

Calculation of Wind Loads on Structures according to ASCE 7-10

Permitted Procedures

The design wind loads for buildings and other structures, including the MWFRS and component and cladding elements thereof, shall be determined using one of the procedures as specified in the following section. An outline of the overall process for the determination of the wind loads, including section references, is provided in Figure (1).

Main Wind-Force Resisting System (MWFRS)

Wind loads for MWFRS shall be determined using one of the following procedures:

- (1) Directional Procedure for buildings of all heights as specified in Chapter 27 for buildings meeting the requirements specified therein;
- (2) Envelope Procedure for low-rise buildings as specified in Chapter 28 for buildings meeting the requirements specified therein;
- (3) Directional Procedure for Building Appurtenances (rooftop structures and rooftop equipment) and Other Structures (such as solid freestanding walls and solid freestanding signs, chimneys, tanks, open signs, lattice frameworks, and trussed towers) as specified in Chapter 29;
- (4) Wind Tunnel Procedure for all buildings and all other structures as specified in Chapter 31.

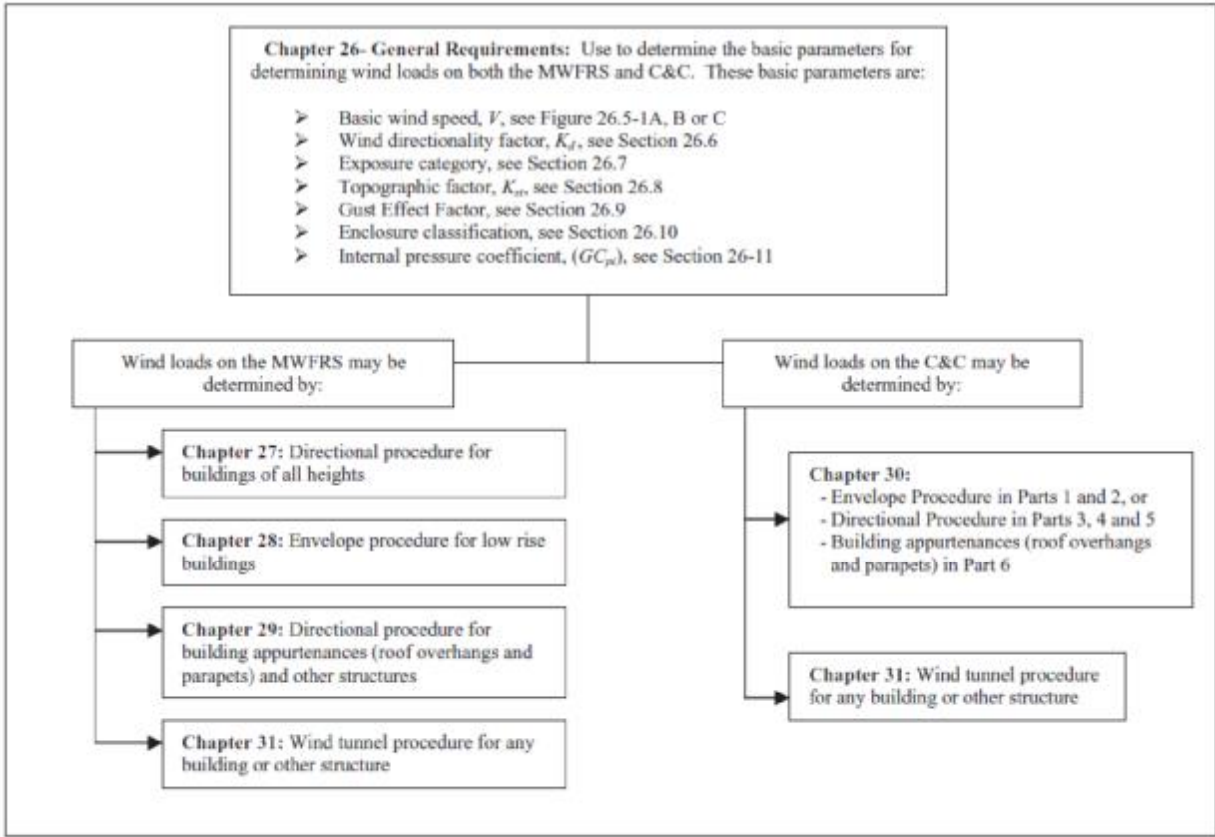


Figure (1): Dtermination of Wind Loads

Directional Procedure

Step 1: Determine risk category of building or other structure, see Table 1.5-1.

