WIND EFFECT ON TALL STRUCTURES

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WIND

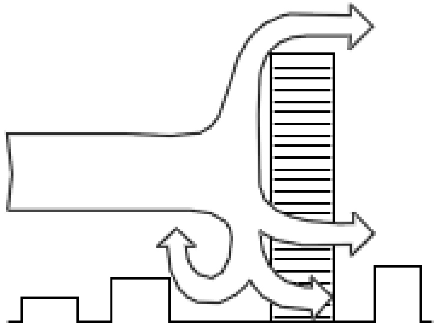
- Wind is flow of gases.
- Wind is caused by difference in pressure.
- Wind is measured by anemometers.
- Wind speed are reported globally at 10 m height and are averaged over 10 minutes time frame.
- A short bust of high speed wind is termed as wind gust

WIND EFFECT ON STRUCTURE

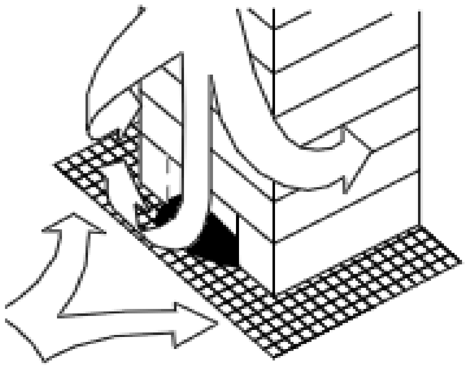
Primary factors that effect wind pressure on building surface:

- Velocity of wind
- Shape and surface of building.
- Protection offered by surrounding natural terrain or man made structure.
- Density of air which decreases with altitude and height.

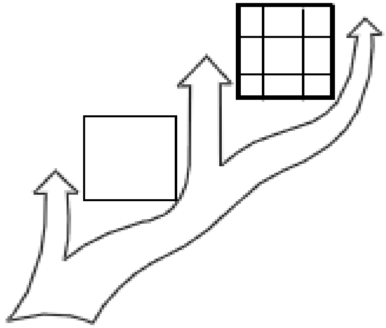
As wind hits a structure and flows around it , several effects are possible:



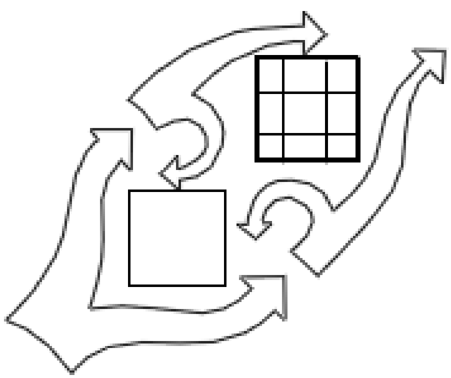
A building significantly taller than its surroundings can experience high wind loads and concentrate pedestrian-level winds



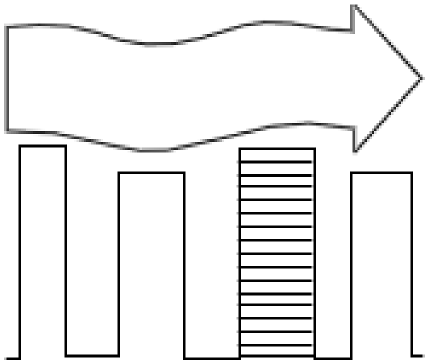
Recessed entry provides low winds at door locations



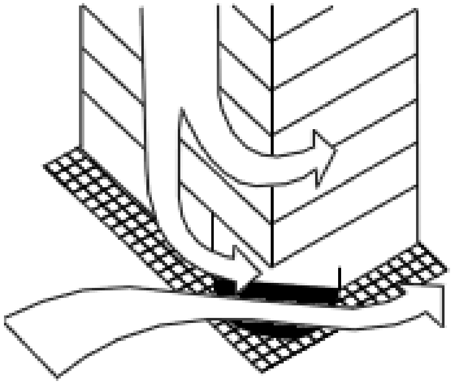
Adjacent building placement may deflect wind, resulting in higher wind loads and pedestrian-level winds



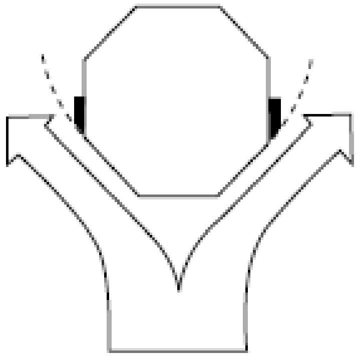
Adjacent building placement may protect from high winds, reducing wind loads and pedestrian-level winds



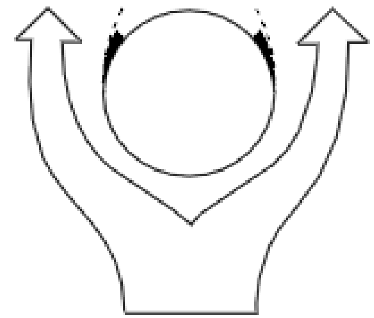
A building of height similar to its surroundings may be protected from large wind loads and concentrated pedestrian winds



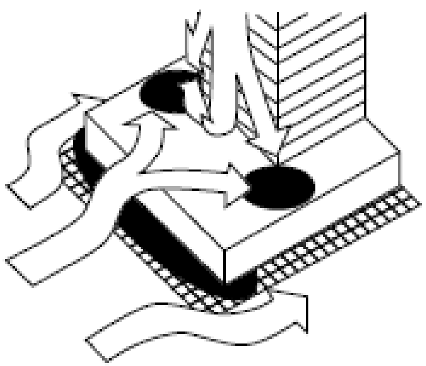
Corner entry may accentuate wind concentration at building corner



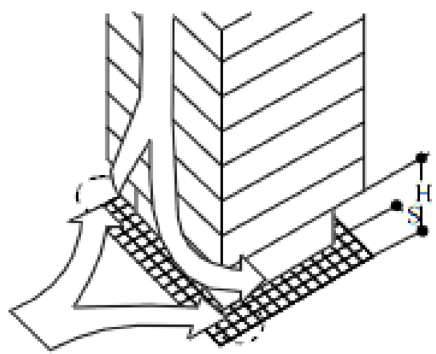
Multisided buildings may not permit full development of local pressures, frame loads, or pedestrian-level winds



Circular buildings may reduce frame loads and pedestrian-level winds but increase local cladded loads at the points where the wind separates from the building



A low-pedestal building concentrates wind on the roof, not at the base



Setback all around the building may improve or worsen wind concentration, depending upon S and H

CHARACTERISTICS OF WIND

- Variation of wind velocity with height.
- Wind turbulence.
- Statistical probability.
- Vortex shedding phenomenon.
- Dynamic nature of wind–structure interaction

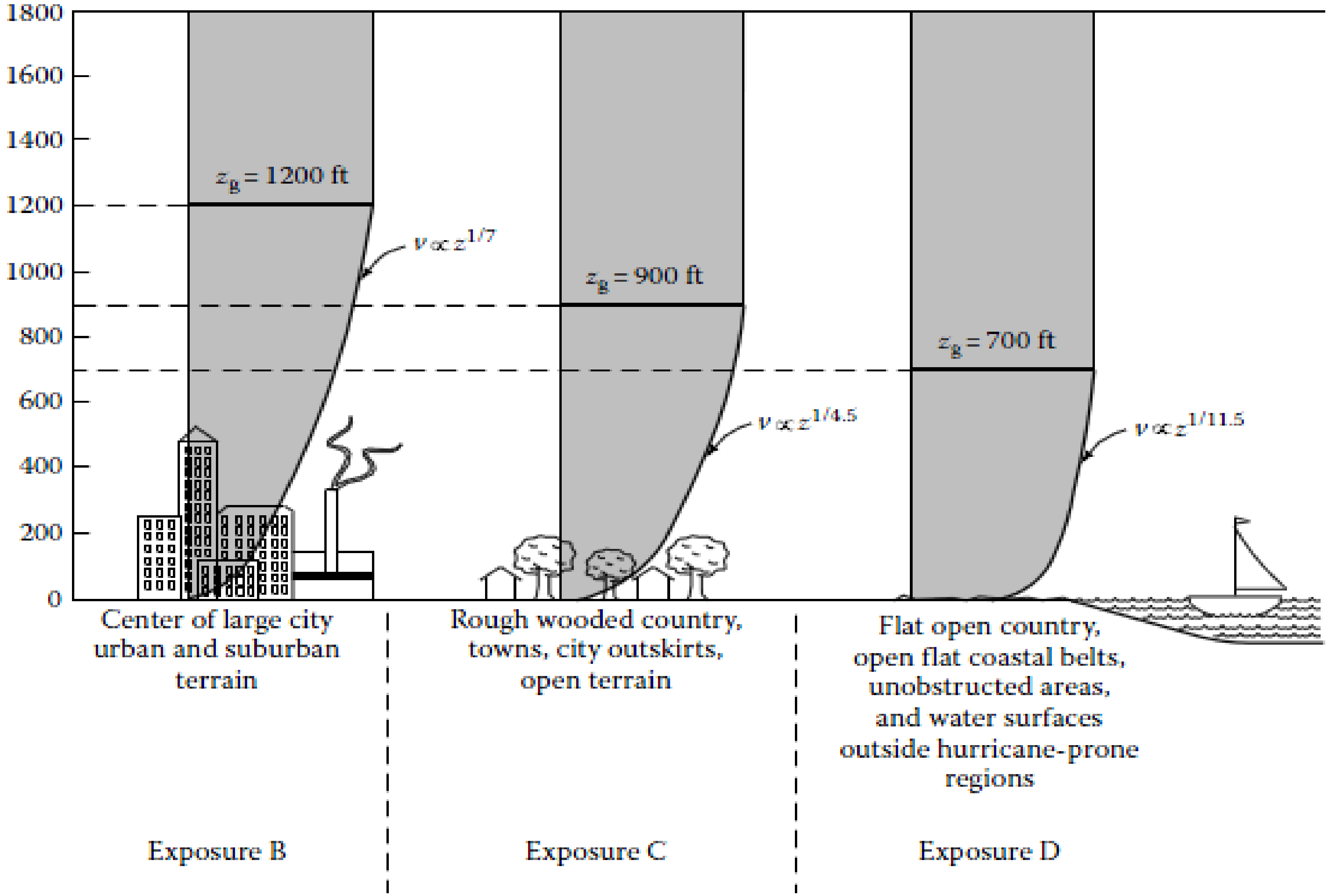
VARIATION OF WIND VELOCITY WITH HEIGHT

- There is a retarding effect on wind speed in wind layers near the surface of earth.
- Height at which the slowdown effect ceases to exist is called gradient height.
- The corresponding wind velocity is called gradient velocity.
- The ensueing height in which the wind speed is affected by topography is called atmospheric boundary layer.

