WIND LOADING HANDBOOK

A practical guide to the Code of Practice on Wind Effects in Hong Kong 2004

Structural Division

The Hong Kong Institution of Engineers

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June 2005

Prepared by a working group of
Structural Division
The Hong Kong Institution of Engineers

Published by the Structural Division of the Hong Kong Institution of Engineers

Foreword

I am honoured to represent the Structural Division of the Hong Kong Institution of Engineers to express our gratitude to the working group writing up this handbook on the Code of Practice on Wind Effects in Hong Kong 2004. In my mind, this handbook would greatly benefit the industry in various perspectives:

(a) It serves as a self-explanatory practical guide to designers and graduates who would hence demand less hand-on individual guidance from their supervisors on the use of the code.

(b) It provides a consistent interpretation and application of the code based on typical worked examples, which could also be taken as good reference for submissions to relevant authorities.

(c) It allows the users to better appreciate the order of magnitude and implications of the code recommendations through the worked examples, which may throw light on the designers in arriving at optimized solutions.

On this particular new wind code, there are several major breakthroughs from the previous code issued in 1983:

(a) The simplification to only one open sea terrain.

(b) The review on the wind velocities and wind pressures.

(c) The introduction of topographic factor for hill and ridges, and cliff and escarpment.

(d) The adoption of dynamic magnification factor for significant resonant dynamic response.

I am delighted to find that all these have been clearly addressed and illustrated in this handbook.

Lastly, I would like to congratulate the team, led by Ir H. K. Ng and including Dr K. M. Lam, Ir K. L. Lo and Ir Y. C. Tsui for their fine works which would not come on stream without their dedicated effort and professionalism.

Joseph Y W Mak
Structural Division Chairman 2004/2005

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Wind loading handbook

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1. Introduction

1.1 The Code of Practice on Wind Effects in Hong Kong 2004 introduces several new concepts in the basis for assessing wind loads. This handbook is intended to provide engineers with a guide to calculate the wind loads effectively in accordance with the Code, for the design of ordinary buildings.

1.2 The handbook does not attempt to interpret the Code for application to complex topography or unusual features of wind loading, nor it attempts to provide solution for situations not covered by the Code. For background information of the Code and considerations reviewed by the Code Drafting Committee, the reader can make reference to the Buildings Department's technical publication "Explanatory Materials to the Code of Practice on Wind Effects in Hong Kong 2004".

1.3 The handbook should be read in conjunction with the Code. It does not override the recommendations of the Code.

2. Calculation procedure

2.1 The calculation of wind loads on buildings consists of three main parts:

(a) The determination of the wind pressure profile

(b) The determination of the total wind force acting on the building

(c) The determination of the force acting on individual elements

2.2 The Code provides general methods for calculating the wind loads. Outline of the calculation procedure for an enclosed building is illustrated in the flowchart given in figure 2.1. Outline of the calculation procedure for an open framework building is illustrated in the flowchart given in figure 2.2.

2.3 The stages given in the flowcharts are to be carried out for each critical wind direction.

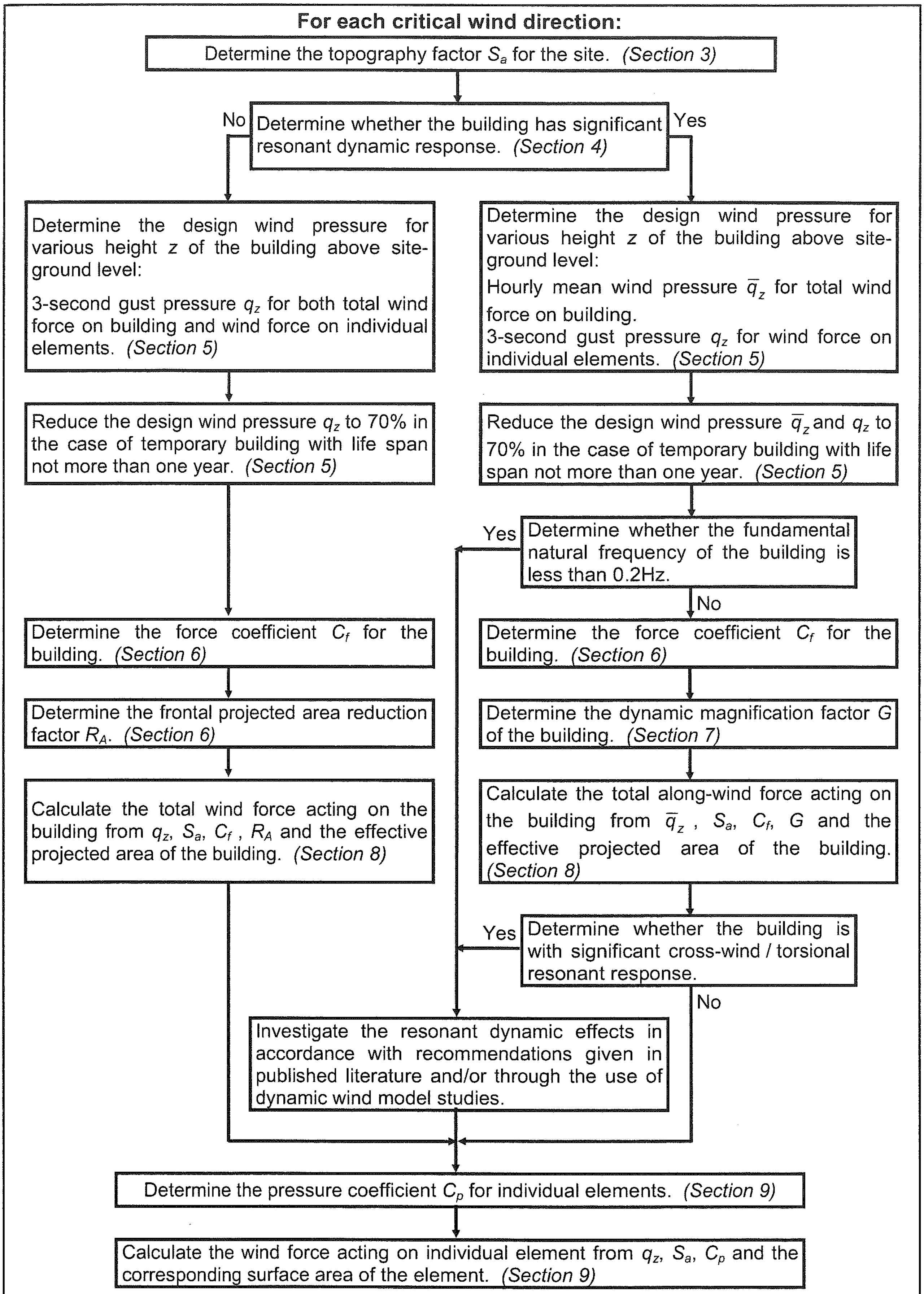


Figure 2.1 – Flowchart illustrating outline procedure for wind load on an enclosed building

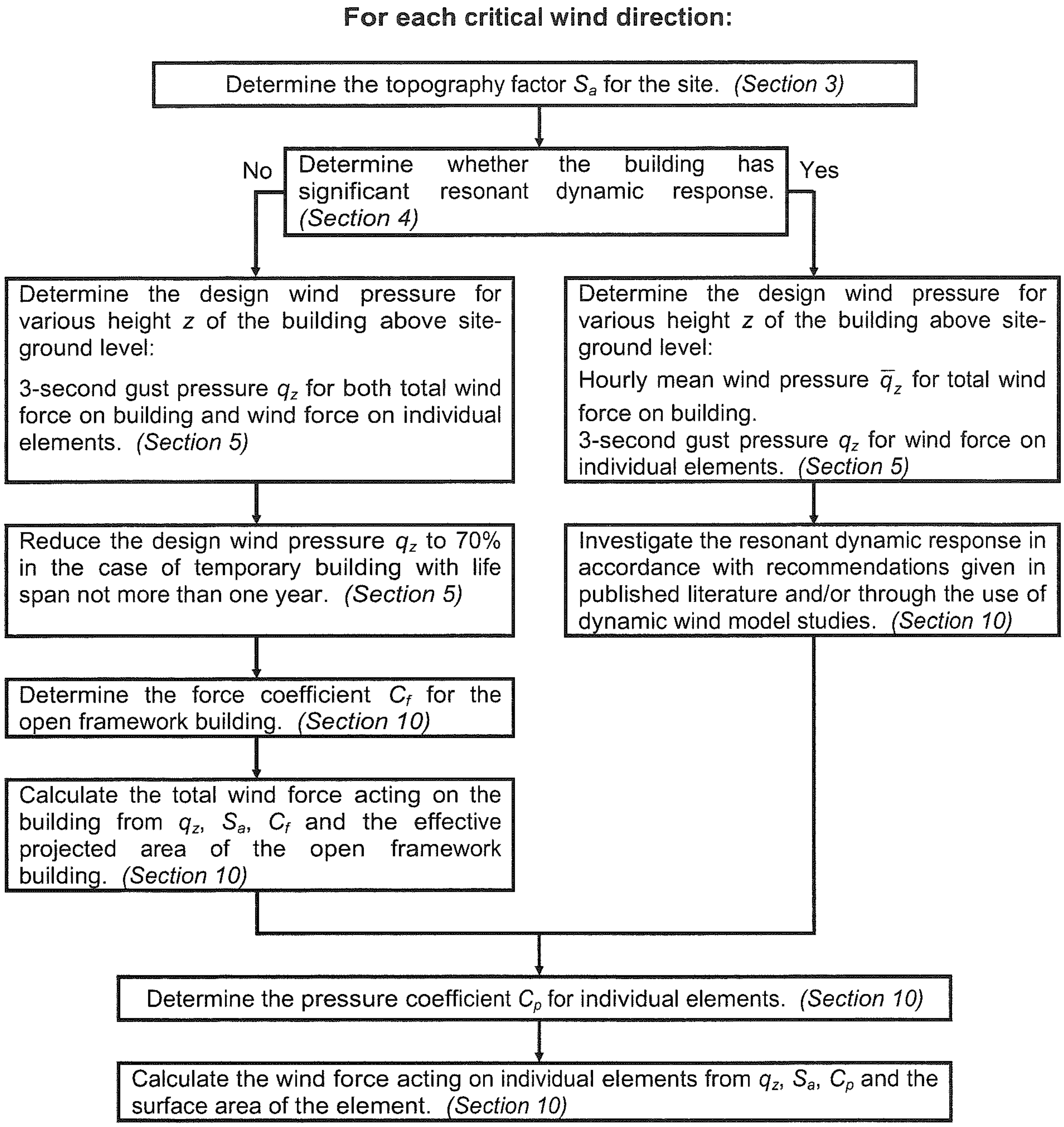


Figure 2.2 – Flowchart illustrating outline procedure for wind load on an open framework building

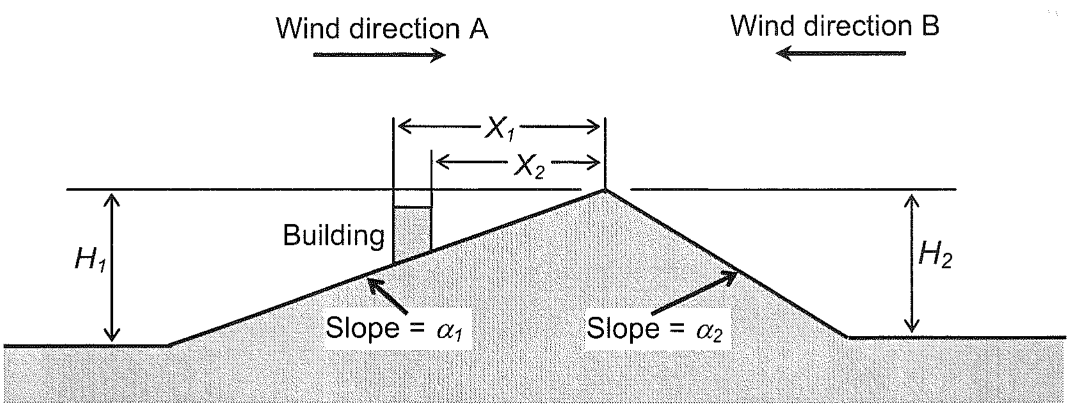
3. Topography factor

3.1 Wind speed increases on blowing up the windward slope of a hill. Clause 4.2 of the Code requires the topography effect to be considered when the local topography is significant.

3.2 When the local topography is significant, the Code recommends the design wind pressure to be increased by multiplication with a topography factor to account for the topography effect of the hill or escarpment.

3.3 The user of the Code may follow the steps outlined in section 3.4 below to consider the topography effect, with reference to Appendix C of the Code.

3.4 The basic data required for the determination of the topography factor are illustrated in figure 3.1.



where α_1 is the upwind slope with respect to wind direction A, which is the slope of the ground where the site is located.

α_2 is the upwind slope with respect to wind direction B.

H_1 is the height of the crest above the foreground of slope α_1.

H_2 is the height of the crest above the foreground of slope α_2.

X_1 is the horizontal distance of the building from the crest, in the upwind direction.

X_2 is the horizontal distance of the building from the crest, in the downwind direction.

Figure 3.1 – Legends of topography data

The step-by-step approach to the calculations are given below. The building should be considered for both upwind and downwind. The topography factors in each wind direction should be respectively determined.

(A) Topography factor for wind direction A (upwind on the building)

(A1) Determine the upwind slope α_U in the wind direction A. This is the value α_1 in figure 3.1.

(A2) Is α_U greater than 0.05?

Yes: Go to step (A3)
No: Local topography for wind direction A is not significant. Take the topography factor $S_a = 1$ and go to step (B1).

(A3) Determine the effective height H of the crest above the foreground level of the upwind slope in the direction of the wind. This is the value H_1 in figure 3.1.

(A4) Determine the horizontal distance X of the building from the crest. X is negative with respective to wind direction A. This is equal to $-X_1$ in figure 3.1.

(A5) Is the site located within a height $0.5H$ from the crest?
(i.e., is $\alpha_U X_1 \leq 0.5H$?)

Yes: Go to step (A6)
No: Site is located outside significant distance from crest. Local topography for wind direction A is not significant. Take the topography factor $S_a = 1$ and go to step (B1).

(A6) Determine the downwind slope α_D in the wind direction. This is the value α_2 in figure 3.1.

(A7) Is α_D in step (A6) greater than 0.05?