Table 1.5-1 Risk Category of Buildings and Other Structures for Flood, Wind, Snow, Earthquake, and Ice Loads

Use or Occupancy of Buildings and Structures	Risk Category
Buildings and other structures that represent a low risk to human life in the event of failure	I
All buildings and other structures except those listed in Risk Categories I, III, and IV	II
Buildings and other structures, the failure of which could pose a substantial risk to human life.	III
Buildings and other structures, not included in Risk 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.	
Buildings and other structures not included in Risk 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 toxic or explosive substances where their quantity exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released.	
Buildings and other structures designated as essential facilities.	IV
Buildings and other structures, the failure of which could pose a substantial hazard to the community.	
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 sufficient quantities of highly toxic substances where the quantity exceeds a threshold quantity established by the authority having jurisdiction to be dangerous to the public if released and is sufficient to pose a threat to the public if released.*	
Buildings and other structures required to maintain the functionality of other Risk Category IV structures.	

*Buildings and other structures containing toxic, highly toxic, or explosive substances shall be eligible for classification to a lower Risk Category if it can be demonstrated to the satisfaction of the authority having jurisdiction by a hazard assessment as described in Section 1.5.2 that a release of the substances is commensurate with the risk associated with that Risk Category.

Step 2: Determine the basic wind speed, V , for the applicable risk category, see Figure 26.5-1A, B or C (United States). Basic wind speed is a three-second gust speed at 10 m above the ground in Exposure C.

Step 3: Determine wind load parameters:

- Wind directionality factor, K_d , see Table 26.6.1

Table 26.6.1: Wind directionality factor, K_d

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

The directionality factor used in the ASCE 7 wind load provisions for components and cladding is a load reduction factor intended to take into account the less than 100% probability that the design event wind direction aligns with the worst case building aerodynamics.

- Exposure category, for each wind direction considered, the upwind exposure shall be based on ground surface roughness that is determined from natural topography, vegetation, and constructed facilities.

Surface Roughness B: Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.

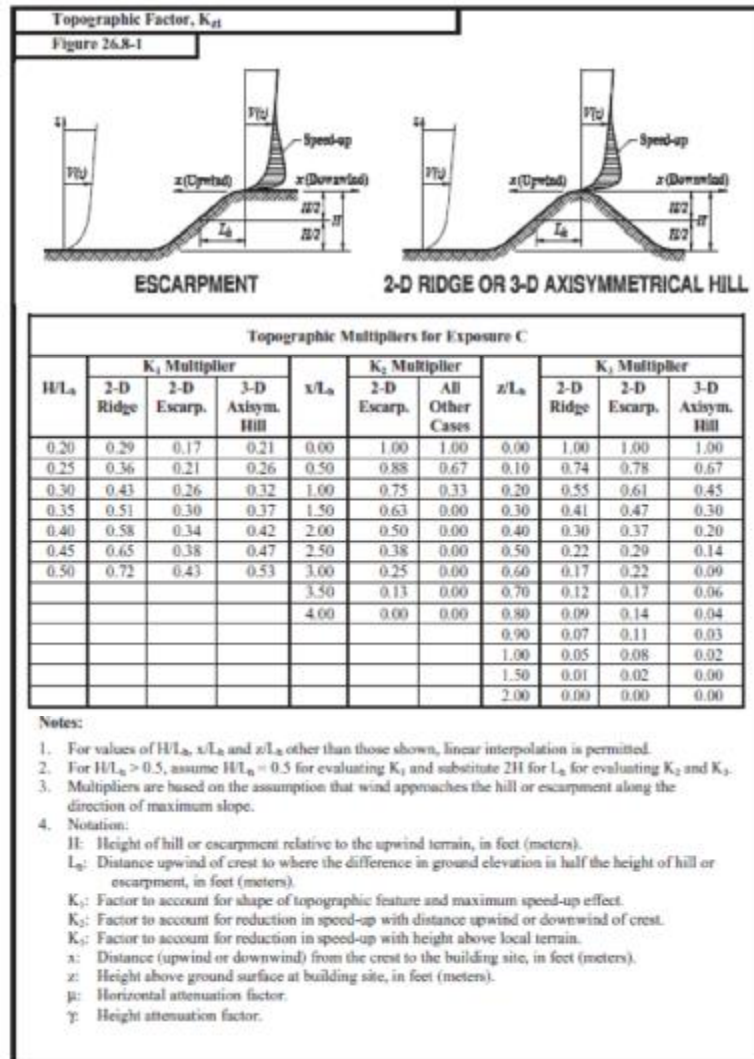
Surface Roughness C: Open terrain with scattered obstructions having heights generally less than 9.1 m. This category includes flat open country and grasslands.