The wind speed profile within *atmospheric boundary layer* is given by:

$$V_z = V_g \, (Z/Z_g)^{1/\alpha}$$

Wind velocity profile as defined in ASCE 7-05



WIND TURBULANCE

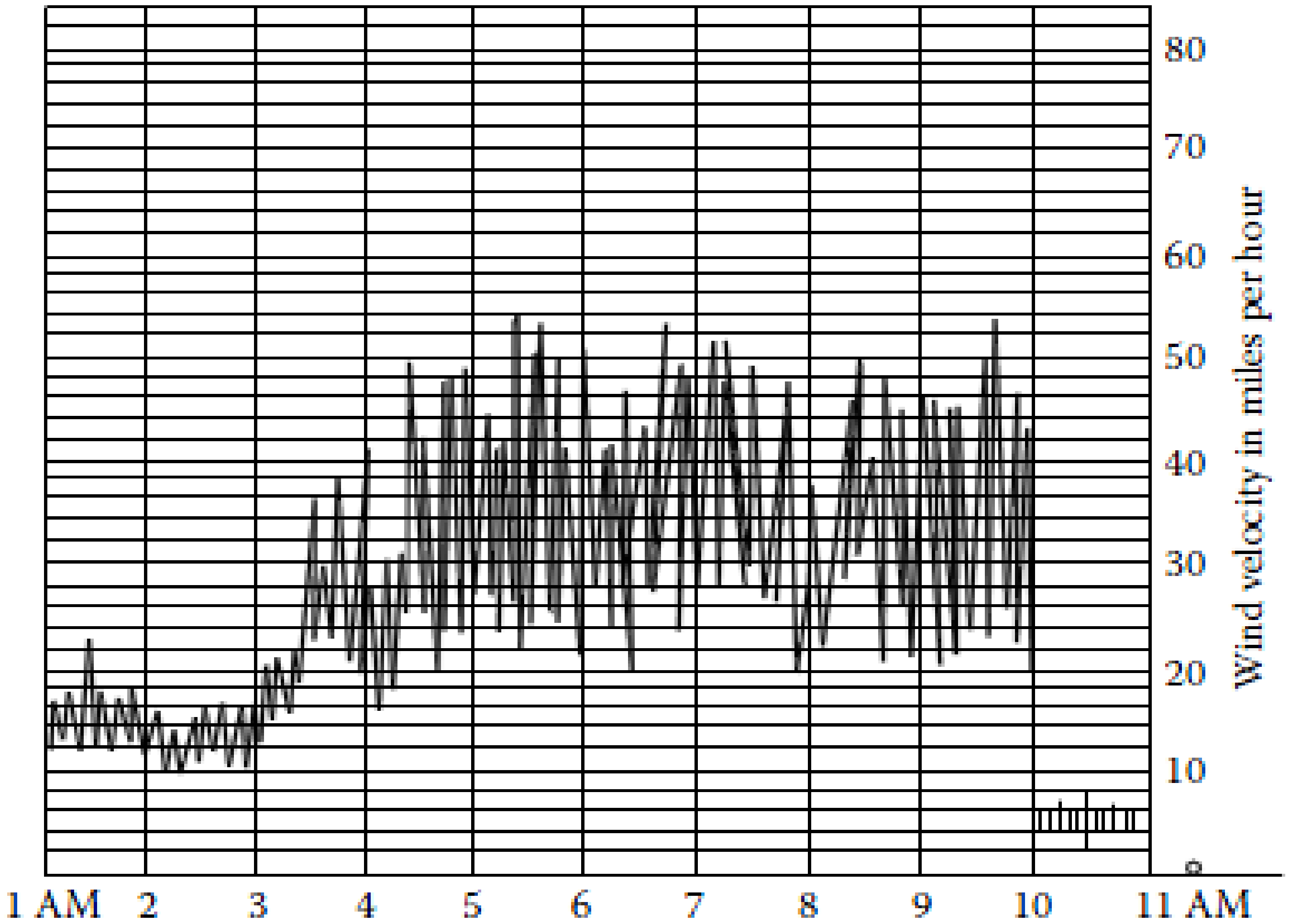
- Motion of wind is turbulent.
- Wind near ground level is highly turbulent.
- Gust is the rapid fluctuations or instantaneous velocity of wind.
- Turbulence is the cause of formation of eddy.
- Structure should be designed to withstand gusts rather than the mean wind speed

$$V_G = G_V V$$

Where,

V_G = Gust speed
G_V = Velocity gust factor
V = Mean wind speed

Wind speed measured by anemometer



PROBABLISTIC APPROCH

- In wind engineering the speed of wind is considered to vary with return periods
- A wind with low annual probability of occurrence is used to design structures.

General expression for probability *P* that a design wind speed will be exceeded at least once during the exposed period of n years is given by:

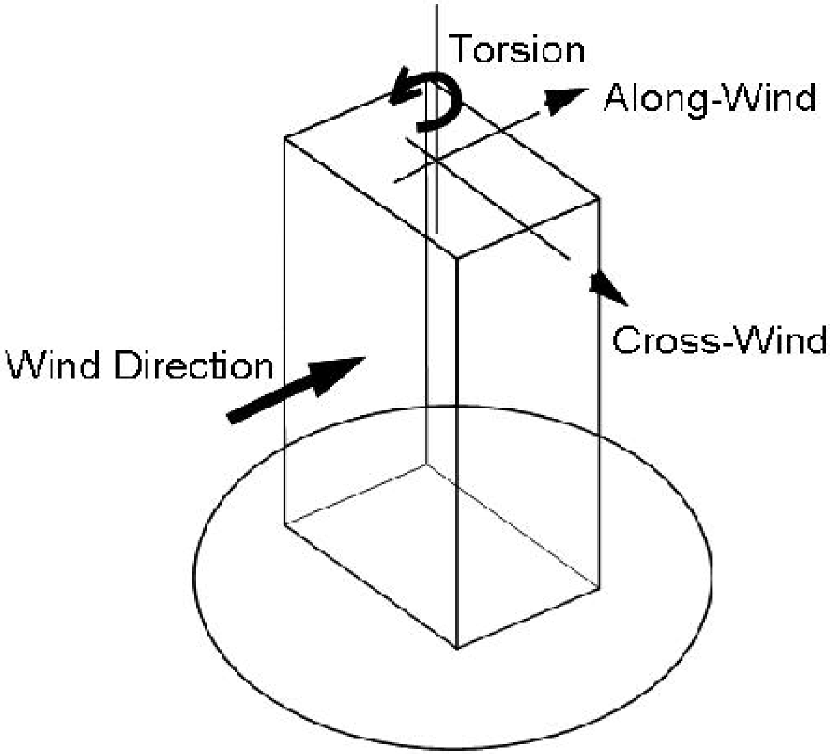
$$P = 1 - (1 - P_a)^n$$

Where,

P_a is the annual probability of being exceeded
n is the exposure period in years

ALONG AND CROSS WIND

- The term along wind is used to refer to drag force.
- The term cross wind is used to refer to the transverse wind.



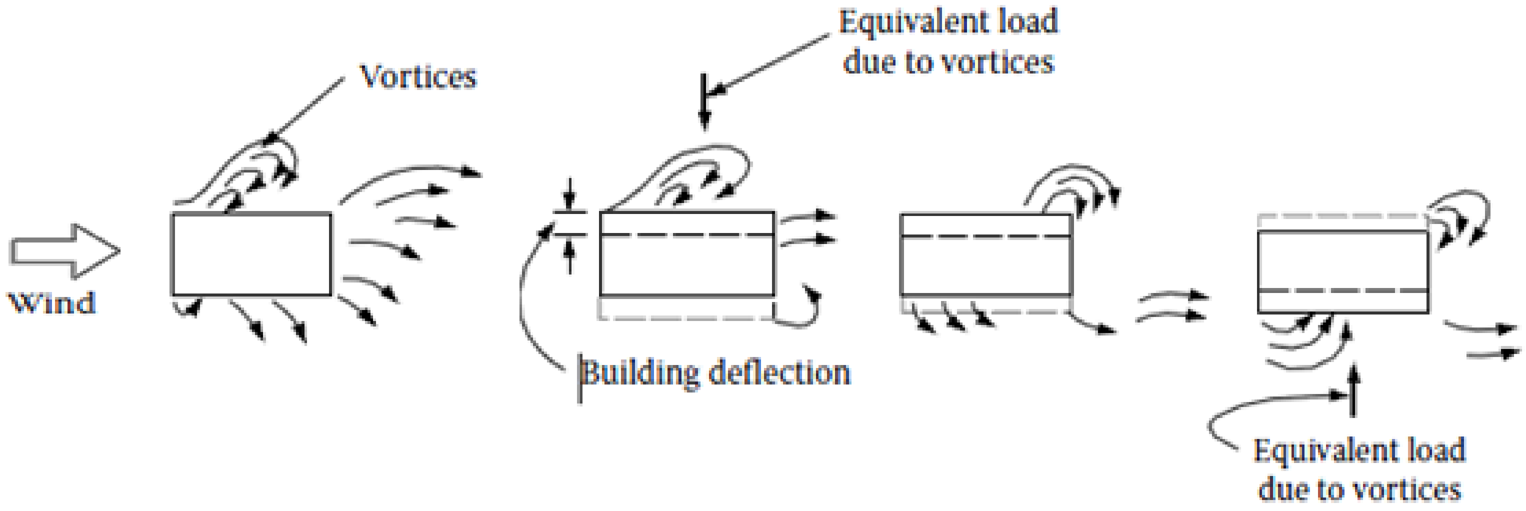
VORTEX SHEDDING

•When wind strikes the surface of building, it displaces it on either side.