Yes: Topography is "hill-and-ridge" with respect to wind direction A.
No: Topography is "cliff-and-escarpment" with respect to wind direction A.

(A8) Determine the length of the upwind slope L_U in the wind direction, by $L_U = H/\alpha_U$.

(A9) Determine the effective slope α_e according to the steepness of the upwind slope α_U:

If α_U is not greater than 0.3, $\alpha_e = \alpha_U$
If α_U is greater than 0.3, $\alpha_e = 0.3$

(A10) Determine the effective slope length L_e according to the steepness of the upwind slope α_U:

If α_U is not greater than 0.3, $L_e = L_U$
If α_U is greater than 0.3, $L_e = H/0.3$

(A11) Calculate the distance ratio X/L_U. (For wind direction A, X/L_U is negative.)

(A12) Determine the topography location factor s for various height z above ground according to the height ratio z/L_e and the distance ratio X/L_U, from the upwind side (left-hand side) of Figure C3 in the Code in the case of "hill-and-ridge" topography, or Figure C4 in the Code in the case of "cliff-and-escarpment" topography.

(A13) Calculate the topography factor S_a for various height z above ground, by the following equation:

$$S_a = (1 + 1.2\alpha_e s)^2$$

(B) Topography factor for wind direction B (downwind on the building)

(B1) Determine the upwind slope α_U in the wind direction B. This is the value α_2 in figure 3.1.

(B2) Is α_U in step (B1) greater than 0.05?

Yes: Go to step (B3)
No: Local topography for wind direction B is not significant. No further calculation is necessary. Take the topography factor $S_a = 1$.

(B3) Determine the downwind slope α_D in the wind direction. This is the value α_1 in figure 3.1.

(B4) Is α_D in step (B3) greater than 0.05?

Yes: Topography is "hill-and-ridge" with respect to wind direction B.
No: Topography is "cliff-and-escarpment" with respect to wind direction B.

(B5) Determine the effective height H of the crest above the foreground level of the upwind slope in the direction of the wind. This is the value H_2 in figure 3.1.

(B6) Determine the length of the upwind slope L_U in the wind direction, by $L_U = H/\alpha_U$.

(B7) Determine the horizontal distance X of the site from the crest. X is positive with respective to wind direction B. This is equal to X_2 in figure 3.1.

(B8) Determine the downwind horizontal influence distance by:

For "hill-and-ridge" topography:
If α_U is less than 0.3, influence distance = $0.5L_U$
If α_U greater than 0.3, influence distance = $1.6H$

For "cliff-and-escarpment" topography:
If α_U is less than 0.3, influence distance = $1.5L_U$
If α_U greater than 0.3, influence distance = $5H$

(B9) Is the site located within the downwind horizontal influence distance from the crest?
(i.e., is X in step (B7) $\leq$ influence distance?)

Yes: Go to step (B10)
No: Local topography for downwind is not significant. No further calculation is necessary. Take the topography factor $S_a = 1$.

(B10) Determine the length of the downwind slope L_D in the wind direction by $L_D = H/\alpha_D$.

(B11) Determine the effective slope α_e according to the steepness of the upwind slope α_U determined in step (B1):

If α_U is not greater than 0.3, $\alpha_e = \alpha_U$
If α_U is greater than 0.3, $\alpha_e = 0.3$

(B12) Determine the effective slope length L_e according to the steepness of the upwind slope α_U determined in step (B1):

If α_U is not greater than 0.3, $L_e = L_U$
If α_U is greater than 0.3, $L_e = H/0.3$

(B13) Calculate the distance ratio X/L_D in the case of "hill-and-ridge" topography, or X/L_e in the case of "cliff-and-escarpment" topography. (X/L_D or X/L_e is positive with respect to wind direction B.)

(B14) Determine the topography location factor s for various height z above ground:

For "hill-and-ridge" topography:
Obtain s from the downwind side (right-hand side) of Figure C3 in the Code, according to the height ratio z/L_e and the distance ratio X/L_D.

For "cliff-and-escarpment" topography:
Obtain s from the downwind side (right-hand side) of Figure C4 in the Code, according to the height ratio z/L_e and the distance ratio X/L_e.

(B15) Calculate the topography factor S_a for various height z above ground, by the following equation:

$$S_a = (1 + 1.2\alpha_e s)^2$$

3.5 In Figures C3 and C4 of the Code, the height above ground ratio is in log scale and the horizontal position ratio is in natural scale. Figures C3 and C4 of the Code are reproduced in figure 3.2 and figure 3.3 respectively, with minor grids added for user's convenience.

3.6 Example calculations of topography factors are given in calculation sheets 3.1, 3.2 and 3.3.

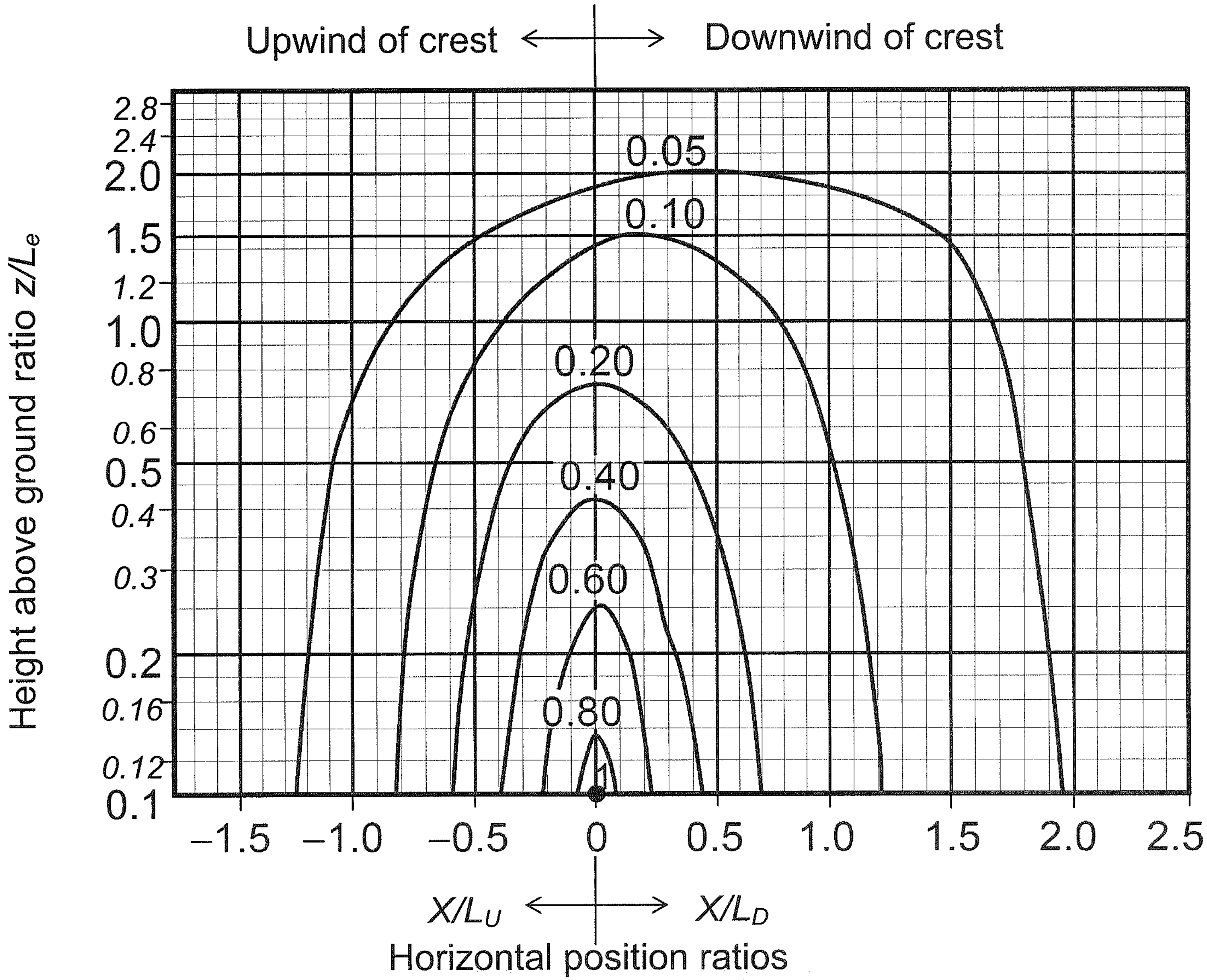


Figure 3.2 – Topography location factor s for hills and ridges (reproduced from Figure C3 of the Code)

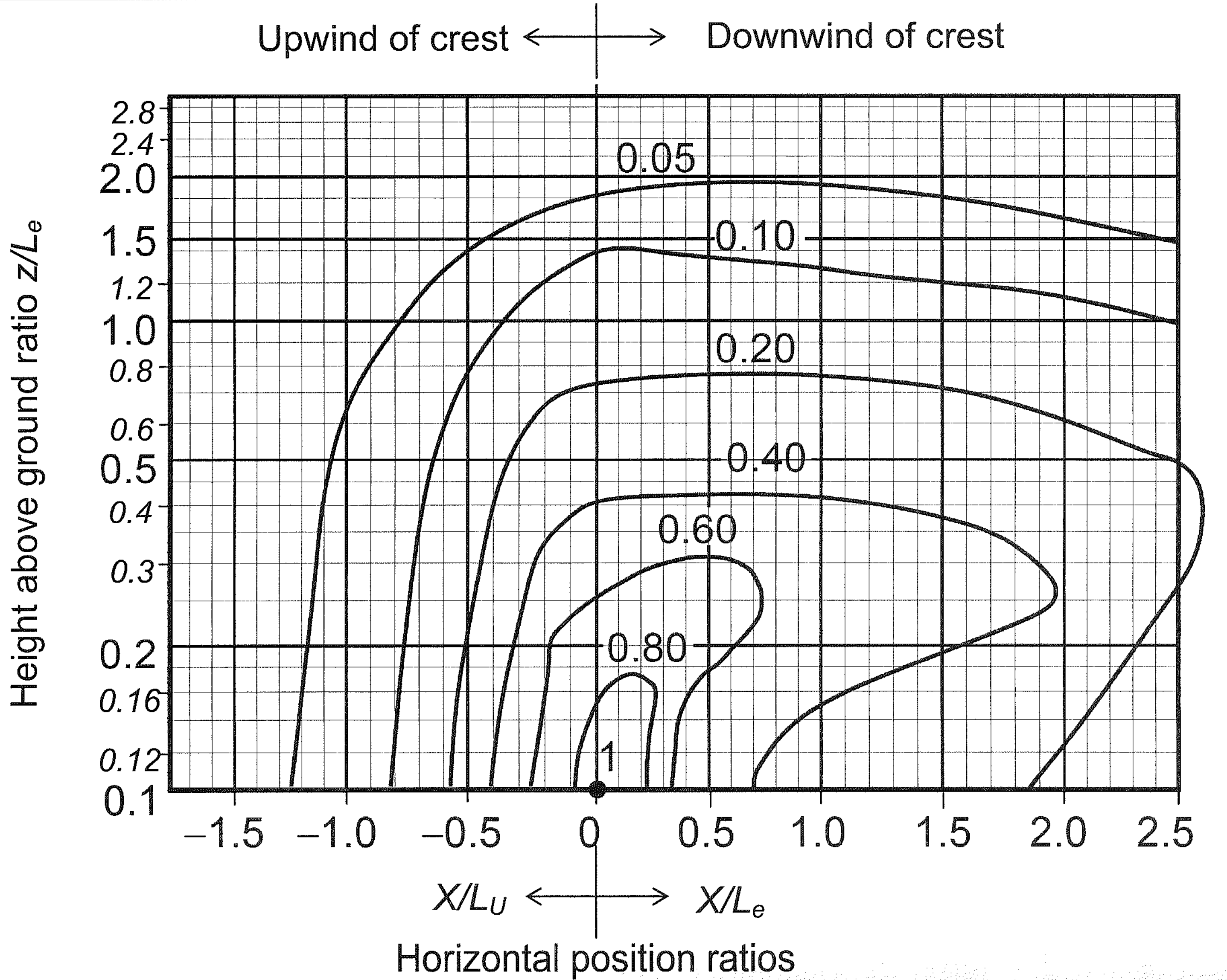
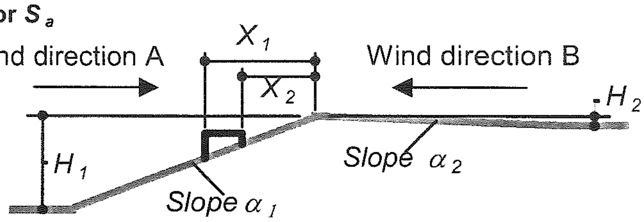


Figure 3.3 –Topography location factor s for cliffs and escarpments (reproduced from Figure C4 of the Code)

Calculation Sheet for Topography Factor S_a

H_1 =	420	(m)
H_2 =	50	(m)
α_1 =	0.6	
α_2 =	0.04	
X_1 =	185	(m)
X_2 =	165	(m)



Wind direction A (upwind on building)

Upwind slope α_U in the wind direction (= α_1 in the figure)		0.60
α_U > 0.05?	**Yes**	
Effective height H of crest (=H_1 in the figure) (m)		420
Horizontal distance X of site from crest (= -X_1 in the figure) (m)		-185
Effective height of site below crest (= $X_1 \alpha_U$) (m)		111
Site within 0.5H below crest?	**Yes**	
Downwind slope α_D in the wind direction (= α_2 in the figure)		0.04
Topography (if α_D>0.05, hill-and-ridge; otherwise cliff-and-escarpment)		Cliff-and-escarpment
Length of upwind slope $L_U = H/\alpha_U$ (m)		700
Effective slope α_e (If $\alpha_U < 0.3$, $\alpha_e = \alpha_U$; otherwise $\alpha_e = 0.3$)		0.30
Effective slope length L_e (If $\alpha_U < 0.3$, $L_e = L_U$; otherwise $L_e = H/0.3$) (m)		1400
X/L_U (X/L_U is negative for upwind)		-0.264

Wind direction B (downwind on building)

Upwind slope α_U in the wind direction (α_2 in the figure)		0.04
α_U > 0.05?	**No**	**Local topography not significant for wind direction B**

