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Comparative Review of Wind Design Codes for Gable Roof Buildings

Submitted in partial fulfilment for the degree of

Bachelor of Technology

In

Civil Engineering

By

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CERTIFICATE

This is to certify that the work entitled, **"comparative review of wind design codes for Gable roof buildings"** submitted by Ashutosh upadhyay-061633, Biral-061628 & Shubham Gupta-061620 in partial fulfilment for the award of degree of Bachelor of Technology in Civil Engineering of Jaypee University of Information Technology has been carried out under my supervision.

Dr. Rajesh Goyal Date: 27/05/10

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This work has not been submitted partially or wholly to any other university or institute for the award of this or any other degree or diploma.

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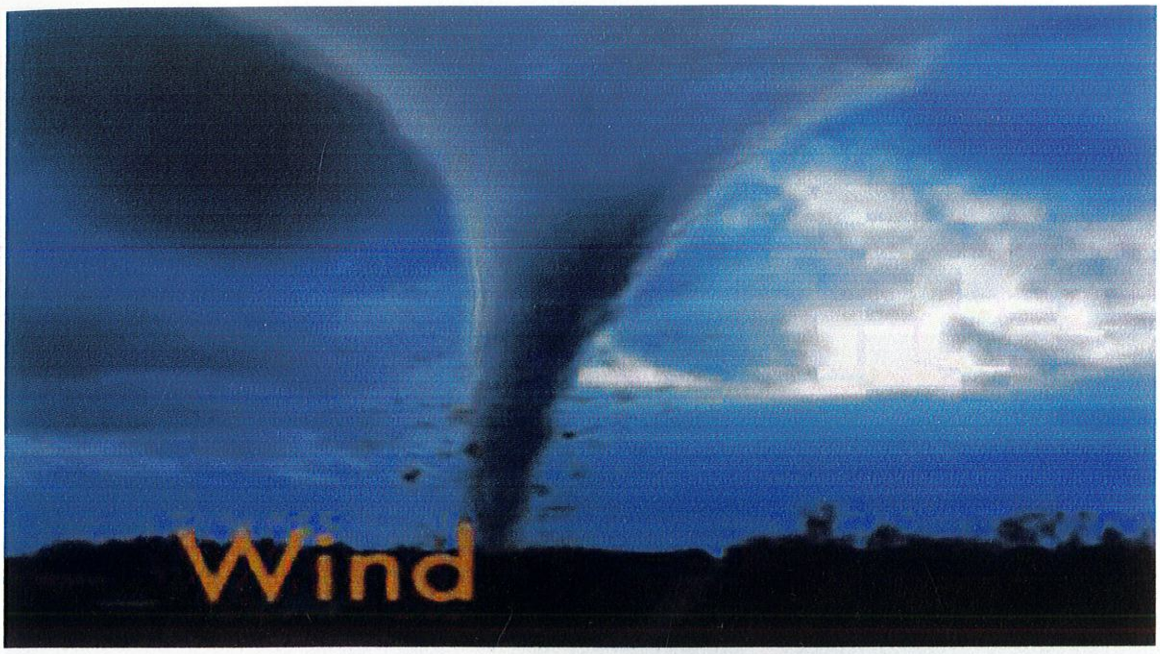
Synopsis

Wind is an important factor in the design of buildings located in the coastal areas & in those areas where annual average wind speed is above average level. For the design of wind resistance building wind codes are available, which are widely used by the designer around the world. Different countries like India, Australia and Japan have their separate wind code for design of wind resistant building in their territory. On analysing these wind codes erratic results were obtained which had brought the validity of these codes in shadows when applied universally. In recent study detail analysis of a particular type of structure is being carried out and differences in their way of designing, loading, parameters involved, basic wind speed etc. were tried to figure out. After the analysis it has been found out that Japanese code is least economical & European code is most economical whereas Indian code is moderately economical. On further analysis much more difference can be found out and a need for unified wind code which is globally feasible can be suggested.

CHAPTER-1



Origin of wind

Wind is simply the air in motion. We cannot actually see the air moving but we can measure its motion by the force that it applies on objects. Wind vane measures the wind direction. Anemometer measures the wind speed. Rising air is cool, often saturated, and can lead to clouds and precipitation. 'H' and 'L' indicate high and low pressure centres.

H = High

L = Low

Highs and lows are lines called isobar. Isobar means equal pressure. We connect these areas of equal pressure with a line. Everywhere along line is constant pressure. The closer the isobars are packed together the stronger the pressure gradient is.

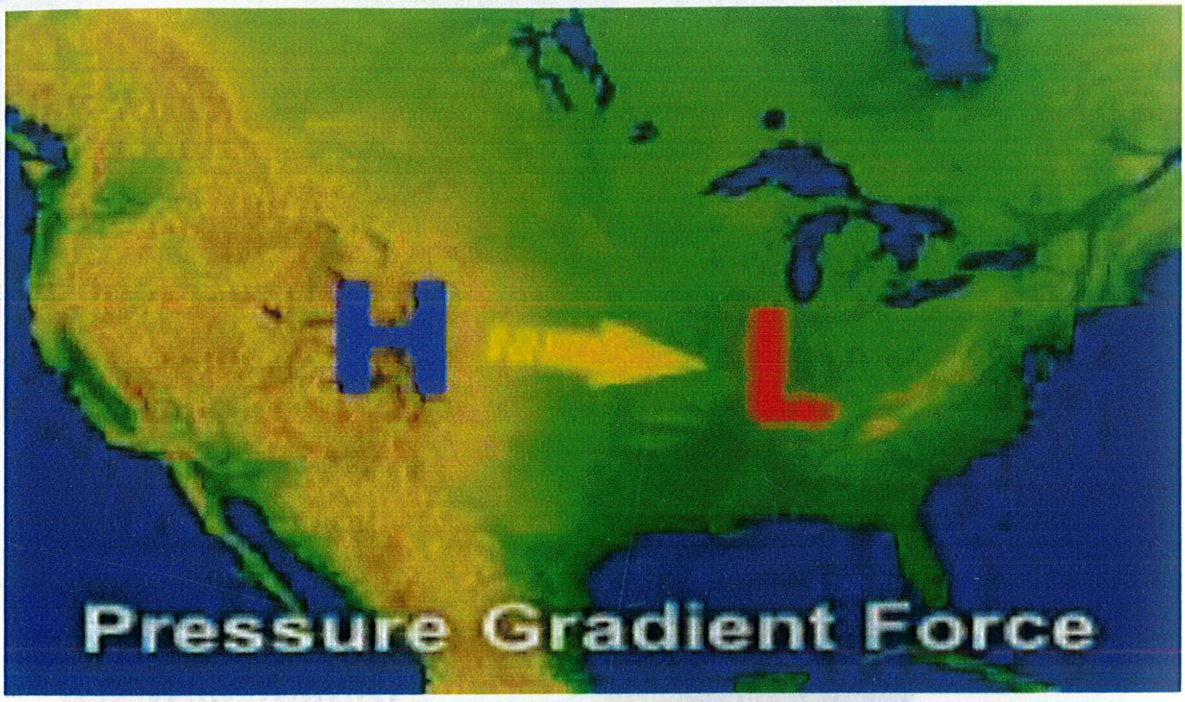
Pressure gradient is the difference in pressure between high and low pressure area. Wind speed is directly proportional to the pressure gradient. This means the strongest wind are in the areas where the pressure gradient is to the greatest.

Three forces cause the wind to move

1)Pressure gradient force(PGF)

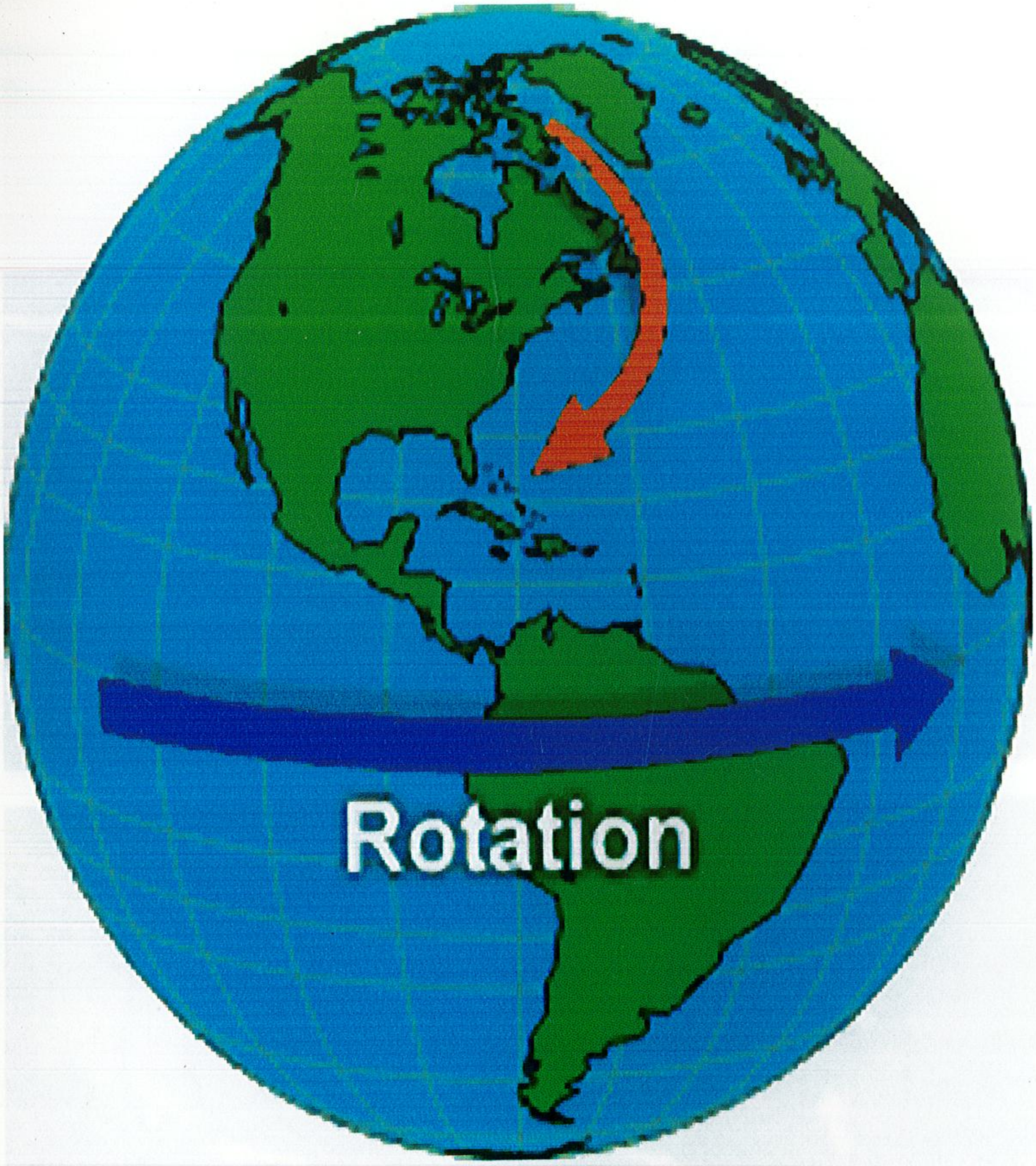
2)Coriolis force

3)Friction

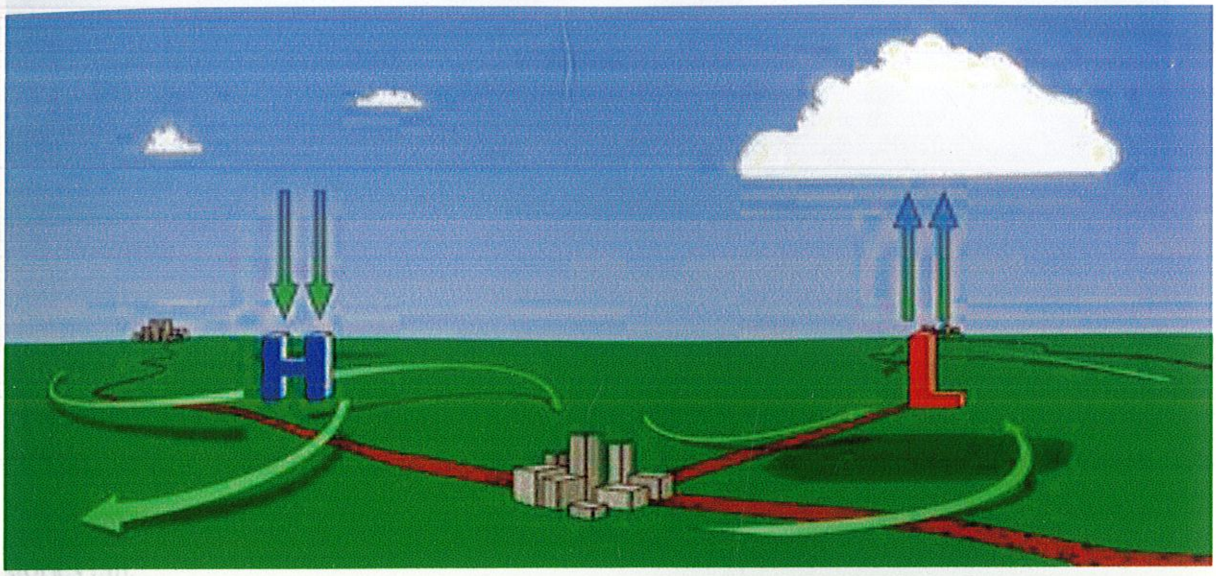


1) Pressure Gradient Force: A force that tries to equalize pressure difference. This is the force that causes high pressure to push air towards low pressure. Thus air would flow from high to low pressure.