• At low speed vortices are shed symmetrically in pairs due to which there no vibration in the transverse direction.

• At high speed vortices are shed alternately resulting in vibration of building in transverse direction.

• This phenomenon is called vortex shedding.



Simple formula to calculate the frequency of the transverse pulsating forces caused by vortex shedding:

$$f = \left\{ \frac{V \times S}{D} \right\}$$

Where,
f is the frequency of vortex shedding in hertz
V is the mean wind speed at the top of the building
S is a dimensionless parameter called the Strouhal number for the given shape
D is the diameter of the building

DYNAMIC NATURE OF WIND

- In low rise building wind is analyzed as static load
- Height rise building has to be studied for the dynamic nature of wind due to higher effect of gustiness or turbulence.

HISTORY

As per Baker (2007) the history of wind engineering is divided in five arbitrary time period

- Traditional period (upto 1750)
- Empirical period (1750-1900)
- Establishment period (1900-1960)
- Period of growth (1960-1980)
- Modern period (1980 onwards)

TRADITIONAL PERIOD

- During this period people have developed ritual systems.
- Circular geometries were of major importance.
- However over the centuries they evolved into polygonal and eventually conical structures

EMPRICAL PERIOD

- This period Industrial revolution began in earnest.
- Development of classical hydrodynamics building on the work of Euler, Newton and Bernoulli and later through Navier's formulation of the fundamental equations of fluid flow in 1845.
- Long span bridges were constructed and many of these collapses due to aero elastic oscillations, most famously Tay (rail) bridge in 1879.

ESTABLISHMENT PERIOD

- Industrial revolution was beginning to influence every aspect of life.
- Also many of the technological advances that were made were largely driven by military consideration.
- Empire state building was constructed and full scale measurement was done to find wind gust.
- Wind tunnel was developed by the aeronautical industry.
- There was development of codes of practice by National standards Organizations.
- Beginning of full scale measurement of wind load on structure.
- Collapse of Tacoma Narrow Bridge.
- During this period we saw important contribution of Dr. Alan Davenport.

MODERN PERIOD

- During this time we saw great revisions codes across the world.
- We saw increase in the frequency of major wind disasters.
- Great advancement in wind tunnel test on structures.

DAVENPORT GUST FACTOR APPROCH

Davenport showed that the average largest response during a period ‘T’ is given by:

$$X_{max} = \bar{X} + g_f \sigma_x$$

Where,

$\bar{X}$ is the response to mean wind load, and
g_f is the peak factor
σ_x is total resonant response

$$g_f = \sqrt{2 \log_e \nu T} + \frac{0.577}{\sqrt{2 \log_e \nu T}}$$

Where ν is the ‘cycling rate’ this is often conservatively taken as natural frequency, n_o. T is the time interval over which max. value is required.

Using the above equation.

$$G = 1 + g_f \frac{\sigma_x}{\bar{X}}$$

Where G is called the gust factor and is the ratio of expected maximum response to the mean response.

Davenport also presented an expression for Gust factor, as follows:

$$G = 1 + g_f r (B + R)^{1/2}$$

Where,

g_f = peak factor
r = roughness factor
k = Drag coefficient

$$r = 4.0\sqrt{k}\left(\frac{10}{h}\right)^{\alpha}$$

B = background turbulence excitation

$$B = 2\left[1 - \frac{1}{\left\{1 + \left(\frac{457}{h}\right)^2\right\}^{\frac{1}{3}}}\right]$$

R = resonant response excitation

$$R = \frac{sF}{\varsigma}$$

ζ = Critical damping ratio
F = spectral density

S = size reduction factor

$$S = \frac{\pi}{3} \frac{1}{\left(1 + \frac{8\xi_0}{3}\right)} \frac{1}{\left(1 + \frac{10\xi_0 b}{h}\right)}$$

$$\xi_0 = \frac{h n_o}{\bar{V}}$$

ξ_o = reduced frequency

- **IS 875 Part 3** is based on the above theory

Yin Z. et al. (2002)

- In their paper did a comparative study of major International codes and standards for along wind load effects on tall structure.
- ASCE 7 (United states), AS1170.2-89 (Australia), NBC-1995 (Canada), RLB-AIJ-1993 (Japan), and Eurocode-1993 (Europe) are examined in this study.
- He took a building of height 200 m with width and breadth of 33 m, Bulk density considered 180kg/m^3 and wind velocity of 40 m/sec
- In this paper it was observed that the difference in the results was due to unique definitions of wind field characteristics employs by different codes.

Following formula were used to find the Gust load factor:

	ASCE 7	AS1170.2	NBC	RLB-AIJ	Eurocode
G[a]	$0.925\left(\frac{1+r\sqrt{g_Q^2B+g_R^2R}}{1+g_v\cdot r}\right)$[a,c]	$1+r\sqrt{g_v^2B(1+w)^2+g_f^2R}$[d]	$1+g_f r\sqrt{B+R}$	$1+g_f r\sqrt{B+R}$	$\frac{1+g_f r\sqrt{B+R}}{1+3.5r}$[c]
T	3,600 s	3,600 s	3,600 s	600 s	600 s
$\bar{z}$	$0.6H$	H	H	H	$0.6H$
r	$r=1.7I_{\bar{z}}$[e]	$r=2\cdot I_{\bar{z}}$	$r=\sqrt{2K/C_{eH}}$[f]	$r=(3+3\alpha)/(2+\alpha)\cdot I_{\bar{z}}$[g]	$r=2I_{\bar{z}}$
g	$g_Q=g_v=3.4$	$g_v=3.7$;	$g_f=g_R(T,\upsilon)$;[g]	$g_f=\sqrt{2\ln(T\cdot\upsilon)+1.2}$	$g_f=g_R(T,\upsilon)$[h]
	$g_R=g_R(T,f_1)$[h]	$g_f=\sqrt{2\ln(T\cdot f_1)}$	$\upsilon=f_1\sqrt{SE/(SE+\zeta B)}$	$\upsilon=f_1\sqrt{R/(B+R)}$	$\upsilon=\sqrt{(\upsilon_0^2B+f_1^2R)/(B+R)}$
B	$\frac{1}{1+0.63\left(\frac{B+H}{L_{\bar{z}}}\right)^{0.63}}$	$\frac{1}{1+\frac{\sqrt{36H^2+64B^2}}{L_H}}$	$\frac{2}{3}\int_0^{914/H}\frac{1}{1+\frac{xH}{457}}\frac{1}{1+\frac{xB}{122}}\frac{x}{(1+x^2)^{4/3}}dx$	$1-\frac{1}{\left\{1+5.1\left(\frac{L_H}{\sqrt{HB}}\right)^{1.3}\left(\frac{B}{H}\right)^{k}\right\}^{1/3}}$	$\frac{1}{1+0.9\left(\frac{B+H}{L_{\bar{z}}}\right)^{0.63}}$
E[i]	$9.5N_1/(1+10.3N_1)^{5/3}$[e]	$0.6N_1/(2+N_1^2)^{5/6}$	$2N_1^2/3(1+N_1^2)^{4/3}$	$4N_1/(1+71N_1^2)^{5/6}$	$6.8N_1/(1+10.2N_1)^{5/3}$
S	$R_HR_B(0.53+0.47R_D)$[j]	$\frac{1}{\left[1+3.5\frac{f_1H}{V_H}\right]\left[1+4\frac{f_1B}{V_H}\right]}$	$\frac{1}{\left[1+\frac{8f_1H}{3V_H}\right]\left[1+\frac{10f_1B}{V_H}\right]}$	$\frac{0.84}{\left[1+\frac{2.1f_1H}{V_H}\right]\cdot\left[1+\frac{2.1f_1B}{V_H}\right]}$[k]	R_HR_B[j]

[a]Expressions for GLF in this table are not necessarily reproduced from the original codes and standards, but are rewritten in the standard form [refer to Eq. (2.1) or Eq. (2.2)].

[b]0.925 is an adjustment factor used to make the wind load in the updated code consistent with the former version.

[c]Numerator is the displacement GLF and the denominator is the GF for the wind velocity pressure.

[d]w is an approximate consideration of the quadratic wind velocity term (Vickery 1995).

[e]A 3 s low-pass filter has been included (Solari and Kareem 1998).

[f]K is provided for different terrains in NBC.

