Calculation Sample

Using program of ‘HK Wind Load Cal’

Based on ‘Code of Practice on Wind Effects in Hong Kong 2019’

1. Selection of basic parameters

According to the ETABS model：

1） Breath of building B = 46.9m

2） Depth of building D = 46.9m

3） Total height of building H = 295.1m

4） Height of building structure above ground level, Hb为295.1m

5） Storey number of building = 66

6） Building shape = rectangular

7） Structure Type = Steel/Concrete

8) Reduction in reference height, Hd, may be taken as zero or as the minimum of the following:

(a) $0.8H_i$

(b) $1.2H_i - 0.2X_i \ but \geq 0$

(c) $0.75H$

Where

H is the actual building height of the proposed building

Hi is the height of obstructing building above ground level within ±45° of the considered wind direction (F. A2-1), Hi⩽H

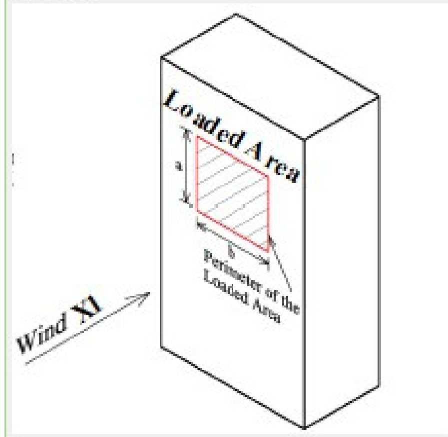
Xi is the horizontal distance from the upwind edge of the proposed building to the obstructing building (F. A2-2). It is sufficient to consider buildings within a distance Xi less than 6times the proposed building height

In this example, due to lack of data from obstructing building around the proposed building, Hd is taken as 0 and the height reduction is not considered.

9)	the zone type is selected according to the location of the Loaded Area (see Figure2).

The Loading Area of this example is considered in the center, so the zone type of "other" should be selected.

Figure 2



10)	Topography multiplier should be taken according to Appendix A3. The method for calculation in Appendix A3 is applicable to hills and ridges, or cliffs and escarpments.

Due to lack of surrounding topography information, St is taken as 1, which means ignoring the topographic effect.

11) Mh is mass of building above 2Hb/3.

Using PKPM to calculate the sample model, building masses of each storey are listed in Table 1-1.

The corresponding storey of 2Hb/3 is 44.

Building mass above 44^{th} floor is 60396.5t.

Thus, Mh=60396.5t。

Table 1-1 Building mass of each storey

Storey	Dead load mass (t)	Live load mass (t)	Mass of each storey (t)	Mass ratio
67	2309.9	69.5	2379.4	0.96
66	2243.4	236.0	2479.4	0.96
65	2308.3	282.9	2591.1	1.02
64	2078.4	454.0	2532.3	1.07
63	2046.2	325.7	2372.0	1.00
62	2046.2	323.1	2369.4	1.00
61	2046.2	325.7	2372.0	1.00
59,60	2059.0	323.1	2382.2	1.00
58	2059.0	325.7	2384.8	0.96
57	2162.8	323.1	2485.9	1.00
56	2162.8	325.7	2488.5	1.00
55	2162.8	323.1	2485.9	1.00
54	2162.8	325.7	2488.5	0.95
53	2296.6	323.1	2619.7	0.92
52	2229.4	616.0	2845.4	0.97
50,51	2608.3	314.8	2923.2	1.00
49	2608.3	314.8	2923.2	0.99
48	2625.8	314.8	2940.6	0.98
44-47	2694.4	314.8	3009.2	1.00
43	2694.4	314.8	3009.2	0.97
42	2776.6	314.8	3091.5	1.00
41	2776.6	314.8	3091.5	1.33
40	2131.2	193.5	2324.7	0.92
39	2291.4	246.1	2537.5	0.73
38	3131.8	366.2	3498.0	1.00
37	2927.6	570.1	3497.7	1.03
32-36	3058.0	330.9	3389.0	1.00
31	3058.0	330.9	3389.0	0.97
30	3164.1	330.9	3495.1	1.00
29	3164.1	330.9	3495.1	0.99
27,28	3207.7	330.9	3538.7	1.00
26	3207.7	330.9	3538.7	0.98
25	3268.6	330.9	3599.6	0.98
24	3325.7	330.9	3656.6	1.00
23	3325.7	330.9	3656.6	0.99
22	3367.8	319.3	3687.1	0.90
21	3760.5	319.3	4079.7	0.99
20	3491.7	637.5	4129.2	1.12
19	3386.1	314.8	3700.9	1.00
18	3393.8	314.8	3708.6	1.00
16,17	3405.3	314.8	3720.1	1.00
15	3405.3	314.8	3720.1	0.96
14	3570.2	314.8	3885.0	1.00
8-13	3577.7	314.8	3892.5	1.00
7	3595.8	314.8	3910.6	0.91
6	3988.9	314.8	4303.7	0.90
5	4265.2	541.1	4806.3	1.04
4	4318.3	286.7	4605.0	0.92
3	4697.3	321.8	5019.1	1.18
2	4070.7	175.9	4246.6	0.31
1	12210.5	1574.8	13785.3	1.00

12) θ is the direction the wind comes from (rotating east from north). Due to lack of wind direction information for the sample model, θ is taken as 45°。

13) Return period of wind, R is taken as 1 year

14) Fundamental frequency Nx、Ny

Using PKPM to analyze the sample model, fundamental periods in X, Y direction are as follow:

