-uniform shapes
- Flexible with natural frequencies less than 1 Hz
- Subject to significant buffeting by the wake of upwind buildings, subject to accelerated flow of wind by channeling or local topographic features.

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Method 2 : Analytical Procedure

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METHOD 2: ANALYTICAL PROCEDURE

Design wind pressure or suction on a building surface is given by the equation:

$$p_z = q_z \times G_f \times C_p$$

where

p_z **is the design wind pressure or suction, at height z, above ground level**

q_z **is the velocity pressure, determined at height *z* above ground for positive pressure, and at roof height *h* for suction**

$$q_z = 0.000613\, K_z K_{zt} K_d V^2 I, \ \text{kN/m}^2, V \text{ in m/s}$$

G_f **is the gust effect factor, dimensionless, denoted as *G* for rigid buildings, and G_f for flexible buildings**

C_p **is the external pressure coefficient, which varies with building height acting as pressure (positive load) on windward face, and as suction (negative load) on the leeward face and roof.**

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Design Wind Pressure, P

Workshop on Design of Steel and Concrete Structures for Lateral Loads Using Proposed BNBC 2015 Code.
Wind Loading Provisions

BNBC 2015 WIND LOAD PROVISIONS

Design wind pressure, *p*

$$p = q\,GC_p - q_i\,(GC_{pi})$$

Where,

$q = q_z$	for windward walls evaluated at height z above the ground
$q = q_h$	for leeward walls, side walls, and roofs, evaluated at height h
$q_i = q_h$	for windward walls, side walls, leeward walls, and roofs of enclosed buildings and for negative internal pressure evaluation in partially enclosed buildings.
$q_i = q_z$	for positive internal pressure evaluation in partially enclosed buildings where height z is defined as the level of the highest opening in the building that could affect the positive internal pressure.
G	gust effect factor from Sec 2.4.8
C_p	external pressure coefficient from Figures 6.2.6 or 6.2.8
C_{pi}	internal pressure coefficient from Figure 6.2.5

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Design Procedure

2.4.3.4 Design procedure

(1) The basic wind speed V and wind directionality factor K_d shall be determined in accordance with Sec 2.4.4.

(2) An importance factor I shall be determined in accordance with Sec 2.4.5.

(3) An exposure category or exposure categories and velocity pressure exposure coefficient K_z or K_h, as applicable, shall be determined for each wind direction in accordance with Sec 2.4.6.

(4) A topographic factor K_{zt} shall be determined in accordance with Sec 2.4.7.

(5) A gust effect factor G or G_f, as applicable, shall be determined in accordance with Sec 2.4.8.

(6) An enclosure classification shall be determined in accordance with Sec 2.4.9.

(7) Internal pressure coefficient GC_{pi} shall be determined in accordance with Sec 2.4.10.1.

(8) External pressure coefficients C_p or GC_{pf}, or force coefficients C_f, as applicable, shall be determined in accordance with Sections 2.4.10.2 or 2.4.10.3, respectively.

(9) Velocity pressure q_z or q_h, as applicable, shall be determined in accordance with Sec 2.4.9.5.

(10) Design wind load P or F shall be determined in accordance with Sec 2.4.11.

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Topographic Factor, K_{zt}

2.4.7.2 Topographic factor

The wind speed-up effect shall be included in the calculation of design wind loads by using the factor K_{zt}:

$$K_{zt} = (1 + K_1 K_2 K_3)^2 \qquad (6.2.5)$$

Where, K_1, K_2, and K_3 are given in Figure 6.2.4. If site conditions and locations of structures do not meet all the conditions specified in Sec 2.4.7.1 then $K_{zt} = 1.0$.

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Wind Directionality Factor, K_d

Table 6.2.12: Wind Directionality Factor, K_d

Structure Type	Directionality Factor K_d *	Structure Type	Directionality Factor K_d *
Buildings		Solid Signs	0.85
Main Wind Force Resisting System	0.85	Open Signs and Lattice Framework	0.85
Components and Cladding	0.85	Trussed Towers	
Arched Roofs	0.85	Triangular, square, rectangular	0.85
Chimneys, Tanks, and Similar Structures		All other cross section	0.95
Square	0.90		
Hexagonal	0.95		
Round	0.95		

* Directionality Factor K_d has been calibrated with combinations of loads specified in Sec 2.7. This factor shall only be applied when used in conjunction with load combinations specified in Sections 2.7.2 and 2.7.3.

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Basic Wind Speed , V (m/s)

Location	Basic Wind Speed (m/s)	Location	Basic Wind Speed (m/s)
Angarpota	47.8	Lalmonirhat	63.7
Bagerhat	77.5	Madaripur	68.1
Bandarban	62.5	Magura	65.0
Barguna	80.0	Manikganj	58.2
Barisal	78.7	Meherpur	58.2
Bhola	69.5	Maheshkhali	80.0
Bogra	61.9	Moulvibazar	53.0
Brahmanbaria	56.7	Munshiganj	57.1
Chandpur	50.6	Mymensingh	67.4
Chapai Nawabganj	41.4	Naogaon	55.2
Chittagong	80.0	Narail	68.6
Chuadanga	61.9	Narayanganj	61.1
Comilla	61.4	Narsinghdi	59.7
Cox's Bazar	80.0	Natore	61.9
Dahagram	47.8	Netrokona	65.6
Dhaka	65.7	Nilphamari	44.7
Dinajpur	41.4	Noakhali	57.1
Faridpur	63.1	Pabna	63.1
Feni	64.1	Panchagarh	41.4
Gaibandha	65.6	Patuakhali	80.0
Gazipur	66.5	Pirojpur	80.0
Gopalganj	74.5	Rajbari	59.1
Habiganj	54.2	Rajshahi	49.2
Hatiya	80.0	Rangamati	56.7
Ishurdi	69.5	Rangpur	65.3
Joypurhat	56.7	Satkhira	57.6
Jamalpur	56.7	Shariatpur	61.9
Jessore	64.1	Sherpur	62.5
Jhalakati	80.0	Sirajganj	50.6
Jhenaidah	65.0	Srimangal	50.6
Khagrachhari	56.7	St. Martin's Island	80.0
Khulna	73.3	Sunamganj	61.1
Kutubdia	80.0	Sylhet	61.1
Kishoreganj	64.7	Sandwip	80.0
Kurigram	65.6	Tangail	50.6
Kushtia	66.9	Teknaf	80.0
Lakshmipur	51.2	Thakurgaon	41.4

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Occupancy Category

Nature of Occupancy	Occupancy Category
Buildings and other structures that represent a low hazard to human life in the event of failure, including, but not limited to: • Agricultural facilities • Certain temporary facilities • Minor storage facilities	I
All buildings and other structures except those listed in Occupancy Categories I, III and IV	II
Buildings and other structures that represent a substantial hazard to human life in the event of failure, including, but not limited to: • Buildings and other structures where more than 300 people congregate in one area • Buildings and other structures with day care facilities with a capacity greater than 150 • Buildings and other structures with elementary school or secondary school facilities with a capacity greater than 250 • Buildings and other structures with a capacity greater than 500 for colleges or adult education facilities • Healthcare facilities with a capacity of 50 or more resident patients, but not having surgery or emergency Treatment facilities • Jails and detention facilities Buildings and other structures, not included in Occupancy Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure, including, but not limited to: • Power generating stations[a] • Water treatment facilities • Sewage treatment facilities • Telecommunication centers Buildings and other structures not included in Occupancy Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released.	III

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Occupancy Category

Buildings and other structures designated as essential facilities, including, but not limited to: • Hospitals and other healthcare facilities having surgery or emergency treatment facilities • Fire, rescue, ambulance, and police stations and emergency vehicle garages • Designated earthquake, hurricane, or other emergency shelters • Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response • Power generating stations and other public utility facilities required in an emergency • Ancillary structures (including, but not limited to, communication towers, fuel storage tanks, cooling towers, • Electrical substation structures, fire water storage tanks or other structures housing or supporting water, or other fire-suppression material or equipment) required for operation of Occupancy Category IV structures during an emergency • Aviation control towers, air traffic control centers, and emergency aircraft hangars • Community water storage facilities and pump structures required to maintain water pressure for fire suppression • Buildings and other structures having critical national defense functions	IV
Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing highly toxic substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction.	