[g]A 0.75 factor is used to account for nonuniform load distribution (RLB-AIJ 1994).

[h]$g_R(T,f_1)$; see Eq. (2.3) by substituting relevant parameters.

[i]$E=f_1S_v(f_1)/\sigma_v^2$ and $N_1=f_1L_{\bar{z}}/\bar{V}_{\bar{z}}$.

[j]$R_l=1/\eta-1/2\eta^2(1-e^{-2\eta})$ for $\eta>0$; and $R_l=1$ for $\eta=0$. R_H, $\eta=4.6f_1H/\bar{V}_{\bar{z}}$; R_B, $\eta=4.6f_1B/\bar{V}_{\bar{z}}$; and R_D, $\eta=15.4f_1D/\bar{V}_{\bar{z}}$.

[k]Aerodynamic admittance function is equal to 0.84 at zero frequency.

And the results obtained were:

		ASCE 7		AS1170.2[a]		NBC		RLB-AIJ		Eurocode	
		A	*C*	*A*	*C*	*A*	*C*	*A*	*C*	*A*	*C*
V_0 (m/s)			40 (3 s)		40 (3 s)		26 (1 h)[b]		27 (10 min)[b]		27 (10 min)[b]
$\bar{z}$ (m)			120		200		200		200		120
$V_{\bar{z}}$ (m/s)		27.5	38.1	26.7	37.3	32.6	39.5	30.4	42.3	30.7	39.3
r		0.506	0.225	0.368	0.210	0.423	0.303	0.276	0.180	0.422	0.254
$L_{\bar{z}}$ (m)		190	250	2115	2115	1220	1220	258	258	197	236
B		0.583	0.624	0.633	0.633	0.300	0.300	0.582	0.582	0.500	0.529
E		0.140	0.144	0.094	0.117	0.170	0.191	0.080	0.100	0.106	0.109
S		0.048	0.079	0.080	0.123	0.077	0.101	0.154	0.212	0.087	0.121
R		0.525	0.889	0.596	1.138	1.031	1.524	0.967	1.655	0.726	1.039
g_f		g_R=3.79; g_v=3.40		g_R=3.63; g_v=3.70		3.759	3.768	3.209	3.235	3.208	3.225
G_B	3 s	0.447	0.316							0.386	0.315
	10 min							0.676	0.443	0.958[c]	0.596[c]
	1 h	1.214[c]	0.559[c]	1.083	0.618	0.870	0.626				
G_R	3 s	0.472	0.421							0.466	0.442
	10 min							0.872	0.747	1.154[c]	0.835[c]
	1 h	1.283[c]	0.742[c]	1.030	0.813	1.614	1.411				
G	3 s	0.990	1.051							1.009	1.073
	10 min							2.103 (78.2%)[g]	1.868 (100.8%)[g]	2.500[c] (92.9%)[g]	2.026[c] (109.2%)[g]
	1 h	2.691[c]	1.854[c]	2.495 (92.8%)[g]	2.021 (109.2%)[g]	2.833 (105.3%)[g]	2.544 (137.3%)[g]				
$\bar{M}$ (kN·m)	3 s	1,035,400	1,465,400								
	10 min							367,810 (86.3%)[g]	833,050 (105%)[g]	528,250 (124%)[g]	837,510 (106%)[g]
	1 h	425,980[d]	790,360[d]	297,600 (69.9%)[g]	644,490 (81.5%)[g]	417,880 (98.1%)[g]	735,690 (93.1%)[g]				
$\hat{\mathbf{M}}$ (kN·m)	10 min							773,410 (75.5%)[g]	1,556,400 (101.1%)[g]	1,320,400 (128.6%)[g]	1,696,700 (110.3%)[g]
	1 h	1,024,808 1,146,260[e]	1,539,848 1,465,015[e]	742,420 (72.4%)[g]	1,302,400 (84.5%)[g]	1,183,900 (115.7%)[g]	1,871,300 (121.1%)[g]				

METHODOLOGY

There are two major ways calculating wind load on structure:

- Wind tunnel
- IS 875 part 3 for static and dynamic method.

WIND TUNNEL

- Wind tunnel was first employed for aerodynamic research.
- Later it came into use to calculate effect of wind on man made structures.
- In this a life like specimen of the structure is prepared and kept in wind tunnel.
- Air is blown or sucked in this wind tunnel using a series of fan.
- Effect of this air is observed on the structure.

WIND ANAYSIS BY IS 875 PART 3

IS 875 Part 3 has given 2 ways of calculating wind load

- Static analysis
- Dynamic analysis

STATIC ANALYSIS

Static analysis consists of following steps:

- Determining basic wind speed
- Obtaining design wind speed
- Calculating design wind pressure
- Calculate wind pressure on building

DYNAMIC ANALYSIS

Dynamic analysis in IS875 Part 3 is based on Davenport Gust factor approach

IS 875 Part 3 gives following requirement for use of dynamic analysis of a structure.

•Buildings and closed structures with a height to minimum lateral dimension ratio of more than 5

•Buildings and closed structures whose natural frequency in the first mode is less than 1.0 Hz

To calculate the times period IS code has given 2 formula

- $T = 0.9\ n$ for building without shear wall or bracing
- $T = 0.09H/(d)^{1/2}$ for all others structures

Shedding frequency, η is determined by:

$$\eta = (SV_d)/b$$

Where,

S = Strouhal number
V_d = Design wind velocity
b = breadth of a structure or structural members in the horizontal plane normal to the wind direction

Variation of hourly mean speed with height

$$V_z = V_b \, k_1 \, k_2 \, k_3$$

Where,
V_z = hourly mean wind speed in m/sec at height z
V_b = regional basic wind speed in m/sec
k_1 = Probability factor
k_2 = terrain, height and structure size factor
k_3 = topography factor

Along Wind load

Along wind load on a structure on a strip area (A_e) at any height (z) is given by:

$$F_z = C_f A_e p_z G$$

Where,

F_z = along wind load on the structure at any height z corresponding to strip area A_e
C_f = force coefficient for the building (Fig 4 of IS 875),
A_e = effective frontal area considered for the structure at height e,
p_z = design pressure at height z due to hourly mean wind obtained as $0.6\ V_z^2$ (N/m^2),
G = gust factor (peak load/mean load), and is given by:

Gust factor, G

$$G = 1 + g_t r \left[B (1+\varphi)^2 + SE/\beta \right]^{1/2}$$

Where,

g_t = peak factor defined as the ratio of the expected peak value to the root mean value of afluctuating load

r = roughness factor which is dependent on the size of the structure in relation to the ground roughness.

*The value of $g_t r$ is given in Fig 8 of IS 875

B = Background factor given in Fig 9 of IS 875

SE/β = measure of the resonant component of the fluctuating wind

S = size reduction factor given in Fig 10 of IS 875

E = measure of available energy in the wind stream at the natural frequency of the structure given in Fig 11 of IS 875

β = damping coefficient (as a fraction of critical damping) of the structure as given in Table 34 of IS 875

$\varphi = [g_t r (B)^{1/2}]/4$ and is to be accountable for building less than 75m high in terrain category 4 and for buildings less than 25m high in terrain category 3, and is taken as zero in all other cases.

IMPLEMENTATION

In this report we have analyzed using IS 875 Part 3 method, 5 building of different dimension with one building dimension same as that on Yin Z et. al. and compared the results.

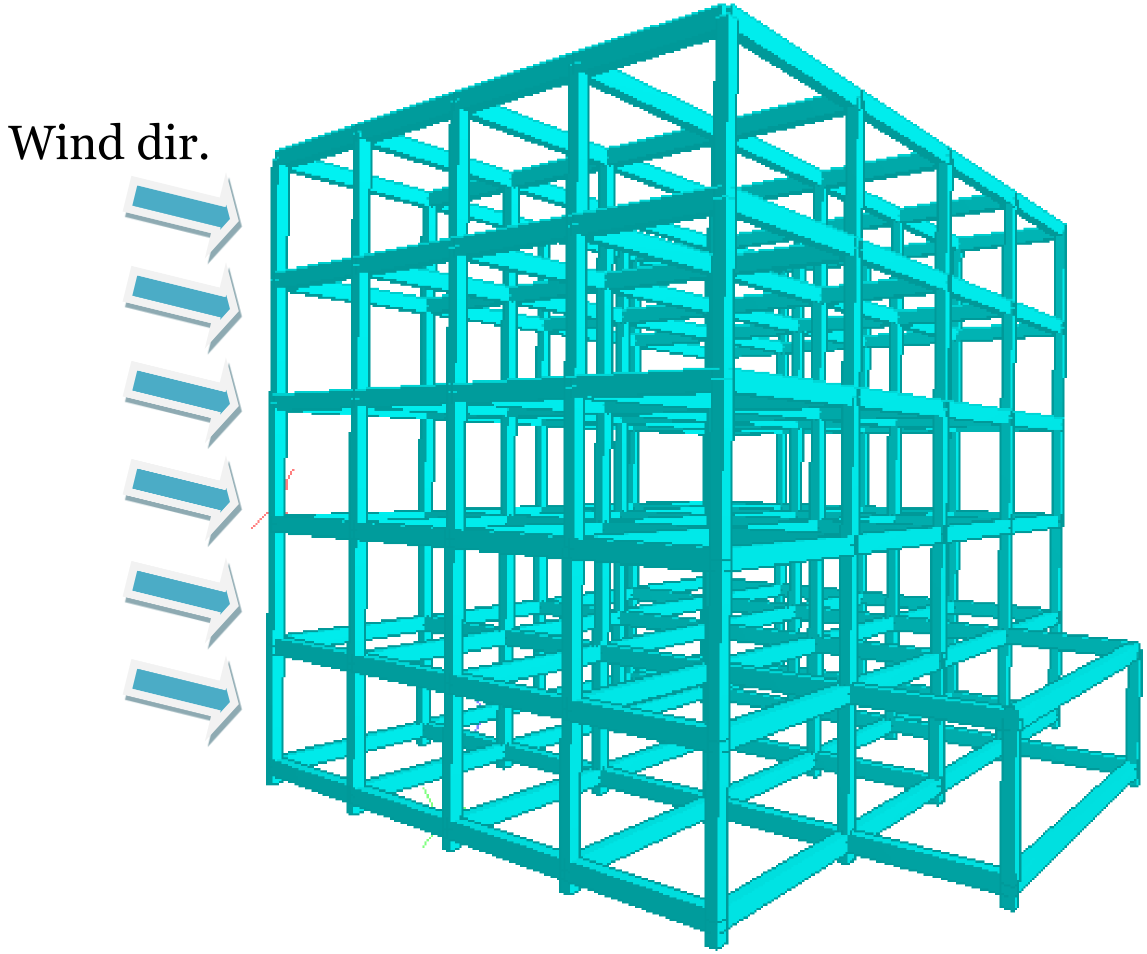
	BLD. 1	BLD. 2	BLD. 3	BLD. 4	BLD. 5
No. of story	5	10	50	100	-
Height (m)	17.5	35	175	350	200
Width (m)	16	20	24	40	33
Breadth (m)	20	35	40	80	33