2) Coriolis force: Due to rotation there is a second force called the coriolis force, which affects the direction of wind flow. This force is what causes objects in northern hemisphere to turn to the right. The combination of the two forces would cause the wind to flow parallel to straight isobars with high pressure on the right



3) Friction: It is the final component to determining the flow of the wind. The surface of the earth is rough and it not slow the wind down but it also causes the diverging wind from highs and converging winds near lows. A property called mass continuity state that mass cannot be created or destroyed in.a given area. So air cannot "pile up" at a given spot. It has to go somewhere so it is forced to rise.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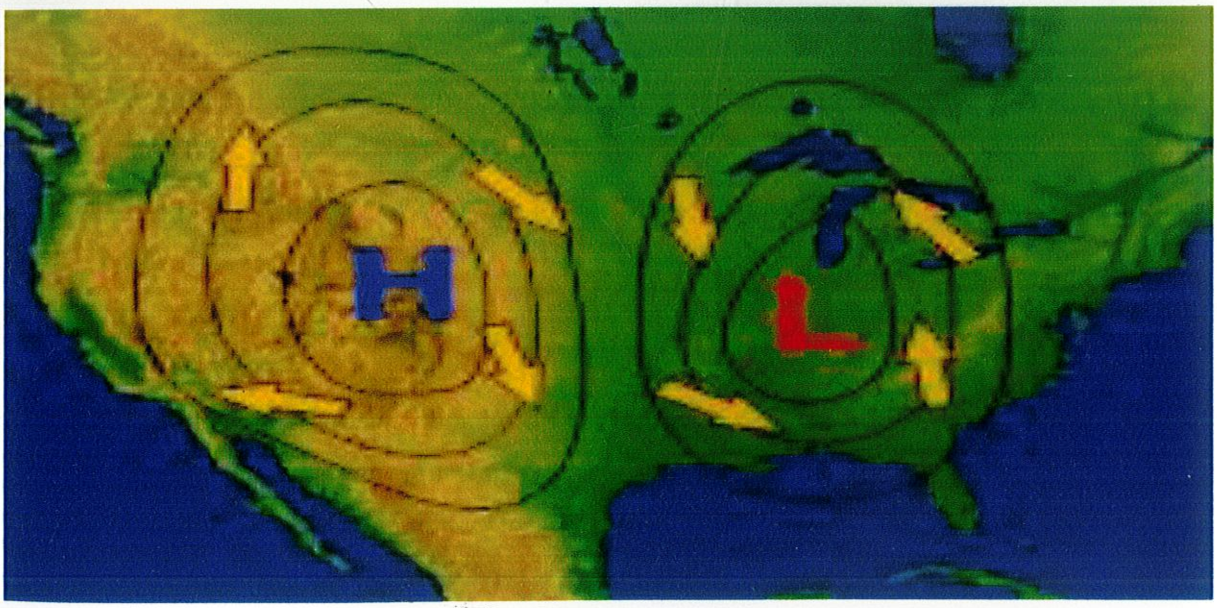
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Low rise buildings

A low – rise building is defined as any acceptable building which is divided at regular interval into occupant levels, which is lower than a high – rise. To be considered a low-rise building an edifice must be based on solid ground, and fabricated along its full height through deliberate processes and have at least one floor above ground. A low-rise building is only few stories tall.

There is no universally accepted height requirement for a building to be considered a low-rise. Some define the term as any building that is shorter than high-rise. Low-rise are enclosed structure below 35 metres which is divided into interior spaces. Any low-rise building with more than one disconnected interior space may only as a single building it was built as a single unit and if the separate from an architecturally integral unit.

Low – rise buildings are considered on the following criteria:-

1. Any building's housing commercial uses.
2. Building added at the request of a company.
3. Building of significant architectural interest.
4. Buildings which are especially prominent because of their size or position.

Low – rise residential buildings

Low-rise or residential buildings include the smallest buildings produced in large quantities. It shall mean a building up to the height of 16.50 metres and having a ground floor plus four floors. Hollow plinth up to 2.8 metres and a parapet on terrace up to 1.5 metres shall not be counted. Single-family detached houses for example are in the walk-up range of one to three stories and typically meet their users need with about 90 to 180 square meters (1000 to 2000 square feet). Other example includes the urban row house and walk-up apartment buildings.

Low – rise commercial, institutional and industrial buildings

The size of buildings in the commercial, institutional and industrial market segment ranges from a few hundred to as much as 45,000 square metres (500 000 square feet). All of these buildings have public access and exit requirement although their populations may differ considerably in density. The unit costs are generally higher than those for dwellings are.

Characteristics of low – rise buildings

Low-rise apartments sometimes offer more privacy and negotiability of rent and utilities than high-rise apartments, although they may have fewer amenities and less flexibility with leases. It is also easier to put out fires in low-rise buildings while less luxurious than high-rises. Some businesses prefer low-rise buildings due to lower costs and more usable space. Having all employees on a single floor may also increase work productivity.

CHAPTER-2

LITERATURE REVIEW

IS 875 Part-3

This Indian Standard (Part 3) (Second Revision) was adopted by the Bureau of Indian Standards on 13 November 1987, after the draft finalized by the Structural Safety Sectional Committee had been approved by the Civil Engineering Division Council.

This standard was first published in 1957 for the guidance of civil engineers, designers and architects associated with the planning and design of buildings. It included the provisions for the basic design loads (dead loads, live loads, wind loads and seismic loads) to be assumed in the design of the buildings. In its first revision in 1964, the wind pressure provisions were modified on the basis of studies of wind phenomenon and its effect on structures, undertaken by the special committee in consultation with the Indian Meteorological Department. In addition to this, new clauses on wind loads for butterfly type structures were included; wind pressure coefficients for sheeted roofs, both curved and sloping were modified; seismic load provisions were deleted (separate code having been prepared) and metric system of weights and measurements was adopted.

Terminology

For the purpose of this code, the following definitions shall apply.

Angle of Attack -Angle between the direction of wind and a reference axis of the structure,

Breadth - Breadth means horizontal dimension of the building measured normal to the direction of wind.

Depth - Depth means the horizontal dimension of the building measured in the direction of the wind.

Developed Height - Developed height is the height of upward penetration of the velocity profile in a new terrain. At large fetch lengths, such penetration reaches the gradient height, above which the wind speed may be taken to be constant. At lesser fetch lengths, a velocity profile of a smaller height but similar to that of the fully developed profile of that terrain category has to be taken, with the additional provision that the velocity at the top of this shorter profile equals that of the un penetrated earlier velocity profile at that height.

Effective Frontal Area - The projected area of the structure is normal to the direction of the wind.

Element of Surface Area - The area of surface over which the pressure coefficient is taken to be constant.

Force Coefficient - A non-dimensional coefficient such that the total wind force on a body is the product of the force coefficient, the dynamic pressure of the incident design wind speed and the reference area over which the force is required.

Ground Roughness - The nature of the earth's surface as influenced by small scale obstructions such as trees and buildings (as distinct from topography) is called ground roughness.

Gust - A positive or negative departure of wind speed from its mean value, lasting for not more than, say, 2 minutes over a specified interval of time.

Peak Gust - Peak gust or peak gust speed is the wind speed associated with the maximum amplitude.

Fetch Length - Fetch length is the distance measured along the wind from a boundary at which a change in the type of terrain occurs. When the changes in terrain types are encountered (such as, the boundary of a town or city, forest, etc), the wind profile changes in character but such changes are gradual and start at ground level, spreading or penetrating upwards with increasing fetch length.

Gradient Height- Gradient height is the height above the mean ground level at which the gradient wind blows as a result of balance among pressure gradient force, coriolis force and centrifugal force. For the purpose of this code, the gradient height is taken as the height above the mean ground level, above which the variation of wind speed with height need not be considered.

Mean ground Level - The mean ground level is the average horizontal plane of the area enclosed by the boundaries of the structure.

Pressure Coefficient - Pressure coefficient is the ratio of the difference between the pressure acting at a point on a surface and the static pressure of the incident wind to the design wind pressure, where the static and design wind pressures are determined at the height of the point considered after taking into account the geographical location, terrain conditions and shielding effect. The pressure coefficient is also equal to $[1 - (V_P/V_z)^2]$ where V_P is the actual wind speed at any point on the structure at a height corresponding to that of V_z.

Wind Speed and Pressure

Nature of Wind in Atmosphere – In general, wind speed in the atmospheric boundary layer increases with height from zero at ground level to a maximum at a height called the gradient height. There is usually a slight change in direction (Ekman effect) but this is ignored in the code. The variation with height depends primarily on the terrain conditions. However, the wind speed at any height never remains constant and it has been found convenient to resolve its instantaneous magnitude into an average or mean value and a fluctuating component around this

Basic Wind Speed – In India basic wind speed is applicable to 10 m height above mean ground level for different zones of the country. Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3 seconds and corresponds to mean heights above ground level in an open terrain. Basic wind speeds have been worked out for a **50** year return period.

Design Wind Speed (V_Z) - Design wind speed up to IO m height from mean ground level is considered constant .The basic wind speed (V_b) for any site shall be obtained and be modified to include the following effects to get design wind velocity at any height (V_z) for the chosen structure:

a) Risk level;

b) Terrain roughness, height and size of structure; and

c) Local topography.

It can be mathematically expressed as follows:

Where,

$v_z = v_b k_1 k_2 k_3$

V_b = design wind speed at any height z in m/s;

K_1 = probability factor (risk coefficient);

K_2= terrain, height and structure size factor; and

K_3= topography factor

Design Wind Pressure - The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind

Velocity:

$p_z = 0.6\ v_z^2$

The coefficient 0.6 (in SI units) in the above formula depends on a number of factors and mainly on the atmospheric pressure and air temperature. The value chosen corresponds to the average appropriate Indian atmospheric conditions

Where,

p_z = design wind pressure in N/ms at

Height z, and

v_z = design wind velocity in m/s at height

Pressure Coefficients –

The pressure coefficients are always given for a particular surface or part of the surface of a building. The wind load acting normal to a surface is obtained by multiplying the area of that surface or its appropriate portion by the pressure coefficient (C,) and the design wind pressure at the height of the surface from the ground.

Wind Load on Individual Members –

When calculating the wind load on individual structural elements such as roofs and walls, and individual cladding units and their fittings, it is essential to take account of the pressure difference between opposite faces of such elements or units. For clad structures, it is, therefore, necessary to know the internal pressure as well as the external pressure.

$F = (Cpe - Cp_i)Ap_a$

Where

F=wind load

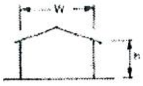
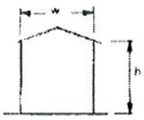
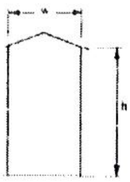
Cp_e = external pressure coefficient,

Cp_i = internal pressure- coefficient,

A = surface area of structural or cladding unit, and

p_a= design wind pressure.

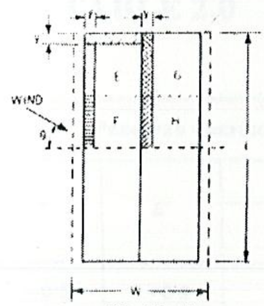
Table 1 External pressure coefficient (C_{pe}) for walls of rectangular clad building with pitched roofs

Building Height Ratio		Roof Angle α	Wind Angle θ 0° EF	Wind Angle θ 0° GH	Wind Angle θ 90° EG	Wind Angle θ 90° FH	Local Coefficients (zone 1)	Local Coefficients (zone 2)	Local Coefficients (zone 3)	Local Coefficients (zone 4)
		degrees								
$\frac{h}{w} \leq \frac{1}{2}$		0	−0·8	−0·4	−0·8	−0·4	−2·0	2·0	−2·0	—
		5	−0·9	−0·4	−0·8	−0·4	−1·4	−1·2	−1·2	−1·0
		10	−1·2	−0·4	−0·8	−0·6	−1·4	−1·4		−1·2
		20	−0·4	−0·4	−0·7	−0·6	−1·0			−1·2
		30	0	−0·4	−0·7	−0·6	−0·8			−1·1
		45	+0·3	−0·5	−0·7	−0·6				−1·1
		60	+0·7	−0·6	−0·7	−0·6				−1·1
$\frac{1}{2} < \frac{h}{w} \leq \frac{3}{2}$		0	−0·8	−0·6	−1·0	−0·6	−2·0	−2·0	−2·0	—
		5	−0·9	−0·6	−0·9	−0·6	−2·0	−2·0	−1·5	−1·0
		10	−1·1	−0·6	−0·8	−0·6	−2·0	−2·0	−1·5	−1·2
		20	−0·7	−0·5	−0·8	−0·6	−1·5	−1·5	−1·5	−1·0
		30	−0·2	−0·5	−0·8	−0·8	−1·0			−1·0
		45	+0·2	−0·5	−0·8	−0·8				
		60	+0·6	−0·5	−0·8	−0·8				
$\frac{3}{2} < \frac{h}{w} < 6$		0	−0·7	−0·6	−0·9	−0·7	−2·0	−2·0	−2·0	—
		5	−0·7	−0·6	−0·8	−0·8	−2·0	−2·0	−1·5	−1·0
		10	−0·7	−0·6	−0·8	−0·8	−2·0	−2·0	−1·5	−1·2
		20	−0·8	−0·6	−0·8	−0·8	−1·5	−1·5	−1·5	−1·2
		30	−1·0	−0·5	−0·8	−0·7	−1·5			
		40	−0·2	−0·5	−0·8	−0·7	−1·0			
		50	+0·2	−0·5	−0·8	−0·7				
		60	+0·5	−0·5	−0·8	−0·7				

NOTE 1 — h is the height to eaves or parapet and w is the lesser horizontal dimension of a building.