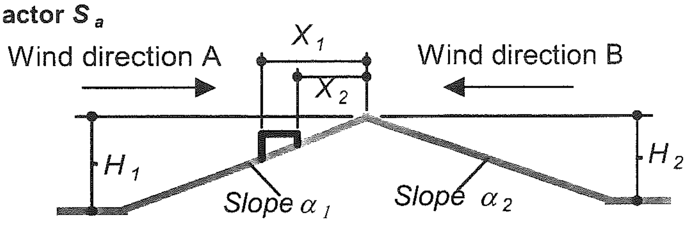
Topography factor S_a for height z above ground

Height above ground z(m)	**Wind direction A (upwind on building)** X/L_U = -0.264 (cliff-and-escpmt)			**Wind direction B not significant**		
	z/L_e	s	$S_a = (1+1.2\alpha_e s)^2$	z/L_e	s	$S_a = (1+1.2\alpha_e s)^2$
5	0.004	0.60	1.48			1.00
30	0.021	0.60	1.48			1.00
50	0.036	0.60	1.48			1.00
75	0.054	0.60	1.48			1.00
100	0.071	0.60	1.48			1.00
150	0.107	0.59	1.47			1.00
200	0.143	0.54	1.43			1.00
250	0.179	0.51	1.40			1.00
300	0.214	0.46	1.36			1.00
400	0.286	0.38	1.29			1.00
500	0.357	0.30	1.23			1.00

Calculation sheet 3.1 – Example calculation of topography factor (1)

Calculation Sheet for Topography Factor S_a

H_1 =	300	(m)
H_2 =	420	(m)
α_1 =	0.35	
α_2 =	0.6	
X_1 =	280	(m)
X_2 =	250	(m)



Wind direction A (upwind on building)

Upwind slope α_U in the wind direction (= α_1 in the figure)	0.35
α_U > 0.05? **Yes**	
Effective height H of crest (=H_1 in the figure) (m)	300
Horizontal distance X of site from crest (= -X_1 in the figure) (m)	-280
Effective height of site below crest (= $X_1 \alpha_U$) (m)	98
Site within 0.5H below crest? **Yes**	
Downwind slope α_D in the wind direction (= α_2 in the figure)	0.60
Topography (if α_D>0.05, hill-and-ridge; otherwise cliff-and-escarpment)	Hill-and-ridge
Length of upwind slope $L_U = H/\alpha_U$ (m)	857
Effective slope α_e (If α_U < 0.3, $\alpha_e = \alpha_U$; otherwise α_e = 0.3)	0.30
Effective slope length L_e (If α_U < 0.3, $L_e = L_U$; otherwise $L_e = H/0.3$) (m)	1000
X/L_U (X/L_U is negative for upwind)	-0.327

Wind direction B (downwind on building)

Upwind slope α_U in the wind direction (α_2 in the figure)	0.60
α_U > 0.05? **Yes**	
Downwind slope α_D in the wind direction (= α_1 in the figure)	0.35
Topography (if α_D>0.05, hill-and-ridge; otherwise cliff-and-escarpment)	Hill-and-ridge
Effective height H of crest (= H_2 in the figure) (m)	420
Length of upwind slope $L_U = H/\alpha_U$ (m)	700
Horizontal distance X of site from crest (= X_2 in the figure) (m)	250
Influence distance from crest: Hill-and-ridge: =0.5L_U if α_U < 0.3; otherwise =1.6H	672
Cliff-and-escarpment: =1.5L_U if α_U < 0.3; otherwise =5H	(N.A.)
Site within influence distance from crest? **Yes**	
Length of downwind slope $L_D = H/\alpha_D$ (m)	1200
Effective slope α_e (If α_U < 0.3, $\alpha_e = \alpha_U$; otherwise α_e = 0.3)	0.30
Effective slope length L_e (If α_U < 0.3, $L_e = L_U$; otherwise $L_e = H/0.3$) (m)	1400
X/L_D (for hill and ridge)	0.208
X/L_e (for cliff and escarpment)	(N.A.)

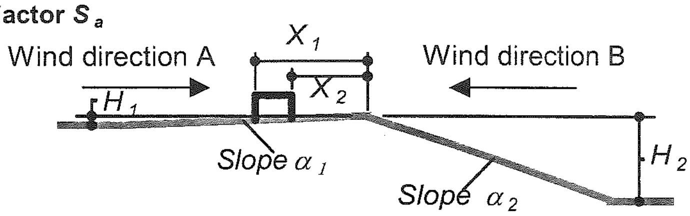
Topography factor S_a for height z above ground

Height above ground z(m)	**Wind direction A (upwind on building)** X/L_U = -0.327 (hill-and-ridge)			**Wind direciton B (downwind on building)** X/L_D = 0.208 (hill-and-ridge)		
	z/L_e	s	$S_a = (1+1.2\alpha_e s)^2$	z/L_e	s	$S_a = (1+1.2\alpha_e s)^2$
5	0.005	0.47	1.37	0.004	0.61	1.49
30	0.030	0.47	1.37	0.021	0.61	1.49
50	0.050	0.47	1.37	0.036	0.61	1.49
75	0.075	0.47	1.37	0.054	0.61	1.49
100	0.100	0.47	1.37	0.071	0.61	1.49
150	0.150	0.45	1.35	0.107	0.61	1.49
200	0.200	0.38	1.29	0.143	0.57	1.45
250	0.250	0.34	1.26	0.179	0.55	1.44
300	0.300	0.31	1.24	0.214	0.51	1.40
400	0.400	0.25	1.19	0.286	0.42	1.33
500	0.500	0.19	1.14	0.357	0.35	1.27

Calculation sheet 3.2 – Example calculation of topography factor (2)

Calculation Sheet for Topography Factor S_a

H_1 =	10	(m)
H_2 =	80	(m)
α_1 =	0.03	
α_2 =	0.27	
X_1 =	230	(m)
X_2 =	200	(m)



Wind direction A (upwind on building)

Upwind slope α_U in the wind direction (= α_1 in the figure) 0.03

α_U > 0.05? **No** **Local topography not significant for wind direction A**

Wind direction B (downwind on building)

Upwind slope α_U in the wind direction (α_2 in the figure)		0.27
α_U > 0.05?	**Yes**	
Downwind slope α_D in the wind direction (= α_1 in the figure)		0.03
Topography (if α_D>0.05, hill-and-ridge; otherwise cliff-and-escarpment)		Cliff-and-escarpment
Effective height H of crest (= H_2 in the figure) (m)		80
Length of upwind slope $L_U = H/\alpha_U$ (m)		296
Horizontal distance X of site from crest (= X_2 in the figure) (m)		200
Influence distance from crest:	Hill-and-ridge: $=0.5L_U$ if $\alpha_U < 0.3$; otherwise $=1.6H$	(N.A.)
	Cliff-and-escarpment: $=1.5L_U$ if $\alpha_U < 0.3$; otherwise $=5H$	444
Site within influence distance from crest?	**Yes**	
Length of downwind slope $L_D = H/\alpha_D$ (m)		(N.A.)
Effective slope α_e (If $\alpha_U < 0.3$, $\alpha_e = \alpha_U$; otherwise $\alpha_e = 0.3$)		0.27
Effective slope length L_e (If $\alpha_U < 0.3$, $L_e = L_U$; otherwise $L_e = H/0.3$) (m)		296
X/L_D (for hill and ridge)		(N.A.)
X/L_e (for cliff and escarpment)		0.675

Topography factor S_a for height z above ground

Height above ground z(m)	Wind direction A not significant			Wind direciton B (downwind on building) X/L_e = 0.675 (cliff-and-escpmt)		
	z/L_e	s	$S_a = (1+1.2\alpha_e s)^2$	z/L_e	s	$S_a = (1+1.2\alpha_e s)^2$
5			1.00	0.017	0.41	1.28
30			1.00	0.101	0.41	1.28
50			1.00	0.169	0.52	1.37
75			1.00	0.253	0.61	1.43
100			1.00	0.338	0.52	1.37
150			1.00	0.506	0.33	1.23
200			1.00	0.675	0.24	1.16
250			1.00	0.844	0.18	1.12
300			1.00	1.013	0.14	1.09
400			1.00	1.350	0.10	1.07
500			1.00	1.688	0.07	1.05

Calculation sheet 3.3 – Example calculation of topography factor (3)

4. Classification rules for significant resonant dynamic response

4.1 The Code recommends a quasi-static approach for the determination of the total wind force acting on buildings that are not significant in resonant dynamic response. In the quasi-static approach, the design wind pressure obtained from the 3-second gusts is applied directly to the calculation of the total wind force.

4.2 When a building is considered with significant resonant dynamic response, the quasi-static approach would not be appropriate for to the determination of total wind force acting on the building. Additional parameters are required to be included in the analysis to assess the response more precisely. The Code recommends the total wind force to be calculated from the pressure obtained from the hourly mean velocity. The force so calculated is to be augmented by a dynamic magnification factor determined from the turbulence intensity of the wind, the damping and natural frequency of the structure and other descriptors of wind energy.

4.3 The Code considers that a building is with significant resonant dynamic response if it has either the following properties, unless it could be justified that the fundamental natural frequency of the building is greater than 1 Hz:

(a) The height exceeds five times the least horizontal dimension.

(b) The height of the building is greater than 100m.

For the purpose of the classification rules, the Code specifies that the least horizontal dimension is the smallest dimension of the rectangular envelop enclosing the main vertical structural elements of the building.

4.4 When the classification is to be determined by the vibration frequency criterion, the user may apply a modal dynamic analysis by computer software to determine the fundamental natural frequency of the building.

5. Wind pressure profile

5.1 The Code provides two sets of wind pressure profile for the design of buildings and building elements. The first set is given in Table 1 of the Code (denoted by q_z), which is obtained from the 3-second gust velocities. The second set is given in Table 2 of the Code (denoted by $\bar{q}_z$), which is obtained from the hourly mean wind velocities.

5.2 For buildings not significant in resonant dynamic response, the 3-second gust wind pressure q_z should be used as the design wind pressure for the determination of the total wind force acting on the building and for the determination of the wind forces acting on the individual elements.

5.3 The Explanatory Materials to the Code published by the Buildings Department provides background information and equations on how the 3-second gust design wind pressures given in Table 1 of the Code are calculated. The following direct expression, derived from the equations in the Explanatory Materials, may be useful for the development of spreadsheets for the computation of the 3-second design wind pressure q_z at various height z:

$$q_z = 0.0006 \times \left(19.26 + 30z^{0.11}\right)^2$$

where q_z is the 3-second gust design wind pressure at height z, in kPa

z is the height above site-ground level, in m

The Code sets the 3-second gust design wind pressure to a maximum value of 3.72 kPa for height z of 500m (the gradient height) and above. The Code also sets the 3-second gust design wind pressure to a minimum value of 1.82 kPa for height z of 5m and below.

5.4 For buildings significant in resonant dynamic response, the Code requires the hourly mean wind pressure $\bar{q}_z$ to be used as the design wind pressure for the determination of the total wind force acting on an enclosed building. However, the 3-second gust wind pressure q_z should be used for the determination of the wind forces acting on the individual elements.

5.5 The Explanatory Materials to the Code also provides background information and equations on how the hourly mean design wind pressures given in Table 2 of the Code are calculated. The following direct expression, derived from the equations in the Explanatory Materials, may be useful for the development of spreadsheets for the computation of the hourly mean design wind pressure $\bar{q}_z$ at various height z:

$$\bar{q}_z = 0.542\, z^{0.22}$$

where $\overline{q}_z$ is the hourly mean design wind pressure at height z, in kPa

z is the height above site-ground level, in m

The Code sets the hourly mean design wind pressure to a maximum value of 2.13 kPa for height z of 500m (the gradient height) and above. The Code also sets the hourly mean design wind pressure to a minimum value of 0.77 kPa for height z of 5m and below.

5.6 By Clauses 4.3 and 7.4 of the Code, the 3-second gust design wind pressures given in Table 1 of the Code and the hourly mean design wind pressures given in Table 2 of the Code may be reduced to 70% when applied to the design of temporary buildings or buildings which will remain in position for a period of not more than one year.

5.7 The design wind pressures should be multiplied by the topography factor S_a determined by the steps in section 3, to account for the topography effect of the site.

6. Force coefficient for enclosed building

6.1 The wind force acting on a building is mainly a function of the shape of the building. The Code adopts the force coefficient method in the determination of the total force on a building due to wind effects. The design total force on the building is expressed as the design wind pressure acting on the projected area of the building multiplied by the force coefficient of the building. The force coefficient is defined in the Code by:

For buildings not significant in resonant dynamic response:

$$F = C_f \sum q_z A_z$$

For buildings significant in resonant dynamic response:

$$F = GC_f \sum \overline{q}_z A_z$$

where F is the total wind force on the building

C_f is the force coefficient for the building

q_z is the 3-second gust design wind pressure at height z

$\overline{q}_z$ is the hourly mean design wind pressure at height z

A_z is the effective projected area of that part of the building corresponding to q_z or $\overline{q}_z$

G is the dynamic magnification factor to account for the dynamic response of the structure

6.2 This section only discusses the steps for the determination of the force coefficient for enclosed buildings. Steps for the determination of the dynamic magnification factor G are given in section 7 and steps for the computation of the total force acting on the building are given in section 8. The determination of wind force acting on open framework buildings is discussed in section 10.

6.3 Appendix D1 of the Code gives the general method for the determination of the force coefficient for an enclosed building. The Code expresses the force coefficient as a function of the basic dimensions of the building, obtained from the product of a height aspect factor C_h and a shape factor C_s. The expression given in the Code is:

$$C_f = C_h \times C_s$$

6.4 For enclosed building of generally uniform section, the height aspect factor C_h is a function of the height to breadth ratio of the building in the direction of the wind, and the shape factor C_s is a function of the breadth to depth ratio of the plan shape. Values of C_h and C_s are given in Tables D1 and D2 of the Code. Although the Code only gives the shape factors for buildings of rectangular and circular plan shapes, the Code recommends using coefficients for the respective enclosing rectangles for all other shapes.

6.5 The force coefficient should be applied to the enclosed building as a whole. In the case of a building with isolated blocks projecting above a general roof level, the Code recommends that individual force coefficients corresponding to the height and shape of each block should be applied.

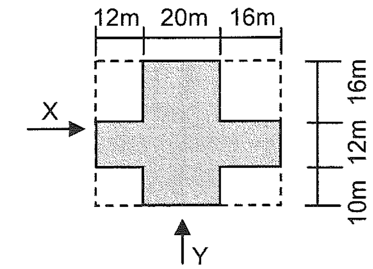
6.6 In the case of a building composed of similar contiguous structures separated by expansion joints, the force coefficient should be determined from the configuration of the whole building because it is the overall shape which conditions the flow pattern.