BUILDING 1

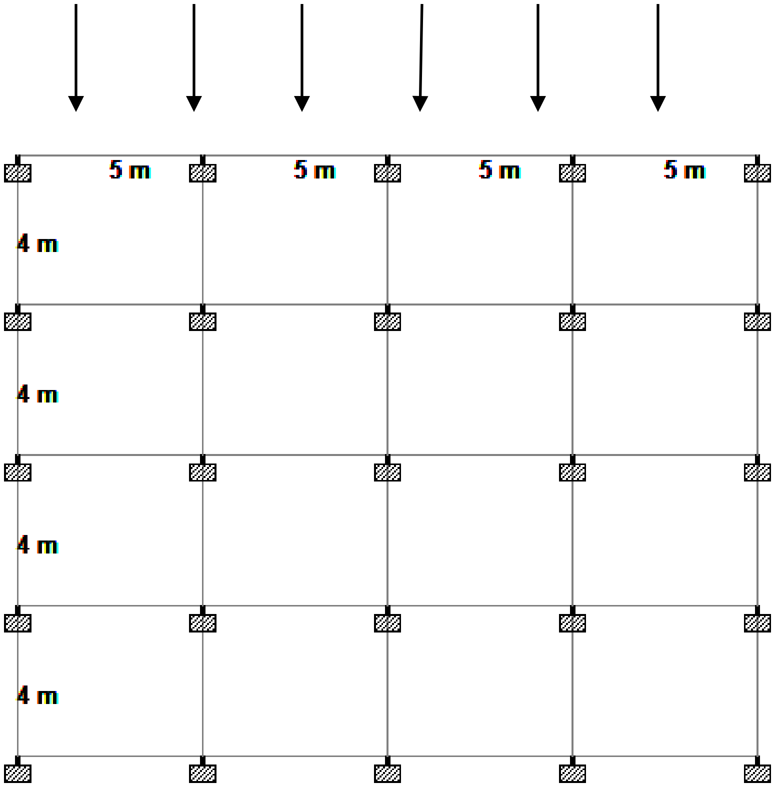
Breadth, b = 20 m
Width, a = 16 m
Height, h = 17.5 m

Dynamic analysis not required

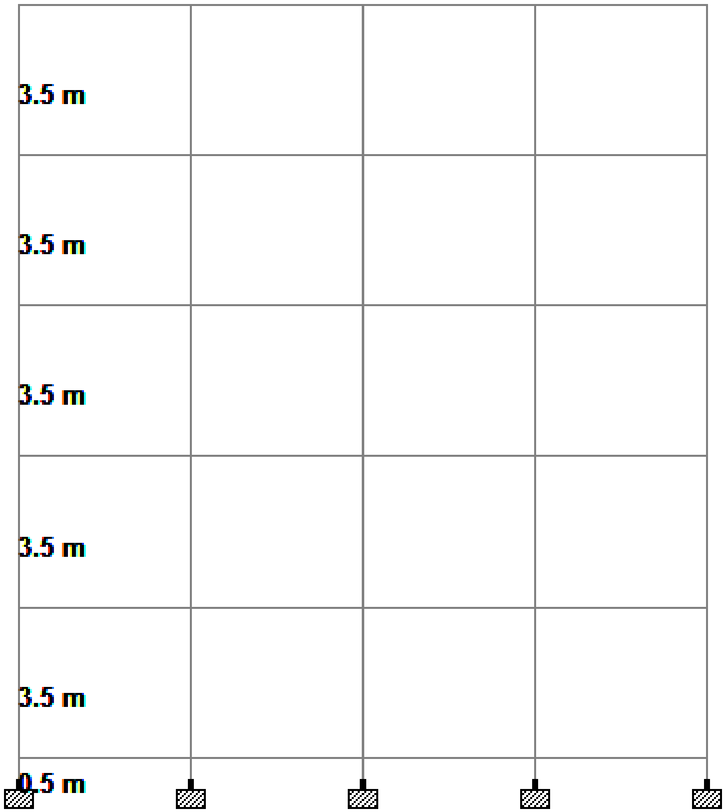
3-D model of 5 story structure



Wind dir.



Plan



Elevation

WIND LOAD CALCULATION

(5 STORY)

GIVEN

DIMENSION OF STRUCTURE			
Breadth, b	20	m	
Width, a	16	m	
Height, h	17.5	m	
DESIGN LIFE OF STRUCTURE	50	yrs	
PROBABITY FACTOR (k1)	1		table 1 of IS 875
TERRAIN CATERGORY	3		clause 5.3.2.1
TOPOGRAPHY FACTOR (k3)	1		
BASIC WIND SPEED	47	m/sec	APPENDIX A
MEAN WIND SPEED FACTOR (10m)	0.88		table 2
MEAN WIND VELOCITY AT 10 m height, V_{10}	47.00	m/sec	

LOAD CALCULATION

EXTERNAL PRESSURE COEFFICIENTS (C_p) for walls of rectangular clad buildings (Table 4)			
BUILDING HEIGHT RATIO (h/b)	0.88		
BREADTH WIDHT RATIO (b/a)	1.25		

AT 90^o									
A							0.7		
B							-0.25		
C							-0.6		
D							-0.6		
AT 0^o									
A							-0.6		
B							-0.6		
C							0.7		
D							-0.25		

NOTATIONS FOR TABLE

For table 1, 3

h(m) = Height of building

dh(m) = Diffrence in height of building

$k_{2(avg)}$ = Average of k_2 factor obtained from table 2 as per heigh

$p_d = 0.6 \times (V_{10} \times k_1 \times k_2 \times k_3)^2 C_p$

A (m^2) = Area of wall (dh x b)

Force (F, kN) = Area x p_d

TABLE 1 : FORCE CASE 1 AT 90^{O}

S.No	h(m)	dh(m)	$k_{2(avg)}$	p_d		A (m^2)	F (kN)	
				WALL A	WALL B		WALL A	WALL B
1	5	5	0.88	0.72	-0.26	100	71.8	-25.7
2	10	5	0.88	0.72	-0.26	100	71.8	-25.7
3	15	5	0.91	0.77	-0.27	100	76.8	-27.4
4	17.5	2.5	0.95	0.83	-0.30	50	41.7	-14.9

TABLE 2 : B.M CASE 1 AT 90^{o}

S.No	h(m)	z (m)	F (Kn)$_{WALL\ A}$	F (Kn)$_{WALL\ B}$	F_{TOTAL}	B.M
1	5	2.5	71.8	-25.7	97.51	243.77
2	10	7.5	71.8	-25.7	97.51	731.30
3	15	12.5	76.8	-27.4	104.27	1303.36
4	17.5	16.25	41.7	-14.9	56.58	919.41
TOTAL					355.86	3197.84