[a] Cogeneration power plants that do not supply power on the national grid shall be designated Occupancy Category II

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Importance Factor, I

Table 6.2.9: Importance Factor, I (Wind Loads)

Occupancy Category[1] or Importance Class	Non-Cyclone Prone Regions and Cyclone Prone Regions with V = 38-44 m/s	Cyclone Prone Regions with V > 44 m/s
I	0.87	0.77
II	1.0	1.00
III	1.15	1.15
IV	1.15	1.15

[1] The building and structure classification categories are listed in Table 6.1.1

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Data for Calculation

1. **Storey : 6**
2. **Building Height : 6@3 = 18 m**
3. **Size : 72 m × 42 m**
4. **Type : Hospital**
5. **Occupancy Category : IV (Hospital)**
6. **Importance Factor, I : 1.15**
7. **Location : Dhaka**
8. **Exposure : A**
9. **K_{zt} : 1**
10. **K_d : 0.85**
11. **Basic Wind Speed , V = 65.7 m/s.**

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Velocity Pressure Exposure Coefficient, K_z

2. The velocity pressure exposure coefficient K_z may be determined from the following formula:

For 4.57 m $\leq z \leq z_g$: $K_z = 2.01\ (z/z_g)^{2/\alpha}$

For $z < 4.57$ m: $K_z = 2.01\ (4.57/z_g)^{2/\alpha}$

Note: z shall not be taken less than 9.1 m for Case 1 in exposure A.

Table 6.2.10: Terrain Exposure Constants

Exposure	α	z_g (m)	$\hat{a}$	$\hat{b}$	$\bar{\alpha}$	$\bar{b}$	c	l (m)	$\bar{\in}$	z_{min} (m)*
A	7.0	365.76	1/7	0.84	1/4.0	0.45	0.30	97.54	1/3.0	9.14
B	9.5	274.32	1/9.5	1.00	1/6.5	0.65	0.20	152.4	1/5.0	4.57
C	11.5	213.36	1/11.5	1.07	1/9.0	0.80	0.15	198.12	1/8.0	2.13

*z_{min} = Minimum height used to ensure that the equivalent height z is greater of $0.6h$ or z_{min}.

For buildings with $h \leq z_{min}$, $\bar{z}$ shall be taken as z_{min}.

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Calculation of q_z

- **Sample Calculation**
- **For floor 1 :**

$K_z = 2.01 \times (4.57/365.76)^{2/7} = 0.57$

$q_z = 0.000613 \times K_z \times K_d \times K_{zt} \times V^2 \times I$

$= 0.000613 \times 0.57 \times 0.85 \times 1 \times 65.7^2 \times 1.15$

$= 1.48$ kPa

- **For floor 2 :**

$K_z = 2.01 \times (6/365.76)^{2/7} = 0.62$

$q_z = 0.000613 \times K_z \times K_d \times K_{zt} \times V^2 \times I$

$= 0.000613 \times 0.62 \times 0.85 \times 1 \times 65.7^2 \times 1.15$

$= 1.61$ kPa

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Calculation of q_z

Floor	Height above ground (m)	α	Z_g(m)	K_z	q_z (kPa)
F1	3	7	365.76	0.574648	1.486311
F2	6	7	365.76	0.621131	1.606539
F3	9	7	365.76	0.697421	1.803861
F4	12	7	365.76	0.757167	1.958393
F5	15	7	365.76	0.807013	2.087317
F6	18	7	365.76	0.850166	2.198931

Z_g and α are taken according Table 6.2.10

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Design Wind Pressure, p

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Design wind pressure, *p*

$$p = q\,GC_p - q_i\,(GC_{pi})$$

Where,

$q = q_z$	for windward walls evaluated at height z above the ground
$q = q_h$	for leeward walls, side walls, and roofs, evaluated at height h
$q_i = q_h$	for windward walls, side walls, leeward walls, and roofs of enclosed buildings and for negative internal pressure evaluation in partially enclosed buildings.
$q_i = q_z$	for positive internal pressure evaluation in partially enclosed buildings where height z is defined as the level of the highest opening in the building that could affect the positive internal pressure.
G	gust effect factor from Sec 2.4.8
C_p	external pressure coefficient from Figures 6.2.6 or 6.2.8
C_{pi}	internal pressure coefficient from Figure 6.2.5

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Rigid Structure

BUILDING OR OTHER STRUCTURES, RIGID	A building or other structure whose fundamental frequency is greater than or equal to 1 Hz.

(b) The building period T (in sec) may be approximated by the following formula:

$$T = C_t(h_n)^m \qquad (6.2.38)$$

Where,

h_n = Height of building in metres from foundation or from top of rigid basement. This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But it includes the basement storeys, when they are not so connected. C_t and m are obtained from Table 6.2.20

Table 6.2.20: Values for Coefficients to Estimate Approximate Period

Structure type	C_t	m	
Concrete moment-resisting frames	0.0466	0.9	Note: Consider moment resisting frames as frames which resist 100% of seismic force and are not enclosed or adjoined by components that are more rigid and will prevent the frames from deflecting under seismic forces.
Steel moment-resisting frames	0.0724	0.8	
Eccentrically braced steel frame	0.0731	0.75	
All other structural systems	0.0488	0.75	

Structural Analysis and Design 1

Rigid Structure

Fundamental Time Period, $T = C_t(h_n)^m$

For Concrete moment resisting frames, $C_t = 0.0466$, $m = 0.9$

Fundamental Time Period, $T = 0.0466 \times (18)^{0.9}$

$= 0.628$ sec

Fundamental Frequency = 1/T

= 1/0.628 Hz

= 1.59 Hz

As Fundamental Frequency > 1 Hz, The structure is Rigid.

Gust Factor, G can be taken as 0.85.

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Gust Factor, G

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METHOD 2: ANALYTICAL PROCEDURE

Gust factor, *G*

Rigid Structure: Simplified Method

Structures having a natural frequency of vibration greater than 1 Hz (or period less than 1 sec), the engineer may use a single value of $G = 0.85$, irrespective of exposure category.

Rigid Structure: Improved Method

We may calculate a more accurate value by including specific features of the wind environment at the building site.

Gust factor, $G = 0.925 \frac{1+1.7 g_Q I_{\bar{z}} Q}{1+1.7 g_v I_{\bar{z}}}$

Intensity of turbulence at height $\bar{z}$, $I_{\bar{z}} = c \left(\frac{10}{\bar{z}}\right)^{1/6}$

$\bar{z} = 0.6h < z_{min}$, h = height of the building.

Parameters z_{min} and c are listed in Table 6.2.10 [see slide 25]

$g_Q = 3.4$, $g_V = 3.4$

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Gust Factor, G

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METHOD 2: ANALYTICAL PROCEDURE

Gust factor, *G*

Rigid Structure: Improved Method (contd...)