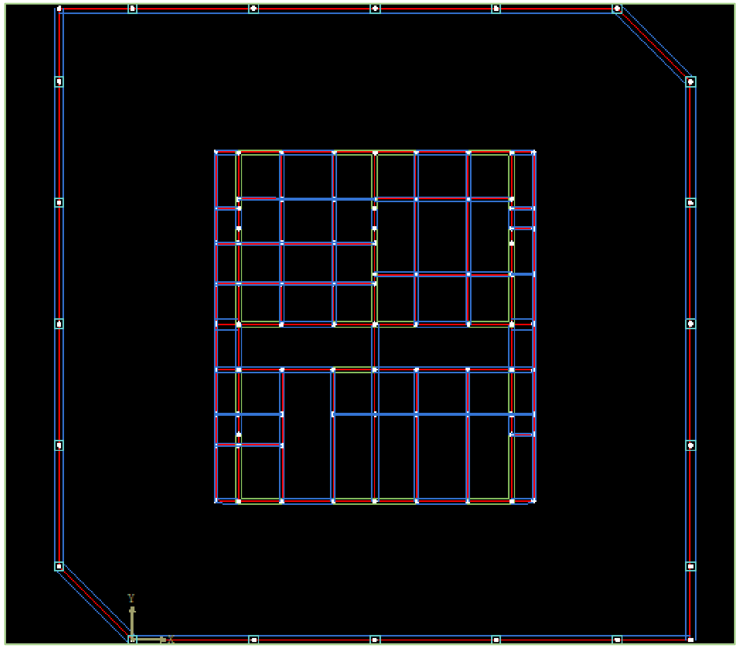
Fundamental periods in X (s)	6.786
Fundamental periods in Y (s)	6.3

Fundamental frequency Nx = 1/6.786 = 0.147 Hz

Fundamental frequency Ny = 1/6.3 = 0.159 Hz

15) Effect of corner shape

From the example model, one pair of opposite corners of the building are cutting corners. The width of wedge is 5.45m and the cutting angle is 45°. The other pair of opposite corners are complete corner. In the wind load code of 2019, when considering the effect of corner shape, all four corners of a building should be cut corners. Therefore, this example will ignore the corner shape effect, and the calculation result is more conservative under this case.



15) The value of each storey's parameter (height, width, depth) is shown in the following Table 1-2

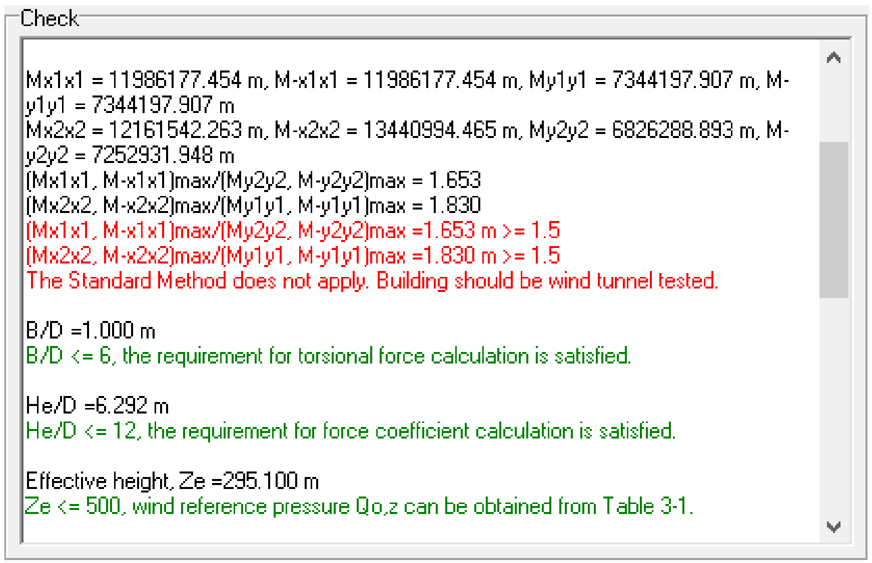
Table 1-2 Value of each storey's parameter

Storey	Floor height(m)	B(m)	D(m)
Ground	7	46.9	46.9
1	6.6	46.9	46.9
2	5.8	46.9	46.9
3	6	46.9	46.9
4	5.5	46.9	46.9
5	5.1	46.9	46.9
6	4.2	46.9	46.9
7	4.2	46.9	46.9
8	4.2	46.9	46.9
9	4.2	46.9	46.9
10	4.2	46.9	46.9
11	4.2	46.9	46.9
12	4.2	46.9	46.9
13	4.2	46.9	46.9
14	4.2	46.9	46.9
15	4.2	46.9	46.9
16	4.2	46.9	46.9
17	4.2	46.9	46.9
18	4.2	46.9	46.9
19	4.4	46.9	46.9
20	5.1	46.9	46.9
21	4.2	46.9	46.9
22	4.2	46.9	46.9
23	4.2	46.9	46.9
24	4.2	46.9	46.9
25	4.2	46.9	46.9
26	4.2	46.9	46.9
27	4.2	46.9	46.9
28	4.2	46.9	46.9
29	4.2	46.9	46.9
30	4.2	46.9	46.9
31	4.2	46.9	46.9
32	4.2	46.9	46.9
33	4.2	46.9	46.9
34	4.2	46.9	46.9
35	4.2	46.9	46.9
36	4.4	46.9	46.9
37	5.1	46.9	46.9
38	4.2	46.9	46.9
39	4.2	46.9	46.9
40	4.2	46.9	46.9
41	4.2	46.9	46.9
42	4.2	46.9	46.9
43	4.2	46.9	46.9
44	4.2	46.9	46.9
45	4.2	46.9	46.9
46	4.2	46.9	46.9
47	4.2	46.9	46.9
48	4.2	46.9	46.9
49	4.2	46.9	46.9
50	4.2	46.9	46.9
51	4.4	46.9	46.9
52	5.1	46.9	46.9
53	4.2	46.9	46.9
54	4.2	46.9	46.9
55	4.2	46.9	46.9
56	4.2	46.9	46.9
57	4.2	46.9	46.9
58	4.2	46.9	46.9
59	4.2	46.9	46.9
60	4.2	46.9	46.9
61	4.2	46.9	46.9
62	4.2	46.9	46.9
63	4.4	46.9	46.9
64	4.2	46.9	46.9
65	4.2	46.9	46.9
66	3.6	46.9	46.9
Roof	0	46.9	46.9