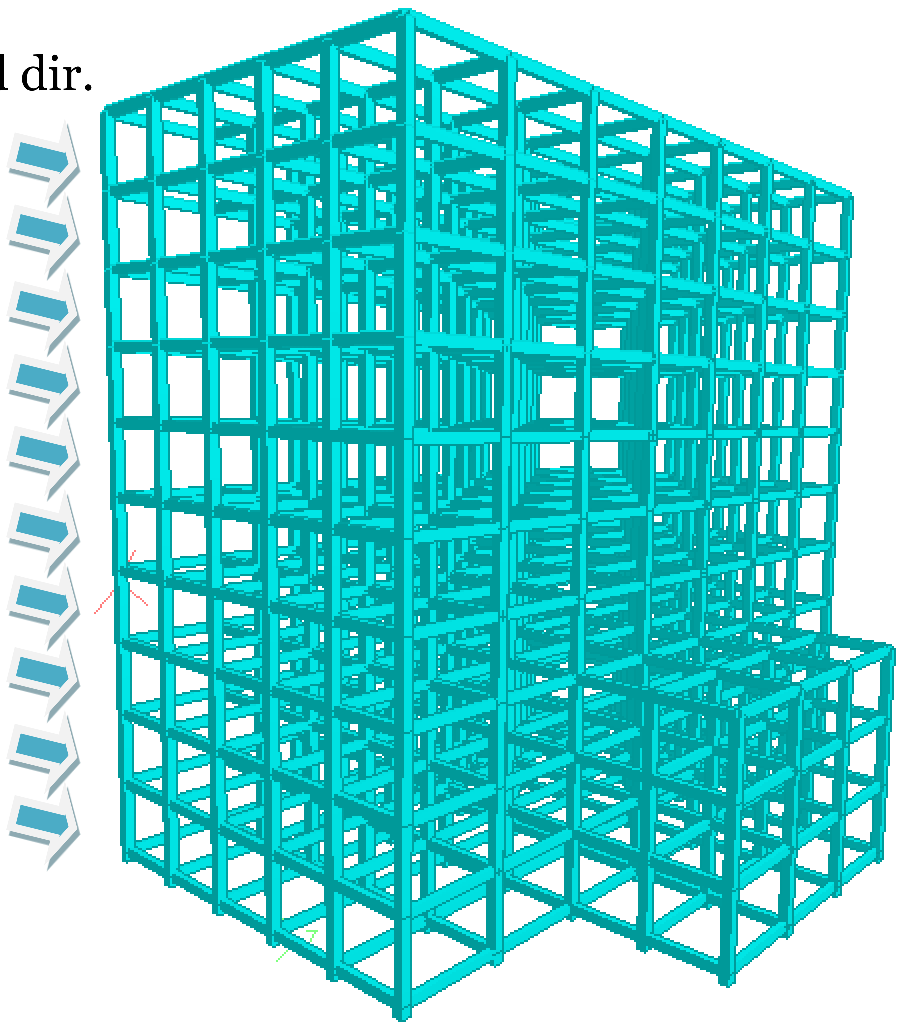
BASE SHEAR FORCE	355.86	Kn
BASE BENDING MOMENT	3197.84	kNm

BUILDING 2

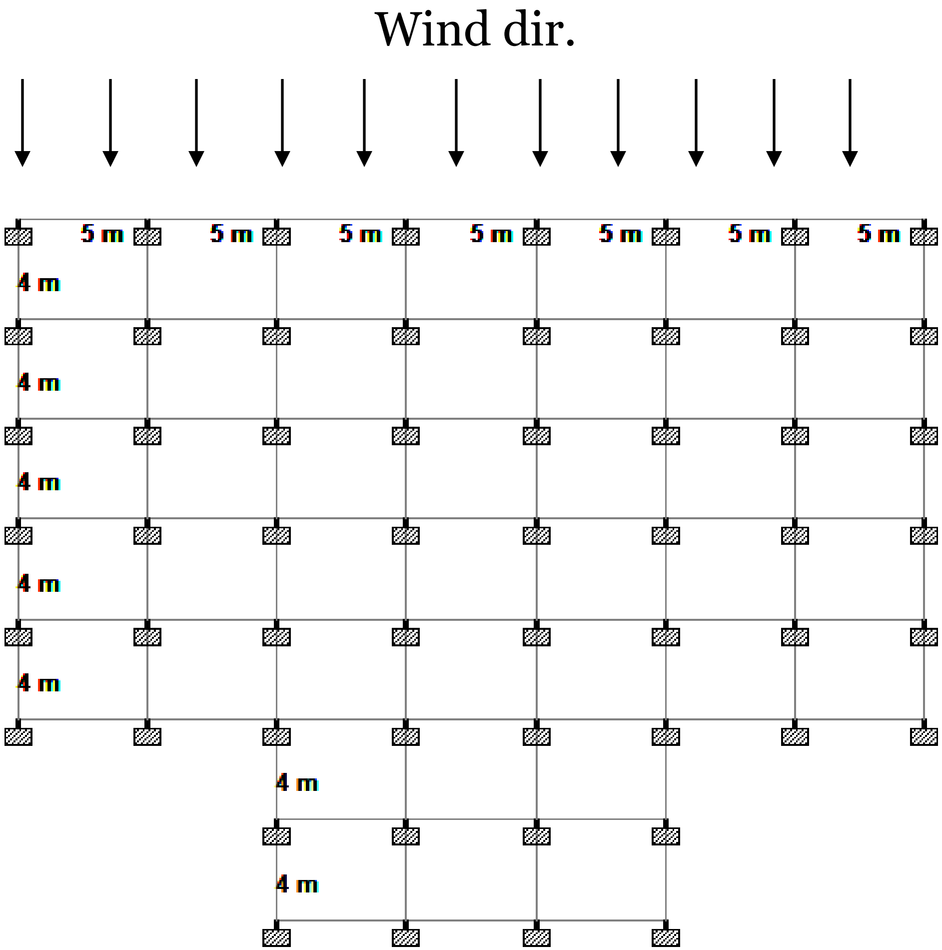
Breadth, b = 35 m
Width, a = 20 m
Height, h = 35 m

Dynamic analysis not required

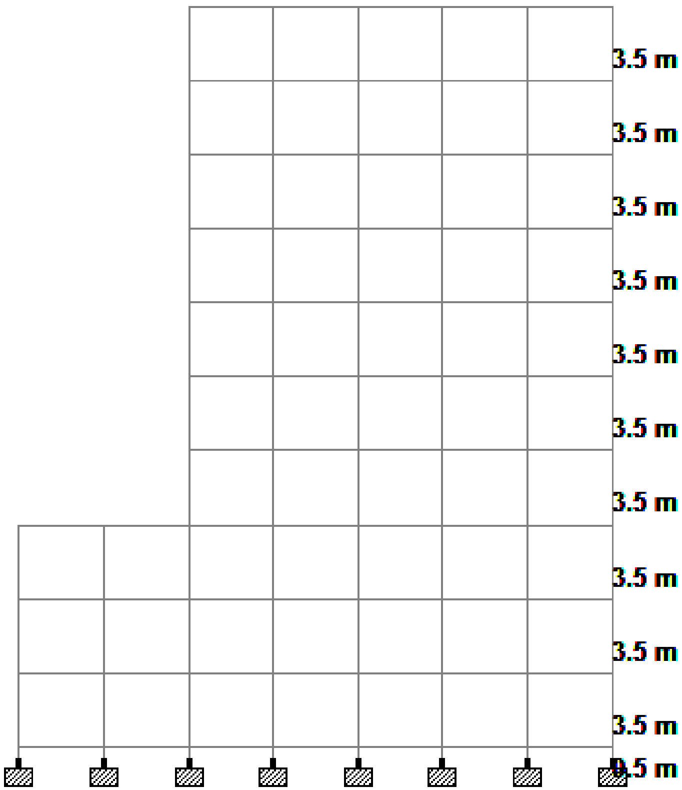
Wind dir.



3-D model of 10 story structure



Plan



Elevation

TABLE 1 : FORCE CASE 1 AT 90^O

S.No	h(m)	dh(m)	$k_{2(avg)}$	p_d		A (m^2)	F (kN)	
				WALL A	WALL B		WALL A	WALL B
1	10	10	0.88	0.72	-0.31	350	143.7	-61.6
2	15	5	0.91	0.77	-0.33	175	76.8	-32.9
3	20	5	0.96	0.86	-0.37	175	85.5	-36.6
4	25	5	0.99	0.91	-0.39	175	91.4	-39.2
5	30	5	1.02	0.96	-0.41	175	96.1	-41.2
6	35	5	1.04	1.00	-0.43	175	99.9	-42.8

TABLE 2 : B.M CASE 1 AT 90^o

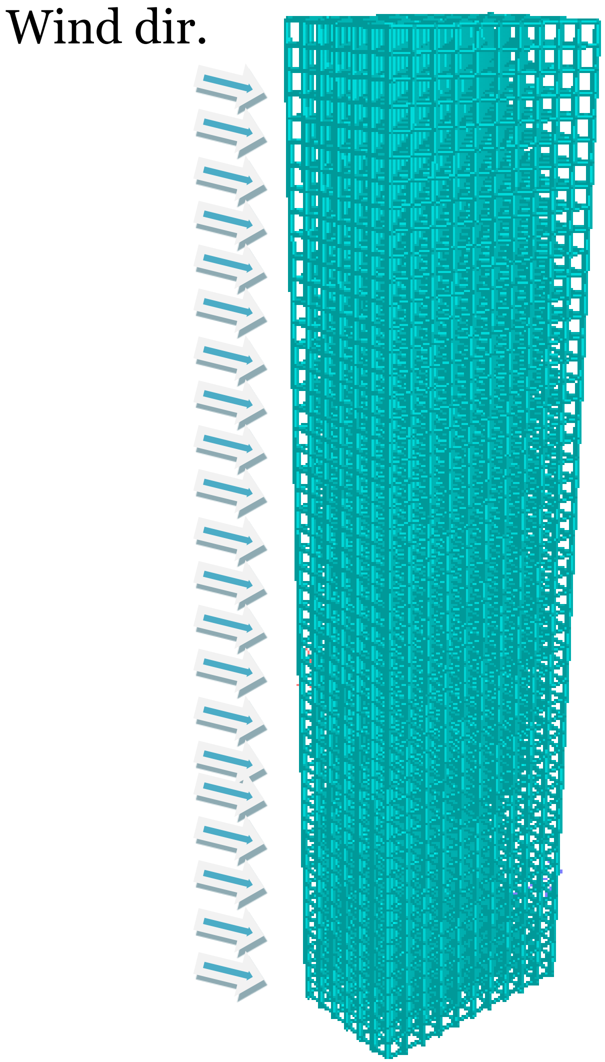
S.No	h(m)	z (m)	F (Kn)$_{WALL A}$	F (Kn)$_{WALL B}$	F_{TOTAL}	B.M
1	10	5	143.7	-61.6	205.28	1026.39
2	15	12.5	76.8	-32.9	109.76	1371.95
3	20	17.5	85.5	-36.6	122.15	2137.61
4	25	22.5	91.4	-39.2	130.56	2937.59
5	30	27.5	96.1	-41.2	137.22	3773.54
6	35	32.5	99.9	-42.8	142.67	4636.67
TOTAL					847.63	15883.74