Background response, $Q = \sqrt{\frac{1}{1+0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}}$

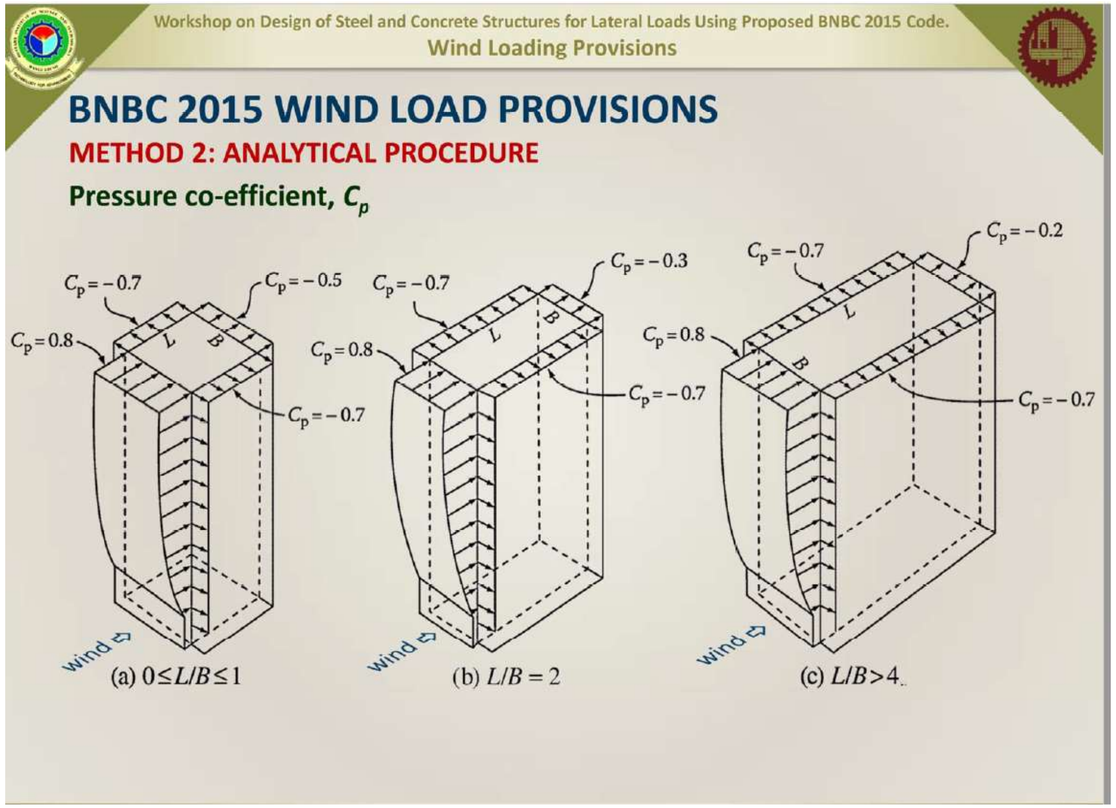
B = width of the building across the wind, ***h*** = mean height of the building.

Integral length scale of turbulence at the equivalent height, $L_{\bar{z}} = l\left(\frac{\bar{z}}{10}\right)^{\bar{\epsilon}}$

In which l and $\bar{\epsilon}$ are constants listed in Table 6.2.10.

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External Pressure Coefficient, C_p



Wall Pressure Coefficients, C_p			
Surface	L/B	C_p	Use With
Windward Wall	All values	0.8	q_z
Leeward Wall	0-1	-0.5	q_h
	2	-0.3	
	≥ 4	-0.2	
Side Wall	All values	-0.7	q_h

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Internal Pressure Coefficient, GC_{pi}

Enclosed, Partially Enclosed, and Open Buildings: Walls & Roofs

Enclosure Classification	GC_{pi}
Open Building	0.00
Partially Enclosed Building	+0.55 -0.55
Enclosed Building	+0.18 -0.18

Notes:

1. Plus and minus signs signify pressures acting toward and away from the internal surfaces, respectively.
2. Values of GC_{pi} shall be used with q_z or q_h as specified in Sec 2.4.11.
3. Two cases shall be considered to determine the critical load requirements for the appropriate condition:

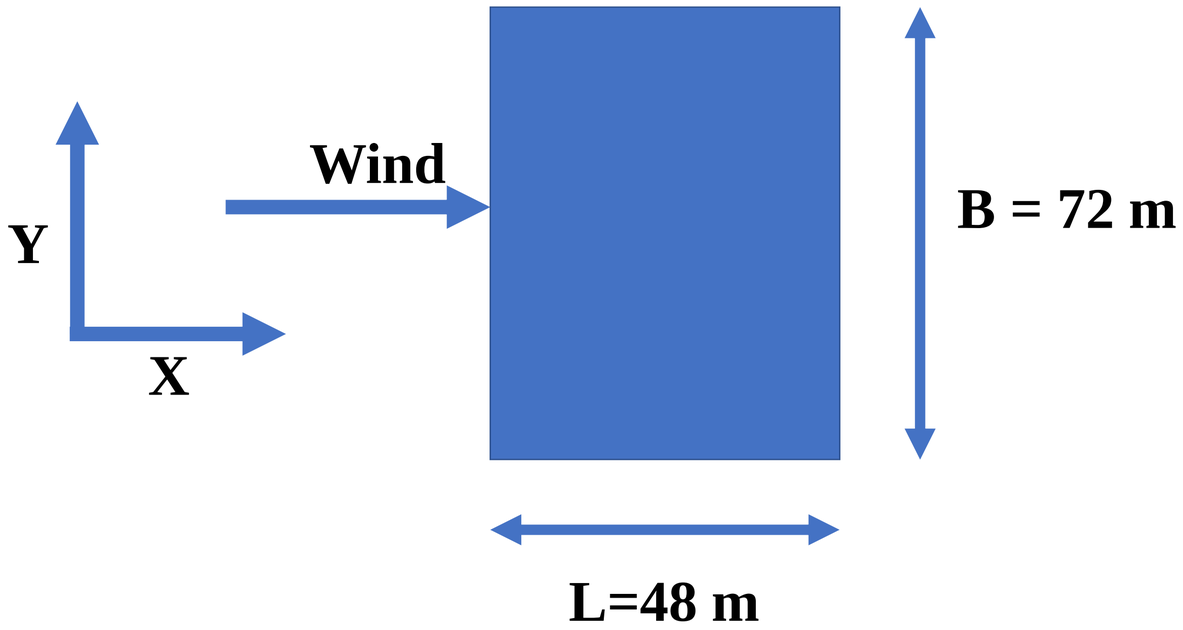
   (i) a positive value of GC_{pi} applied to all internal surfaces

   (ii) a negative value of GC_{pi} applied to all internal surfaces.

Figure 6.2.5 Internal pressure coefficient, GC_{pi} main wind force resisting system component and cladding - Method 2 (All Heights)