Surface Roughness D: Flat, unobstructed areas and water surfaces. This category includes smooth mud flats, salt flats, and unbroken ice.

- Topographic factor, K_{zt} , see Figure 26.8-1.

$K_{zt} = (1 + K_1 K_2 K_3)^2$, where K_1 , K_2 and K_3 are given in Fig. 26.8-1.

For flat terrains, $K_{zt} = .0$.



- Gust factor, G :

The gust effect factor for a rigid building is permitted to be taken as 0.85.

- Enclosure classification:

Open Building: A building having each wall at least 80 percent open. This condition is expressed for each wall by the equation $A_o \geq 0.8 A_g$ where

A_o = total area of openings in a wall that receives positive external pressure

A_g = the gross area of that wall in which A_o is identified

Partially Enclosed Building: A building that complies with both of the following conditions:

1. The total area of openings in a wall that receives positive external pressure exceeds the sum of the areas of openings in the balance of the building envelope (walls and roof) by more than 10 percent.
2. The total area of openings in a wall that receives positive external pressure exceeds (0.37 m²) or 1 percent of the area of that wall, whichever is smaller, and the percentage of openings in the balance of the building envelope does not exceed 20 percent.

Enclosed Building: It is a building that is not classified as open or partially enclosed.

- Internal pressure coefficient, GC_{pi} , see Table 26.11-1.

Table 26.11-1; Internal Pressure Coefficient

Enclosure Classification	(GC_{pi})
Open Buildings	0.00
Partially Enclosed Buildings	+0.55 -0.55
Enclosed Buildings	+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.
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

Step 4: Determine velocity pressure exposure coefficient, K_z or K_h , see Table 27.3-1. Note that K_h is constant and calculated for mean height of the building, while K_z varies with heights measured from the base of the building.

Main Wind Force Resisting System – Part 1		All Heights		
Velocity Pressure Exposure Coefficients, K_z , and K_{zt}				
Table 27.3-1				
Height above ground level, z		Exposure		
		B	C	D
ft	(m)			
0-15	(0-4.6)	0.57	0.85	1.03
20	(6.1)	0.62	0.90	1.08
25	(7.6)	0.66	0.94	1.12
30	(9.1)	0.70	0.98	1.16
40	(12.2)	0.76	1.04	1.22
50	(15.2)	0.81	1.09	1.27
60	(18)	0.85	1.13	1.31
70	(21.3)	0.89	1.17	1.34
80	(24.4)	0.93	1.21	1.38
90	(27.4)	0.96	1.24	1.40
100	(30.5)	0.99	1.26	1.43
120	(36.6)	1.04	1.31	1.48
140	(42.7)	1.09	1.36	1.52
160	(48.8)	1.13	1.39	1.55
180	(54.9)	1.17	1.43	1.58
200	(61.0)	1.20	1.46	1.61
250	(76.2)	1.28	1.53	1.68
300	(91.4)	1.35	1.59	1.73
350	(106.7)	1.41	1.64	1.78
400	(121.9)	1.47	1.69	1.82
450	(137.2)	1.52	1.73	1.86
500	(152.4)	1.56	1.77	1.89

Notes:

- The velocity pressure exposure coefficient K_z may be determined from the following formula:
 For $15 \text{ ft} \leq z \leq z_g$ For $z < 15 \text{ ft}$
 $K_z = 2.01 (z/z_g)^{\alpha}$ $K_z = 2.01 (15/z)^{\alpha}$
- α and z_g are tabulated in Table 26.9.1.
- Linear interpolation for intermediate values of height z is acceptable.
- Exposure categories are defined in Section 26.7.