NOTE 2 — Where no local coefficients are given, the overall coefficients apply.

NOTE 3 — For hipped roofs the local coefficient for the hip ridge may be conservatively taken as the appropriate ridge value.

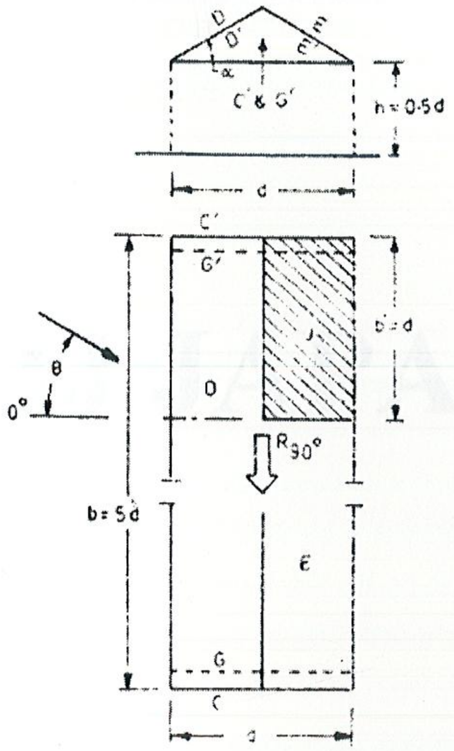


KEY PLAN

$y = h$ or $0.15\,w$, whichever is the lesser.

figure 1 **PRESSURE COEFFICIENTS (TOP AND BOTTOM) FOR PITCHED ROOFS, $\alpha = 30°$**

(*Clause* 6.2.2.4)



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Roof slope $\alpha = 30°$
$\theta = 0° - 45°$, D, D', E, E' full length
$\theta = 90°$, D, D', E, E' part length b', thereafter $C_p = 0$

TABLE 2.0

θ	Pressure Coefficients, C_p							
					End Surfaces			
	D	D'	E	E'	C	C'	G	G'
0	0·6	−1·0	−0·5	−0·9				
45°	0·1	−0·3	−0·6	−0·3				
90°	−0·3	−0·4	−0·3	−0·4	−0·3	0·8	0·3	0·4
45°	For j : C_p top = −1·0; C_p bottom = −0·2							
90°	Tangentially acting friction: $R_{90°} = 0·05\ p_d bd$							

AIJ JAPAN

Wind loads

Each wind load is determined by a probabilistic-statistical method based on the concept of "equivalent static wind load", on the assumption that structural frames and components/cladding behave elastically in strong wind. Mean wind force based on the mean wind speed and fluctuating wind force based on a fluctuating flow field act on a building. The effect of fluctuating wind force on a building or part thereof depends not only on the characteristics of fluctuating wind force but also on the size and vibration characteristics of the building or part thereof. These recommendations evaluate the maximum loading effect on a building due to fluctuating wind force by a probabilistic-statistical method, and calculate the static wind load that gives the equivalent effect. The design wind load can be obtained from the summation of this equivalent static wind load and the mean wind load.

Wind loads on structural frames and wind loads on components/cladding

The wind loads provided in these recommendations is composed of those for structural frames and those for components/cladding. The former are for the design of structural frames such as columns and beams. The latter are for the design of finishing and bedding members of components/cladding and their joints. Wind loads on structural frames and on components/cladding are different, because there are large differences in their sizes, dynamic characteristics and dominant phenomena and behaviours. Wind loads on structural frames are calculated on the basis of the elastic response of the whole building against fluctuating wind forces. Wind loads on components/cladding are calculated on the basis of fluctuating wind forces acting on a small part.

Wind force coefficients and wind pressure coefficients

Wind force coefficients and wind pressure coefficients fall into two categories corresponding to the design of the structural frames and components/claddings. The coefficients shall be estimated from wind tunnel experiments or from the following procedure using the wind pressure coefficients (external and internal pressure coefficients) and wind force coefficients provided in this clause.

Procedure for estimating wind force coefficients

1) Wind force coefficients for design of structural frames

2) Wind force coefficients for estimating horizontal wind loads on structural frames DC

3) Wind force coefficients are calculated using the external pressure coefficients

Roof Wind Load on Structural Frames

Roof wind loads on structural frames are calculated from

$W_R = q_H C_R G_R A_R$

Where,

W_R(N): wind load

q_H(N/m^2): design velocity pressure as defined

C_R: wind force coefficient as defined

G_R: gust effect factor for roof wind load as defined

A_R(m^2): subject area

The design velocity pressure, q_H(N/m), is calculated from:

$q_H=(1\backslash 2)\ \rho.U_H^2$

where,

ρ (kg/m^3): air density, assumed

U_H (m/s): design wind speed, which depends on wind direction

Design wind speed, U_H(m/s), is calculated for each wind direction from:

$U_H=U_0K_DE_HK_{R,W}$

Where,

U_0: basic wind speed (m/s) depending on the geographic location of the construction site, as defined

K_D: wind directionality factor as defined.

E_H: wind speed profile factor at reference height H defined

K_{RW}: return period conversion factor

Wind speed profile factor

Wind speed profile factor E is calculated from:

$E=E_RE_G$

Where,

E_R: exposure factor for flat terrain categories,

E_G: topography factor defined

Exposure factor based on flat terrain categories

$E_R = 1.7(Z\backslash Z_G)^{\alpha}$

Z(m): height above ground

Z_G, α: parameters determining the exposure factor

Wind force coefficients for estimating roof wind loads on structural frames

Wind force coefficients are calculated using the external pressure coefficients and the internal pressure coefficients:

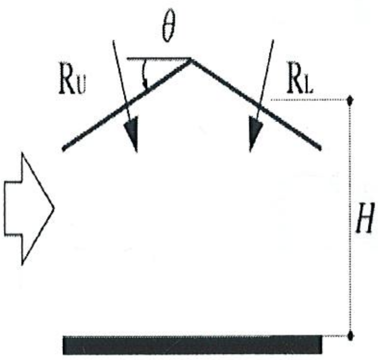
$C_d = C_{pe1} - C_{pe2}$

C_{pe1} = Ext. pressure coefficient on windward side.

C_{pe2} = Ext. pressure coefficient on leeward side.

Wind force coefficient C_R for free roofs with rectangular base

roof angle θ (°)	windward roof R_U		leeward roof R_L	
	positive	negative	positive	negative
$-30 \leq \theta \leq -10$	$0.7+0.01\theta$	$-0.6+0.03\theta$	$0.05-0.025\theta$	$-1.2-0.03\theta$
$-10 < \theta < 10$	0.6	-0.9	0.3	-0.9
$10 \leq \theta \leq 30$	$0.3+0.03\theta$	$-1.15+0.025\theta$	0.3	$-0.6-0.03\theta$



H(m): reference height

θ (°): roof angle

Positive indicates downwards.

Pressure coefficient C_p for free roofs with rectangular base

Table 3

EURO CODE

This European Standard has been prepared by Technical Committee CEN/TC250 "Structural Euro codes ", the Secretariat for which is held by BSI.

Background of the Euro code programme

In 1975, the Commission of the European Community decided on an action programme in the field of construction based on article 95 of the Treaty. The objective of the programme was the elimination of technical obstacles to trade and the harmonisation of technical specifications.

Definitions

Fundamental basic wind velocity

Exceeded of 0, 02, irrespective of wind direction, at a height of 10 m above flat open country terrain and accounting for altitude effects (if required) The 10 minute mean wind velocity with an annual risk of being

Basic wind velocity

The fundamental basic wind velocity modified to account for the direction of the wind being considered.

Mean wind velocity

The basic wind velocity modified to account for the effect of terrain roughness and orography

Pressure coefficient

External pressure coefficients give the effect of the wind on the external surfaces of buildings; internal pressure coefficients give the effect of the wind on the internal surfaces of buildings. The external pressure coefficients are divided into overall coefficients and local coefficients. Local coefficients give the pressure coefficients for loaded areas of 1 m^2 or less e.g. for the design of small elements and fixings; overall coefficients give the pressure coefficients for loaded areas larger than 10 m^2 .Net pressure coefficients give the resulting effect of the wind on a structure, structural element or component per unit area.

Force coefficient

Force coefficients give the overall effect of the wind on a structure, structural element or component as a whole, including friction, if not specifically excluded

Design situations

(1) The relevant wind actions shall be determined for each design situation identified in accordance with EN 1990, 3.2.

(2) In accordance with EN 1990, 3.2 (3) other actions (such as snow, traffic or ice) which will modify the effects due to wind should be taken into account.

(3) In accordance with EN 1990, 3.2 (3), the changes to the structure during stages of execution (such as different stages of the form of the structure, dynamic characteristics, etc.), which may modify the effects due to wind, should be taken into account.

Wind velocity and velocity pressure

Basis for calculation

(1) The wind velocity and the velocity pressure are composed of a mean and a fluctuating component. The mean wind velocity v_m should be determined from the basic wind velocity v_b which depends on the wind climate as described in 4.2, and the height variation of the wind determined from the terrain roughness andorography . The peak velocity pressure is determined.

Basic values

The fundamental value of the basic wind velocity, $v_{b,0}$, is the characteristic 10 minutes mean wind velocity, irrespective of wind direction and time of year, at 10 m above ground level in open country terrain with low vegetation such as grass and isolated obstacles with separations of at least 20 obstacle heights.

The basic wind velocity shall be calculated from Expression

$V_b = C_{dir} C_{season} V_{b0}$

V_{b0} = fundamental value of basic wind velocity taken as 44m/s

V_{b0}= recommended value = 1

C_{season} = recommended value = 1

.

Mean wind

Variation with height

It depends on the terrain roughness and orography and on the basic wind velocity, v_b, and should be determined using Expression

$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b$$

Where:

$v_m(z)$ is the mean wind velocity at a height z above the terrain

$c_r(z)$ is the roughness factor, $c_o(z)$ is the orography factor, taken as 1, 0 unless otherwise specified. The influence of neighbouring structures on the wind velocity should be considered.

Wind pressure on surfaces

The wind pressure acting on the external surfaces, w_e, should be obtained from Expression

$$w_e = q_p(z_e) \cdot c_{pe}$$

where:

$q_p(z_e)$ = is the peak velocity pressure

z_e = is the reference height for the external pressure

c_{pe} = is the pressure coefficient for the external pressure

The wind pressure acting on the internal surfaces of a structure, w_i, should be obtained from Expression

$$w_i = q_p(z_i) \cdot c_{pi}$$

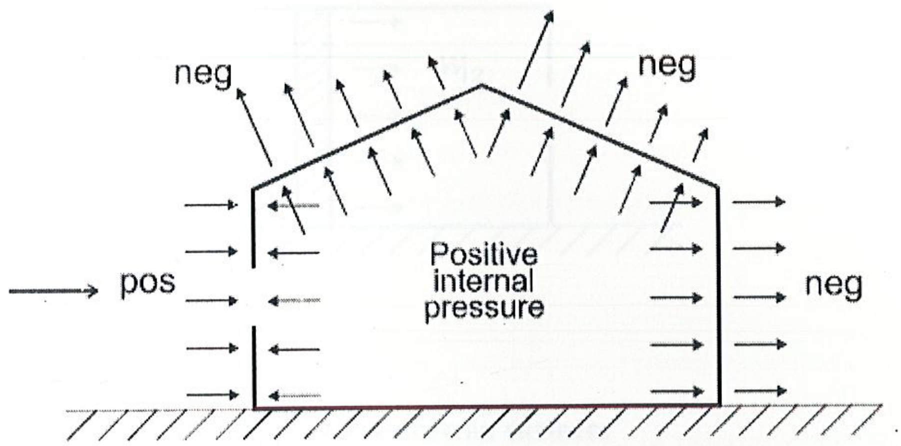
Where:

$q_p(z_i)$ = is the peak velocity pressure

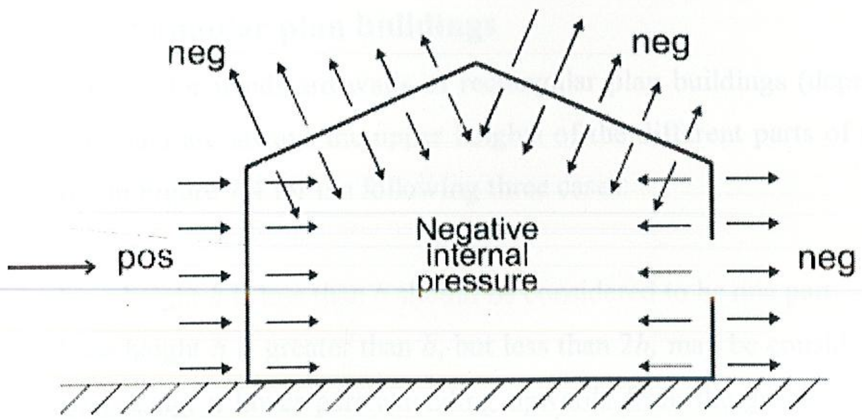
z_i = reference height for the internal pressure

c_{pi} = pressure coefficient for the internal pressure

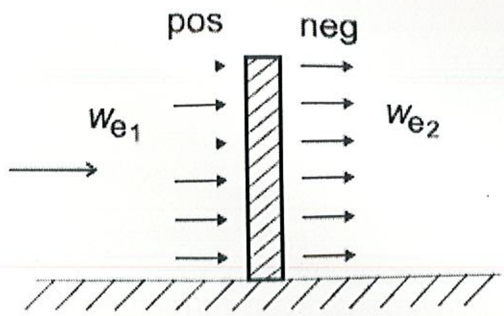
The net pressure on a wall, roof or element is the difference between the pressures on the opposite surfaces taking due account of their signs. Pressure, directed towards the surface is taken as positive, and suction, directed away from the surface as negative.