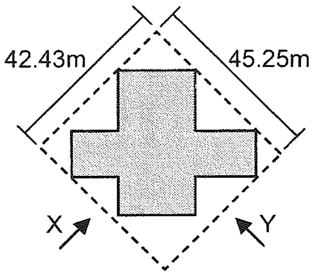
6.7 The size of a gust is related to it duration. The 3-second duration gust wind may not be large enough to envelop entirely a building of large size. For larger buildings, a longer duration gust corresponding to lower wind velocity is required to be effective over the whole building. Since the 3-second gust design wind pressure is adopted for the determination of the total force on buildings not significant in resonant dynamic response, the Code recommends applying a frontal projected area reduction factor R_A to buildings with frontal projected area larger than $500m^2$ to account for the reduced wind pressure. Values of frontal area reduction factor are given in Table D3 of the Code.

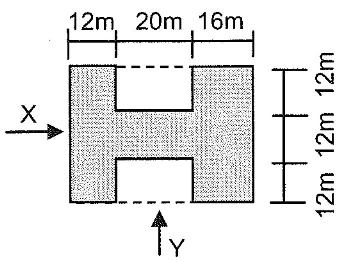
6.8 The user may adopt appropriate values of force coefficient for enclosed buildings specified in other International Codes acceptable to the Building Authority.

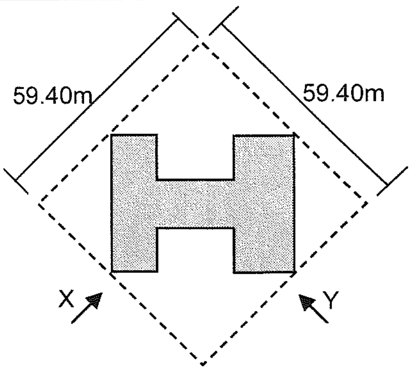
6.9 When the actual shape of a building renders it to become sensitive to wind acting not perpendicular to its face, the diagonal wind effects and torsional wind effects should be considered.

6.10 Example calculations of force coefficient for enclosed buildings are given in calculation sheet 6.1.

<table>
<tr><th>General plan shape</th><th>Wind direction</th><th>b (m)</th><th>d (m)</th><th>h (m)</th><th>h/b</th><th>b/d</th><th>C_h</th><th>C_s</th><th>$C_f = C_h x C_s$</th></tr>
<tr><td rowspan="2">

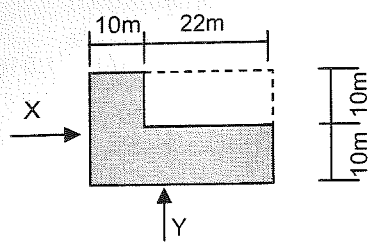
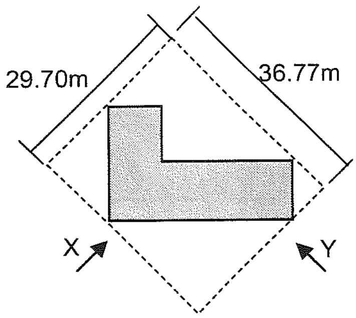
Wind parallel to building axes</td><td>X</td><td>38</td><td>48</td><td rowspan="2">100</td><td>2.632</td><td>0.792</td><td>1.016</td><td>1.000</td><td>1.016</td></tr>
<tr><td>Y</td><td>48</td><td>38</td><td>1.083</td><td>1.263</td><td>1.002</td><td>1.026</td><td>1.028</td></tr>
<tr><td rowspan="2">

Wind 45° to building axes</td><td>X</td><td>45.25</td><td>42.43</td><td rowspan="2">100</td><td>2.210</td><td>1.068</td><td>1.005</td><td>1.007</td><td>1.012</td></tr>
<tr><td>Y</td><td>42.43</td><td>45.25</td><td>2.357</td><td>0.938</td><td>1.009</td><td>1.000</td><td>1.009</td></tr>
<tr><td rowspan="2">

Wind parallel to building axes</td><td>X</td><td>36</td><td>48</td><td rowspan="2">100</td><td>2.778</td><td>0.750</td><td>1.019</td><td>1.000</td><td>1.019</td></tr>
<tr><td>Y</td><td>48</td><td>36</td><td>2.083</td><td>1.333</td><td>1.002</td><td>1.033</td><td>1.035</td></tr>
<tr><td rowspan="2">

Wind 45° to building axes</td><td>X</td><td>59.40</td><td>59.40</td><td rowspan="2">100</td><td>1.684</td><td>1.000</td><td>0.984</td><td>1.000</td><td>0.984</td></tr>
<tr><td>Y</td><td>59.40</td><td>59.40</td><td>1.684</td><td>1.000</td><td>0.984</td><td>1.000</td><td>0.984</td></tr>
</table>

Calculation sheet 6.1 – Example calculation of force coefficients

General plan shape	Wind direction	b (m)	d (m)	h (m)	h/b	b/d	C_h	C_s	$C_f = C_h x C_s$
 Wind parallel to building axes	X	20	35	100	5.000	0.507	1.075	1.000	1.075
	Y	35	20		2.857	1.750	1.021	1.075	1.098
 Wind 45° to buildiing axes	X	36.77	29.70	100	2.720	1.238	1.018	1.024	1.042
	Y	29.70	36.77		3.367	0.808	1.034	1.000	1.034

Calculation sheet 6.1 – Example calculation of force coefficients (continued)

7. Dynamic magnification factor for enclosed building

7.1 The quasi-static method using 3-second gust wind pressures is not applicable to structures prone to dynamic excitation. For buildings with significant resonant dynamic response, the Code requires a dynamic analysis to be applied.

7.2 Clause 7 of the Code recommends a dynamic magnification factor method for the determination of the total wind force acting on an enclosed building under along-wind motion. In this method, the total force on the enclosed building is determined from the hourly mean wind pressure $\overline{q}_z$ in conjunction with the effective projected area A_z and the force coefficient C_f. The wind force so obtained is then augmented by a dynamic magnification factor G.

7.3 The dynamic magnification factor G is a function of the turbulence intensity and hurly mean velocity at the roof level, the height and breadth of the building, the natural frequency and damping ratio of the fundamental mode of vibration and the other descriptors of the wind energy parameters. Appendix F of the Code provides the equation for calculating the dynamic magnification factor G. The following is the step-by-step procedure:

(1) Determine the height h of the building above ground.

(2) Determine the breadth b of the building (horizontal dimension normal to the direction of the wind).

(3) Determine the fundamental natural frequency n_a in Hertz of the building in the direction of the wind.

The Code provides an empirical expression $n_a = 46/h$ for the determination of the fundamental natural frequency of the building. This is a very general expression with no specific account on the shape and structural form of the building. In critical cases, the user may apply a modal dynamic analysis by computer methods to determine the fundamental natural frequency.

(4) Determine the critical damping ratio ζ of the structure.

The Code recommends the critical damping ratio to be normally taken as 1.5% for steel structures and 2.0% for concrete structures. Lower values of critical damping ratio may be appropriate for particularly slender buildings. Stocky buildings may have higher damping values.

(5) Determine the design hourly mean velocity $\overline{V}_h$ at the top of the building.

The design hourly mean velocities at various heights above ground are given in Table F3 of the Code. The following direct expression may be useful for the development of spreadsheets for the computation of the design hourly mean velocity $\overline{V}_h$ at height h:

$$\bar{V}_h = 59.5\left(\frac{h}{500}\right)^{0.11}$$

(6) Determine the turbulence intensity I_h at the top of the building.

The Code gives the following expression for the computation of the turbulence intensity I_h at height h:

$$I_h = 0.1055\left(\frac{h}{90}\right)^{-0.11}$$

(7) Determine the effective turbulence length scale L_h by:

$$L_h = 1000\left(\frac{h}{10}\right)^{0.25}$$

(8) Determine the background factor B by:

$$B = \frac{1}{1 + \frac{\sqrt{36h^2 + 64b^2}}{L_h}}$$

(9) Determine the size factor S by:

$$S = \frac{1}{\left(1 + \frac{3.5 n_a h}{\bar{V}_h}\right)\left(1 + \frac{4 n_a b}{\bar{V}_h}\right)}$$

(10) Determine the effective reduced frequency N by:

$$N = \frac{n_a L_h}{\bar{V}_h}$$

(11) Determine the wind energy spectrum E by:

$$E = \frac{0.47N}{(2+N)^{5/6}}$$

(12) Determine the peak factor for background response g_v.

The Code recommends the peak factor g_v for background response to be 3.7.

(13) Determine the peak factor for resonance response g_f by:

$$g_f = \sqrt{2 \log_e (3600 n_a)}$$

(14) Compute the dynamic magnification factor G by:

$$G = 1 + 2I_h\sqrt{g_v^{\,2}B + \frac{g_f^{\,2}SE}{\zeta}}$$

7.4 Example calculation of dynamic magnification factor is given in calculation sheets 7.1.

Calculation sheet for dynamic magnification factor G		
Particulars	Wind along X-direction	Wind along Y-direction
Height of building h (m)	160	160
Breadth of building b (m)	40	30
Fundamental natural frequency of building n_a (taken as $46/h$) (Hz)	0.29	0.29
Damping ratio of the fundamental mode ζ (reinforced concrete)	2.0%	2.0%
Hourly mean velocity at top of building $\bar{V}_h = 59.5 \times \left(\frac{h}{500}\right)^{0.11}$	52.5	52.5
Turbulence intensity at top of building $I_h = 0.1055 \times \left(\frac{h}{90}\right)^{-011}$	0.0990	0.0990
Effective turbulence length scale $L_h = 1000 \times \left(\frac{h}{10}\right)^{0.25}$	2000	2000
Background factor $B = \frac{1}{1 + \frac{\sqrt{36h^2 + 64b^2}}{L_h}}$	0.664	0.669
Size factor $S = \frac{1}{\left(1 + \frac{3.5 n_a h}{\bar{V}_h}\right)\left(1 + \frac{4 n_a b}{\bar{V}_h}\right)}$	0.131	0.148
Effective reduced frequency $N = \frac{n_a L_h}{\bar{V}_h}$	10.954	10.954
Wind energy spectrum $E = \frac{0.47N}{(2+N)^{5/6}}$	0.0940	0.0940
Peak factor for background response g_v (taken as 3.7)	3.7	3.7
Peak factor for resonance response $g_f = \sqrt{2 \log_e(3600\ n_a)}$	3.726	3.726
Dynamic magnification factor $G = 1 + 2I_h\sqrt{g_v^2 B + \frac{g_f^2 SE}{\zeta}}$	**1.83**	**1.86**

Calculation sheet 7.1 – Example calculation of dynamic magnification factor

8. Total force on enclosed building

8.1 Building not significant in resonant dynamic response

Referring to section 3, the design wind pressure is required to be modified by the topography factor S_a to account for the topography effect. Following section 6, the general expression for calculating the total force F acting on an enclosed building not significant in resonant dynamic response becomes:

$$F = R_A C_f \sum S_a q_z A_z$$

where R_A is the reduction factor according to frontal projected area

C_f is the force coefficient for the building

S_a is the topography factor for the site (determined by the method in section 3, or taken as 1.0 when topography effect is not significant)

q_z is the 3-second gust design wind pressure at height z

A_z is the effective projected area of that part of the building corresponding to q_z

8.2 Building significant in resonant dynamic response

For an enclosed building significant in resonant dynamic response, the general expression for calculating the total along-wind force F acting on the building is:

$$F = GC_f \sum S_a \bar{q}_z A_z$$

where G is the dynamic magnification factor to account for the dynamic response of the structure

C_f is the force coefficient for the building

S_a is the topography factor for the site (determined by the method in section 3, or taken as 1.0 when topography effect is not significant)

$\bar{q}_z$ is the hourly mean design wind pressure at height z

A_z is the effective projected area of that part of the building corresponding to $\bar{q}_z$

8.3 For multi-storey enclosed buildings, the total force on the building is usually computed as horizontal forces acting at story levels. In this respect the along-wind force F_z acting at storey level z is expressed by:

$F_z = R_A C_f S_a q_z A_z$ for force on an enclosed building not significant in resonant dynamic response

$F_z = G C_f S_a \overline{q}_z A_z$ for along-wind force on an enclosed building significant in resonant dynamic response

The effective projected area A_z corresponding to the force at storey level z may be computed by:

A_z = *half of the effective projected area of storey above level z*
+ half of the effective projected area of storey below level z

8.4 Clause 7.6 of the Code requires the resonant dynamic effects of the following categories of enclosed buildings to be investigated in accordance with recommendations given in published literature or through the use of dynamic wind tunnel model studies:

(1) Buildings for which the fundamental natural frequency is less than 0.2 Hz.

(2) Buildings with significant cross-wind resonant response or torsional resonant response.

8.5 Example calculation of the total force acting on a multi-storey building not significant in resonant dynamic response is given in Appendix A. Example calculation of the total force acting on a multi-storey building significant in resonant dynamic response is given in Appendix B.

9. Pressure coefficient and force on building elements of enclosed building

9.1 The Code recommends the total wind force acting on the surface or part of the surface of an enclosed building to be calculated from the area of that particular surface multiplied by total pressure coefficient and the design wind pressure q_z appropriate to the height of the surface. The total force F_p acting in a direction normal to the individual elements therefore is:

$$F_p = C_p S_a q_z A_m$$

where C_p is the total pressure coefficient for the individual element

q_z is the 3-second gust design wind pressure corresponding to the height z of the element

S_a is the topography factor of the site (determined by the method in section 3, or taken as 1.0 when topography effect is not significant)

A_m is the surface area of the element

It is to be noted that the 3-second gust design wind pressure q_z should be used in the determination of the force acting on individual elements, and the equation for the total force F_p should be applied to buildings with and without significant resonant dynamic response.

9.2 For the determination of the wind force acting on individual elements of an enclosed building, Clause 6.2 of the Code further requires the 3-second gust design wind pressure q_z to be a constant value over the lower part of the building. The height up to this constant value occurs is to be taken as the lesser of the height equal to the breadth of the building (the horizontal dimension of the building normal to the direction of the wind) or the actual height of the building. The constant value in this respect is the design wind pressure at this height. In the case of a building with isolated blocks projecting above a general roof level, individual constant values corresponding to the height and shape of each block may be applied.