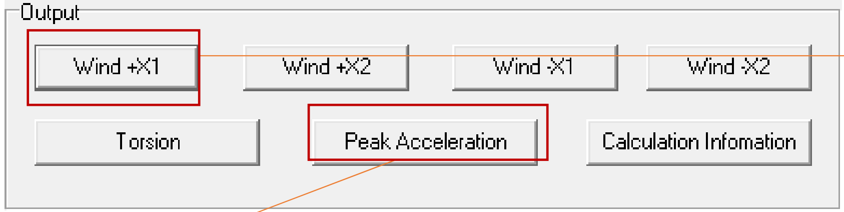
2. Run the program

1) After entering all parameters above, click button ‘Check And Calculate’.

2) See the information in ‘Check’ box to check if this program is applicable for target model.



3) See the output result by selecting different categories.



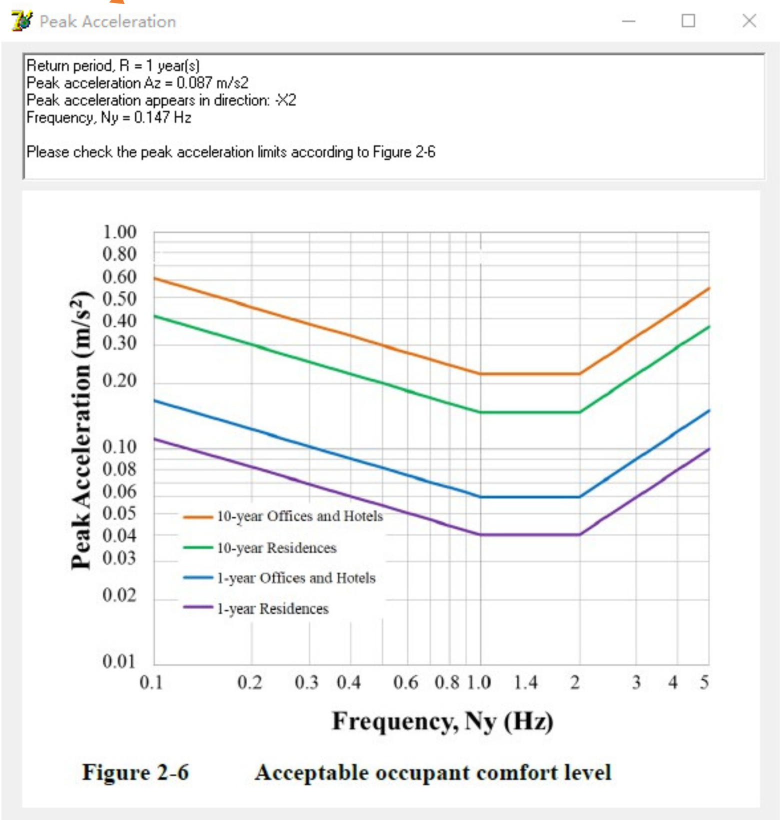
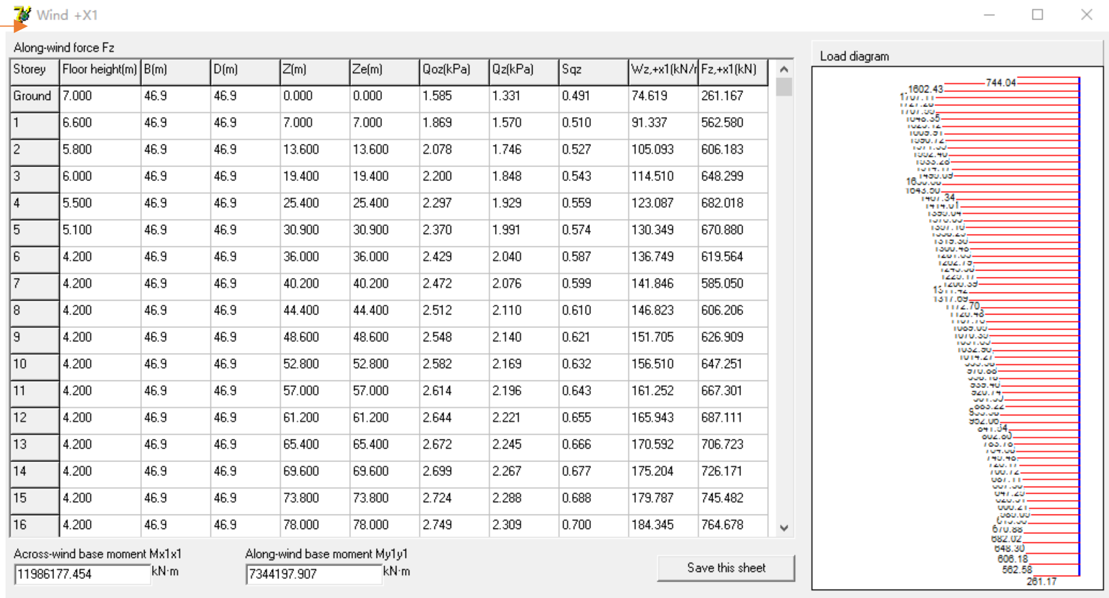