(a)



(b)



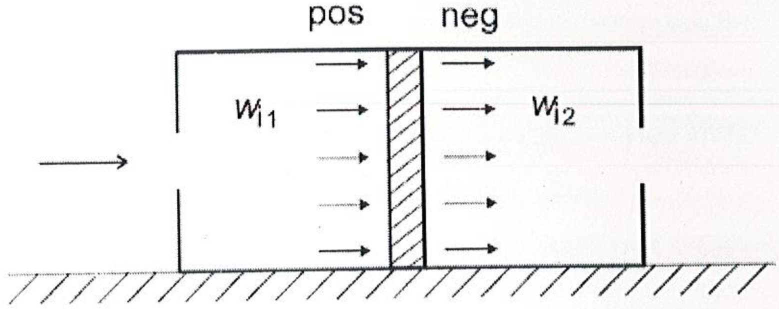


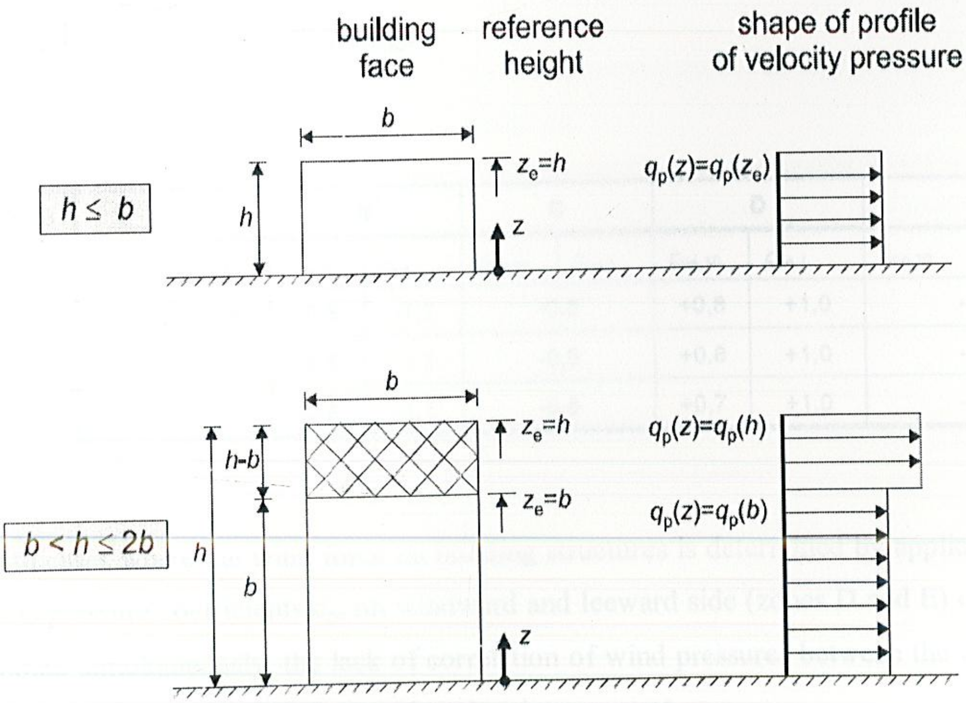
Figure 2 Pressure on surfaces

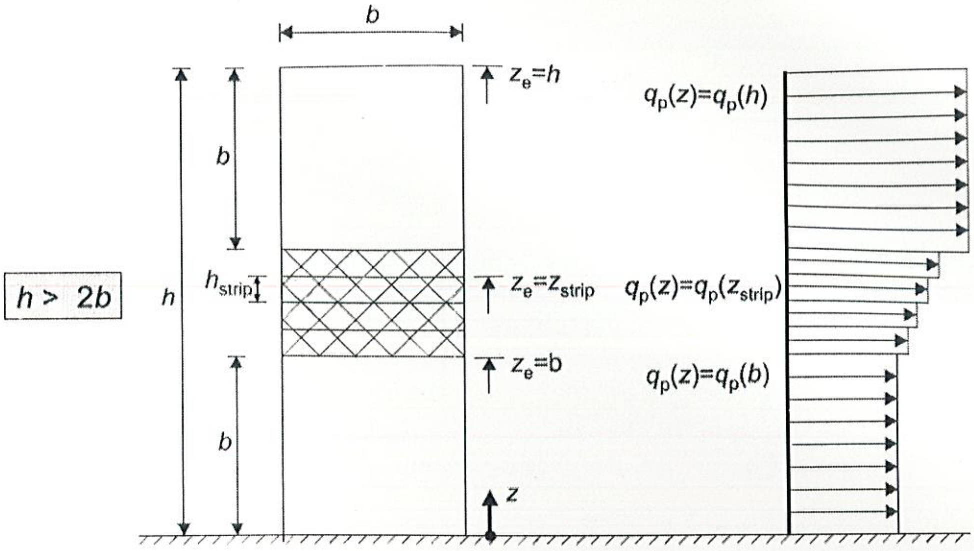
Vertical walls of rectangular plan buildings

The reference heights, z_e, for windward walls of rectangular plan buildings (depend on the aspect ratio *h/b* and are always the upper heights of the different parts of the walls. They are given in Figure 7.4 for the following three cases:

- A building, whose height *h* is less than *b* should be considered to be one part.
- A building, whose height *h* is greater than *b*, but less than 2*b*, may be considered to be two parts, comprising: a lower part extending upwards from the ground by a height equal to *b* and an upper part consisting of the remainder.A building, whose height *h* is greater than 2*b* may be considered to be in multiple parts, comprising: a

lower part extending upwards from the ground by a height equalo b; an upper part extending downwards from the top by a height equal to b and a middle region, between the upper and lower parts, which may be divided into horizontal strips with a height h strip as shown in Figure 2.





NOTE The velocity pressure should be assumed to be uniform over each horizontal strip considered.

Reference height, z_e, depending on h and b, and corresponding velocity pressure profile

Figure -3

(2) The external pressure coefficients C_{pe},10 and Cpe,1 for zone A, B, C, D and E are defined in figure 1.2

Table 4 — Recommended values of external pressure coefficients for vertical walls of rectangular plan buildings

Zone	A		B		C		D		E	
h/d	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
≤ 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

(3) In cases where the wind force on building structures is determined by application of the pressure coefficients c_{pe} on windward and leeward side (zones D and E) of the building simultaneously, the lack of correlation of wind pressures between the windward and leeward side may have to be taken into account.

Flat roofs

(1) Flat roofs are defined as having a slope of $-5° < \alpha < 5°$

(2) The roof should be divided into zones as shown in Figure 2

(3) The reference height for flat roof and roofs with curved or mansard eaves should be taken

as h. The reference height of flat roofs with parapets should be taken as $h + h$p.

(4) Pressure coefficients for each zone are given.

(5) The resulting pressure coefficient on the parapet should be determined.

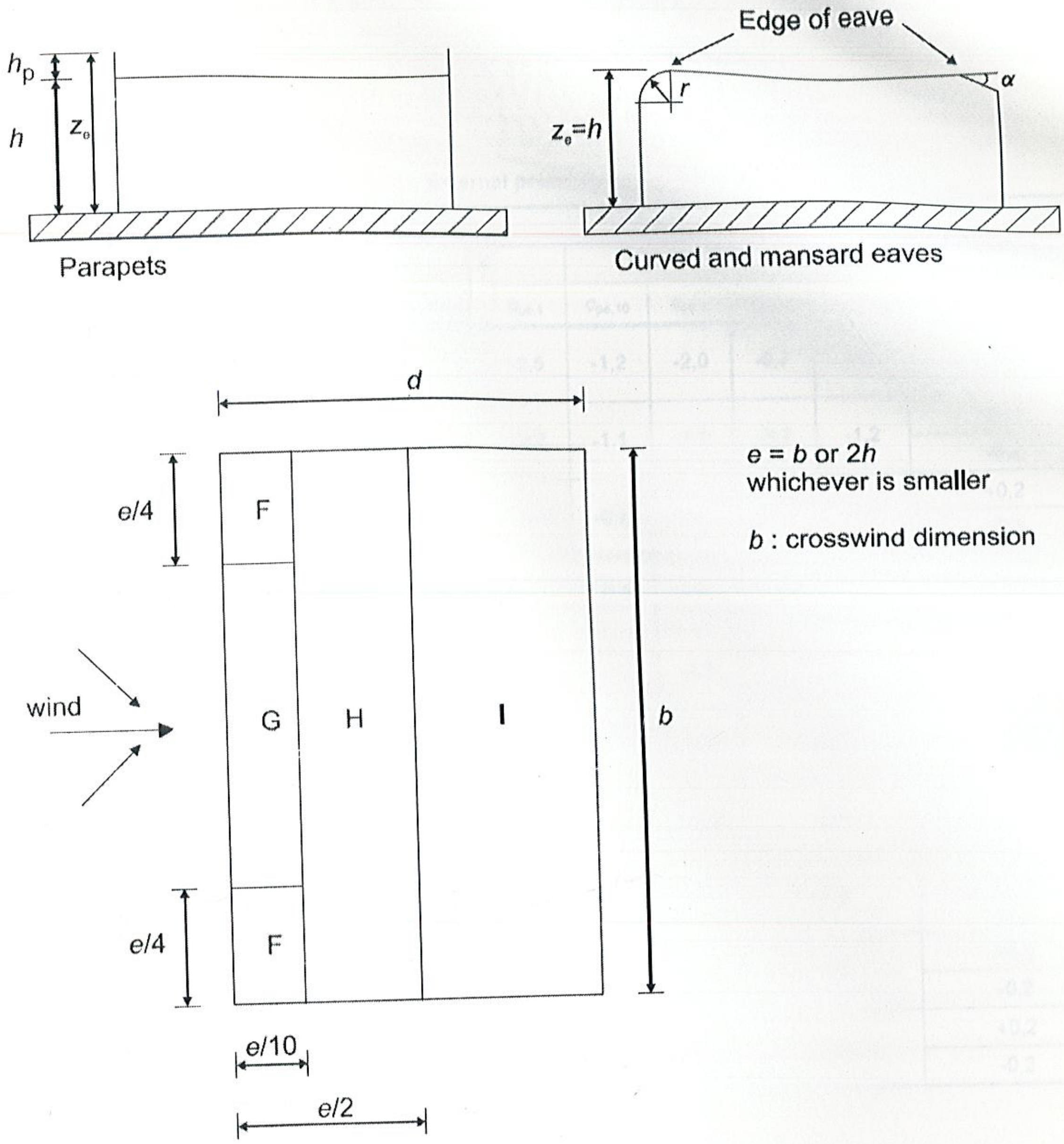


Figure 4 — Key for flat roofs

TABLE 5

External pressure coefficients for flat roofs

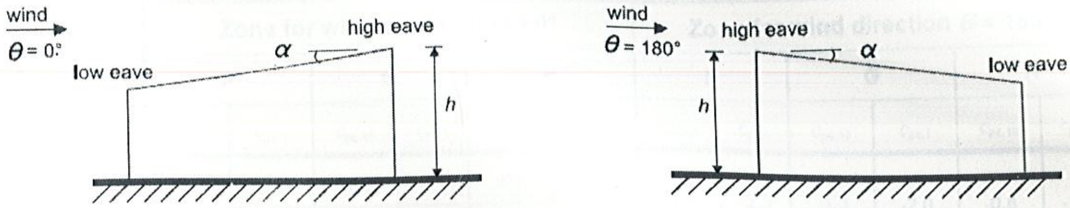
Roof type		Zone F $c_{pe,10}$	F $c_{pe,1}$	G $c_{pe,10}$	G $c_{pe,1}$	H $c_{pe,10}$	H $c_{pe,1}$	I $c_{pe,10}$ / $c_{pe,1}$
Sharp eaves		-1,8	-2,5	-1,2	-2,0	-0,7	-1,2	+0,2 -0,2
With Parapets	h_p/h=0,025	-1,6	-2,2	-1,1	-1,8	-0,7	-1,2	+0,2 -0,2
	h_p/h=0,05	-1,4	-2,0	-0,9	-1,6	-0,7	-1,2	+0,2 -0,2
	h_p/h=0,10	-1,2	-1,8	-0,8	-1,4	-0,7	-1,2	+0,2 -0,2
Curved Eaves	r/h = 0,05	-1,0	-1,5	-1,2	-1,8	-0,4		+0,2 -0,2
	r/h = 0,10	-0,7	-1,2	-0,8	-1,4	-0,3		+0,2 -0,2
	r/h = 0,20	-0,5	-0,8	-0,5	-0,8	-0,3		+0,2 -0,2
Mansard Eaves	α = 30°	-1,0	-1,5	-1,0	-1,5	-0,3		+0,2 -0,2
	α = 45°	-1,2	-1,8	-1,3	-1,9	-0,4		+0,2 -0,2
	α = 60°	-1,3	-1,9	-1,3	-1,9	-0,5		+0,2 -0,2

Monopitch roofs

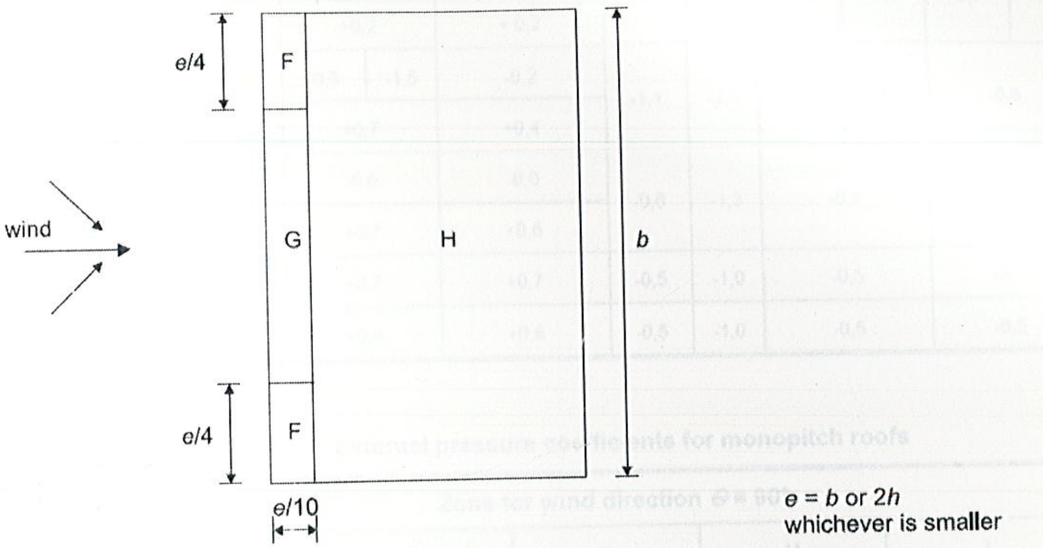
(1) The roof, including protruding parts, should be divided into zones.