9.3 The total pressure coefficient C_p for walls, claddings and flat roofs of enclosed buildings with negligible probability of dominant opening are given in Table E1 of the Code. These coefficients represent the most onerous effect on a particular surface with respect to various wind directions on the building. It will be appropriate to use these coefficients in conjunction with the design wind pressure corresponding to the most critical wind direction on the building irrespective of the orientation of the surface, unless a detailed directional analysis on the pressure effects is carried out.

9.4 The total pressure coefficients C_p for canopies are given in Table E1 of the Code. These coefficients represent the most onerous effect on the canopy surface with respect to the wind towards the building elevation adjacent to the canopy, and should be used in conjunction with the design wind pressure from such wind direction. For the determination of the edge zones of the canopy, the span refers to the projection of the canopy from the adjacent wall and the edge zones exclude the edge abutting the adjacent wall, as illustrated in figure 9.1.

It is to be noted that canopy is defined in the Code are a structure projecting more than 500 mm from the wall of a building and at a height of not more than 7.5 m above the level of the ground.

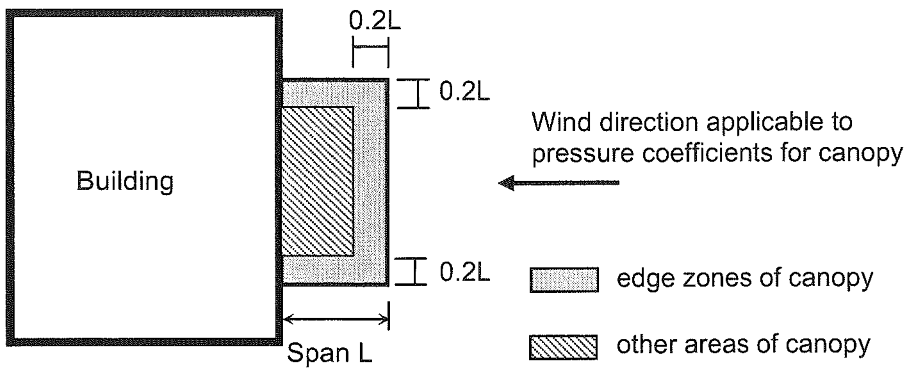


Figure 9.1 – Wind direction and zone locations corresponding to pressure coefficients for canopy

9.5 In the case where a dominant opening is likely to occur during a severe storm, the total pressure on walls and roofs of an enclosed building should be determined with the aid of other published materials acceptable to the Building Authority or through the use of wind tunnel model studies.

9.6 Example calculations of pressure coefficients and total force acting on individual elements of enclosed buildings are given in the calculation sheets A4 and A5 in Appendix A.

10. Open framework building

Total force on the whole structure

10.1 For open framework buildings (e.g. sign frames, lattice towers) the total force on the whole structure can be determined from the sum of the force acting on the individual members using the total pressure coefficient of the element member, provided that the element members are separated wide apart. When the spacing of the elements is small, the flow around the element members will interfere with each other, and the interference is a function of the solidity ratio.

10.2 The general equation for the determination of total force on an open framework building not significant in dynamic resonant response is:

$$F = C_f \sum S_a q_z A_z$$

where C_f is the force coefficient for the open framework building

S_a is the topography factor for the site (determined by the method in section 3, or taken as 1.0 when topography effect is not significant)

q_z is the 3-second gust design wind pressure at height z

A_z is the effective projected area of that part of the open framework building corresponding to q_z

10.3 Table D4 of the Code gives the values of force coefficient for an open framework building not significant in resonant dynamic response. The force coefficient is given as a function of the solidity ratio ϕ of the framework. The solidity ratio is defined as:

$$\phi = \frac{\text{Effective projected area of the open framework building}}{\text{Area enclosed by the boundary of the frame normal to the wind direciton}}$$

10.3 The effective projected area of the open framework building is the aggregate projected area of all members of the frame projected on a plane normal to the direction of the wind front.

10.4 It is to be noted from Table D4 of the Code that the force coefficient has a value of 2.0 when the solidity ratio is 0.01. This value represents the force coefficient for long and small cross-sectional size members separated wide apart. The force coefficient for a frame of solidity ratio approaching 1.0 also has the value of 2.0. This represents the case that long and small cross-sectional size members are very closely spaced and their total projected areas amount to 100% of the bounded area of the frame. If the cross-sectional size of the members is not small, then the structure will become a solid body and the force coefficient will be that of a solid body.

10.5 The user may adopt appropriate values of force coefficient for open framework buildings specified in other International Codes acceptable to the Building Authority.

10.6 The windward frame of a structure having two or more parallel frames may have a shielding effect upon the frame to leeward. In this respect the wind load acting on the windward frame can be determined by the force coefficient method based on the solidity ratio of the windward frame and an appropriate shielding factor may be applied to the wind load on the parts of frames that are sheltered to account for the shielding effect. The loads on the various frames are added together to obtain the total load on the structure. The user may refer to the recommendations on multiple frames given in other International Codes acceptable to the Building Authority.

10.7 Lattice towers (such as transmission towers and pylons) are usually regarded as special cases of open framework building for which it may be convenient to use an overall force coefficient in the calculation of wind load. The user may refer to the recommendations on lattice tower structures given in other International Codes acceptable to the Building Authority.

10.8 Clause 7.6 of the Code requires the resonant dynamic effects of the open framed buildings with significant resonant dynamic response to be investigated in accordance with recommendations given in published literature or through the use of dynamic wind tunnel model studies.

Force on individual members

10.9 The general equation for the determination of the force on individual members of an open framework building not significant in dynamic resonant response is:

$$F_p = C_p S_a q_z A_m$$

where C_p is the total pressure coefficient for individual elements

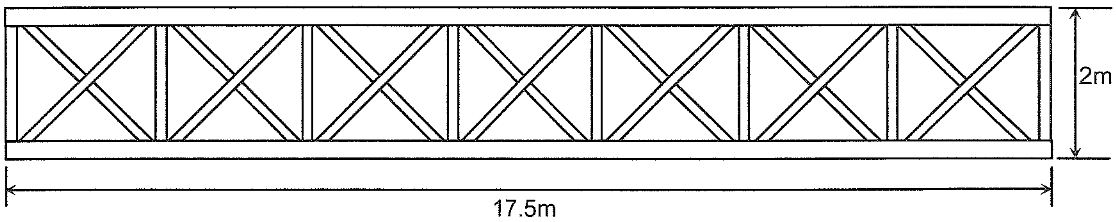
q_z is the 3-second gust design wind pressure corresponding to the height z of the element

S_a is the topography factor for the site (determined by the method in section 3, or taken as 1.0 when topography effect is not significant)

A_m is the projected area of the element in the direction of the wind

10.10 The total pressure coefficient C_p for individual elements of open framework buildings should be taken as 2.0, or appropriate value specified in other International Codes acceptable to the Building Authority.

10.11 Example calculation of total force coefficient and force on an open framework structure is given in calculation sheet 10.1.



Total force on frame

Member	Projected area of each member A_m	Total projected area
Diagonal	0.3 m^2	0.3 x 14 = 4.2 m^2
Vertical	0.2 m^2	0.2 x 8 = 1.6 m^2
Horizontal chord	2.7 m^2	2.7 x 2 = 5.4 m^2
		Sum = 11.2 m^2

Effective projected area of frame A = 11.2 m^2
Area enclosed by boundary of frame = 17.5 x 2 = 35 m^2
Solidity ratio ϕ = 11.2 / 35 = 0.32
Force coefficient $\mathbf{C_f}$ **= 1.66**
Height of frame above ground = 15 m
3-second gust design wind pressure at z = 15m, $\mathbf{q_z}$ **= 2.14 kPa**
Topography factor of site S_a = 1.30
Total force on the frame $F = C_pS_aq_zA$ = 1.7 x 1.3 x 2.14 x 11.2 = **53.0 kN**

Force on individual element of frame

Member	Projected area of each member A_m	Force on individual member $F_p = C_pq_zA_m$ (Total pressure coefficient C_p = 2.0)
Diagonal	0.3 m^2	2.0 x 1.3 x 2.14 x 0.3 = 1.67 kN
Vertical	0.2 m^2	2.0 x 1.3 x 2.14 x 0.2 = 1.11 kN
Horizontal chord	2.7 m^2	2.0 x 1.3 x 2.14 x 2.7 = 15.02 kN

Calculation sheet 10.1 – Example calculation of total force on a framework and total force on individual members

11. Information to be provided in a wind tunnel testing report

11.1 The necessary provisions for wind tunnel testing are given in Appendix A of the Code. A brief description of the principles, methodology, procedures and quality assurance procedures of wind tunnel testing of building for wind loading is given in Section 5 of the Explanatory Materials. This section is intended to provide guidance to the engineer on the essential information to be included in a report on wind tunnel testing.

11.2 The report on wind tunnel testing should describe fully the aspects of methodology, testing procedures and quality assurance. Sufficient information and data are to be included in the report to support the quality of wind simulation, building models, testing instrumentation and test data. It is important to include some intermediate data to enable validation checking.

Method statement

11.3 It is a good practice to include a method statement for the wind tunnel test to describe the facilities, instrumentation, measurement procedures and analysis methods employed. The requirements of the Code should be specifically addressed.

Background and scope of study

11.4 A general description of the building being tested and the special features of wind effects is to be given in the report. The scope of study is to be given. The scope of study may be specific to one or all of the following areas:

(a) wind pressure investigation using pressure models;

(b) dynamic wind load and wind effect investigation using the high-frequency base balance technique or equivalent method; and

(c) wind environment investigation.

The conventions for the wind load directions and the wind incidence directions are to be shown in a plan. The number of wind angles tested is to be stated.

Boundary-layer wind flow simulation

11.5 A description of simulation method and results of natural wind is to be given with the following information:

(a) geometric scale of wind simulation;

(b) wind tunnel speeds used in the tests and the corresponding full-scale/model velocity scale;

(c) profile of mean wind speed variation with height measured in the wind tunnel and comparison with target profile;

(d) variation of longitudinal component of turbulence with height;

(e) integral scale of turbulence measured in the wind tunnel, or wind spectrum; and

(f) evidence of a zero longitudinal pressure gradient.

Surrounding buildings and topography

11.6 The following details of the proximity model and of the topographic model (if any) are to be given:

(a) extent of coverage of the proximity model and the surrounding buildings;

(b) effects of removal/inclusion of some particular surrounding buildings if judged to be significant;

(c) approach flow characteristics in the "near-field" flow which are modified from the "far-field" flow by adjacent natural (topographical) and man-made features;

(d) photographs or sketches of topography and proximity models; and

(e) value of blockage ratio.

Scaling ratios in wind tunnel tests

11.7 The scaling ratio refers to the ratio between full scale and wind tunnel values. Wind forces, moments, time and frequencies are derived from the geometric length and velocity scales. The following information is to be given in the report:

(a) geometric scaling ratio of building model, which is normally the same as that of wind simulation;

(b) velocity scaling ratio used in different parts of the testing, preferably stated as the values of wind speeds used in the wind tunnel and the corresponding full-scale wind speeds;

(c) reference height for wind speed, with clear indication that velocity scaling is made on the mean wind speed or gust wind speed;

(d) justifications for the chosen full-scale wind speeds, as appropriate to the relevant return periods; and

(e) minimum Reynolds number of the wind tunnel flow based on the model building dimensions.

Measurement of wind pressure

11.8 The following information on the pressure model is to be given in the report:

(a) design of the pressure model to approximate the test building including information on any simplification of building shape, any omission of architectural features and the accuracy of building dimensions;

(b) arrangement of pressure taps around the building plan and along the building height (shown by a diagram with pressure tap identification labels); and

(c) number of pressure taps and the average pressure tap density.

11.9 The following descriptions on the instrumentation, measurement and data analysis procedures are to be given:

(a) number of wind directions tested;

(b) frequency response of the wind pressure measurement system;

(c) evidence to show that the any extraneous acoustic pressure fluctuations are minimal;

(d) sampling rate and measurement duration for a pressure tap;

(e) methodology used in statistical determination of peak pressure; and

(f) methodology used to estimate internal pressures, if applicable.

11.10 The following minimum amount of pressure data is to be given:

(a) full listing of the measured mean, standard deviation, minimum and maximum pressure coefficients for each wind direction (with clear statement of the reference wind speed used); and

(b) expected largest mean and peak positive and negative full-scale pressure on all pressure tap locations at the chosen full-scale design wind speed over all possible wind angles (with consideration of wind directionality effects if applicable), provided in the form of table or contour map.

If desirable, force and moment coefficients can be derived from the mean pressure data and given in the report as follows:

(a) force and moment coefficients applicable to different vertical sections of the building; and

(b) force and moment coefficients on the entire building and their variations with wind angles.

Wind-Induced overall loads and dynamic responses

11.11 The assessment of wind-induced dynamic effect on the test building is carried out with the base-balance technique or equivalent method. The following information is to be given in the report on the base-balance model or the equivalent building model for dynamic modeling:

(a) point of connection (load centre) of the base-balance model onto the force balance;

(b) evidence that the model/balance assembly is sensitive enough to measure small wind loads in the wind tunnel but yet stiff enough to suppress its own vibration (usually by stating the natural frequency of the model-balance assembly and the extent higher than the frequency of the dominant wind eddies);

(c) wind speed in the wind tunnel during wind load measurement;

(d) corresponding values of velocity scale and frequency scale when converting to appropriate full-scale wind speeds of different return periods; and

(e) sampling rate and duration of wind load measurement.

11.12 The base moments measured by the balance are used to represent the generalized wind forces. The following data are to be given as intermediate results of the test:

(a) mean values, root-mean-square values and power spectral densities of the base moments (in wind tunnel scale or at appropriate full-scale wind speeds); and

(b) some representative, if not the whole set of, power spectra densities of the moments.

The base-balance technique uses the dynamic properties of the building in the computation of wind-induced responses. These properties are usually provided by the design engineer. The essential information to be stated in the report includes:

(a) general dynamical characteristics of the prototype building;

(b) mode shapes and natural frequencies of at least the first three modes of vibration of the prototype building (to judge whether the assumption of near-linear mode shapes is valid and whether there is strong mode coupling);

(c) mass distribution along the building height; and

(d) characteristics of structural damping of the prototype building and the assumed values of critical damping ratio to be used in the computation.