Step 5: Determine velocity pressure, q_z or q_h , see equation below.

$$q_z = 0.613 K_z K_{zt} K_d V^2$$

where:

q_z = velocity pressure calculated at height z , (N/m^2)

q_h = velocity pressure calculated at mean roof height h , (N/m^2)

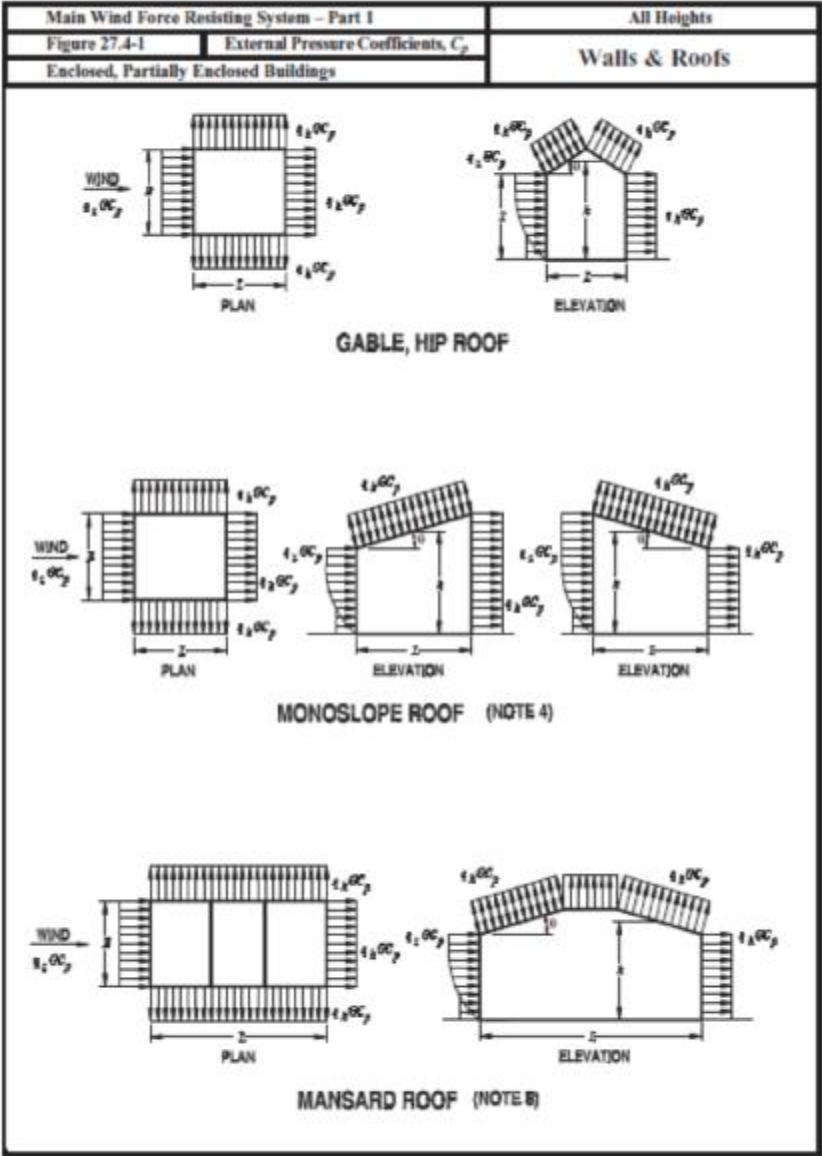
K_d = wind directionality factor

K_z = velocity pressure exposure coefficient

K_{zt} = topographic factor

V = basic wind speed, in m/s

Step 6: Determine external pressure coefficients, C_p (Figure 27.4-1)


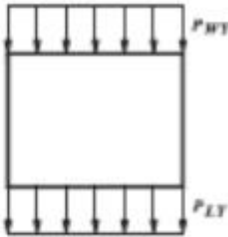
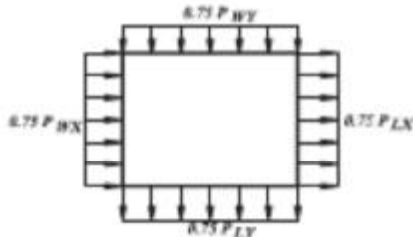
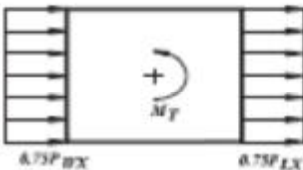
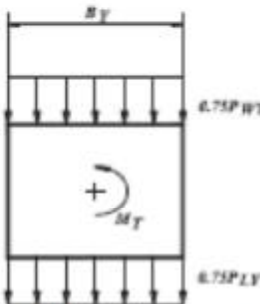
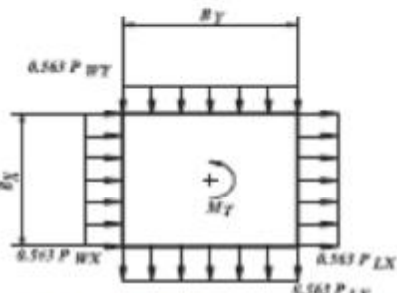