(2) The reference height z_e should be taken equal to h.

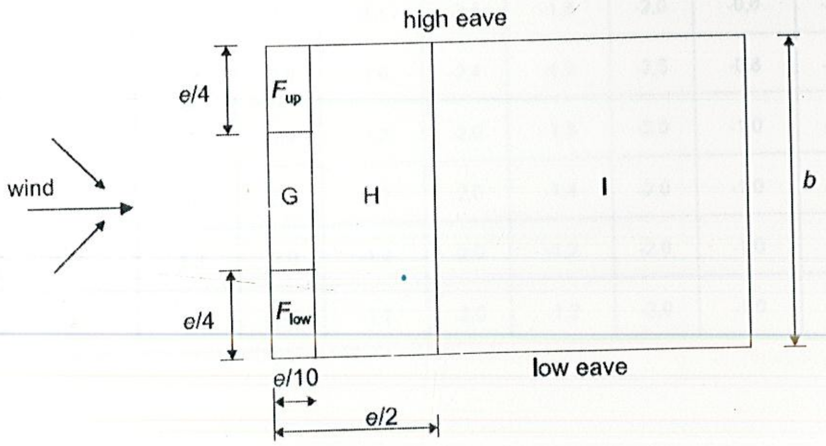
(3) The pressure coefficients for each zone that should be used.



(a) general



(b) wind directions $\theta = 0°$ and $\theta = 180°$



(c) wind direction $\theta = 90°$

Figure 5 — Key for monopitch roofs

TABLE 6 and 7

External pressure coefficients for monopitch roofs

Pitch Angle α	Zone for wind direction $\Theta = 0°$						Zone for wind direction $\Theta = 180°$					
	F		G		H		F		G		H	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-2,3	-2,5	-1,3	-2,0	-0,8	-1,2
	+0,0		+0,0		+0,0							
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-2,5	-2,8	-1,3	-2,0	-0,9	-1,2
	+0,2		+0,2		+0,2							
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-1,1	-2,3	-0,8	-1,5	-0,8	
	+0,7		+0,7		+0,4							
45°	-0,0		-0,0		-0,0		-0,6	-1,3	-0,5		-0,7	
	+0,7		+0,7		+0,6							
60°	+0,7		+0,7		+0,7		-0,5	-1,0	-0,5		-0,5	
75°	+0,8		+0,8		+0,8		-0,5	-1,0	-0,5		-0,5	

External pressure coefficients for monopitch roofs

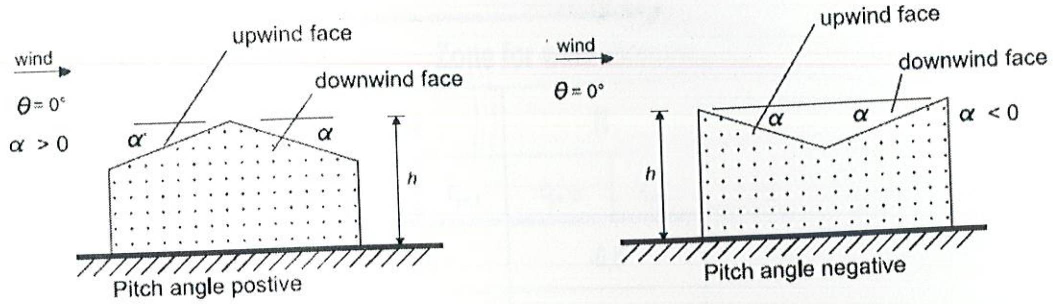
Pitch Angle α	Zone for wind direction $\Theta = 90°$									
	F_{up}		F_{low}		G		H		I	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5°	-2,1	-2,6	-2,1	-2,4	-1,8	-2,0	-0,6	-1,2	-0,5	
15°	-2,4	-2,9	-1,6	-2,4	-1,9	-2,5	-0,8	-1,2	-0,7	-1,2
30°	-2,1	-2,9	-1,3	-2,0	-1,5	-2,0	-1,0	-1,3	-0,8	-1,2
45°	-1,5	-2,4	-1,3	-2,0	-1,4	-2,0	-1,0	-1,3	-0,9	-1,2
60°	-1,2	-2,0	-1,2	-2,0	-1,2	-2,0	-1,0	-1,3	-0,7	-1,2
75°	-1,2	-2,0	-1,2	-2,0	-1,2	-2,0	-1,0	-1,3	-0,5	

Duo pitch roofs

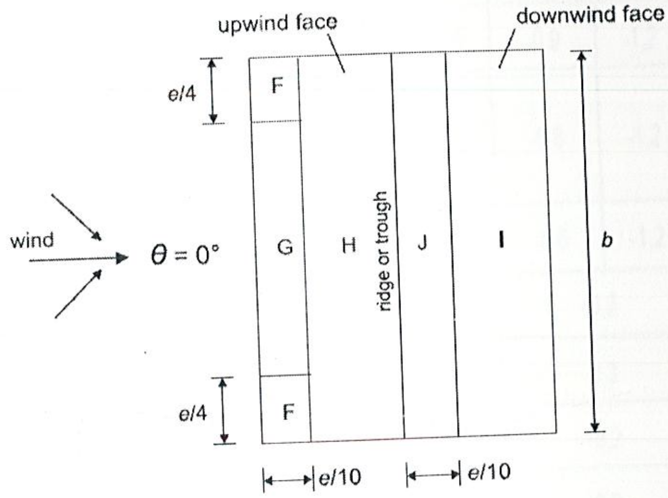
(1) The roof, including protruding parts, should be divided in zones.

(2) The reference height z_e should be taken as h.

(3) The pressure coefficients for each zone that should be used.



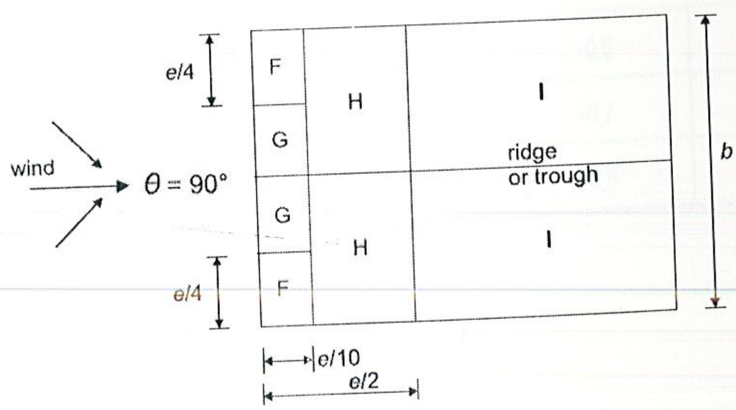
(a) general



e = b or 2h
whichever is smaller

(b) wind direction θ = 0°

b : crosswind dimension



(c) wind direction θ = 90°

Figure 6 — Key for duo pitch roofs

External pressure coefficients for duopitch roofs

Pitch Angle α	Zone for wind direction $\Theta = 0°$									
	F		G		H		I		J	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-0,6		-0,6		-0,8		-0,7		-1,0	-1,5
-30°	-1,1	-2,0	-0,8	-1,5	-0,8		-0,6		-0,8	-1,4
-15°	-2,5	-2,8	-1,3	-2,0	-0,9	-1,2	-0,5		-0,7	-1,2
-5°	-2,3	-2,5	-1,2	-2,0	-0,8	-1,2	+0,2		+0,2	
							-0,6		-0,6	
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-0,6		+0,2	
	+0,0		+0,0		+0,0				-0,6	
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-0,4		-1,0	-1,5
	+0,2		+0,2		+0,2		+0,0		+0,0	+0,0
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-0,4		-0,5	
	+0,7		+0,7		+0,4		+0,0		+0,0	
45°	-0,0		-0,0		-0,0		-0,2		-0,3	
	+0,7		+0,7		+0,6		+0,0		+0,0	
60°	+0,7		+0,7		+0,7		-0,2		-0,3	
75°	+0,8		+0,8		+0,8		-0,2		-0,3	

Figure-7

External pressure coefficients for duopitch roofs

Pitch angle α	Zone for wind direction $\Theta = 90°$							
	F		G		H		I	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-1,4	-2,0	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-30°	-1,5	-2,1	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-15°	-1,9	-2,5	-1,2	-2,0	-0,8	-1,2	-0,8	-1,2
-5°	-1,8	-2,5	-1,2	-2,0	-0,7	-1,2	-0,6	-1,2
5°	-1,6	-2,2	-1,3	-2,0	-0,7	-1,2	-0,6	
15°	-1,3	-2,0	-1,3	-2,0	-0,6	-1,2	-0,5	
30°	-1,1	-1,5	-1,4	-2,0	-0,8	-1,2	-0,5	
45°	-1,1	-1,5	-1,4	-2,0	-0,9	-1,2	-0,5	
60°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	
75°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	

Table-8

Australian

New Zealand code

AS\NZS 1170.2

This joint Australian\new Zealand standard was prepared by joint technical committee BD-006, general design requirement and loading on structures. It was approved on behalf of the council of standard Australia on 29^{th} march 2002 and on the behalf of council standards new Zealand on march 28^{th} 2002.It was published on 4^{th} June 2002.this standard may be used as a means for demonstrating compliance with the requirements of part (B) of the building code of Australia.

AS\NZS 1170.2- part 2 is used for calculation of wind load. This standard sets out procedures for determining wind speeds and resulting wind actions to be used in the structural design of structures subjected to wind actions other than those caused by tornados. The standard covers structures within the following criteria:

(a) Buildings less than 20m high.
(b) Structures with roof span less than 100m.
(c) Structures other than off shore structures, bridges and off shore structures.

Design wind pressure and distributed forces

The design wind pressure (p) in Pascal shall be determined for structures and parts of structures as follows:

$P= (.5Q_{air})[V_{d,}]^2.C_{fig}.C_{dyn}$

P = design wind pressure (Pascal)

Q_{air} = density of air, 1.2 kg/m³

V_d = building orthogonal; design wind speed taken as 40 m/s

C_{fig} = aerodynamic shape factor

C_{dyn} = dynamic response factor (generally value is taken as (1)

Aerodynamic shape factor

$C_{fig} = C_{pe}.K_a.k_c.k_i.k_p$

Where,

C_{pe} = external pressure coefficient (-.4)

K_a = area reduction factor (.8)

K_c = combination factor (.8)

K_i =local pressure factor (1)

K_p = porous cladding (1)

Area reduction factor (k_a)

For roofs and side walls the area reduction factor shall be given in the table for all other cases it shall be taken as 1.tributary area is the area contributing to the force being considered

AREA REDUCTION FACTOR (K_a)

Tributary area (A), m^2 (see Note)	Area reduction factor (K_a)
≤ 10	1.0
25	0.9
≥ 100	0.8

NOTE: For intermediate values of A, use linear interpolation.

Combination factor (K_c)

Where wind pressures acting on two or more surfaces of an enclosed building eg. Windward wall, upwind roof, side walls etc contribute simultaneously to a structural action effect on a major structural element, the combination factor given in the table may be applied to the combined forces calculated for the critical external and internal surfaces. This factor shall not be applied to cladding or immediate supporting structure such as purling.

Permeable cladding reduction factor (K_p)

The permeable cladding reduction factor shall be taken as 1 except that where an external surface consists of permeable cladding and the solidity ratio is less than .999

and exceed .99. The solidity ratio of the surface is the ratio of solid area to total area of the surface.