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Wind in X Direction

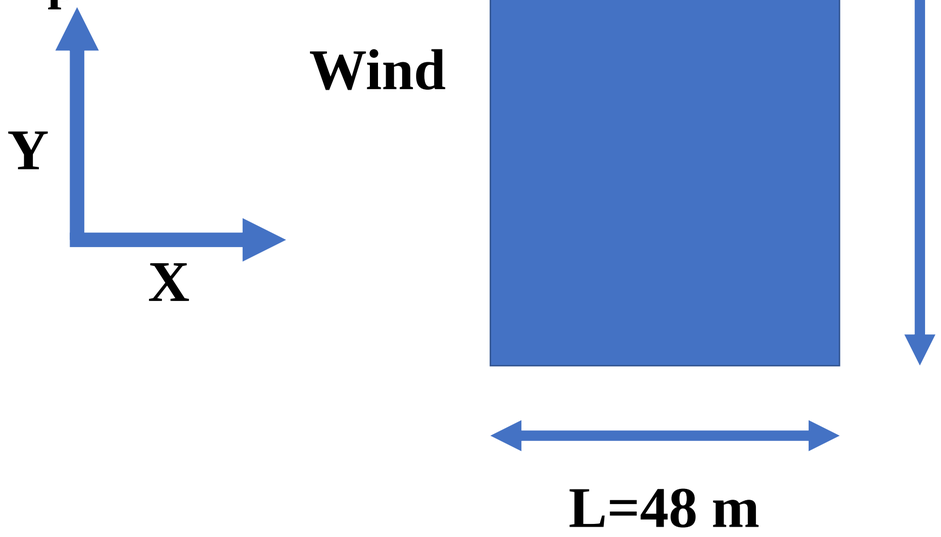


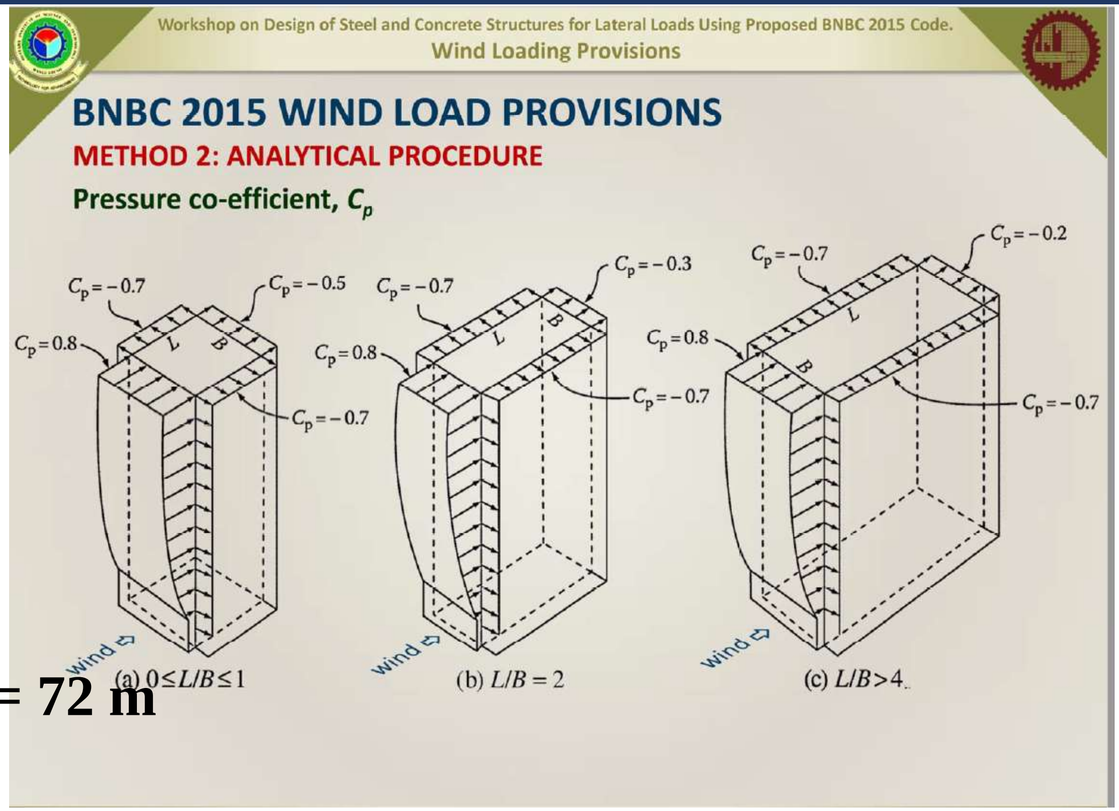
Structural Analysis and Design 1

C_p for X Direction

Calculating External Pressure Coefficient:

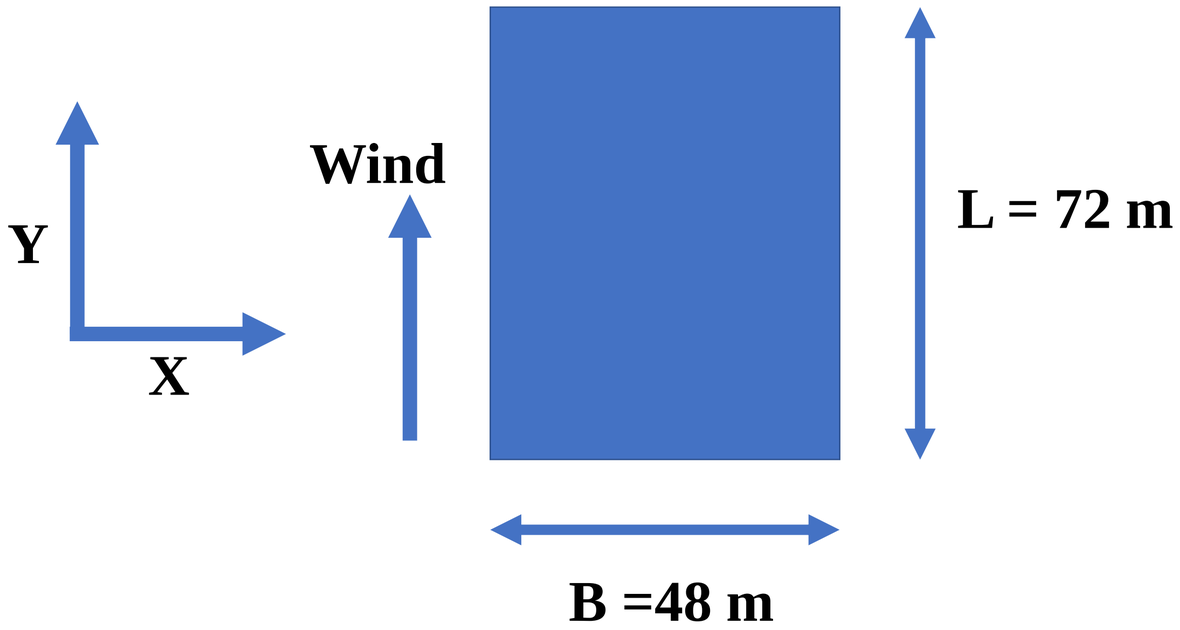
- **For Wind at X Direction:**
- **L/B = 48/72 = 0.667**
- **Windward Wall, C_p = 0.80**
- **Leeward Wall, C_p = -0.50**
- **Side Wall, C_p = -0.70**