Wall Pressure Coefficients, C_p			
Surface	L/B	C_p	Use With
Windward Wall	All values	0.8	q_z
Leeward Wall	0-1	-0.5	q_h
	2	-0.3	
	≥ 4	-0.2	
Side Wall	All values	-0.7	q_h

Step 7: Determine wind pressure, p , on each building surface (enclosed and partially enclosed).

$$p = qG C_p - q_i(G C_{pi})$$

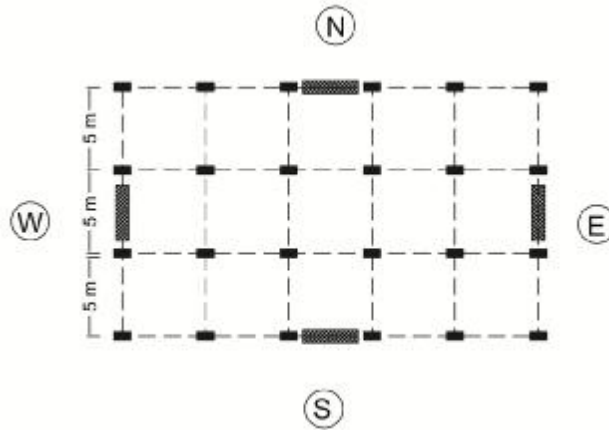
Design wind load cases are shown in Figure 27.4-8.

Main Wind Force Resisting System – Part I		All Heights
Figure 27.4-8	Design Wind Load Cases	
 <p style="text-align: center;">CASE 1</p>	 <p style="text-align: center;">CASE 2</p>	 <p style="text-align: center;">CASE 3</p>
 <p style="text-align: center;">CASE 4</p>	 <p style="text-align: center;">CASE 4</p>	 <p style="text-align: center;">CASE 4</p>
$M_T = 0.75 (P_{WX} + P_{LX}) B_X e_X$ $e_X = \pm 0.15 B_T$	$M_T = 0.75 (P_{WY} + P_{LY}) B_Y e_Y$ $e_Y = \pm 0.15 B_T$	$M_T = 0.563 (P_{WX} + P_{LX}) B_X e_X + 0.563 (P_{WY} + P_{LY}) B_Y e_Y$ $e_X = \pm 0.15 B_T$ $e_Y = \pm 0.15 B_T$
<p>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.</p> <p>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.</p> <p>Case 3. Wind loading as defined in Case 1, but considered to act simultaneously at 75% of the specified value.</p> <p>Case 4. Wind loading as defined in Case 2, but considered to act simultaneously at 75% of the specified value.</p> <p>Notes:</p> <ol style="list-style-type: none"> Design wind pressures for windward and leeward faces shall be determined in accordance with the provisions of 27.4.1 and 27.4.2 as applicable for building of all heights. Diagrams show plan views of building. Notation: <ul style="list-style-type: none"> P_{WX}, P_{WY}: Windward face design pressure acting in the x, y principal axis, respectively. P_{LX}, P_{LY}: Leeward face design pressure acting in the x, y principal axis, respectively. $e (e_X, e_Y)$: Eccentricity for the x, y principal axis of the structure, respectively. M_T: Torsional moment per unit height acting about a vertical axis of the building. 		