* Final result are displayed (Calculated as previous)

BUILDING 3

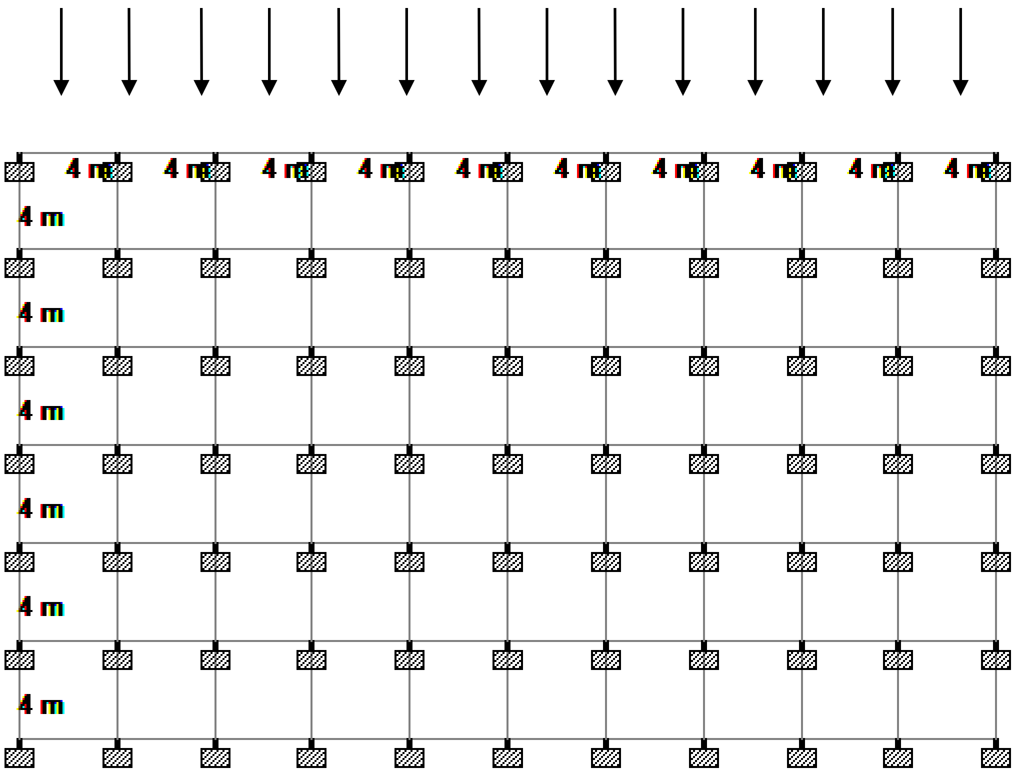
Breadth, b = 40 m
Width, a = 24 m
Height, h = 175m

Dynamic analysis required

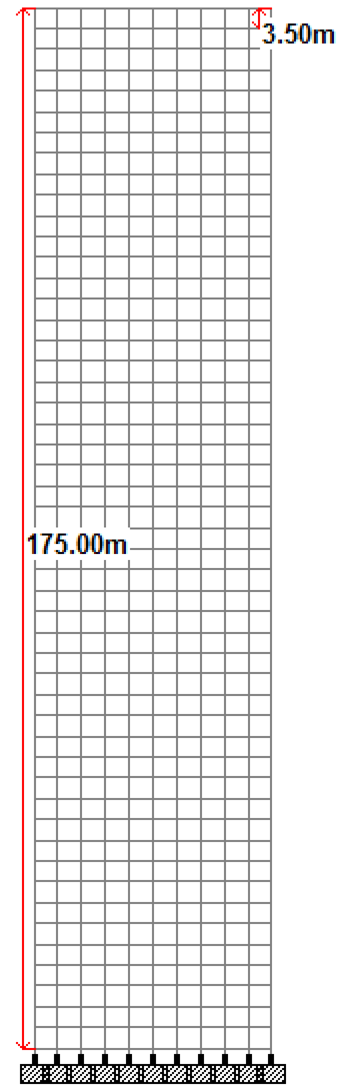


3-D model of 50 story structure

Wind dir.



Plan



Elevation

WIND LOAD CALCULATION

(50 STORY)

GIVEN

DIMENSION OF STRUCTURE			
Breadth, b	40	m	
Width, a	24	m	
Height, h	175	m	
DESIGN LIFE OF STRUCTURE	50	yrs	
TYPE OF STRUCTURE (S)	0.15		clause 7.2
TERRAIN CATERGORY	3		clause 5.3.2.1
WIND SPEED FACTOR (k2)	0.86		table 33
TOPOGRAPHY FACTOR (k3)	1		
STRUCTURE DAMPING COFFICIENT (β)	0.016		Table 34
TIME PERIOD (T)	2.49		clause 7.1 note 1 (a)
SWAY FREQUENCY, (f_o)	0.40	Hz	1/T
MODE SHAPE (k)	1		
AVERAGE BUILDING DENSITY	275	kg/m^2	
BASIC WIND SPEED	47	m/sec	APPENDIX A
HOURLY MEAN WIND SPEED FACTOR (10m)	0.5		table 33
HOURLY MEAN WIND VELOCITY AT 10 m height, V_{10}	23.50	m/sec	
HOURLY MEAN WIND VELOCITY AT ROOF LEVEL, V_n	40.42	m/sec	

LOAD CALCULATION

SHEDDING FREQUENCY $(\eta) = SxV_d/b$	0.15	< .2	
Factor g/r	0.78		Fig 8
BACKGROUND FACTORS			
Longitudnal correlation constant C_Z	12		Pg 52 of IS 875
Lateral correlation constant Cy	10		Pg 52 of IS 875
L(h)	1800		Fig 8
C_z x h/L(h)	1.17		
$\lambda = (C_y \times b)/(C_z \times h)$	0.19		
Background factor, B	0.6		Fig 9
Reduced frequency, $F_o = (C_z \times f_o \times h)/V_n$	20.86		
Size reduction factor, S	0.075		Fig 10
$f_oL(h)/V_n$	17.88		
Gust energy factor, E	0.09		Fig 11
SE/β	0.42		
Gust factor, $G=1+g_fr(B+(SE/\beta))^{1/2}$	1.79		
FORCE COEFFICIENT, C_f			
a/b	0.60		
h/b	4.38	>1	
C_f	1.4		Fig 4A

h(m) = Height of building

d(h)m =Diffrence between height

z (m) = Avg of height

k_2 = Table 33 of IS 875

A_c = Area of wall

Force (along wind) at height z on strip area Ae = $C_f G A_e F_z$

Pressure at height z due to $V_z = (V_{10} \text{ x } (k_2/0.50))$

$F_z = C_f G A_e p_z$

Bending Moment = Force x Area

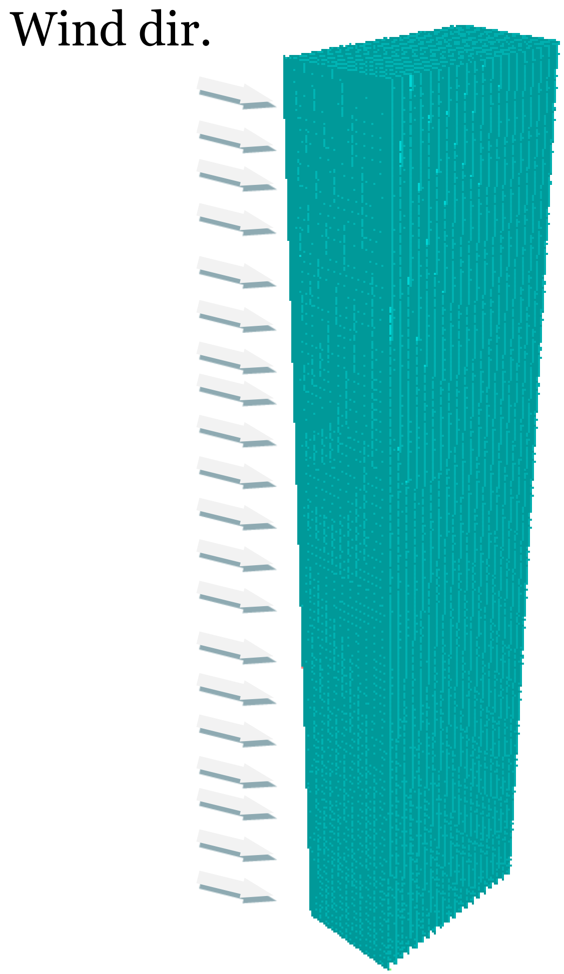
S.No	h(m)	dh(m)	z (m)	k_2	V_z (m/sec)	p_z (N/m^2)	A_c (m^2)	Fz (kN)	B.M
1	10	10	5	0.5	23.50	331.35	400	331.86	1659.32
2	15	5	12.5	0.55	25.85	400.93	200	200.78	2509.72
3	20	5	17.5	0.59	27.73	461.37	200	231.04	4043.27
4	30	10	25	0.64	30.08	542.88	400	543.73	13593.16
5	50	20	40	0.7	32.90	649.45	800	1300.91	52036.30
6	125	75	87.5	0.815	38.31	880.36	3000	6612.97	578635.20
7	150	25	137.5	0.84	39.48	935.20	1000	2341.63	321974.59
8	175	25	162.5	0.86	40.42	980.27	1000	2454.47	398850.92
TOTAL							7000	14017.39	1373302.47