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Wind in Y Direction

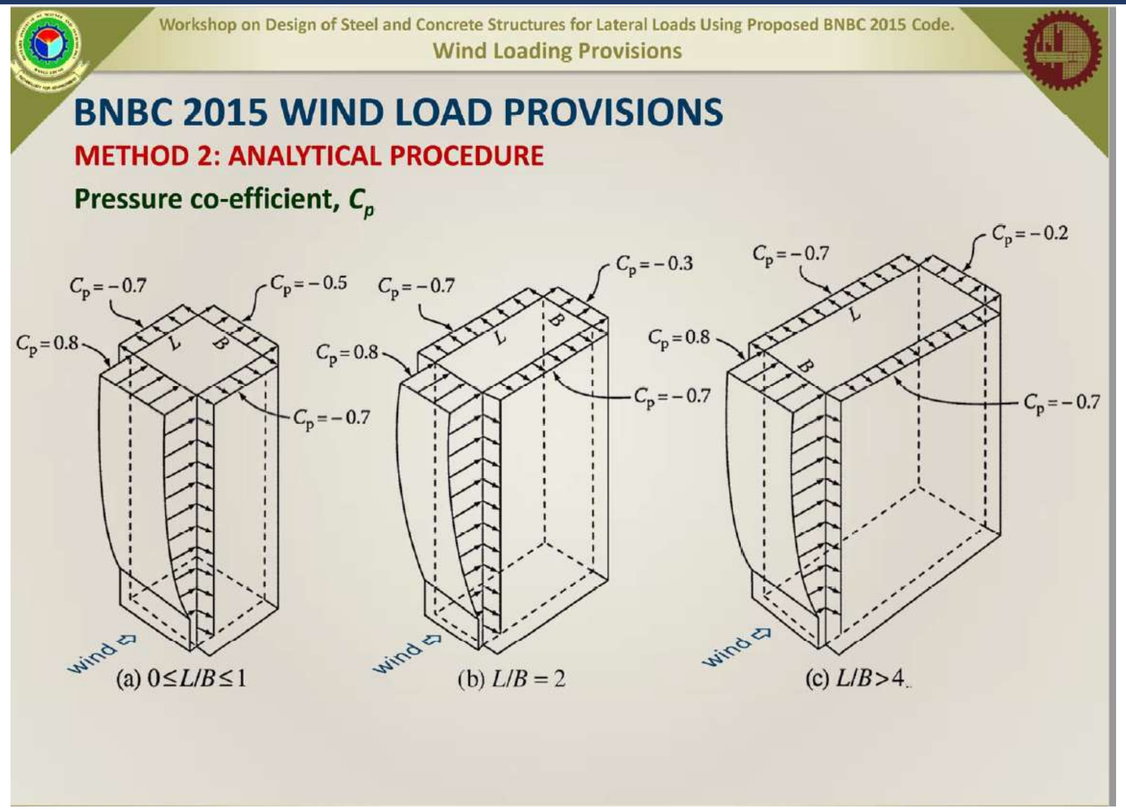


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C_p for Y Direction

Calculating External Pressure Coefficient:

- **For Wind at Y Direction:**
- **L/B = 72/48 = 1.5**
- **Windward Wall, C_p = 0.80**
- **Leeward Wall, C_p = -0.40 (Interpolation)**
- **Side Wall, C_p = -0.70**



Structural Analysis and Design 1

Wind Pressure For X Direction, B = 72 m

						External Pressure				Internal Pressure		
Location	Floor	Height above ground (m)	α	Z_g(m)	K_z	qz (kPa)	G	Cp	qz*G*Cp (kPa)	qi=qh	Gcpi ±	qi*Gcpi (kPa)
Windward Wall	F1	3	7	365.76	0.58	1.51	0.85	0.8	1.03	2.23	±0.18	±0.40
	F2	6	7	365.76	0.63	1.63	0.85	0.8	1.11	2.23	±0.18	±0.40
	F3	9	7	365.76	0.7	1.82	0.85	0.8	1.24	2.23	±0.18	±0.40
	F4	12	7	365.76	0.76	1.97	0.85	0.8	1.34	2.23	±0.18	±0.40
	F5	15	7	365.76	0.81	2.1	0.85	0.8	1.43	2.23	±0.18	±0.40
	F6	18	7	365.76	0.86	2.23(qh)	0.85	0.8	1.52	2.23	±0.18	±0.40
Leeward Wall	All	All	7	365.76		2.23(qh)	0.85	-0.5	-0.95	2.23	±0.18	±0.40
Side Wall	All	All	7	365.76		2.23(qh)	0.85	-0.7	-1.33	2.23	±0.18	±0.40

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Wind Pressure For X Direction, B = 72 m

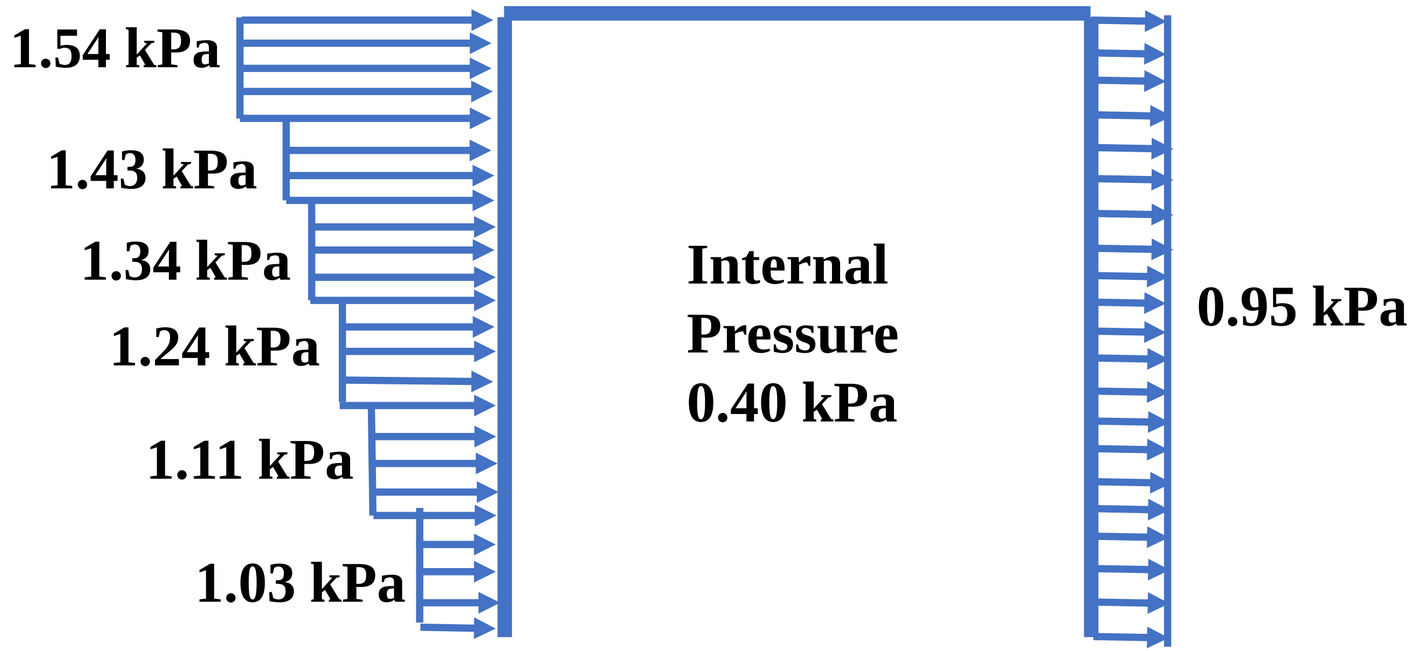
$q = q_z$	for windward walls evaluated at height z above the ground
$q = q_h$	for leeward walls, side walls, and roofs, evaluated at height h
$q_i = q_h$	for windward walls, side walls, leeward walls, and roofs of enclosed buildings and for negative internal pressure evaluation in partially enclosed buildings.
$q_i = q_z$	for positive internal pressure evaluation in partially enclosed buildings where height z is defined as the level of the highest opening in the building that could affect the positive internal pressure.

Structural Analysis and Design 1

Wind Pressure For X Direction, B = 72 m

External Wind Pressure (Windward Direction)

External Wind Pressure (Leeward Direction)



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Wind Pressure For Y Direction, B = 48 m