ACTION COMBINATION FACTORS FOR WIND PRESSURE CONTRIBUTING FROM TWO OR MORE BUILDING SURFACES TO EFFECTS ON MAJOR STRUCTURAL ELEMENTS

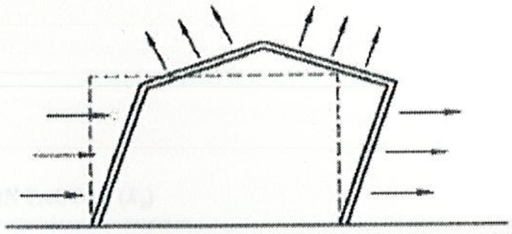
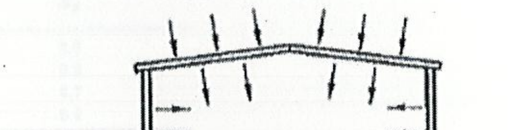
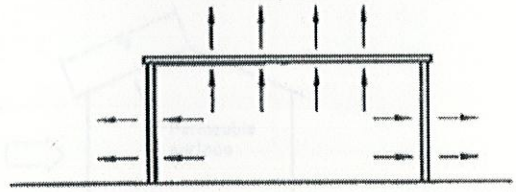
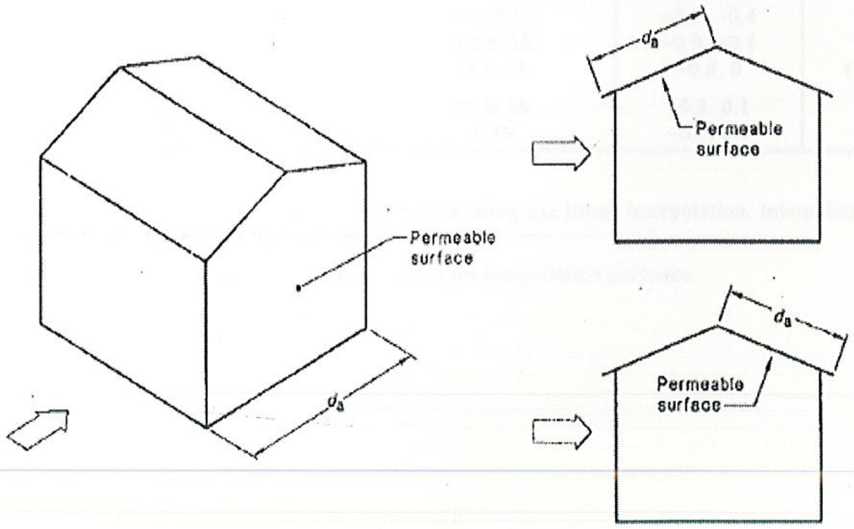
Design case	Combination factor (K_c)	Example diagrams
(a) Where wind action from any single surface contributes 75 percent or more to an action effect	1.0	—
(b) Pressures from windward and leeward walls in combination with positive or negative roof pressures	0.8	
(c) Positive pressures on roofs in combination with negative internal pressures (from a wall opening)	0.8	
(d) Negative pressures on roofs or walls in combination with positive internal pressures	0.95	
(e) All other cases	1.0	—

TABLE-9

PERMEABLE CLADDING REDUCTION FACTOR (K_p)

Horizontal distance from windward edge (see Note)	K_p
0 to $0.2d_s$	0.9
$0.2d_s$ to $0.4d_s$	0.8
$0.4d_s$ to $0.8d_s$	0.7
$0.8d_s$ to $1.0d_s$	0.8

NOTE: d_s is the along-wind depth of the surface in metres.



NOTATION FOR PERMEABLE SURFACES

Figure 8

ıtable 9 ROOFS—EXTERNAL PRESSURE COEFFICIENTS ($C_{p,e}$) FOR 'ANGULAR ENCLOSED BUILDINGS—FOR UPWIND SLOPE (U) AND DOWNWIND SLOPE, (D) FOR $\alpha < 10°$ AND FOR (R) FOR GABLE ROOFS

Roof type and slope		Horizontal distance from windward edge of roof	External pressure coefficient ($C_{p,e}$)	
Crosswind slopes for gable roofs, (R)	Upwind slope, (U), Downwind slope, (D)		$h/d \leq 0.5$ (see Note 1)	$h/d \geq 1.0$ (see Note 1)
All α	$\alpha < 10°$	0 to 0.5h	−0.9, −0.4	−1.3, −0.6
		0.5 to 1h	−0.9, −0.4	−0.7, −0.3
		1h to 2h	−0.5, 0	(−0.7), (−0.3)
		2h to 3h	−0.3, 0.1	see Note 2
		> 3h	−0.2, 0.2	

NOTES:

1 For intermediate values of roof slopes and h/d ratios, use linear interpolation. Interpolation shall only be carried out on values of the same sign.

2 The values given in parentheses are provided for interpolation purposes.

TABLE-10

ROOFS—EXTERNAL PRESSURE COEFFICIENTS ($C_{p,e}$) FOR TANGULAR ENCLOSED BUILDINGS—UPWIND SLOPE (U) $\alpha \geq 10°$

Roof type and slope	Ratio h/d (see Note)	External pressure coefficients ($C_{p,e}$)						
Upwind slope, (U)		Roof pitch, α degrees (see Note)						
		10	15	20	25	30	35	≥ 45
$\alpha \geq 10°$	≤ 0.25	−0.7, −0.3	−0.5, 0.0	−0.3, 0.2	−0.2, 0.3	−0.2, 0.4	0.0, 0.5	0, 0.8 sin α
	0.5	−0.9, −0.4	−0.7, −0.3	−0.4, 0.0	−0.3, 0.2	−0.2, 0.3	−0.2, 0.4	
	≥ 1.0	−1.3, −0.6	−1.0, −0.5	−0.7, −0.3	−0.5, 0.0	−0.3, 0.2	−0.2, 0.3	

IOTE: For intermediate values of roof slopes and h/d ratios, use linear interpolation. Interpolation shall only e carried out on values of the same sign.

ASCE 7-98

AMERICA

ASCE standard, minimum design loads for buildings and other structure gives requirements for dead, live, soil, flood, wind, snow, rain, ice and earthquake loads and there combinations, that are suitable for inclusion in building codes and other documents. The major revision of this standard involves the section on wind loads. This section has been greatly expanded to the latest information in the field of wind load engineering. Requirements have been added for flood loads and ice load , an appendix on serviceability requirements has also been added. The structural load requirements provided by this standard are intended for use by architects, structural engineers, and those engaged in preparing and administering local building codes

Design procedure

1. The basic wind speed V and wind directionality factor K_d shall be determined.
2. An important factor I should be determined
3. An exposure category or exposure categories and velocity pressure exposure coefficient K_z or K_h as applicable, shall be determined for each wind direction.
4. A topographic factor K_v shall be determined
5. A gust effect factor G or G_f as applicable shall be determined.
6. An enclosure classification shall be determined.
7. Internal pressure coefficient $G_{Cp}i$ shall be determined.
8. External pressure coefficient C_p or GC_{pf}, or force coefficient C_f as applicable shall be determined.
9. Velocity pressure q_z as applicable shall be determined.
10. Design wind load P or F shall be determined.

Exposure categories

For each wind direction considered, an exposure category that adequately reflects the characteristics of ground surface irregularities shall be determined for the site at which the building or the structure is to be constructed. For a site located in the transition zone between categories , the categories resulting in the largest wind force shall apply, account shall be taken of variation & ground surface roughness that arise from natural topography and vegetation as well as from constructed features. For any given wind direction, the exposure in which specific building or other structure is sited shall be assessed as being one of the following categories.

1) EXPOSURE A : A large city centre with at least 50% of the building having height in excess of 70 ft. this exposure category shall be limited to those areas for which terrain representative of exposure A prevails in the up wind direction for a distance of at least 0.8 km or 10 time the height of the building or other structure, whichever is greater. Possible channelling effects of increasing velocity pressure due to the building or structure being located in the wake of adjacent buildings shall be taken into account.

2) EXPOSURE B: Urban and sub urban area, wooded areas or other terrain with numerous closely spaced obstructions having the size of single family dwelling or larger. Use of this exposure category shall be limited to those areas for which terrain representative of exposure B prevails in the upwind direction for a distance of at least 460 m or 10 times the height of the building or other structure, whichever is greater.

3) EXPOSURE C open terrain with scattered obstruction having height generally less than 9.1 m. This category includes flat open country, grassland and shorelines in hurricanes prone regions.

4) EXPOSURE D: Flat unobstructed area exposed to wind flowing over open water for a distance of at least 1.61 km. Shorelines in exposure D include inland waterways the great lakes and costal area of California ,Oregon, Washington and Alaska. This exposure shall apply only to those buildings and other structures exposed to the e wind coming over the water. Exposure D extends inland from the shoreline a distance of 460mts. Or 10 time the height of building or structure, whichever is greater.

Velocity pressure exposure coefficient

It is Based on exposure category .velocity pressure exposure coefficient K_Z shall be determined.

Topographic effect

Wind speed over hill, ridge and escarpment:

Wind speed-up effects at isolated hills, ridges, and escarpment constituting abrupt changes in the general topography, located in any exposure category, and shall be included in the design when buildings and other site conditions and located structure meet all of the following conditions:

1. The hill, ridge, or escarpment is isolated and unobstructed upwind by other similar topographic features of comparable height for 100 times the height of the topographic feature (100h) or 3.22 km whichever is less. This distance shall be measured horizontally from the point at which the ht H of the hill, ridge. Or escarpment is determined.

2. The hill, ridge or escarpment protrudes above the height of upwind terrain features with in 3.22 km radius in any quadrant by a factor of 2 or more

3. $H/L_H \geq 0.2$ and

4. H greater than equal to 15 ft for exposure C and D and 60 ft for exposure A and B.

Topographic factor:

The top speed –up effect shall be include in the calculation of design wind loads by using the factor K_V.

$K_V = (1+ K_1K_2K_3)^2$

Velocity pressure:

Velocity pressure q_z evaluated at a height z shall be calculated by the following eqn:

$q_z = .613 K_Z K_D K_U V^2 (N/m^2)$

Where

K_D =wind directionality factor

K_Z=velocity pressure exposure coefficient

K_U=topographic factor

q_z = velocity pressure calculated at mean root height h.

The numerical coefficient .613 shall be used except where sufficient climatic data are available to justify the selection of a different value of this factor for a design application

Design wind pressure for low rise buildings:

Design wind pressure for the main wind force resisting system of low rise buildings shall be determined by the following equation:

$P=q_h[(GC_{pf})$ (N/mm^2)

Where:

q_h=velocity pressure evaluated at a mean root height h

(GC_{pf})=external pressure coefficients

CHAPTER-3

COMPARISON BETWEEN CODES

COMPARISON BETWEEN IS-875-3 AND AIJ

1) In **IS 875** probability factor terrain height factor and topography factor are taken into account for design wind speed where as in **AIJ** air density is used for calculating design velocity pressure.

2) In **AIJ** guest effect factor is used for calculating wind load where as **IS 875** it is not used.

3) In **AIJ** for calculating roof wind load different parameter like design wind speed, wind direction factor, wind speed profile factor, topographic factor, return period conversion factor where used, which makes the designing difficult & sometimes erroneous if not done meticulously whereas in **IS 875** it is quite easy.

4) In **IS 875** there is separate table for pressure coefficient at wind angle of 0 & 90 degree but in **AIJ** there is no table for pressure coefficient at 90 degree wind angle.

COMPARISON BETWEEN IS 875-3 & EURO CODE

1) In IS 875 basic wind velocity is determined simply from the figure applicable to 10 meter height whereas in EURO code basic wind velocity depends upon various parameters like fundamental value of basic wind velocity directional factor and seasonal factor.

2) In IS 875 there is a separate table for internal pressure coefficient where as in EURO code internal pressure coefficient is taken 0.75 of external pressure coefficient.

3) In IS 875 force on the cladding is directly obtained from the formulas given in the code whereas in EURO CODE, pressure on the cladding is obtained & it is then multiplied by cladding area to get the force.

4) In EURO code terrain category is given more stress in calculating basic wind speed than in IS 875.

Comparison between IS-875-3 and AS/NZS

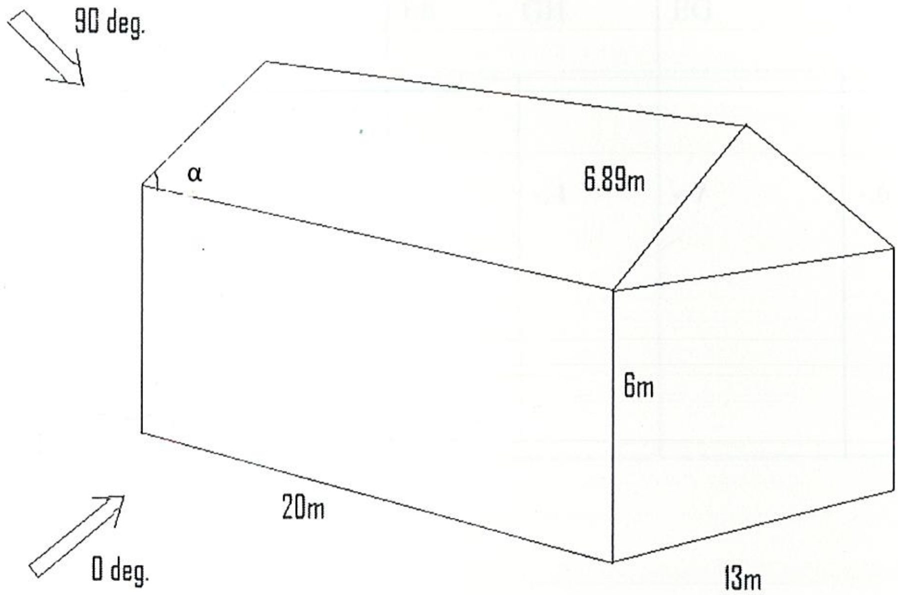
1) In AS/NZS aerodynamic factor is used to take into account the effect of external coefficient, area, pressure by incorporating different parameters like area reduction factor, combination factor, local pressure factor etc. in it, whereas in IS 875-3 design wind speed accounts for such parameters.
2) In AS/NZS a special factor called permeable cladding reduction factor is used in case the cladding is permeable but no such factor is used in IS 875-3.
3) Unlike IS 875-3, in AS/NZS the cladding is not divided into sections while calculating the forces, only windward & leeward sides were considered.