BASE BENDING MOMENT 1373302.5 kNm

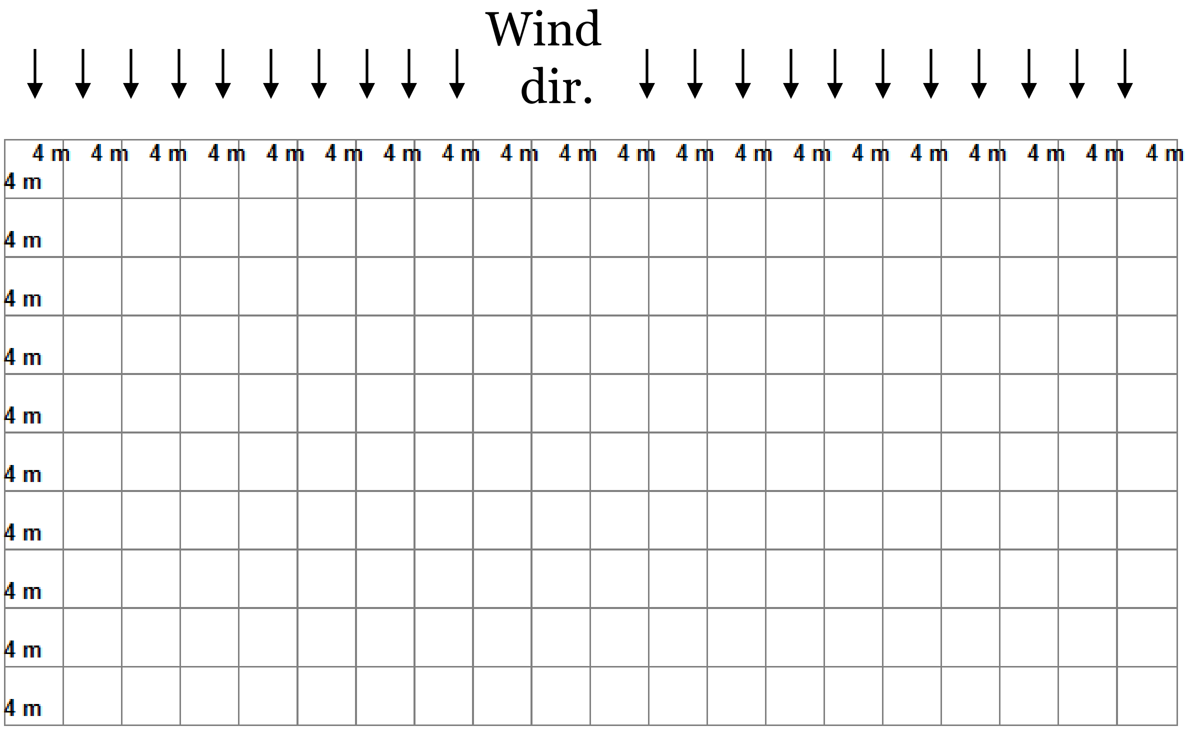
BUILDING 4

Breadth, b = 80 m
Width, a = 40 m
Height, h = 350 m

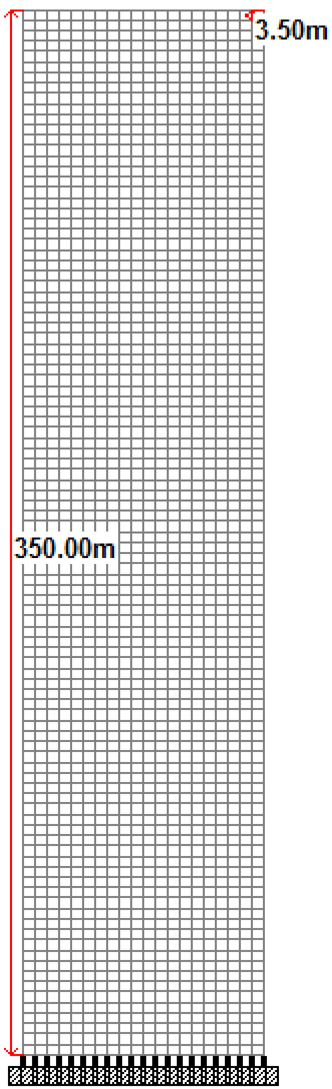
Dynamic analysis required



3-D model of 100 story structure



Plan



Elevation

h(m) = Height of building

d(h)m =Diffrence between height

z (m) = Avg of height

k_2 = Table 33 of IS 875

A_c = Area of wall

Force (along wind) at height z on strip area Ae = $C_f G A_e F_z$

Pressure at height z due to $V_z = (V_{10} \times (k_2/0.50))$

$F_z = C_f G A_e p_z$

Bending Moment = Force x Area

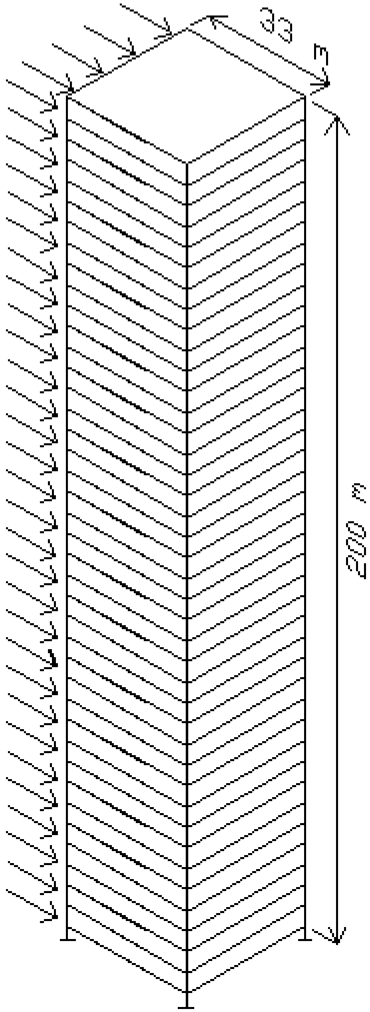
S.No	h(m)	dh(m)	z (m)	k_2	V_z (m/sec)	p_z (N/m^2)	A_c (m^2)	Fz (kN)	B.M
1	10	10	5	0.5	23.50	331.35	800	590.64	2953.19
2	15	5	12.5	0.59	27.73	461.37	400	411.20	5140.03
3	20	5	17.5	0.59	27.73	461.37	400	411.20	7196.04
4	30	10	25	0.64	30.08	542.88	800	967.70	24192.55
5	50	20	40	0.7	32.90	649.45	1600	2315.30	92612.11
6	100	50	75	0.79	37.13	827.18	4000	7372.35	552926.18
7	150	50	125	0.84	39.48	935.20	4000	8335.09	1041886.21
8	200	50	175	0.88	41.36	1026.39	4000	9147.81	1600866.43
9	250	50	225	0.91	42.77	1097.56	4000	9782.15	2200984.62
10	300	50	275	0.93	43.71	1146.34	4000	10216.86	2809637.53
11	350	50	325	0.95	44.65	1196.17	4000	10661.02	3464832.75
TOTAL							16000	60211.34	11803227.65

BASE BENDING MOMENT 11803227.65 kNm

BUILDING 5

Breadth, b = 33 m
Width, a = 33 m
Height, h = 200 m
Wind speed = 40 m/sec
Density = 180 kg/m^3

Dynamic analysis required



3-D model of 200 m height structure

h(m) = Height of building

d(h)m =Diffrence between height

z (m) = Avg of height

k_2 = Table 33 of IS 875

A_c = Area of wall

Force (along wind) at height z on strip area Ae = $C_f G A_e F_z$

Pressure at height z due to $V_z = (V_{10} \times (k_2/0.50))$

$F_z = C_f G A_e p_z$

Bending Moment = Force x Area

S.No	h(m)	dh(m)	z (m)	k_2	V_z (m/sec)	p_z (N/m^2)	A_c (m^2)	Fz (kN)	B.M
1	10	10	5	0.5	20.00	240.00	330	199.76	998.78
2	15	5	12.5	0.59	23.60	334.18	165	139.07	1738.37
3	20	5	17.5	0.59	23.60	334.18	165	139.07	2433.72
4	30	10	25	0.64	25.60	393.22	330	327.28	8181.99
5	50	20	40	0.7	28.00	470.40	660	783.04	31321.68
6	125	75	87.5	0.815	32.60	637.66	2475	3980.48	348292.02
7	150	25	137.5	0.84	33.60	677.38	825	1409.48	193802.90
8	200	50	175	0.88	35.20	743.42	1650	3093.82	541417.63
TOTAL							6600	10071.99	1128187.10

BASE BENDING MOMENT	1128187	kNm	

RESULTS

The results of the 4 buildings are:

S.No.	TYPEE OF BUILDING	BASE SHEAR (kN)	MOMENT (kNm)
1	5 story	355.86	3179.84
2	10 story	847.63	15883.74
3	50 story	14047.66	1373680.8
4	100 story	60211.34	11803227.65

This shows that with height of structure the effect of wind tremendously increases

The result of 200 m high building is also shown below in the table for different codes

	ASCE 7	AS1170.2	NBC	RLB-AIJ	Eurocode	IS 875
G.L.F	1.854	2.021	2.544	1.868	2.026	1.74
Moment (kNm)	1539848	1302400	1871300	1556400	1696700	1128187

Here we can see that G.L.F and moment are different for all codes. This is because of difference in wind characterisation in the codes

THANK YOU