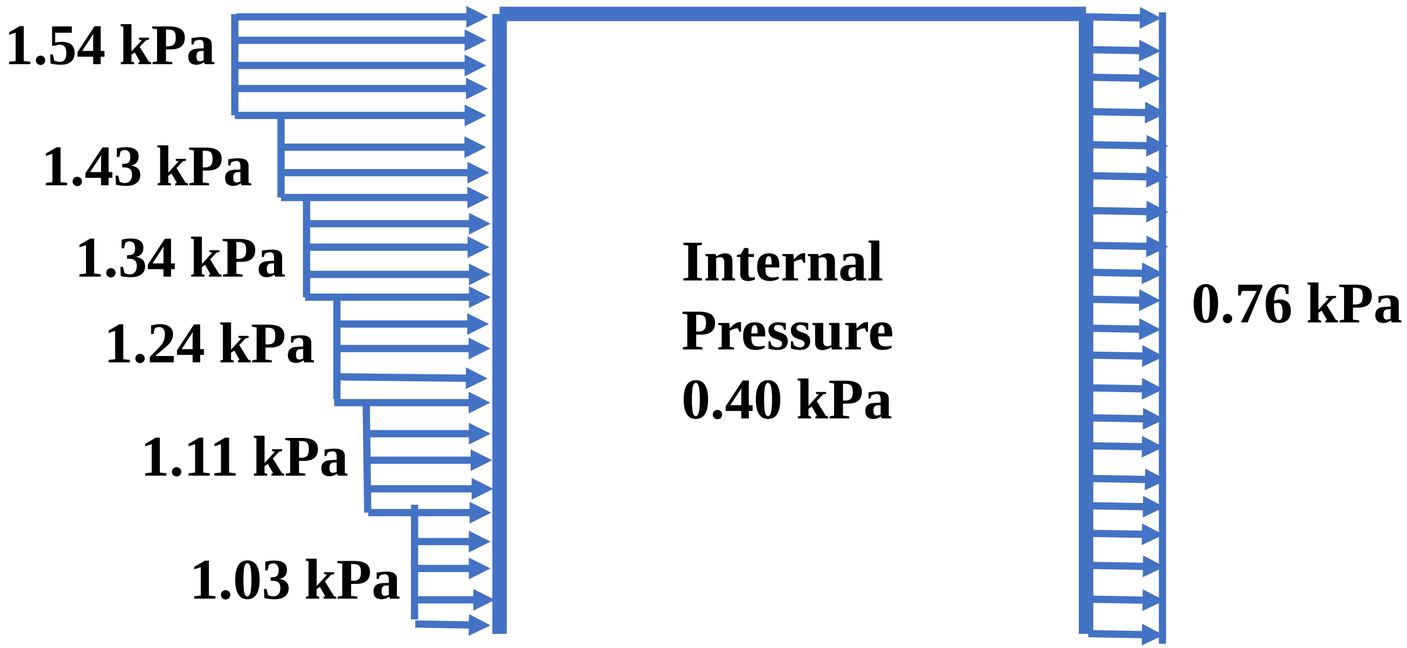
						External Pressure				Internal Pressure		
Location	**Floor**	**Height above ground (m)**	**α**	**Zg(m)**	**K_z**	**qz (kPa)**	**G**	**Cp**	**qz*G*Cp (kPa)**	**qi=qh**	**Gcpi ±**	**qi*Gcpi (kPa)**
Windward Wall	**F1**	**3**	**7**	**365.76**	**0.58**	**1.51**	**0.85**	**0.8**	**1.03**	**2.23**	**±0.18**	**±0.40**
	F2	**6**	**7**	**365.76**	**0.63**	**1.63**	**0.85**	**0.8**	**1.11**	**2.23**	**±0.18**	**±0.40**
	F3	**9**	**7**	**365.76**	**0.7**	**1.82**	**0.85**	**0.8**	**1.24**	**2.23**	**±0.18**	**±0.40**
	F4	**12**	**7**	**365.76**	**0.76**	**1.97**	**0.85**	**0.8**	**1.34**	**2.23**	**±0.18**	**±0.40**
	F5	**15**	**7**	**365.76**	**0.81**	**2.1**	**0.85**	**0.8**	**1.43**	**2.23**	**±0.18**	**±0.40**
	F6	**18**	**7**	**365.76**	**0.86**	**2.23(qh)**	**0.85**	**0.8**	**1.52**	**2.23**	**±0.18**	**±0.40**
Leeward Wall	**All**	**All**	**7**	**365.76**		**2.23(qh)**	**0.85**	**-0.4**	**-0.76**	**2.23**	**±0.18**	**±0.40**
Side Wall	**All**	**All**	**7**	**365.76**		**2.23(qh)**	**0.85**	**-0.7**	**-1.33**	**2.23**	**±0.18**	**±0.40**

Structural Analysis and Design 1

Wind Pressure For Y Direction, B = 48 m

External Wind Pressure (Windward Direction)

External Wind Pressure (Leeward Direction)



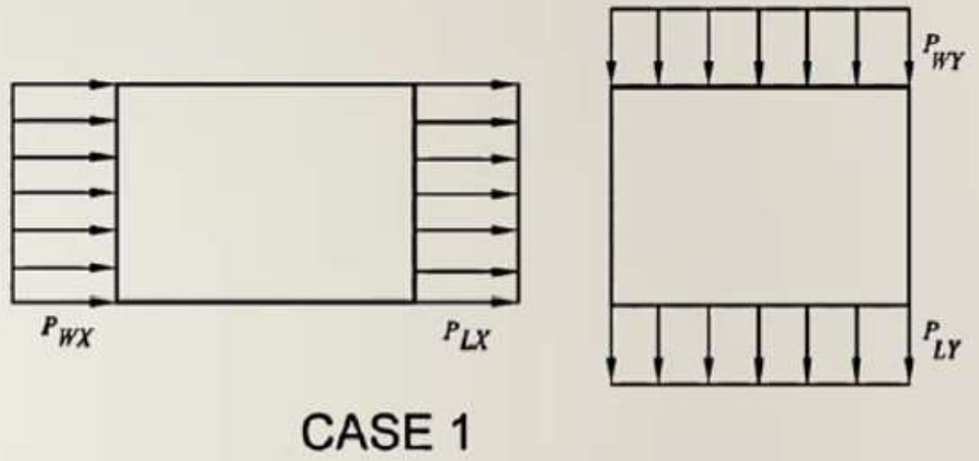
Structural Analysis and Design 1

Wind Force Calculation (Case-1)

Design Wind Force with Case-1

Case 1.

Full design wind pressure acting on the projected area perpendicular to each principal axis of the structure, considered separately along each principal axis.



CASE 1

Structural Analysis and Design 1

Wind Force Calculation (Case-1)

Design Wind Force For X Direction, B = 72 m

CASE-1					Windward Wall		Leeward Wall		
Floor	Height above ground (m)	B (m)	Tributary Height (m)	Area	External Design Wind Pressure (kPa)	Design Wind Force, P_{wx} (kN)	External Design Wind Pressure (kPa)	Design Wind Force, P_{Lx} (kN)	Total Design Wind Force, P_{netx} (kN)
F1	3	72	3	216	1.03	222.48	-0.95	-205.2	427.68
F2	6	72	3	216	1.11	239.76	-0.95	-205.2	444.96
F3	9	72	3	216	1.24	267.84	-0.95	-205.2	473.04
F4	12	72	3	216	1.34	289.44	-0.95	-205.2	494.64
F5	15	72	3	216	1.43	308.88	-0.95	-205.2	514.08
F6	18	72	1.5	108	1.52	164.16	-0.95	-102.6	266.76

Structural Analysis and Design 1

Wind Force Calculation (Case-1)