Figure 2-6 **Acceptable occupant comfort level**



Wind +X1

Along-wind force Fz

Storey	Floor height(m)	B(m)	D(m)	Z(m)	Ze(m)	Qoz(kPa)	Qz(kPa)	Sqz	Wz,+x1(kN/r	Fz,+x1(kN)
Ground	7.000	46.9	46.9	0.000	0.000	1.585	1.331	0.491	74.619	261.167
1	6.600	46.9	46.9	7.000	7.000	1.869	1.570	0.510	91.337	562.580
2	5.800	46.9	46.9	13.600	13.600	2.078	1.746	0.527	105.093	606.183
3	6.000	46.9	46.9	19.400	19.400	2.200	1.848	0.543	114.510	648.299
4	5.500	46.9	46.9	25.400	25.400	2.297	1.929	0.559	123.087	682.018
5	5.100	46.9	46.9	30.900	30.900	2.370	1.991	0.574	130.349	670.880
6	4.200	46.9	46.9	36.000	36.000	2.429	2.040	0.587	136.749	619.564
7	4.200	46.9	46.9	40.200	40.200	2.472	2.076	0.599	141.846	585.050
8	4.200	46.9	46.9	44.400	44.400	2.512	2.110	0.610	146.823	606.206
9	4.200	46.9	46.9	48.600	48.600	2.548	2.140	0.621	151.705	626.909
10	4.200	46.9	46.9	52.800	52.800	2.582	2.169	0.632	156.510	647.251
11	4.200	46.9	46.9	57.000	57.000	2.614	2.196	0.643	161.252	667.301
12	4.200	46.9	46.9	61.200	61.200	2.644	2.221	0.655	165.943	687.111
13	4.200	46.9	46.9	65.400	65.400	2.672	2.245	0.666	170.592	706.723
14	4.200	46.9	46.9	69.600	69.600	2.699	2.267	0.677	175.204	726.171
15	4.200	46.9	46.9	73.800	73.800	2.724	2.288	0.688	179.787	745.482
16	4.200	46.9	46.9	78.000	78.000	2.749	2.309	0.700	184.345	764.678

Across-wind base moment Mx1x1: 11986177.454 kN·m

Along-wind base moment My1y1: 7344197.907 kN·m

Save this sheet

3. Program Calculation Procedure (Taking 'Roof' as an example)

3.1 Calculation of along-wind Force

1） Calculation of effective height

Height at roof Z=295.1m

Height of reduction Hd=0

Z-Hd=295.1-0=295.1m， 0.25Z=295.1*0.25 = 73.775m

Ze=max{ (Z-Hd) , (0.25Z) }=295.1m

The effective height, Z_e, is taken as the maximum of $(Z - H_d)$ and $(0.25Z)$, where H_d is the height of reduction and may be taken as zero or as the minimum of the following:

2） Calculate Sθ

By looking up to Appendix A1.1

Table A1-1 Directionality factor on pressure, S_θ

Wind Direction	Direction factor, S_θ
N	0.82
NE	0.84
E	0.85
SE	0.85
S	0.85
SW	0.84
W	0.82
NW	0.80

By linear interpolation,

X1： Sθ = 0.84 (Wind direction X1 is 45°, corresponding to NE)

X2： Sθ = 0.80 (Wind direction X2 is -45°, corresponding to NW)

-X1： Sθ = 0.84 (Wind direction -X1 is 225°, corresponding to SW)

-X2： Sθ = 0.85 (Wind direction -X2 is 135°, corresponding to SE)

3） Calculate damping ratio

By looking up to Table C2-1:

Structure type in this sample is Steel/Concrete, intermediate values should be used

typical buildings. For composite steel/concrete constructions, intermediate values should be used.

Aspect ratio = 295.1/46.9 = 6.29 (at both directions X, Y)

Recommended damping ratio for accelerations：

$$\xi_x = 0.009 , \xi_y = 0.009$$

Tentative damping ratio for structure loads：

$$\xi_x = 0.014 , \xi_y = 0.014$$

Table C2-1 Damping ratio for typical RC buildings, ξ_x, ξ_y

Aspect ratio in the direction of vibration	Recommended damping ratio for accelerations	Tentative damping ratio for structural loads
	Maximum damping ratio	Maximum damping ratio
≥ 8	0.010	0.015
7	0.011	0.017
6	0.013	0.020
5	0.016	0.024
<4	0.020	0.030

Table C2-2 Damping ratio for typical steel buildings, ξ_x, ξ_y

Aspect ratio in the direction of vibration	Recommended damping ratio for accelerations	Tentative damping ratio for structural loads
	Maximum damping ratio	Maximum damping ratio
≥ 8	0.005	0.008
7	0.006	0.009
6	0.007	0.010
5	0.008	0.012
<4	0.010	0.015

4) Calculate wind reference pressure Qo,z

By looking up Table 3-1, at 295.1m, using linear interpolation,

Qo,z=3.31+(3.41-3.31)*(295.1-250)/(300-250)=3.401kPa

Table 3-1 Wind reference pressure, $Q_{o,z}$

Effective height Z_e (m)	Wind reference pressure $Q_{o,z}$ (kPa)
≤ 2.5	1.59
5	1.77
10	1.98
20	2.21
30	2.36
50	2.56
75	2.73
100	2.86
150	3.05
200	3.20
250	3.31
300	3.41
400	3.57
500	3.70
>500	Seek specialist advice

5） Calculate Qz

$$Q_z = Q_{o,z}\, S_t\, S_\theta \quad - \quad \text{Equation 3-1}$$

Where

$Q_{o,z}$	defined in clause 3.2,
S_t	the topography factor in Section 3.4,
S_θ	the wind directionality factor in Appendix A1.