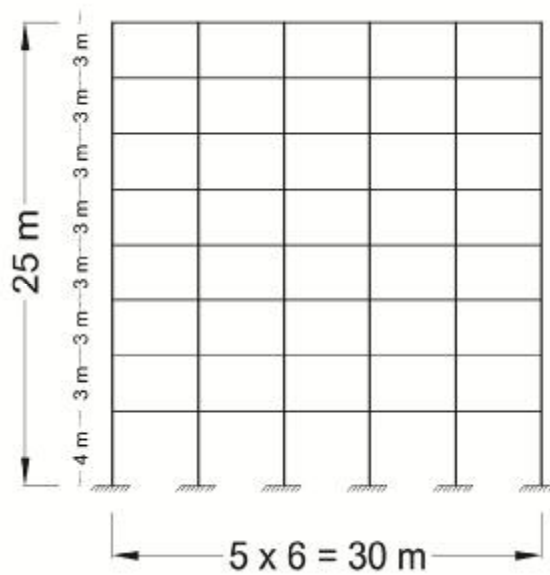
Example:

It is required to calculate the lateral wind loads acting on the 8-story building, considering that the wind acts in the North-South direction. The building which is used as headquarter for police operation, is 30 m x 15 m in plan as shown in the figure (enclosed), and located right on the Gaza Beach (flat terrain).

Note: Use a basic wind speed of 100 Km/hr and ASCE 7-10 Directional Procedure.



Plan



Elevation

Step 1: Building risk category:

- Based on Table 1.5-1, building risk category is IV.

Step 2: Basic wind speed:

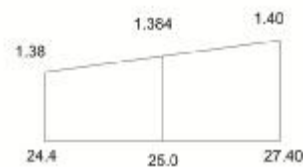
- It is given as 100 km/hr.

Step 3: Building wind load parameters:

- $K_d=0.85$ (wind directionality factored evaluated from Table 26.6.1)
- Exposure category is D
- $K_{zt}=1.0$ (Topographic factor for flat terrain)
- Gust factor, G , is 0.85 for rigid buildings
- Building is enclosed
- Internal pressure coefficient for enclosed buildings, GC_{pi} , is ± 0.18

Step 4: Velocity pressure coefficients, K_h and K_z :

- $K_h=1.384$ (Interpolating from Table 27.3-1) and K_z varies with height



Step 5: Determine velocity pressure, q_h and q_z :

- $q_h = 0.613 K_h K_{zt} K_d V^2$
 $= 0.613 (1.384) (1.0) (0.85) \left(\frac{100,000}{60 * 60} \right)^2 = 556.43 \text{ N/m}^2$
- $q_z = 0.613 K_z K_{zt} K_d V^2$
 $= 0.613 (K_z) (1.0) (0.85) \left(\frac{100,000}{60 * 60} \right)^2 = 402.05 K_z \text{ N/m}^2$

Step 6: External pressure coefficients, C_p :

For $L/B = \frac{15}{30} = 0.5$ and using Figure 27.4.1, the external pressure coefficients are shown in the figure.

Step 7: Wind pressure, p :

For the windward walls,

$$\begin{aligned}
 p &= q_z G C_p - q_i (G C_{pi}) \\
 &= q_z (0.85)(0.8) - 556.43 (0.85)(\pm 0.18) \\
 &= (0.68 q_z \pm 85.13) N / m^2 \text{ (max)}
 \end{aligned}$$

For the leeward walls,

$$\begin{aligned}
 p &= q_h G C_p - q_i (G C_{pi}) \\
 &= 556.43 (0.85)(-0.5) - 556.43 (0.85)(\pm 0.18) \\
 &= -321.62 N / m^2 \text{ (max)}
 \end{aligned}$$

For the side walls,

$$\begin{aligned}
 p &= q_h G C_p - q_i (G C_{pi}) \\
 &= 556.43 (0.85)(-0.7) - 556.43 (0.85)(\pm 0.18) \\
 &= -416.21 N / m^2 \text{ (max)}
 \end{aligned}$$

Height, meters	K_z	q_z	p
0 to 4.6 m	1.03	414.17	366.76
4.6 to 6.1 m	1.08	434.17	380.36
6.1 to 7.6 m	1.12	450.28	391.32
7.6 to 9.1 m	1.16	466.39	402.27
9.1 to 12.2 m	1.22	490.56	418.71
12.2 to 15.2 m	1.27	510.56	432.31
15.2 to 18 m	1.31	526.67	443.26
18 to 21.3 m	1.34	538.89	451.57
21.3 to 24.4 m	1.38	554.72	462.34
24.4 to 25 m	1.40	562.78	467.82