Comparison between IS 875-3 and ASCE

1) In ASCE some new factors like wind directionality factor, importance factor etc. are used which is not used in IS 875-3.
2) In IS 875-3 for obtaining pressure coefficient table are given only for 0 & 90 degree wind angle whereas in ASCE tables for range of angles 0 to 45 degree & 45 to 90 degree are given which covers the entire range of attacking wing angle.
3) Like IS 875-3, in ASCE the cladding is divided among four sections for calculating force with slight variations.

CHAPTER-4

NUMERICAL



IS 875-3

Design wind speed

$V_z = v_b k_1 k_2 k_3$

A = 20 degree

V_b = basic wind speed, taken as 44m/s

K_1 = probability factor, from table1 k_1=.91

K_2 = terrain height, structure size factor, from table 2

Taking class A, terrain category-3 at height 10m

$K_2 = .91$

K_3 = topography factor,

Considering upwind slope greater than 3 degree,

$k_3 = 1.25$

hence,

Building ht. Ratio	Roof angle	Wind angle 0		Wind angle 90	
		EF	GH	EG	FH
h\w<(1\2)	20	-.4	-.4	-.7	-.6

design wind speed = 44∗.91∗.91∗1.25

=45.54 m/s

Design wind pressure $p_a = .6v_z^2 = .6*(45.54)^2 = 1244.33\ N/m^2$

h\w <(1/2) = .46

from table 3

Force (F) = $C_{pe}AP_a$,

Area,

Wind angle 0 degree = $137.8m^2$

Wind angle 90 degree

Windward = $68.9m^2$

Leeward = $206.7.5m^2$

	Wind angle 0 degree		Wind angle 90 degree	
	windward EF (kN)	leeward GH (kN)	windward EG (kN)	leeward FH (kN)
FORCE	-69.184	-69.184	-60.53	-155.66

EURO CODE

Wind pressure on external surface.

$w_e = q_p(ze).c_{pe}$

where:

$q_p(ze)$ is the peak velocity pressure

z_e is the reference height for the external pressure

c_{pe} is the pressure coefficient for the external pressure,

now,

basic wind velocity

$V_b = C_{dir}C_{season}V_{b0}$

V_{b0} = fundamental value of basic wind velocity taken as 44m/s

V_{b0}= recommended value = 1

C_{season} = recommended value = 1

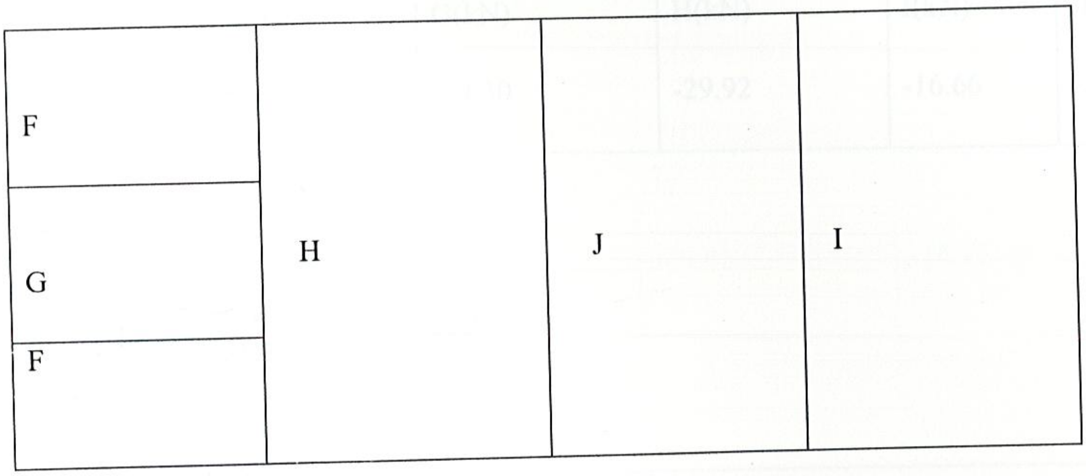
So, $V_b = 1*1*44 = 44$ m/s

Peak velocity pressure:

$q_{p(z)} = c_{e(z)} q_b$ & $q_b = (1/2)\ V_b^2 p$

so, $q_b = .5*1.22*44 = 26.84$ m/s

hence, $q_{p(z)} = 1.8*26.84 = 48.312$ N/m^2



Pressure coefficient for θ= 0 degr

	WINDWARD	LEEWARD

	F	G	H	I	J
COEFF.	-2.5	-1.3	-.9	-.5	-.7

	WINDWARD			LEEWARD	
	F(kN)	G(kN)	H(kN)	I(kN)	J(kN)
FORCE	-27..26	-14.30	-29.92	-16.66	-23.30

Pressure coefficient for θ=90°

F	H	I
G		
F	H	I

Pressure coefficient

	WINDWARD		LEEWARD	
	F	G	H	I
Coeff.	-1.9	-1.2	-.8	-.8

	WINDWARD		LEEWARD	
	F	G	H	I
FORCE	-21.07	-28.36	-18.91	-18.91

AIJ JAPAN

Roof wind loads on structural frames are calculated from

$W_R = q_H C_R G_R A_R$

Where,

W_R(N): wind load

q_H(N/m^2): design velocity pressure

C_R: wind force coefficient

G_R: gust effect factor for roof wind load

A_R(m^2): subject area

The design velocity pressure, Q_H(N/m), is calculated from:

$Q_H=(1\backslash 2)\ \rho.U_H^2$

Where,

ρ (kg/m^3): air density, assumed to be 1.22

U_H (m/s): design wind speed, which depends on wind direction

Design wind speed, U_H(m/s), is calculated for each wind direction from:

$U_H=U_0K_DE_HK_{RW}$

where

U_0: basic wind speed (m/s) depending on the geographic location of the construction site,

K_D: wind directionality factor

E_H: wind speed profile factor at reference height H defined

K_{RW}: return period conversion factor

Wind speed profile factor:

Wind speed profile factor E is calculated from:

$E=E_RE_G$

Where,

E_R: exposure factor for flat terrain categories,

E_G: topography factor defined

Exposure factor based on flat terrain categories

$E_R = 1.7(Z\backslash Z_G)^{\alpha}$

Z(m): height above ground

Z_B, α: parameters determining the exposure factor

So, E_R=1.7(10/350)$^{.15}$ = .99

E_G=1, K_{RW}= 3.9,

U_H= 44*.85*.99*3.9 = 144.4

So, q_h= .5*1.22*144.4^2 = 12719.32 N

Force coefficient

ROOF ANGLE	WINDWARD R_U		LEEWARD R_L	
	.3+.03θ	-1.15+.025θ		-.6-.03θ
20	.9	-.65	.3	-1.2

	WINDWARD R_U		LEEWARD R_L	
	+VE (kN)	-VE (kN)	+VE (kN)	-VE (kN)
FORCE	76.47	-55.23	25.49	-10.19

AS\NZS

Design wind pressure

$P= (.5Q_{air})[V_{d,\Theta}]^2.C_{fig}.C_{dyn}$

P = design wind pressure(Pascal's)

Q_{air} = density of air,1.2 kg/m^3

V_d = building orthogonal; design wind speed taken as 40 m/s

C_{fig}= aerodynamic shape factor

C_{dyn} = dynamic response factor (generally value is taken as 1)

Aerodynamic shape factor

$C_{fig} = C_{pe}.K_a.k_c.k_i.k_p$

Where,

C_{pe} = external pressure coefficient (-.4) from table9

K_a = area reduction factor (.8) from table10

K_c = combination factor(.8) from table 11

K_i =local pressure factor (1)

K_p = porous cladding (1)

For windward side

C_{fig} = -.4*.8*.8*1*1

= -.256

P = .5*1.2*[40]2*-.256*1

= -34.16kN

For leeward side

C_{fig} = .6*.8*.8*1*1

= -.384

P = .5*1.2*[40]2*-.384*1

= -51.24kN

ASCE

Design wind pressure

$P = q_h(GC_{pf})$

q_h = velocity pressure.

GC_{pf} = External pressure coefficient

So,

$q_h = .613k_z.k_{zt}.k_d.V^2\ (N/m^2)$

k_d = wind directionality factor (.85) from table 12

k_z = velocity exposure factor, from table 13

$k_z = 2.01\ (Z/Z_g)^{2/\alpha}$

$\alpha = 7.0,\ \ Z = 30,\ \ Z_g = 1200$

Hence, $k_z = .702$

So, $q_h = 0613*.702*1*.85*44^2$

= 708 N/m

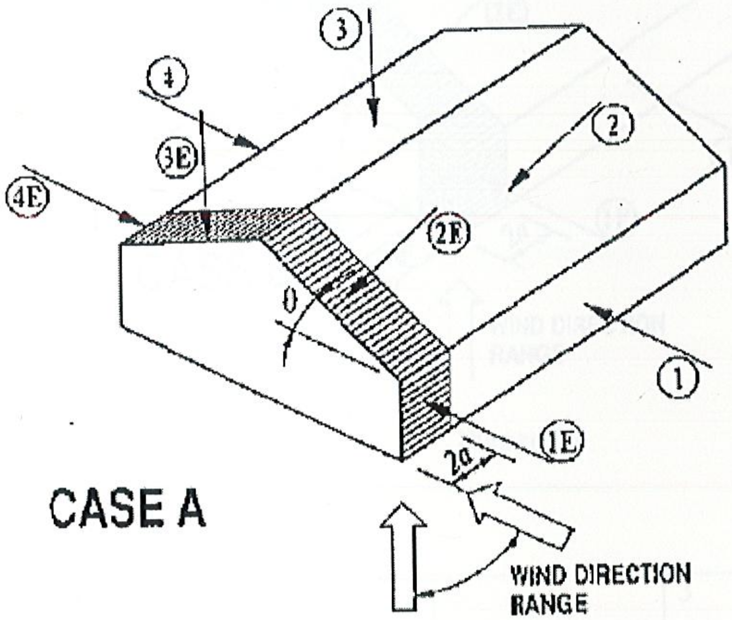


Figure 9

a = 10% of horizontal distance.

CASE A	2E	2	3	3E
Coefficient	-1.07	-.69	-.69	-.48
Pressure	-754.56	-488.52	-488.52	-339.84
Area	13.7	124.02	124.02	13.7
Force (kN)	10.37	60.58	60.58	4.65

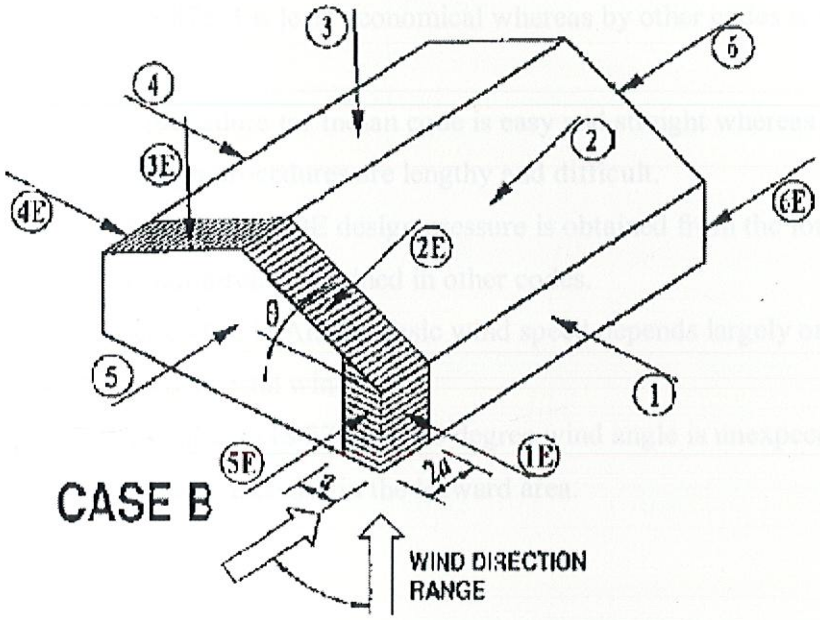


Figure 10

CASE B	2E	2	3	3E
Coefficient	-1.07	-.69	-.37	-.53
Pressure	-757.56	-488.52	-261.96	-375.24
Area	13.7	124.02	124.02	13.7
Force (kN)	10.37	60.58	32.48	5.14