11.13 Computation of wind-induced responses of the building from the measured base-balance signals and the dynamic properties of the building is based on modal analysis. The computed wind-induced responses depend on the full-scale (mean) wind speeds used and the structural damping ratio assumed. The following results of responses are to be given in the report:

(a) mean, root-mean-square and peak deflections at different floor levels;

(b) mean and peak moments at the building base;

(c) root-mean-square and peak accelerations at different floor levels, with comparison to comfort criteria (these are related to serviceability aspect of the building at short return periods, not being part of the wind loading requirements in the Code); and

(d) the return period, full-scale wind speed and damping ratio in use corresponding to the responses in peak and normal loading conditions for the derivation of wind loads for structural safety and serviceability.

11.14 For structural design of the building, the following summary loading information is to be provided in the report:

(a) wind-induced peak dynamic base moments expected at the most critical wind directions or integrated over all wind angles with wind directionality effect; and

(b) equivalent static wind load distribution along the height of the building (by apportioning the design base moments along the building height).

Environmental wind studies

11.15 Assessment of environmental wind conditions at the pedestrian level around the base of the building is not part of the wind loading requirements in the Code but is a convenient add-on to the wind tunnel test. The following information are usually given in this part of the report:

(a) number of wind speed measurement positions;

(b) diagrams of measurement locations and identification labels;

(c) instrumentation of wind speed measurement, frequency response of instrumentation, identification of mean or gust wind speed, identification of omni-directional or velocity components;

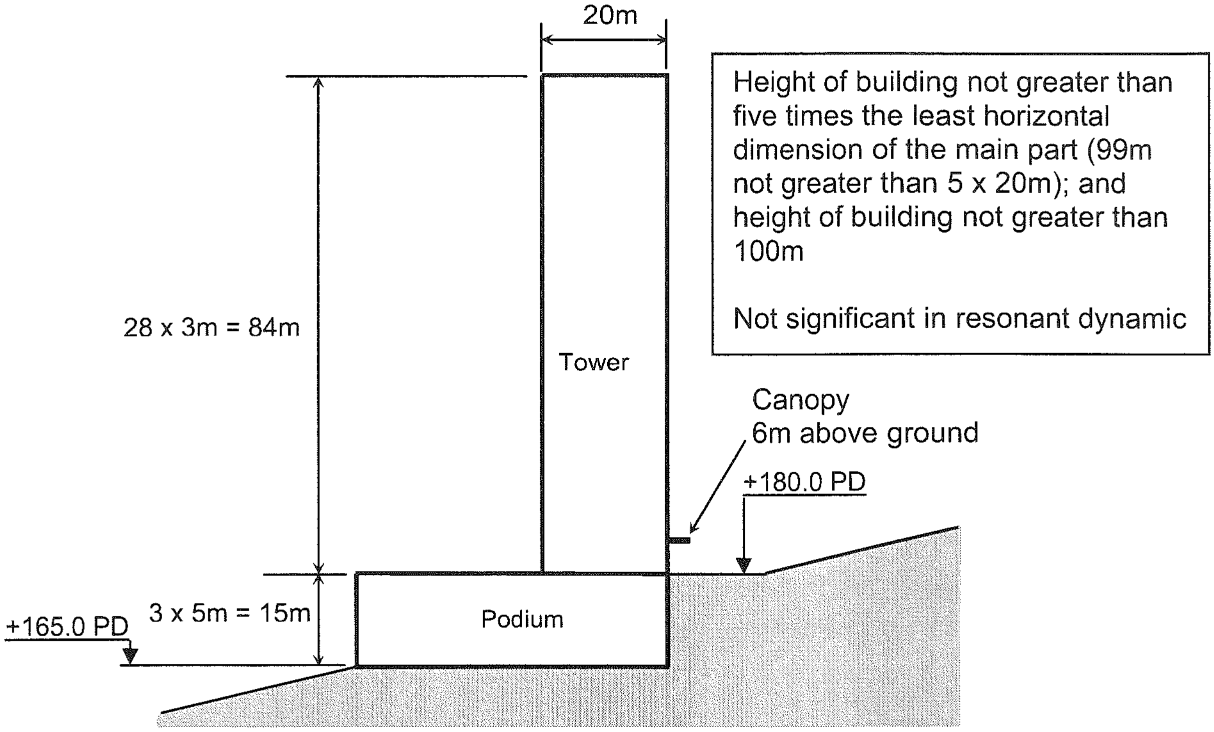
(d) number of wind directions tested;

(e) a description of the analysis method for the determination of wind climate, including analysis of directionality effects;

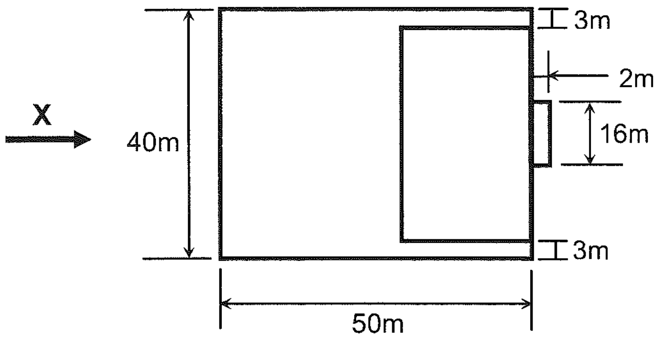
(f) effects of variation in vegetation modeling; and

(g) assessment criteria of wind environment.

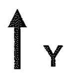
Appendix A
Example calculation on a multi-storey building not significant in resonant dynamic response – Building A

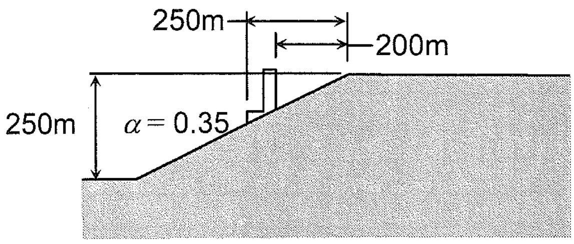


Elevation

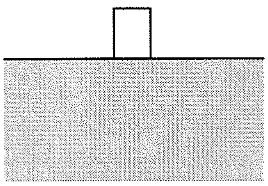


Plan





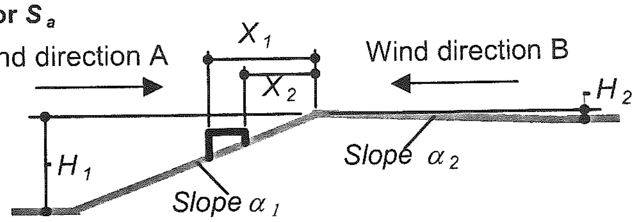
Topography section of site along X



Topography section of site along Y

Calculation Sheet for Topography Factor S_a

H_1 =	250	(m)
H_2 =	0	(m)
α_1 =	0.35	
α_2 =	0	
X_1 =	250	(m)
X_2 =	200	(m)



Wind direction A (upwind on building)

Upwind slope α_U in the wind direction (= α_1 in the figure)		0.35
α_U > 0.05?	**Yes**	
Effective height H of crest (=H_1 in the figure) (m)		250
Horizontal distance X of site from crest (= -X_1 in the figure) (m)		-250
Effective height of site below crest (= $X_1 \alpha_U$) (m)		88
Site within 0.5H below crest?	**Yes**	
Downwind slope α_D in the wind direction (= α_2 in the figure)		0.00
Topography (if α_D>0.05, hill-and-ridge; otherwise cliff-and-escarpment)		Cliff-and-escarpment
Length of upwind slope $L_U = H/\alpha_U$ (m)		714
Effective slope α_e (If α_U < 0.3, $\alpha_e = \alpha_U$; otherwise α_e = 0.3)		0.30
Effective slope length L_e (If α_U < 0.3, $L_e = L_U$; otherwise $L_e = H/0.3$) (m)		833
X/L_U (X/L_U is negative for upwind)		-0.350

Wind direction B (downwind on building)

Upwind slope α_U in the wind direction (α_2 in the figure)		0.00
α_U > 0.05?	**No**	**Local topography not significant for wind direction B**

Topography factor S_a for height z above ground

Height above ground z(m)	**Wind direction A (upwind on building)** X/L_U = -0.350 (cliff-and-escpmt)			**Wind direction B not significant**		
	z/L_e	s	$S_a = (1+ 1.2\alpha_e s)^2$	z/L_e	s	$S_a = (1+ 1.2\alpha_e s)^2$
5	0.006	0.48	1.38			1.00
10	0.012	0.48	1.38			1.00
15	0.018	0.48	1.38			1.00
20	0.024	0.48	1.38			1.00
40	0.048	0.48	1.38			1.00
60	0.072	0.48	1.38			1.00
80	0.096	0.48	1.38			1.00
84	0.101	0.47	1.37			1.00
99	0.119	0.46	1.36			1.00

Calculation sheet A1 – Building A: Topography of site along X

Calculation sheet for wind forces acting on building - wind along and opposite to X-direction

Height not greater than 5 x least horizontal dimension, and height not greater than 100m

Resonant dynamic response is not significant

Determination of force coefficient C_f and frontal area reduction factor R_A

Part	*h* (m)	*b* (m)	*d* (m)	*h/b*	*b/d*	C_h	C_s	C_f	*A=hxb*	R_A
3/F-Roof (tower)	84	34	20	2.47	1.70	1.012	1.070	1.083	2856	0.92
G-3/F (podium)	15	40	50	0.38	0.80	0.950	1.000	0.950	600	0.98

Note:

(1) A_z = 0.5x(effective projected area of storey above level *z* + effective projected area of storey below level *z*)

(2) $F_z = R_a C_f S_a q_z A_z$

Level ref.	P.D. level	**Wind along X-direction (uphill)**					**Wind opposite to X-direction (downhill)**				
		Height above ground z	Effective projected area A_z (Note 1)	Design 3-sec gust wind pressure q_z	Topo-graphy factor S_a	Wind force at height z F_z (Note 2)	Height above ground z	Effective projected area A_z (Note 1)	Design 3-sec gust wind pressure q_z	Topo-graphy factor S_a	Wind force at height z F_z (Note 2)
	(m)	(m)	(m^2)	(kPa)		(kN)	(m)	(m^2)	(kPa)		(kN)
Roof	+264.0	99.0	51.0	2.86	1.36	197.2	84.0	51.0	2.78	1.00	141.3
30F	+261.0	96.0	102.0	2.84	1.36	392.4	81.0	102.0	2.77	1.00	280.9
29F	+258.0	93.0	102.0	2.83	1.36	390.4	78.0	102.0	2.75	1.00	279.2
28F	+255.0	90.0	102.0	2.81	1.36	388.4	75.0	102.0	2.73	1.00	277.5
27F	+252.0	87.0	102.0	2.80	1.37	389.2	72.0	102.0	2.72	1.00	275.7
26F	+249.0	84.0	102.0	2.78	1.37	387.0	69.0	102.0	2.70	1.00	273.9
25F	+246.0	81.0	102.0	2.77	1.38	387.6	66.0	102.0	2.68	1.00	272.0
24F	+243.0	78.0	102.0	2.75	1.38	385.3	63.0	102.0	2.66	1.00	270.0
23F	+240.0	75.0	102.0	2.73	1.38	383.0	60.0	102.0	2.64	1.00	268.0
22F	+237.0	72.0	102.0	2.72	1.38	380.5	57.0	102.0	2.62	1.00	265.8
21F	+234.0	69.0	102.0	2.70	1.38	378.0	54.0	102.0	2.60	1.00	263.6
20F	+231.0	66.0	102.0	2.68	1.38	375.4	51.0	102.0	2.57	1.00	261.3
19F	+228.0	63.0	102.0	2.66	1.38	372.6	48.0	102.0	2.55	1.00	258.8
18F	+225.0	60.0	102.0	2.64	1.38	369.8	45.0	102.0	2.52	1.00	256.3
17F	+222.0	57.0	102.0	2.62	1.38	366.9	42.0	102.0	2.50	1.00	253.5
16F	+219.0	54.0	102.0	2.60	1.38	363.8	39.0	102.0	2.47	1.00	250.7
15F	+216.0	51.0	102.0	2.57	1.38	360.6	36.0	102.0	2.44	1.00	247.6
14F	+213.0	48.0	102.0	2.55	1.38	357.2	33.0	102.0	2.41	1.00	244.3
13F	+210.0	45.0	102.0	2.52	1.38	353.6	30.0	102.0	2.37	1.00	240.8
12F	+207.0	42.0	102.0	2.50	1.38	349.9	27.0	102.0	2.33	1.00	236.9
11F	+204.0	39.0	102.0	2.47	1.38	345.9	24.0	102.0	2.29	1.00	232.8
10F	+201.0	36.0	102.0	2.44	1.38	341.7	21.0	102.0	2.25	1.00	228.1
9F	+198.0	33.0	102.0	2.41	1.38	337.2	18.0	102.0	2.20	1.00	222.9
8F	+195.0	30.0	102.0	2.37	1.38	332.3	15.0	102.0	2.14	1.00	216.9
7F	+192.0	27.0	102.0	2.33	1.38	327.0	12.0	102.0	2.07	1.00	209.8
6F	+189.0	24.0	102.0	2.29	1.38	321.2	9.0	102.0	1.98	1.00	201.1
5F	+186.0	21.0	102.0	2.25	1.38	314.8	6.0	102.0	1.87	1.00	189.6
4F	+183.0	18.0	102.0	2.20	1.38	307.6	3.0	102.0	1.82	1.00	184.8
3F	+180.0	15.0	51.0	2.14	1.38	149.6	0.0	51.0	1.82	1.00	92.4
P3F	+180.0	15.0	100.0	2.14	1.38	275.4					
P2F	+175.0	10.0	200.0	2.01	1.38	518.8					
P1F	+170.0	5.0	200.0	1.82	1.38	469.2					
G	+165.0	0.0	100.0	1.82	1.38	234.6					

Calculation sheet A2 – Building A: Total force on building (wind along and opposite to X-direction)

Calculation sheet for wind forces acting on building - wind along and opposite to Y-direction

Height not greater than 5 x least horizontal dimension, and height not greater than 100m