+X1: Qz=3.401*1*0.84=2.857kPa

+X2: Qz=3.401*1*0.80=2.721kPa

-X1: Qz=3.401*1*0.84=2.857kPa

-X2: Qz=3.401*1*0.85=2.891kPa

6） Calculate Ss

See Appendix C1

Other zones and for Overall Wind Loads

$$S_{s=L_{0.5p}} = Exp\left(0.17 - 0.07\, L_{0.5p}{}^{0.32}\right) \quad - \quad \text{Equation C1-1a}$$

Edge zones if $L_{0.5p} < 15\text{m}$

$$S_{s=L_{0.5p}} = 1.3 - \log_n\left(L_{0.5p}\right)/9.0 > 1.0 \quad - \quad \text{Equation C1-1b}$$

Corner zones if $L_{0.5p} < 15\text{m}$

$$S_{s=L_{0.5p}} = 1.5 - \log_n\left(L_{0.5p}\right)/5.4 > 1.0 \quad - \quad \text{Equation C1-1c}$$

Where

S_s	size factor depending on the half-perimeter length, $L_{0.5p}$, of the loaded area (this may be greater than 1.0 for small elements)
$L_{0.5p}$	half-perimeter length around a tributary area

Zone type of the sample is “Other”， using Equation C1-1a

H>50m， L0.5p=B

Because B=D， L0.5p in ±X1, ±X2 is the same.

±X1, ±X2: L0.5p=B=46.9m

±X1, ±X2: Ss=Exp(0.17-0.07*46.90.32)= 0.933

7) Calculate Sq,h, Sq,z

H>50m, Equation 5-1 and 5-2 can be used.

±X1: $S_{q,h} = 0.5 + \sqrt{(0.933 - 0.5)^2 + \frac{0.25}{46.9^{0.5} \times 295.1 \times 0.147^2 \times 0.014}} = 1.280$

±X2: $S_{q,h} = 0.5 + \sqrt{(0.933 - 0.5)^2 + \frac{0.25}{46.9^{0.5} \times 295.1 \times 0.159^2 \times 0.014}} = 1.240$

±X1: $S_{q,z} = 1.280 - 1.2 \times \left(1.280 - \left(\frac{10}{295.1}\right)^{0.14}\right)\left(1 - \frac{295.1}{295.1}\right) = 1.280$

±X2: $S_{q,z} = 1.280 - 1.2 \times \left(1.240 - \left(\frac{10}{295.1}\right)^{0.14}\right)\left(1 - \frac{295.1}{295.1}\right) = 1.240$

The combined size and dynamic factor applied to the gust forces at the top of the building is given by:

$$S_{q,h} = 0.5 + \sqrt{\left(S_{s(L_{0.5p}=B)} - 0.5\right)^2 + \frac{0.25}{B^{0.5} H N_x^{\ 2} \xi_x}} \quad \text{- Equation 5-1}$$

Where

S_s size factor, depends on the half-perimeter length, $L_{0.5p} = B$ of the loaded area at the top of the building. For evaluation of S_s in Figure 5-2, the curve for 'Other' should be used.

H building height

B breadth of building

N_x fundamental frequency for mode mainly aligned with the along-wind direction

ξ_x ratio of damping to critical damping in the relevant direction of vibration

This factor can be reduced over the height of the building using the formula below:

$$S_{q,z} = S_{q,h} - 1.2\left(S_{q,h} - (10/H)^{0.14}\right)(1 - Z/H) \quad \text{- Equation 5-2}$$

These formulas are dimensional with units of metres and Hertz.

8) Calculate Cf

He/D = 295.1/46.9 = 6.29 < 12， Equation 4-1 can be used

$$C_f = 1.1 + \frac{0.055\, H_e/D}{\exp\{|log_e[(0.6B/D)(1-0.011\ H_e/D)\ ]|^{[1.7-0.0013(H_e/D)^2]}\}}$$

\- Equation 4-1

Where

- H_e effective building height, based on H, taking account of surroundings.
- B breadth of building
- D depth of building

Equation 4-1 can be used for $H_e/D \leq 12$.

Because B=D, Cf in direction ±X1, ±X2 is the same

±X1、±X2：

$$C_f = 1.1 + \frac{0.055 \times 295.1 \times 46.9}{\exp\{|\ln[(0.6 \times 46.9/46.9)(1 - 0.011 \times 295.1/46.9)]|^{[1.7-0.0013\times(295.1/46.9)^2]}\}} = 1.330$$

9) Calculate along-wind load per unit height Wz (Without modification)

Because H >= 200m, Equation 2-1 cannot be used to calculate the wind load, and the wind tunnel test is needed theoretically. However, in order to use this program to analyze the super high-rise building, the calculation is still carried out according to the standard formula.

$W_z = Q_z C_f S_{q,z} B$ - Equation 2-1

Where

W_z	along-wind load per unit height, at height, Z
Q_z	wind reference pressure adjusted for effects from sheltering, topography and wind direction in accordance with clause 3.1
C_f	force coefficient determined in accordance with clause 4.2
$S_{q,z}$	size and dynamic factor from clause 5.2
B	breadth of building

+X1: Wz=2.857*1.330*1.280*46.9=228.11kN/m

+X2: Wz=2.721*1.330*1.240*46.9=210.462kN/m

-X1: Wz=2.857*1.330*1.280*46.9=228.11kN/m

-X2: Wz=2.891*1.330*1.240*46.9=223.612kN/m

10） Calculate wind force Fz (Without modification)