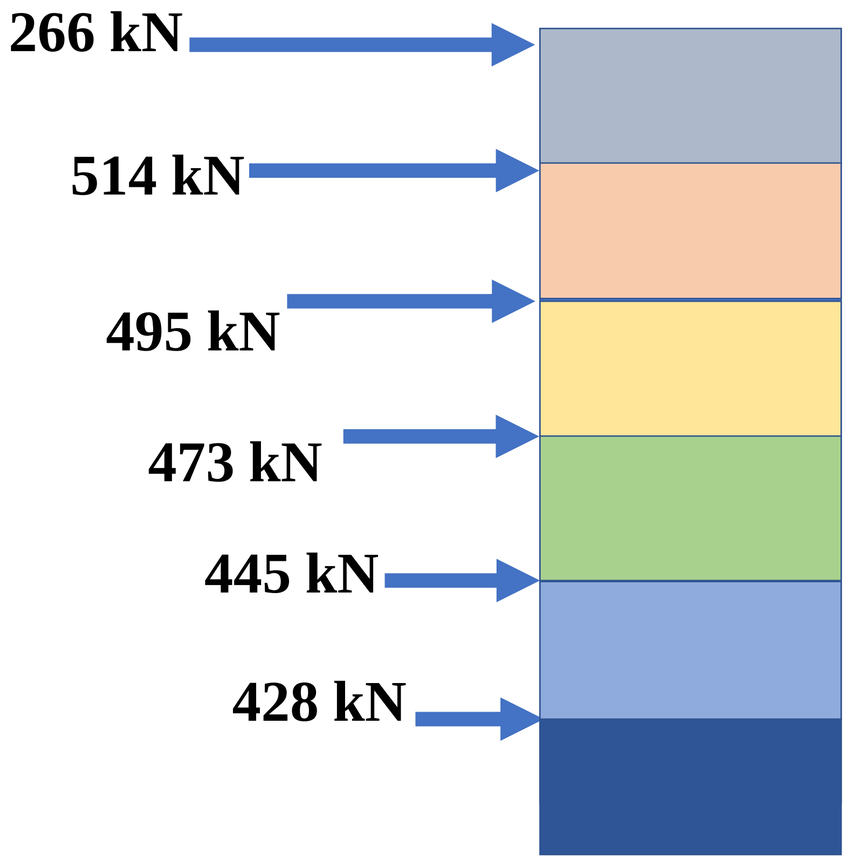
Design Wind Force For Y Direction, B = 48 m

CASE-1					Windward Wall		Leeward Wall		
Floor	Height above ground (m)	B (m)	Tributary Height (m)	Area	External Design Wind Pressure (kPa)	Design Wind Force, P_{wy} (kN)	External Design Wind Pressure (kPa)	Design Wind Force, P_{Ly} (kN)	Total Design Wind Force, P_{nety} (kN)
F1	3	48	3	144	1.03	148.32	-0.76	-109.44	257.76
F2	6	48	3	144	1.11	159.84	-0.76	-109.44	269.28
F3	9	48	3	144	1.24	178.56	-0.76	-109.44	288
F4	12	48	3	144	1.34	192.96	-0.76	-109.44	302.4
F5	15	48	3	144	1.43	205.92	-0.76	-109.44	315.36
F6	18	48	1.5	72	1.52	109.44	-0.76	-54.72	164.16

Structural Analysis and Design 1

Wind Force Diagram (Case-1)

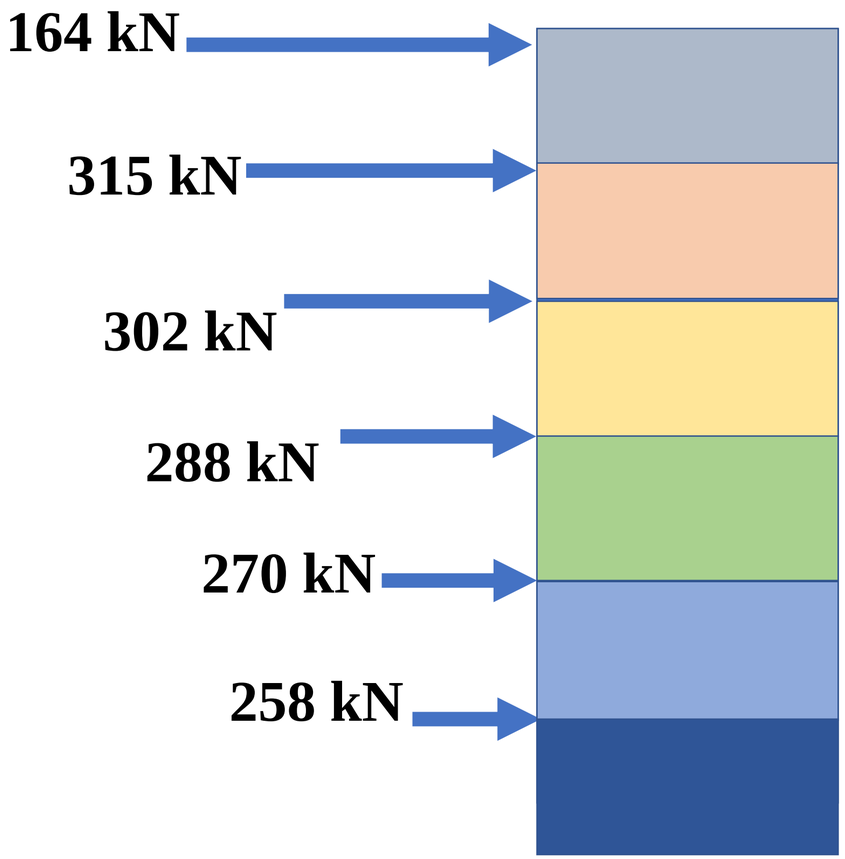
Design Wind Force For X Direction, B = 72 m



Structural Analysis and Design 1

Wind Force Diagram (Case-1)

Design Wind Force For Y Direction, B = 48 m

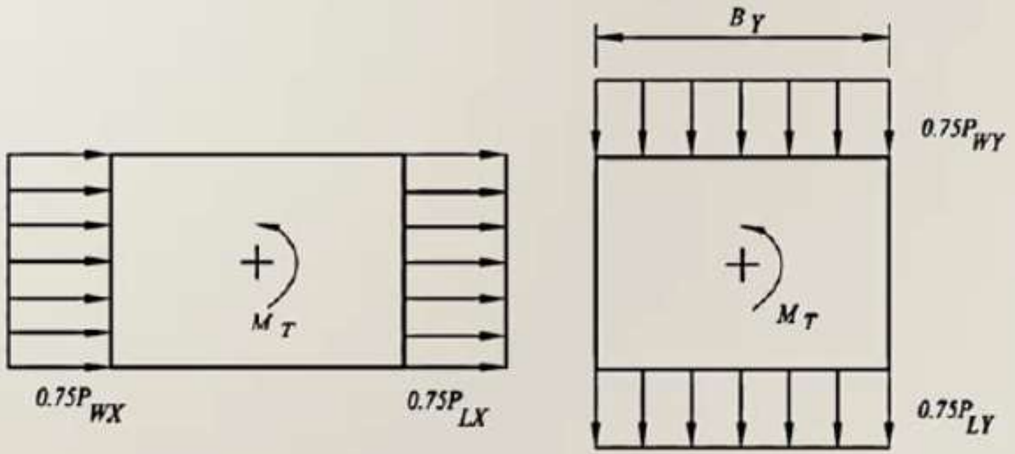


Wind Force Calculation (Case-2)

Design Wind Force with Case-2

Case 2.

Three quarters of the design wind pressure acting on the projected area perpendicular to each principal axis of the structure in conjunction with a torsional moment as shown, considered separately for each principal axis.