Resonant dynamic response is not significant

Determination of force coefficient C_f and frontal area reduction factor R_A

Part	h (m)	b (m)	d (m)	h/b	b/d	C_h	C_s	C_f	$A=hxb$	R_A
3/F-Roof (tower)	84	20	40	4.20	0.50	1.055	1.000	1.055	1680	0.94
G-3/F (podium)	15	50	40	0.30	1.25	0.950	1.025	0.974	750	0.97

Note:

(1) A_z = 0.5 x(effective projected area of storey above level z + effective projected area of storey below level z)

(2) $F_z = R_a C_f S_a q_z A_z$

Level ref.	P.D. level	Wind along Y-direction					Wind opposite to Y-direction				
		Height above ground z	Effective projected area A_z *(Note 1)*	Design 3-sec gust wind pressure q_z	Topography factor S_a	Wind force at height z F_z *(Note 2)*	Height above ground z	Effective projected area A_z *(Note 1)*	Design 3-sec gust wind pressure q_z	Topography factor S_a	Wind force at height z F_z *(Note 2)*
	(m)	(m)	(m^2)	(kPa)		(kN)	(m)	(m^2)	(kPa)		(kN)
Roof	+264.0	99.0	30.0	2.86	1.00	85.2	Same as wind along Y-direction				
30F	+261.0	96.0	60.0	2.84	1.00	169.6					
29F	+258.0	93.0	60.0	2.83	1.00	168.8					
28F	+255.0	90.0	60.0	2.81	1.00	167.9					
27F	+252.0	87.0	60.0	2.80	1.00	167.0					
26F	+249.0	84.0	60.0	2.78	1.00	166.1					
25F	+246.0	81.0	60.0	2.77	1.00	165.1					
24F	+243.0	78.0	60.0	2.75	1.00	164.2					
23F	+240.0	75.0	60.0	2.73	1.00	163.2					
22F	+237.0	72.0	60.0	2.72	1.00	162.1					
21F	+234.0	69.0	60.0	2.70	1.00	161.0					
20F	+231.0	66.0	60.0	2.68	1.00	159.9					
19F	+228.0	63.0	60.0	2.66	1.00	158.8					
18F	+225.0	60.0	60.0	2.64	1.00	157.6					
17F	+222.0	57.0	60.0	2.62	1.00	156.3					
16F	+219.0	54.0	60.0	2.60	1.00	155.0					
15F	+216.0	51.0	60.0	2.57	1.00	153.6					
14F	+213.0	48.0	60.0	2.55	1.00	152.2					
13F	+210.0	45.0	60.0	2.52	1.00	150.7					
12F	+207.0	42.0	60.0	2.50	1.00	149.1					
11F	+204.0	39.0	60.0	2.47	1.00	147.4					
10F	+201.0	36.0	60.0	2.44	1.00	145.6					
9F	+198.0	33.0	60.0	2.41	1.00	143.6					
8F	+195.0	30.0	60.0	2.37	1.00	141.6					
7F	+192.0	27.0	60.0	2.33	1.00	139.3					
6F	+189.0	24.0	60.0	2.29	1.00	136.8					
5F	+186.0	21.0	60.0	2.25	1.00	134.1					
4F	+183.0	18.0	60.0	2.20	1.00	131.0					
3F	+180.0	15.0	30.0	2.14	1.00	63.8					
P3F	+180.0	15.0	125.0	2.14	1.00	253.2					
P2F	+175.0	10.0	250.0	2.01	1.00	476.9					
P1F	+170.0	5.0	250.0	1.82	1.00	431.3					
G	+165.0	0.0	125.0	1.82	1.00	215.7					

Calculation sheet A3 – Building A: Total force on building (wind along and opposite to Y-direction)

Level ref.	P.D. level	Wind along X-direction (uphill)				Wind opposite to X-direction (downhill)		Wind along and opposite to Y-direction		**Design wind pressure for walls, claddings and roofs (maximum of [A], [B] and [C])**
		Height above ground z	Basic 3-sec gust wind pressure q_z	Topo-graphy factor S_a	[A] 3-second gust design wind pressure $S_a q_z$	Height above ground z	[B] 3-second gust design wind pressure (S_a = 1.0) q_z	Height above ground z	[C] 3-second gust design wind pressure (S_a = 1.0) q_z	
	(m)	(m)	(kPa)		(kPa)	(m)	(kPa)	(m)	(kPa)	**(kPa)**
		Design wind pressure for building elements in tower block								
		Breadth of tower block = 34m Value of constant wind pressure taken at 34m above podium roof (i.e. at +214.0 P.D.)						Breadth of tower block = 20m Value of constant wind pressure taken at 20m above podium roof (i.e. at +200.0 P.D.)		
Roof	+264.0	99.0	2.86	1.36	3.88	84.0	2.78	99.0	2.86	**3.88**
30F	+261.0	96.0	2.84	1.36	3.87	81.0	2.77	96.0	2.84	3.87
		19F-29/F omitted								
18F	+225.0	60.0	2.64	1.38	3.64	45.0	2.52	60.0	2.64	3.64
17F	+222.0	57.0	2.62	1.38	3.61	42.0	2.50	57.0	2.62	3.61
16F	+219.0	54.0	2.60	1.38	3.58	39.0	2.47	54.0	2.60	3.58
15F	+216.0	51.0	2.57	1.38	3.55	36.0	2.44	51.0	2.57	3.55
	+214.0	**49.0**	2.56	1.38	**3.53**	34.0	**2.42**	49.0	2.56	**3.53**
14F	+213.0	48.0	2.55	1.38	3.53	33.0	2.42	48.0	2.55	3.53
13F	+210.0	45.0	2.52	1.38	3.53	30.0	2.42	45.0	2.52	3.53
	+200.0	35.0	2.43	1.38	3.53	20.0	2.42	**35.0**	**2.43**	3.53
12F	+207.0	42.0	2.50	1.38	3.53	27.0	2.42	42.0	2.43	3.53
11F	+204.0	39.0	2.47	1.38	3.53	24.0	2.42	39.0	2.43	3.53
10F	+201.0	36.0	2.44	1.38	3.53	21.0	2.42	36.0	2.43	3.53
9F	+198.0	33.0	2.41	1.38	3.53	18.0	2.42	33.0	2.43	3.53
8F	+195.0	30.0	2.37	1.38	3.53	15.0	2.42	30.0	2.43	3.53
7F	+192.0	27.0	2.33	1.38	3.53	12.0	2.42	27.0	2.43	3.53
6F	+189.0	24.0	2.29	1.38	3.53	9.0	2.42	24.0	2.43	3.53
5F	+186.0	21.0	2.25	1.38	3.53	6.0	**2.42***	21.0	2.43	3.53
4F	+183.0	18.0	2.20	1.38	3.53	3.0	2.42	18.0	2.43	3.53
3F	+180.0	15.0	2.14	1.38	3.53	0.0	2.42	15.0	2.43	3.53
							*For canopy			
		Design wind pressure for building elements in podium block								
		Breadth of podium block = 40m Height of podium roof = 15m Value of constant wind pressure taken at height of podium roof (i.e. at +180.0 P.D.)						Breadth of podium block = 50m Height of podium roof = 15m Value of constant wind pressure taken at height of podium roof (i.e. at +180.0 P.D.)		
P3F	**+180.0**	**15.0**	2.14	1.38	**2.95**	N.A.		15.0	2.43	**2.95**
P2F	+175.0	10.0	2.01	1.38	**2.95**			10.0	2.43	2.95
P1F	+170.0	5.0	1.82	1.38	**2.95**			5.0	2.43	2.95
G	+165.0	0.0	1.82	1.38	**2.95**			0.0	2.43	2.95

Calculation sheet A4 – Building A: Design wind pressure for force on building elements

Element of building	Total pressure coefficient C_p for outward or upward force	Total pressure coefficient C_p for inward or downward force	Design 3-second gust wind pressure q (after topography factor modification) kPa
All edge zones of tower roof	−2.2	N.A.	3.88
Other surfaces of tower roof	−1.2	N.A.	3.88
Cladding near tower roof, all edge zones of tower block	−1.4	+1.0	3.88
Cladding near tower roof, all other surfaces of tower block	−1.0	+1.0	3.88
Cladding between 3/F to 14/F, all edge zones of tower block	−1.4	+1.0	3.53
Cladding at 11/F, all other surfaces of tower block	−1.0	+1.0	3.53
All edge zones of podium roof	−2.2	N.A.	2.95
Other surfaces of podium roof	−1.2	N.A.	2.95
Cladding in all edge zones of podium block	−1.4	+1.0	2.95
Cladding in all other surfaces of podium block	−1.0	+1.0	2.95
All edge zones of canopy	−2.0	+2.0	2.42
Other surfaces of canopy	−1.2	+1.2	2.42

Note:

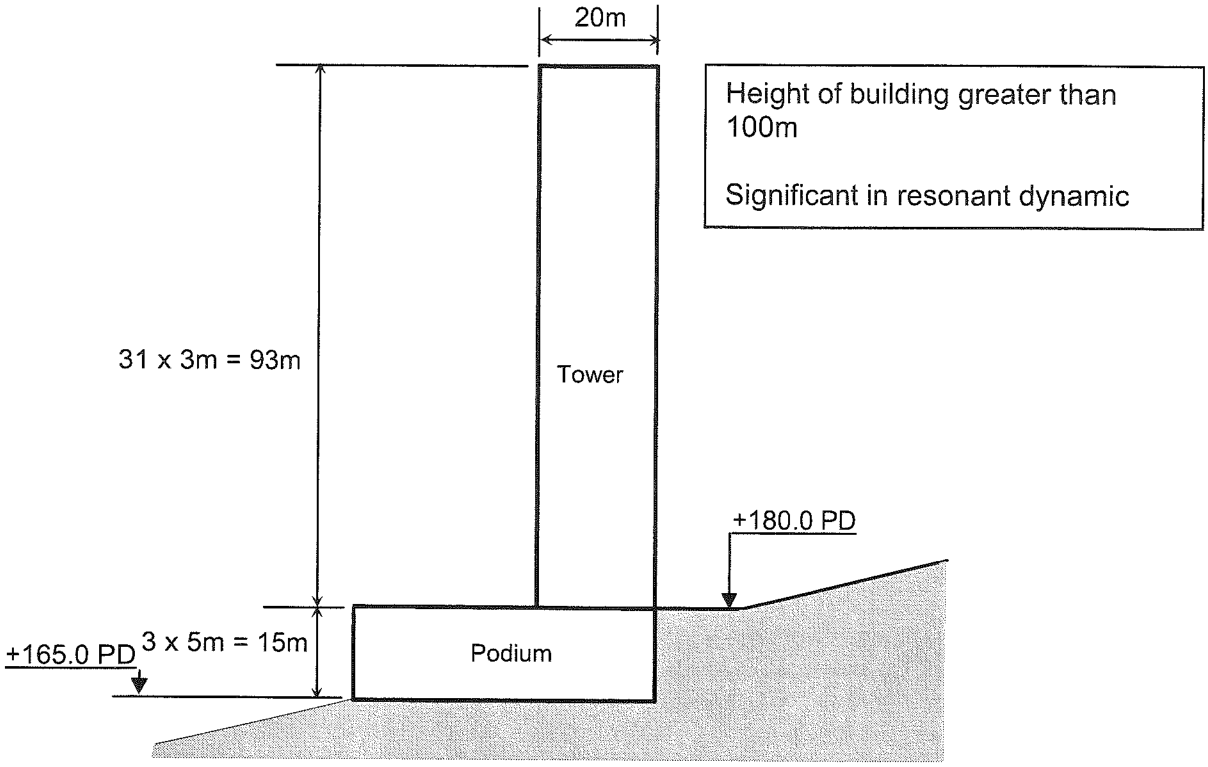
For claddings and roofs, the design wind pressure corresponds to the most critical wind direction (i.e. uphill wind along X-direction) with the application of conatant value over the lower part of the respective building block.

For canopy, the design wind pressure corresponds to the wind direction towardsthe building elevation adjacent to the canopy (i.e. downhill wind opposite to X-direction) at canopy level, with the application of constant value over the lower part of the tower block.

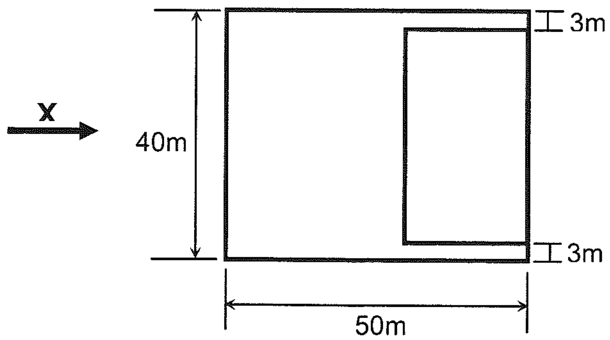
Determination of the design wind pressure for the building elements is given in calculation sheet A4.