Floor height of the 66th floor is 3.6m

Roof consider half of it

+X1: Fz = Wz*3.6/2 = 228.11*3.6/2 = 410.598kN/m

+X2: Fz = Wz*3.6/2 = 210.462*3.6/2 = 378.832kN/m

-X1: Fz = Wz*3.6/2 = 228.11*3.6/2 = 410.598kN/m

-X2: Fz = Wz*3.6/2 = 223.612*3.6/2 = 402.501kN/m

3.2 Calculation of across-wind base moment

1) Calculate Gry

G_{ry}	peak factor on standard deviation of across-wind resonant response in one hour $= \sqrt{2\ Log_e(1800\ N_y)}$

+X1: $G_{ry} = \sqrt{2 \times \ln(1800 \times 0.159)} = 3.364$

+X2: $G_{ry} = \sqrt{2 \times \ln(1800 \times 0.147)} = 3.340$

-X1: $G_{ry} = \sqrt{2 \times \ln(1800 \times 0.159)} = 3.364$

-X2: $G_{ry} = \sqrt{2 \times \ln(1800 \times 0.147)} = 3.340$

2) Calculate (BD)b

$(BD)_b$	the average plan area of the enclosing rectangle over the top third of the building

(BD)b in four directions is the same

44th floor corresponds to the top third of the building

The average plan area, (BD)b=46.9*46.9*22/22=2199.61m2

3) Calculate Iv,h

He/H = 1, use Equation 3-3

$I_{o,z} = I_{v,h} = 0.087*(295.1/500)^{-0.11} = 0.092$

$I_{v,h}$	wind turbulence intensity at building height, H, may be taken as $I_{o,h}$ in Equation 3-3 or 3-4, from wind tunnel testing, or be calculated by the method of the Engineering Sciences Data Unit (ESDU)

The turbulence intensity can be taken as:

$I_{o,z} = 0.087(Z_e/500)^{-0.11}$ - Equation 3-3

Where

$Q_{o,z}$	wind reference pressure at height, Z_e
Z_e	effective height, taking account of surroundings
$I_{o,z}$	wind turbulence intensity at height Z_e

For across-wind base moment and for acceleration calculation, if $0.25 \le H_e/H \le 0.5$, the turbulence intensity may be modified as:

$I_{o,z} = [4 - (6H_e/H)]\ 0.087(Z_e/500)^{-0.11}$ - Equation 3-4

4) Calculate Mxx,base

+X1: $$M_{+x1x1}=\pm\frac{3.364}{1.4\times0.014^{0.5}}\frac{1.2\times10^{-3}}{0.159^{1.3}\times2199.61^{0.15}}\left(\frac{0.215\sqrt{2\times1.4\times2.857/1.2\times10^{-3}}}{1+3.7\times0.092}\right)^{3.3}\times\frac{295.1^{2}}{3}=11986177.454\text{ kN·m}$$

+X2: $$M_{+x2x2}=\pm\frac{3.340}{1.4\times0.014^{0.5}}\frac{1.2\times10^{-3}}{0.147^{1.3}\times2199.61^{0.15}}\left(\frac{0.215\sqrt{2\times1.4\times2.721/1.2\times10^{-3}}}{1+3.7\times0.092}\right)^{3.3}\times\frac{295.1^{2}}{3}=12161542.263\text{ kN·m}$$

-X1: $$M_{-x1x1}=\pm\frac{3.364}{1.4\times0.014^{0.5}}\frac{1.2\times10^{-3}}{0.159^{1.3}\times2199.61^{0.15}}\left(\frac{0.215\sqrt{2\times1.4\times2.857/1.2\times10^{-3}}}{1+3.7\times0.092}\right)^{3.3}\times\frac{295.1^{2}}{3}=11986177.454\text{ kN·m}$$

-X2: $$M_{-x2x2}=\pm\frac{3.340}{1.4\times0.014^{0.5}}\frac{1.2\times10^{-3}}{0.147^{1.3}\times2199.61^{0.15}}\left(\frac{0.215\sqrt{2\times1.4\times2.891/1.2\times10^{-3}}}{1+3.7\times0.092}\right)^{3.3}\times\frac{295.1^{2}}{3}=13440994.465\text{ kN·m}$$

$$M_{xx,base}=\pm\frac{G_{ry}}{\gamma_w\,\xi_y^{0.5}}\frac{\rho_a}{N_y^{1.3}(BD)_b^{0.15}}\left(\frac{0.215\sqrt{2\gamma_w Q_h/\rho_a}}{1+3.7I_{v,h}}\right)^{3.3}\frac{H_b^{2}}{3}$$

\- Equation 2-2

Where

G_{ry}	peak factor on standard deviation of across-wind resonant response in one hour $=\sqrt{2\,Log_e(1800\,N_y)}$
γ_w	ultimate wind load factor, taken as 1.4
ξ_y	ratio of damping to critical damping in across-wind direction of vibration in Appendix C2
ρ_a	mass density of air, taken as 1.2x10^{-3} T/m^{3}
N_y	fundamental frequency for mode mainly aligned with the across-wind direction
$(BD)_b$	the average plan area of the enclosing rectangle over the top third of the building
Q_h	wind reference pressure, Q_z, at effective building height, H_e
$I_{v,h}$	wind turbulence intensity at building height, H, may be taken as $I_{o,h}$ in Equation 3-3 or 3-4, from wind tunnel testing, or be calculated by the method of the Engineering Sciences Data Unit (ESDU)
H_b	height of building structure above ground level, but

3.3 Calculation of along-wind base moment

+Y1: $M_{+y1y1} = \sum F_{z,+x1} \times Z_e = 7344197.907 kN \cdot m$

+Y2: $M_{+y2y2} = \sum F_{z,+x2} \times Z_e = 6826288.893 kN \cdot m$

-Y1: $M_{-y1y1} = \sum F_{z,-x1} \times Z_e = 7344197.907 kN \cdot m$

-Y2: $M_{-y2y2} = \sum F_{z,-x2} \times Z_e = 7252931.948 kN \cdot m$

3.4 Modification of along-wind force

In this sample, H>100m, H/[B,D]min >=5 and Ny<0.5Hz, modification in along-wind force is needed.