$M_T = 0.75\,(P_{WX} + P_{LX})\,B_X e_X$
$e_X = \pm 0.15\,B_X$

$M_T = 0.75\,(P_{WY} + P_{LY})\,B_X e_Y$
$e_Y = \pm 0.15\,B_Y$

CASE 2

Structural Analysis and Design 1

Wind Force Calculation (Case-2)

Design Wind Force For X Direction, B = 72 m

CASE-2					Windward Wall		Leeward Wall					
Floor	Height above ground (m)	B (m)	Tributary Height (m)	Area	External Design Wind Pressure (kPa)	Design Wind Force, P_{wx} (kN)	External Design Wind Pressure (kPa)	Design Wind Force, P_{Lx} (kN)	Total Wind Force, P_{netx} (kN)	$e_x = 0.15*B_x$	Design Wind Force, $0.75*P_{netx}$ (kN)	Design Torsional Moment, $M_T = 0.75*P_{netx}*e_x$ (kN-m)
F1	3	72	3	216	1.03	222.48	-0.95	-205.2	427.68	10.8	320.76	±3464.208
F2	6	72	3	216	1.11	239.76	-0.95	-205.2	444.96	10.8	333.72	±3604.176
F3	9	72	3	216	1.24	267.84	-0.95	-205.2	473.04	10.8	354.78	±3831.624
F4	12	72	3	216	1.34	289.44	-0.95	-205.2	494.64	10.8	370.98	±4006.584
F5	15	72	3	216	1.43	308.88	-0.95	-205.2	514.08	10.8	385.56	±4164.048
F6	18	72	1.5	108	1.52	164.16	-0.95	-102.6	266.76	10.8	200.07	±2160.756

Structural Analysis and Design 1

Wind Force Calculation (Case-2)

Design Wind Force For Y Direction, B = 48 m

CASE-2					Windward Wall		Leeward Wall					
Floor	Height above ground (m)	B (m)	Tributary Height (m)	Area	External Design Wind Pressure (kPa)	Design Wind Force, P_{wy} (kN)	External Design Wind Pressure (kPa)	Design Wind Force, P_{Ly} (kN)	Total Wind Force, P_{nety} (kN)	$e_y = 0.15*B_y$	Design Wind Force, $0.75*P_{nety}$ (kN)	Design Torsional Moment, $M_T = 0.75*P_{nety}*e_y$ (kN-m)
F1	3	48	3	144	1.03	148.32	-0.76	-109.44	257.76	7.2	193.32	±1391.904
F2	6	48	3	144	1.11	159.84	-0.76	-109.44	269.28	7.2	201.96	±1454.112
F3	9	48	3	144	1.24	178.56	-0.76	-109.44	288	7.2	216	±1555.2
F4	12	48	3	144	1.34	192.96	-0.76	-109.44	302.4	7.2	226.8	±1632.96
F5	15	48	3	144	1.43	205.92	-0.76	-109.44	315.36	7.2	236.52	±1702.944
F6	18	48	1.5	72	1.52	109.44	-0.76	-54.72	164.16	7.2	123.12	±886.464

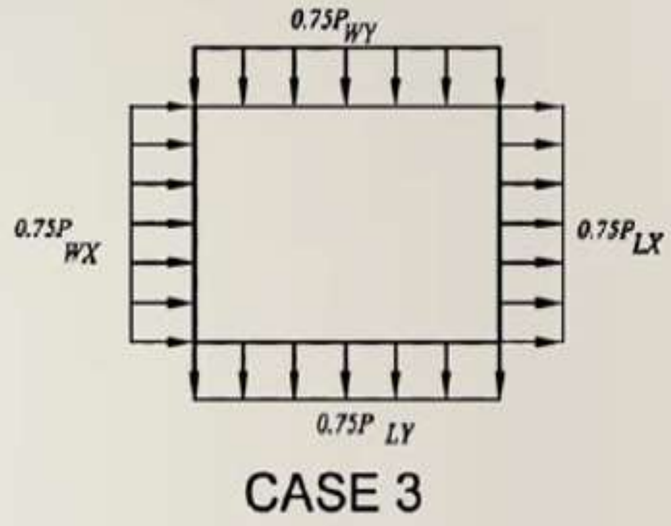
Structural Analysis and Design 1

Wind Force Calculation (Case-3)

Design Wind Force with Case-3

Case 3.

Wind loading as defined in Case 1, but considered to act simultaneously at 75% of the specified value.



CASE 3

Structural Analysis and Design 1

Wind Force Calculation (Case-3)

Design Wind Force For Both Direction

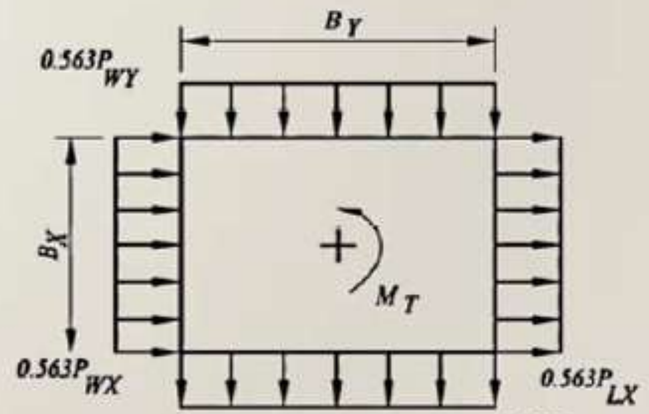
		CASE-3							
		X- Direction				Y- Direction			
Floor	Height above ground (m)	Wind Force, P_{wx} (kN)	Wind Force, P_{Lx} (kN)	Total Wind Force, P_{netx} (kN)	Design Wind Force, $0.75*P_{netx}$ (kN)	Wind Force, P_{wy} (kN)	Wind Force, P_{Ly} (kN)	Total Wind Force, P_{nety} (kN)	Design Wind Force, $0.75*P_{nety}$ (kN)
F1	3	222.48	-205.2	427.68	320.76	148.32	-109.44	257.76	193.32
F2	6	239.76	-205.2	444.96	333.72	159.84	-109.44	269.28	201.96
F3	9	267.84	-205.2	473.04	354.78	178.56	-109.44	288	216
F4	12	289.44	-205.2	494.64	370.98	192.96	-109.44	302.4	226.8
F5	15	308.88	-205.2	514.08	385.56	205.92	-109.44	315.36	236.52
F6	18	164.16	-102.6	266.76	200.07	109.44	-54.72	164.16	123.12

Wind Force Calculation (Case-4)

Design Wind Force with Case-4

Case 4.

Wind loading as defined in Case 2, but considered to act simultaneously at 75% of the specified value.



$$M_T = 0.563\,(P_{WX} + P_{LX})\,B_X e_X + 0.563\,(P_{WY} + P_{LY})\,B_Y e_Y$$

$$e_X = \pm 0.15\,B_X \qquad e_Y = \pm 0.15\,B_Y$$

CASE 4

Structural Analysis and Design 1

Wind Force Calculation (Case-4)

Design Wind Force For Both Direction

CASE-4												
Floor	Height above ground (m)	X- Direction					Y- Direction					Design Torsional Moment, M_T = 0.563*P_{netx}*e_x + 0.563*P_{nety}*e_y (kN-m)
		e_x = 0.15*B_x	Wind Force, P_{wx} (kN)	Wind Force, P_{Lx} (kN)	Total Wind Force, P_{netx} (kN)	Design Wind Force, 0.563*P_{netx} (kN)	Wind Force, P_{wy} (kN)	Wind Force, P_{Ly} (kN)	Total Wind Force, P_{nety} (kN)	Design Wind Force, 0.563*P_{nety} (kN)	e_y = 0.15*B_y	
F1	3	10.8	222.48	-205.2	427.68	240.78384	148.32	-109.44	257.76	145.1189	7.2	±3645.321408
F2	6	10.8	239.76	-205.2	444.96	250.51248	159.84	-109.44	269.28	151.6046	7.2	±3797.088192
F3	9	10.8	267.84	-205.2	473.04	266.32152	178.56	-109.44	288	162.144	7.2	±4043.709216
F4	12	10.8	289.44	-205.2	494.64	278.48232	192.96	-109.44	302.4	170.2512	7.2	±4233.417696
F5	15	10.8	308.88	-205.2	514.08	289.42704	205.92	-109.44	315.36	177.5477	7.2	±4404.155328
F6	18	10.8	164.16	-102.6	266.76	150.18588	109.44	-54.72	164.16	92.42208	7.2	±2287.44648

Structural Analysis and Design 1

Structural Analysis and Design 1

Assignment 2

- **Calculate the design load of the following building. Rectangular (80X50m). Hospital building (10 storied). Storey height = 3m. City Dhaka/Chittagong/Sylhet, Exposure = B. Calculate as per BNBC-2020.**

Follow Method-2: Analytical Procedure