Calculation sheet A5 – Buildiing A: Total pressure coefficient and design wind pressure for building elements

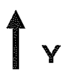
Appendix B
Example calculation on a multi-storey building significant in resonant dynamic response – Building B

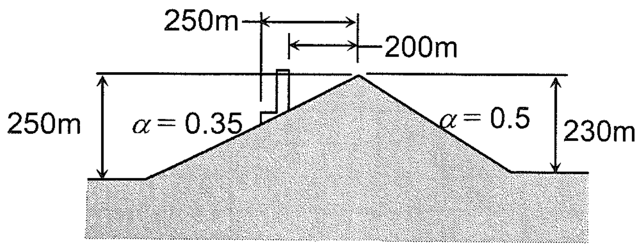


Elevation

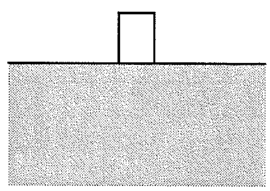


Plan





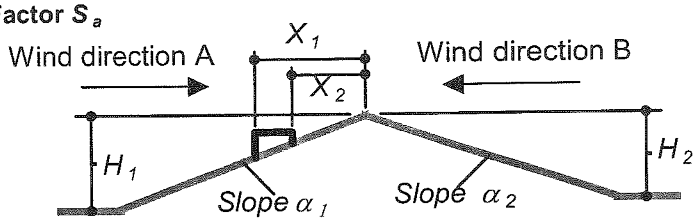
Topography section of site along X



Topography section of site along Y

Calculation Sheet for Topography Factor S_a

H_1 =	250	(m)
H_2 =	230	(m)
α_1 =	0.35	
α_2 =	0.5	
X_1 =	250	(m)
X_2 =	200	(m)



Wind direction A (upwind on building)

Upwind slope α_U in the wind direction (= α_1 in the figure)		0.35
α_U > 0.05?	**Yes**	
Effective height H of crest (=H_1 in the figure) (m)		250
Horizontal distance X of site from crest (= -X_1 in the figure) (m)		-250
Effective height of site below crest (= $X_1 \alpha_U$) (m)		88
Site within 0.5H below crest?	**Yes**	
Downwind slope α_D in the wind direction (= α_2 in the figure)		0.50
Topography (if α_D>0.05, hill-and-ridge; otherwise cliff-and-escarpment)		Hill-and-ridge
Length of upwind slope $L_U = H/\alpha_U$ (m)		714
Effective slope α_e (If α_U < 0.3, $\alpha_e = \alpha_U$; otherwise α_e = 0.3)		0.30
Effective slope length L_e (If α_U < 0.3, $L_e = L_U$; otherwise $L_e = H/0.3$) (m)		833
X/L_U (X/L_U is negative for upwind)		-0.350

Wind direction B (downwind on building)

Upwind slope α_U in the wind direction (α_2 in the figure)		0.50
α_U > 0.05?	**Yes**	
Downwind slope α_D in the wind direction (= α_1 in the figure)		0.35
Topography (if α_D>0.05, hill-and-ridge; otherwise cliff-and-escarpment)		Hill-and-ridge
Effective height H of crest (= H_2 in the figure) (m)		230
Length of upwind slope $L_U = H/\alpha_U$ (m)		460
Horizontal distance X of site from crest (= X_2 in the figure) (m)		200
Influence distance from crest:	Hill-and-ridge: =0.5L_U if α_U < 0.3; otherwise =1.6H	368
	Cliff-and-escarpment: =1.5L_U if α_U < 0.3; otherwise =5H	(N.A.)
Site within influence distance from crest?	**Yes**	
Length of downwind slope $L_D = H/\alpha_D$ (m)		657
Effective slope α_e (If α_U < 0.3, $\alpha_e = \alpha_U$; otherwise α_e = 0.3)		0.30
Effective slope length L_e (If α_U < 0.3, $L_e = L_U$; otherwise $L_e = H/0.3$) (m)		767
X/L_D (for hill and ridge)		0.304
X/L_e (for cliff and escarpment)		(N.A.)

Topography factor S_a for height z above ground

Height above ground z(m)	Wind direction A (upwind on building) X/L_U = -0.350 (hill-and-ridge)			Wind direciton B (downwind on building) X/L_D = 0.304 (hill-and-ridge)		
	z/L_e	s	$S_a = (1+1.2\alpha_e s)^2$	z/L_e	s	$S_a = (1+1.2\alpha_e s)^2$
5	0.006	0.44	1.34	0.007	0.51	1.40
30	0.036	0.44	1.34	0.039	0.51	1.40
50	0.060	0.44	1.34	0.065	0.51	1.40
78	0.094	0.44	1.34	0.102	0.51	1.40
81	0.097	0.44	1.34	0.106	0.50	1.39
87	0.104	0.43	1.33	0.113	0.50	1.39
90	0.108	0.43	1.33	0.117	0.49	1.38
99	0.119	0.41	1.32	0.129	0.49	1.38
102	0.122	0.41	1.32	0.133	0.48	1.38
108	0.130	0.40	1.31	0.141	0.48	1.38

Calculation sheet B1 – Building B: Topography of site along X

Calculation sheet for dynamic magnification factor G		
Particulars	Wind along X-direction	Wind along Y-direction
Height of building h (m)	108	108
Breadth of building b (m)	34	20
Fundamental natural frequency of building n_a (taken as $46/h$) (Hz)	0.43	0.43
Damping ratio of the fundamental mode ζ (reinforced concrete)	2.0%	2.0%
Hourly mean velocity at top of building $\overline{V}_h = 59.5 \times \left(\frac{h}{500}\right)^{0.11}$	50.3	50.3
Turbulence intensity at top of building $I_h = 0.1055 \times \left(\frac{h}{90}\right)^{-011}$	0.1034	0.1034
Effective turbulence length scale $L_h = 1000 \times \left(\frac{h}{10}\right)^{0.25}$	1813	1813
Background factor $B = \frac{1}{1 + \frac{\sqrt{36h^2 + 64b^2}}{L_h}}$	0.721	0.731
Size factor $S = \frac{1}{\left(1 + \frac{3.5 n_a h}{\overline{V}_h}\right)\left(1 + \frac{4 n_a b}{\overline{V}_h}\right)}$	0.111	0.142
Effective reduced frequency $N = \frac{n_a L_h}{\overline{V}_h}$	15.360	15.360
Wind energy spectrum $E = \frac{0.47N}{(2+N)^{5/6}}$	0.0755	0.0755
Peak factor for background response g_v (taken as 3.7)	3.7	3.7
Peak factor for resonance response $g_f = \sqrt{2 \log_e (3600\, n_a)}$	3.830	3.830
Dynamic magnification factor $G = 1 + 2I_h \sqrt{g_v^2 B + \frac{g_f^2 SE}{\zeta}}$	**1.83**	**1.87**

Calculation sheet B2 – Building B: Dynamic magnificaion factor

Calculation sheet for wind forces acting on building - wind along and opposite to X-direction

Resonant dynamic response is significant (height > 100m) Dynamic magnification factor G = 1.83

Determination of force coefficient C_f

Part	h (m)	b (m)	d (m)	h/b	b/d	C_h	C_s	C_f
3/F-Roof (tower)	93	34	20	2.74	1.70	1.018	1.070	1.090
G-3/F (podium)	15	40	50	0.38	0.80	0.950	1.000	0.950

Note:

(1) A_z = 0.5 x(effective projected area of storey above level z + effective projected area of storey below level z)

(2) $F_z = GC_fS_a\overline{q}_zA_z$

Level ref.	P.D. level (m)	Wind along X-direction (uphill): Height above ground z (m)	Effective projected area A_z (Note 1) (m^2)	Design hourly mean wind pressure $\overline{q}_z$ (kPa)	Topo-graphy factor S_a	Wind force at height z F_z (Note 2) (kN)	Wind opposite to X-direction (downhill): Height above ground z (m)	Effective projected area A_z (Note 1) (m^2)	Design hourly mean wind pressure $\overline{q}_z$ (kPa)	Topo-graphy factor S_a	Wind force at height z F_z (Note 2) (kN)
Roof	+273.0	108.0	60.0	1.52	1.32	240.1	93.0	60.0	1.47	1.38	242.6
33F	+270.0	105.0	120.0	1.51	1.32	477.0	90.0	120.0	1.46	1.38	481.7
32F	+267.0	102.0	120.0	1.50	1.33	477.4	87.0	120.0	1.45	1.39	481.5
31F	+264.0	99.0	120.0	1.49	1.33	474.2	84.0	120.0	1.44	1.39	477.8
30F	+261.0	96.0	120.0	1.48	1.33	471.0	81.0	120.0	1.43	1.39	474.0
29F	+258.0	93.0	120.0	1.47	1.34	471.4	78.0	120.0	1.41	1.40	473.5
28F	+255.0	90.0	120.0	1.46	1.34	468.1	75.0	120.0	1.40	1.40	469.4
27F	+252.0	87.0	120.0	1.45	1.34	464.9	72.0	120.0	1.39	1.40	465.2
26F	+249.0	84.0	120.0	1.44	1.35	465.2	69.0	120.0	1.38	1.40	460.9
25F	+246.0	81.0	120.0	1.43	1.34	458.5	66.0	120.0	1.36	1.40	456.4
24F	+243.0	78.0	120.0	1.41	1.34	452.1	63.0	120.0	1.35	1.40	451.8
23F	+240.0	75.0	120.0	1.40	1.34	448.9	60.0	120.0	1.33	1.40	446.9
22F	+237.0	72.0	120.0	1.39	1.34	445.7	57.0	120.0	1.32	1.40	441.9
21F	+234.0	69.0	120.0	1.38	1.34	442.5	54.0	120.0	1.30	1.40	436.7
20F	+231.0	66.0	120.0	1.36	1.34	436.1	51.0	120.0	1.29	1.40	431.2
19F	+228.0	63.0	120.0	1.35	1.34	432.9	48.0	120.0	1.27	1.40	425.5
18F	+225.0	60.0	120.0	1.33	1.34	426.5	45.0	120.0	1.25	1.40	419.5
17F	+222.0	57.0	120.0	1.32	1.34	423.3	42.0	120.0	1.23	1.40	413.2
16F	+219.0	54.0	120.0	1.30	1.34	416.8	39.0	120.0	1.21	1.40	406.5
15F	+216.0	51.0	120.0	1.29	1.34	413.6	36.0	120.0	1.19	1.40	399.4
14F	+213.0	48.0	120.0	1.27	1.34	407.2	33.0	120.0	1.17	1.40	391.9
13F	+210.0	45.0	120.0	1.25	1.34	400.8	30.0	120.0	1.15	1.40	383.7
12F	+207.0	42.0	120.0	1.23	1.34	394.4	27.0	120.0	1.12	1.40	374.9
11F	+204.0	39.0	120.0	1.21	1.34	388.0	24.0	120.0	1.09	1.40	365.3
10F	+201.0	36.0	120.0	1.19	1.34	381.6	21.0	120.0	1.06	1.40	354.8
9F	+198.0	33.0	120.0	1.17	1.34	375.2	18.0	120.0	1.02	1.40	342.9
8F	+195.0	30.0	120.0	1.15	1.34	368.7	15.0	120.0	0.98	1.40	329.5
7F	+192.0	27.0	120.0	1.12	1.34	359.1	12.0	120.0	0.94	1.40	313.7
6F	+189.0	24.0	120.0	1.09	1.34	349.5	9.0	120.0	0.88	1.40	294.4
5F	+186.0	21.0	120.0	1.06	1.34	339.9	6.0	120.0	0.80	1.40	269.3
4F	+183.0	18.0	120.0	1.02	1.34	327.1	3.0	120.0	0.77	1.40	258.0
3F	+180.0	15.0	60.0	0.98	1.34	157.1	0.0	60.0	0.77	1.40	129.0
P3F	+180.0	15.0	100.0	0.98	1.34	228.3					
P2F	+175.0	10.0	200.0	0.90	1.34	419.3					
P1F	+170.0	5.0	200.0	0.77	1.34	358.8					
G	+165.0	0.0	100.0	0.77	1.34	179.4					

Calculation sheet B3 – Building B: Total force on building (wind along and opposite to X-direction)

Calculation sheet for wind forces acting on building - wind along and opposite to Y-direction

Resonant dynamic response is significant (height > 100m) Dynamic magnification factor G = 1.87

Determination of force coefficient C_f

Part	h (m)	b (m)	d (m)	h/b	b/d	C_h	C_s	C_f
3/F-Roof (tower)	93	20	34	4.65	0.59	1.066	1.000	1.066
G-3/F (podium)	15	50	40	0.30	1.25	0.950	1.025	0.974

Note:

(1) A_z = 0.5 x(effective projected area of storey above level z + effective projected area of storey below level z)

(2) $F_z = GC_fS_a\bar{q}_zA_z$

Level ref.	P.D. level (m)	Wind along Y-direction: Height above ground z (m)	Effective projected area A_z (Note 1) (m²)	Design hourly mean wind pressure $\bar{q}_z$ (kPa)	Topography factor S_a	Wind force at height z F_z (Note 2) (kN)	Wind opposite to Y-direction: Height above ground z (m)	Effective projected area A_z (Note 1) (m²)	Design hourly mean wind pressure $\bar{q}_z$ (kPa)	Topography factor S_a	Wind force at height z F_z (Note 2) (kN)
Roof	+273.0	108.0	30.0	1.52	1.00	90.9	Same as wind along Y-direction				
33F	+270.0	105.0	60.0	1.51	1.00	180.6					
32F	+267.0	102.0	60.0	1.50	1.00	179.4					
31F	+264.0	99.0	60.0	1.49	1.00	178.3					
30F	+261.0	96.0	60.0	1.48	1.00	177.1					
29F	+258.0	93.0	60.0	1.47	1.00	175.9					
28F	+255.0	90.0	60.0	1.46	1.00	174.7					
27F	+252.0	87.0	60.0	1.45	1.00	173.5					
26F	+249.0	84.0	60.0	1.44	1.00	172.3					
25F	+246.0	81.0	60.0	1.43	1.00	171.1					
24F	+243.0	78.0	60.0	1.41	1.00	168.7					
23F	+240.0	75.0	60.0	1.40	1.00	167.5					
22F	+237.0	72.0	60.0	1.39	1.00	166.3					
21F	+234.0	69.0	60.0	1.38	1.00	165.1					
20F	+231.0	66.0	60.0	1.36	1.00	162.7					
19F	+228.0	63.0	60.0	1.35	1.00	161.5					
18F	+225.0	60.0	60.0	1.33	1.00	159.1					
17F	+222.0	57.0	60.0	1.32	1.00	157.9					
16F	+219.0	54.0	60.0	1.30	1.00	155.5					
15F	+216.0	51.0	60.0	1.29	1.00	154.3					
14F	+213.0	48.0	60.0	1.27	1.00	151.9					
13F	+210.0	45.0	60.0	1.25	1.00	149.5					
12F	+207.0	42.0	60.0	1.23	1.00	147.1					
11F	+204.0	39.0	60.0	1.21	1.00	144.8					
10F	+201.0	36.0	60.0	1.19	1.00	142.4					
9F	+198.0	33.0	60.0	1.17	1.00	140.0					
8F	+195.0	30.0	60.0	1.15	1.00	137.6					
7F	+192.0	27.0	60.0	1.12	1.00	134.0					
6F	+189.0	24.0	60.0	1.09	1.00	130.4					
5F	+186.0	21.0	60.0	1.06	1.00	126.8					
4F	+183.0	18.0	60.0	1.02	1.00	122.0					
3F	+180.0	15.0	30.0	0.98	1.00	58.6					
P3F	+180.0	15.0	125.0	0.98	1.00	223.1					
P2F	+175.0	10.0	250.0	0.90	1.00	409.7					
P1F	+170.0	5.0	250.0	0.77	1.00	350.5					
G	+165.0	0.0	125.0	0.77	1.00	175.3					

Calculation sheet B4 – Building B: Total force on building (wind along and opposite to Y-direction)

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