If the factor $\frac{max(M_{-x1x1}, M_{+x1x1})}{max(|M_{-y2y2}|, |M_{+y2y2}|)}$ or $\frac{max(M_{-x2x2}, M_{+x2x2})}{max(|M_{-y1y1}|, |M_{+y1y1}|)}$ is greater than 1.5, then wind tunnel testing must be conducted. The along-wind and the across-wind effects for wind directions X_1 and X_2 are shown in Figure 2-4(a) and Figure 2-4(b).

X1: (Mx1x1, M-x1x1)max/(My2y2, M-y2y2)max =11986177.454/7344197.907 =1.653 m >= 1.5

X2: (Mx2x2, M-x2x2)max/(My1y1, M-y1y1)max =13440994.465/7252931.948 =1.830 m >= 1.5

Theoretically, the following equations cannot be used to modify the along-wind force, and wind tunnel test is needed. However, in order to use the program to analyze the super high-rise building, calculation is still carried out according to the standard formula.

Where the calculated across-wind base moment is larger than the along-wind base moment, then the along-wind forces should be factored upwards to match the across-wind moment. i.e.

(a) If $\frac{max(M_{-x1x1}, M_{+x1x1})}{|M_{-y2y2}|} > 1$, $W_{z,-x2}$ should be factored with $\frac{max(M_{-x1x1}, M_{+x1x1})}{|M_{-y2y2}|}$,

(b) If $\frac{max(M_{-x1x1}, M_{+x1x1})}{|M_{+y2y2}|} > 1$, $W_{z,+x2}$ should be factored with $\frac{max(M_{-x1x1}, M_{+x1x1})}{|M_{+y2y2}|}$,

(c) If $\frac{max(M_{-x2x2}, M_{+x2x2})}{|M_{-y1y1}|} > 1$, $W_{z,-x1}$ should be factored with $\frac{max(M_{-x2x2}, M_{x2x2})}{|M_{-y1y1}|}$

(d) If $\frac{max(M_{-x2x2}, M_{+x2x2})}{|M_{+y1y1}|} > 1$, $W_{z,+x1}$ should be factored with $\frac{max(M_{-x2x2}, M_{x2x2})}{|M_{+y1y1}|}$

Modification of along-wind force at roof:

- +X1: $\frac{\max(M_{-x2x2}, M_{+x2x2})}{|M_{+y1y1}|}$ =13440994.465 / 7344197.907 = 1.830 > 1,
- Wz,+x1 should be factored with 1.830
- +X2: $\frac{\max(M_{-x1x1}, M_{+x1x1})}{|M_{+y2y2}|}$ =11986177.454 / 6826288.893 = 1.756 > 1,
- Wz,+x2 should be factored with 1.756
- -X1: $\frac{\max(M_{-x2x2}, M_{+x2x2})}{|M_{-y1y1}|}$ =13440994.465 / 7344197.907 = 1.830 > 1,
- Wz,-x1 should be factored with 1.830
- -X2: $\frac{\max(M_{-x1x1}, M_{+x1x1})}{|M_{-y2y2}|}$ =11986177.454 / 7252931.948 = 1.653 > 1,
- Wz,-x2 should be factored with 1.653

Along-wind load per unit height Wz at roof (With modification)

+X1: Wz=228.11*1.830 = 417.309kN/m

+X2: Wz=210.462*1.756 = 369.313kN/m

-X1: Wz=228.11*1.830 = 417.309kN/m

-X2: Wz=223.612*1.653 = 369.313kN/m

Along-wind force Fz at roof (With modification)

+X1: Fz = 410.598*1.830 = 744.045kN/m

+X2: Fz = 378.832*1.756 = 658.623kN/m

-X1: Fz = 410.598*1.830 = 744.045kN/m

-X2: Fz = 402.501*1.653 = 658.623kN/m

3.5 Calculation of torsional force

1） Calculate e

For buildings that may be treated as rectangular, the variable torsional load at height, Z, ΔT_z, is derived assuming the along-wind force, W_z, in each direction (see Figure 2-3), is applied at a point offset from the geometric centre of area by a horizontal distance given by:

$$e = \pm 0.05B \quad \text{for } B/D \leq 1$$

$$e = \pm 0.20B \quad \text{for } B/D = 6$$

Use linear interpolation for intermediate values of B/D. For extrapolation outside this range, data from wind tunnel testing should be used.

For non-rectangular building shapes that may be treated as rectangular, see clause 4.2 for relevant dimensions B and D.

Building shape of the sample model is rectangular

X1: B/D=1, e1=±0.05B=±2.345

X2: B/D=1, e2=±0.05B=±2.345

2）Calculate torsional force

+X1: ΔTz=e1·Wz=2.345*417.309=978.590kN/m

+X2: ΔTz=e2·Wz=2.345*369.313=866.039kN/m

-X1: ΔTz=e1·Wz=2.345*417.309=978.590k kN/m

-X2: ΔTz=e2·Wz=2.345*369.313=866.039kN/m

For buildings that may be treated as rectangular,

$$\Delta T_z = e_1 \cdot W_{z,x1} \qquad \text{or} \qquad \Delta T_z = e_2 \cdot W_{z,x2}$$

whichever is of greater magnitude.

Take the maximum value of the results above, torsional force at roof is 978.590kN/m.

3.6 Calculation of peak acceleration

1） Looking up Appendix A1

Table A1-2 Return period factor on pressure, S_r

Return Period, R (years)	Return Period Factor, S_r
1	0.25
10	0.55

Return period in this sample is 1 year, the corresponding return period factor Sr=0.25。

2) Calculate peak acceleration using Equation 2-4

$$A_z = \frac{G_{ry}\,\rho_a}{\xi_y{}^{0.5} N_y{}^{1.3} (BD)_b^{0.15}} \left(\frac{0.215\sqrt{2S_r Q_h/\rho_a}}{1 + 3.7 I_{v,h}} \right)^{3.3} \frac{H_b}{3M_h} \cdot \frac{2+\eta_y}{3} \cdot \left(\frac{Z}{H_b}\right)^{\eta_y}$$

\- Equation 2-4

G_{ry}	peak factor on standard deviation of resonant response in one hour $= \sqrt{2\,Log_e(1800\,N_y)}$
ξ_y	ratio of damping to critical damping in across-wind direction of vibration in Appendix C2
N_y	fundamental frequency for mode mainly aligned with the across-wind direction
$(BD)_b$	is the plan area of the enclosing rectangle, averaged over the top third of the building, excluding upper level cut-backs. If $(BD)_b > H^2/9$, take $(BD)_b = H^2/9$.
S_r	factor on wind pressure for different return period in Appendix A1
Q_h	wind reference pressure, Q_z, at effective building height, H_e
ρ_a	mass density of air, taken as 1.2×10^{-3} T/m^3
$I_{v,h}$	wind turbulence intensity at building height, H, may be taken as $I_{o,h}$ in Equation 3-3 or 3-4, from wind tunnel testing, or as calculated by the ESDU method
H_b	height of building structure above ground level, but excluding the height of irregular roof features above main roof
M_h	mass of the building above $2H_b/3$
η_y	parameter used to describe the approximate mode deflection variation with height. Where this is not obtained

+X1: $A_z = \pm \frac{3.364}{0.009^{0.5}} \frac{1.2\times10^{-3}}{0.159^{1.3}\times2199.61^{0.15}} (\frac{0.215\sqrt{2\times0.25\times2.857/1.2\times10^{-3}}}{1+3.7\times0.092})^{3.3} \times \frac{295.1}{3\times60396.5} \times \frac{2+1.5}{3} \cdot (\frac{295.1}{295.1})^{1.5} = 0.079\ m/s^2$

+X2: $A_z = \pm \frac{3.364}{0.009^{0.5}} \frac{1.2\times10^{-3}}{0.147^{1.3}\times2199.61^{0.15}} (\frac{0.215\sqrt{2\times0.25\times2.721/1.2\times10^{-3}}}{1+3.7\times0.092})^{3.3} \times \frac{295.1}{3\times60396.5} \times \frac{2+1.5}{3} \cdot (\frac{295.1}{295.1})^{1.5} = 0.081\ m/s^2$

-X1: $A_z = \pm \frac{3.364}{0.009^{0.5}} \frac{1.2\times10^{-3}}{0.159^{1.3}\times2199.61^{0.15}} (\frac{0.215\sqrt{2\times0.25\times2.857/1.2\times10^{-3}}}{1+3.7\times0.092})^{3.3} \times \frac{295.1}{3\times60396.5} \times \frac{2+1.5}{3} \cdot (\frac{295.1}{295.1})^{1.5} = 0.079\ m/s^2$

-X2: $A_z = \pm \frac{3.364}{0.009^{0.5}} \frac{1.2\times10^{-3}}{0.147^{1.3}\times2199.61^{0.15}} (\frac{0.215\sqrt{2\times0.25\times2.891/1.2\times10^{-3}}}{1+3.7\times0.092})^{3.3} \times \frac{295.1}{3\times60396.5} \times \frac{2+1.5}{3} \cdot (\frac{295.1}{295.1})^{1.5} = 0.087\ m/s^2$

Take the maximum value of the results above, acceleration at roof (peak acceleration) is Az=±0.087m/s2, the corresponding frequency Ny is 0.147Hz

Looking up Figure 2-6

Limits of peak acceleration is 0.092m/s2, which is larger than 0.087m/s2

Peak acceleration satisfies the requirement.

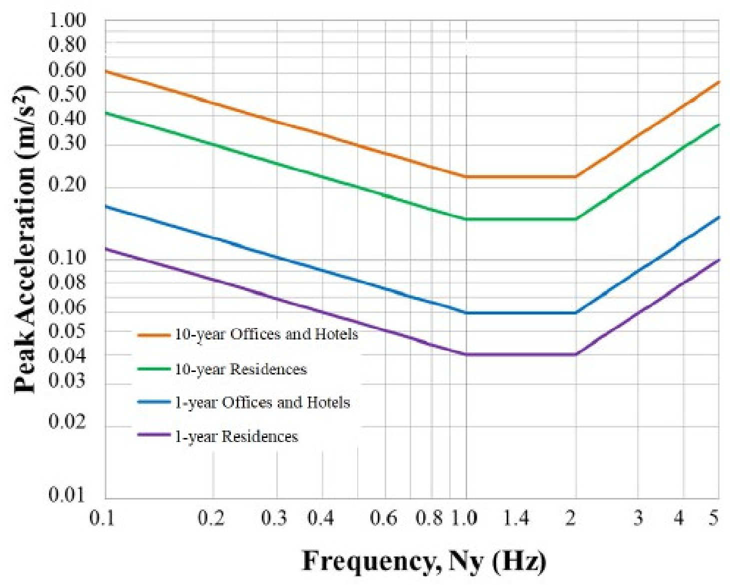


Figure 2-6 **Acceptable occupant comfort level**