CHAPTER-5

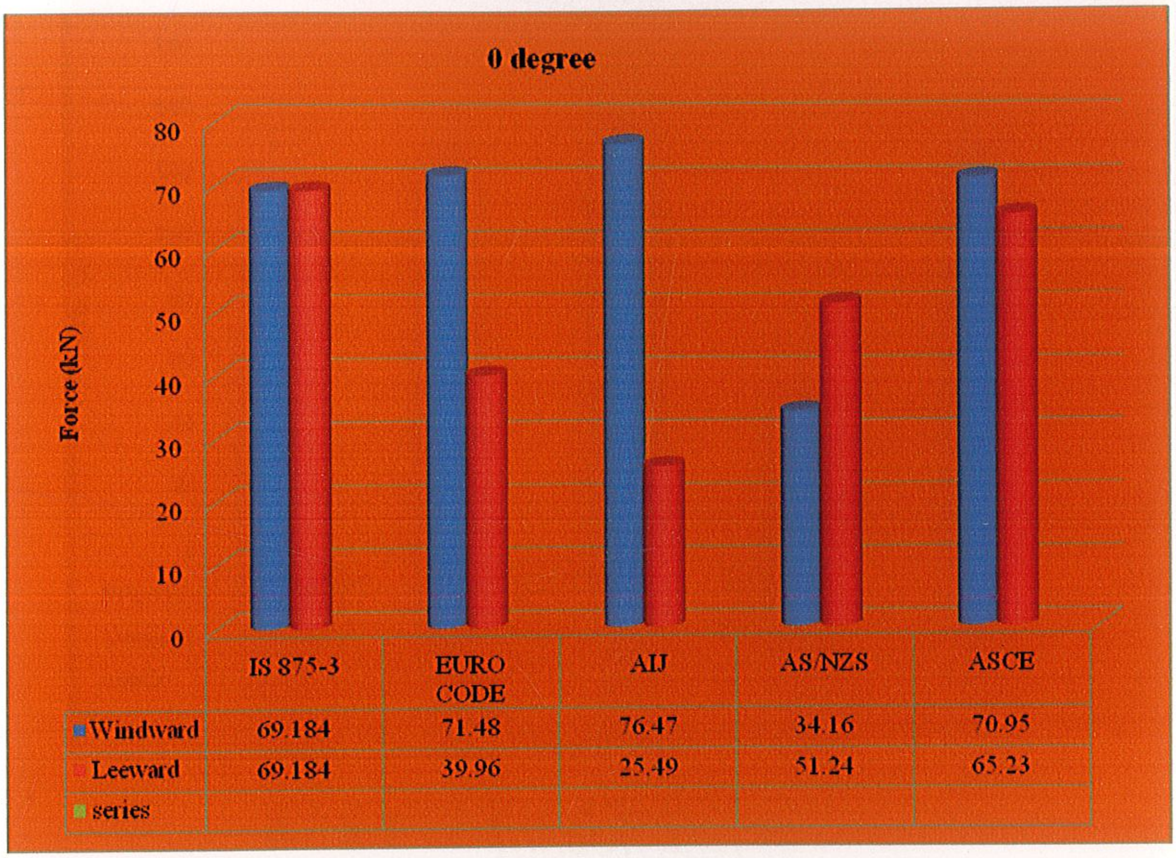
CONCLUSION

1) The design value for IS 875-3 is max. & AS/NZS is min., it means that, construction of a wind resistance building according to AS/NZS is most economical and by IS 875-3 is least economical whereas by other codes is moderately economical.
2) The design procedure for Indian code is easy and straight whereas in other codes the design procedures are lengthy and difficult.
3) In ASCE & EURO CODE design pressure is obtained from the formula whereas design force is obtained in other codes.
4) Unlike other codes, in AIJ the basic wind speed depends largely on frequency of tornadoes & coastal winds.
5) The leeward value in IS 875-3 at 90 degree wind angle is unexpectedly large, it is due to drastic increase in the leeward area.

Comparative values

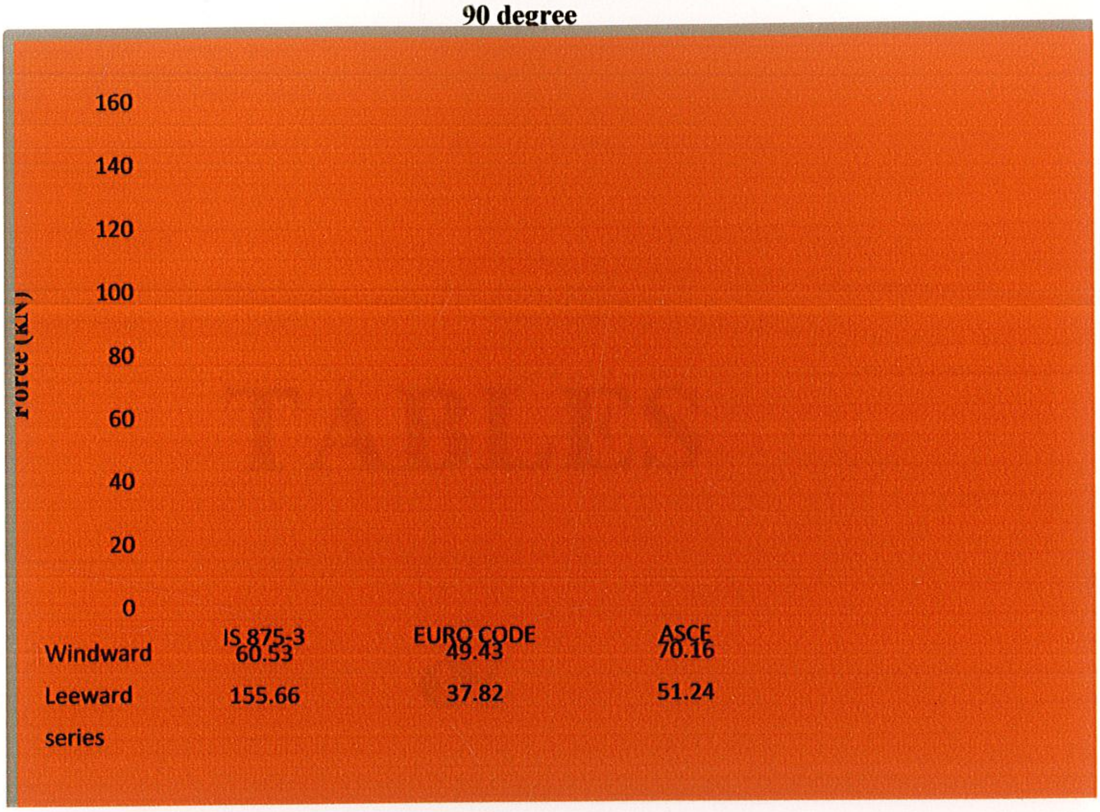
Codes	Wind angle 0 degree		Wind angle 90 degree	
	Windward(kN)	Leeward(kN)	Windward(kN)	Leeward(kN)
IS 875-3	69.184	69.184	60.53	155.66
EURO CODE	71.48	39.96	49.43	37.82
AIJ	76.47	25.49		
AS/NZS	34.16	51.24		
ASCE	70.95	65.23	70.95	37.62

Bar-Chart


0 degree
80
70
60
50
40
30
20
10
0
Force (kN)
IS 875-3
EURO CODE
AIJ
AS/NZS
ASCE
Windward
69.184
71.48
76.47
34.16
70.95
Leeward
69.184
39.96
25.49
51.24
65.23
series

Bar-Chart

90 degree



TABLES

&

FIGURES

Table 11

TABLE 1 RISK COEFFICIENTS FOR DIFFERENT CLASSES OF STRUCTURES IN DIFFERENT WIND SPEED ZONES

(*Clause* 5.3.1)

CLASS OF STRUCTURE	MEAN PROBABLE DESIGN LIFE OF STRUCTURE IN YEARS	k_1 FACTOR FOR BASIC WIND SPEED (m/s) OF					
		33	39	44	47	50	55
All general buildings and structures	50	1·0	1·0	1·0	1·0	1·0	1·0
Temporary sheds, structures such as those used during construction operations (for example, formwork and falsework), structures during construction stages and boundary walls	5	0·82	0·76	0·73	0·71	0·70	0·67
Buildings and structures presenting a low degree of hazard to life and property in the event of failure, such as isolated towers in wooded areas, farm buildings other than residential buildings	25	0·94	0·92	0·91	0·90	0·90	0·89
Important buildings and structures such as hospitals communication buildings / towers, power plant structures	100	1·05	1·06	1·07	1·07	1·08	1·08

NOTE — The factor k_1 is based on statistical concepts which take account of the degree of reliability required and period of time in years during which these will be exposure to wind, that is, life of the structure. Whatever wind speed is adopted for design purposes, there is always a probability (however small) that it may be exceeded in a storm of exceptional violence; the greater the period of years over which these will be exposure to the wind, the greater is the probability. Higher return periods ranging from 100 to 1 000 years (implying lower risk level) in association with greater periods of exposure may have to be selected for exceptionally important structures, such as, nuclear power reactors and satellite communication towers. Equation given below may be used in such cases to estimate k_1 factors for different periods of exposure and chosen probability of exceedance (risk level). The probability level of 0·63 is normally considered sufficient for design of buildings and structures against wind effects and the values of k_1 corresponding to this risk level are given above.

$$k_1 = \frac{X_{N,\,P}}{X_{50,\,0\cdot63}} = \frac{A - B\left[\ln\left\{-\frac{1}{N}\ln\left(1 - P_N\right)\right\}\right]}{A + 4B}$$

Table 12

TABLE 2 k_1 FACTORS TO OBTAIN DESIGN WIND SPEED VARIATION WITH HEIGHT IN DIFFERENT TERRAINS FOR DIFFERENT CLASSES OF BUILDINGS/STRUCTURES

(*Clause* 5.3.2.2)

HEIGHT	TERRAIN CATEGORY 1 CLASS			TERRAIN CATEGORY 2 CLASS			TERRAIN CATEGORY 3 CLASS			TERRAIN CATEGORY 4 CLASS		
m	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
10	1·05	1·03	0·99	1·00	0·98	0·93	0·91	0·88	0·82	0·80	0·76	0·67
15	1·09	1·07	1·03	1·05	1·02	0·97	0·97	0·94	0·87	0·80	0·76	0·67
20	1·12	1·10	1·06	1·07	1·05	1·00	1·01	0·98	0·91	0·80	0·76	0·67
30	1·15	1·13	1·09	1·12	1·10	1·04	1·06	1·03	0·96	0·97	0·93	0·83
50	1·20	1·18	1·14	1·17	1·15	1·10	1·12	1·09	1·02	1·10	1·05	0·95
100	1·26	1·24	1·20	1·24	1·22	1·17	1·20	1·17	1·10	1·20	1·15	1·05
150	1·30	1·28	1·24	1·28	1·25	1·21	1·24	1·21	1·15	1·24	1·20	1·10
200	1·32	1·30	1·26	1·30	1·28	1·24	1·27	1·24	1·18	1·27	1·22	1·13
250	1·34	1·32	1·28	1·32	1·31	1·26	1·29	1·26	1·20	1·28	1·24	1·16
300	1·35	1·34	1·30	1·34	1·32	1·28	1·31	1·28	1·22	1·30	1·26	1·17
350	1·37	1·35	1·31	1·36	1·34	1·29	1·32	1·30	1·24	1·31	1·27	1·19
400	1·38	1·36	1·32	1·37	1·35	1·30	1·34	1·31	1·25	1·32	1·28	1·20
450	1·39	1·37	1·33	1·38	1·36	1·31	1·35	1·32	1·26	1·33	1·29	1·21
500	1·40	1·38	1·34	1·39	1·37	1·32	1·36	1·33	1·28	1·34	1·30	1·22

Intermediate values may be obtained by linear interpolation, if desired. It is permissible to assume constant wind speed between 2 heights for simplicity.

Table 13

TABLE 5 EXTERNAL PRESSURE COEFFICIENTS (C_{pe}) FOR PITCHED ROOFS OF RECTANGULAR CLAD BUILDINGS

(*Clause* 6.2.2.2)

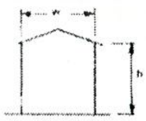
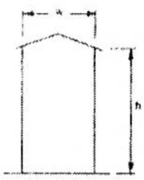
Building Height Ratio	Roof Angle α (degrees)	Wind Angle θ 0°: EF	Wind Angle θ 0°: GH	Wind Angle θ 90°: EG	Wind Angle θ 90°: FH	Local Coefficients (1)	Local Coefficients (2)	Local Coefficients (3)	Local Coefficients (4)
$\frac{h}{w} \leq \frac{1}{2}$ 	0	−0·8	−0·4	−0·8	−0·4	−2·0	−2·0	−2·0	—
	5	−0·9	−0·4	−0·8	−0·4	−1·4	−1·2	−1·2	−1·0
	10	−1·2	−0·4	−0·8	−0·6	−1·4	−1·4		−1·2
	20	−0·4	−0·4	−0·7	−0·6	−1·0			−1·2
	30	0	−0·4	−0·7	−0·6	−0·8			−1·1
	45	+0·3	−0·5	−0·7	−0·6				−1·1
	60	+0·7	−0·6	−0·7	−0·6				−1·1
$\frac{1}{2} < \frac{h}{w} \leq \frac{3}{2}$ 	0	−0·8	−0·6	−1·0	−0·6	−2·0	−2·0	−2·0	—
	5	−0·9	−0·6	−0·9	−0·6	−2·0	−2·0	−1·5	−1·0
	10	−1·1	−0·6	−0·8	−0·6	−2·0	−2·0	−1·5	−1·2
	20	−0·7	−0·5	−0·8	−0·6	−1·5	−1·5	−1·5	−1·0
	30	−0·2	−0·5	−0·8	−0·8	−1·0			−1·0
	45	+0·2	−0·5	−0·8	−0·8				
	60	+0·6	−0·5	−0·8	−0·8				
$\frac{3}{2} < \frac{h}{w} < 6$ 	0	−0·7	−0·6	−0·9	−0·7	−2·0	−2·0	−2·0	—
	5	−0·7	−0·6	−0·8	−0·8	−2·0	−2·0	−1·5	−1·0
	10	−0·7	−0·6	−0·8	−0·8	−2·0	−2·0	−1·5	−1·2
	20	−0·8	−0·6	−0·8	−0·8	−1·5	−1·5	−1·5	−1·2
	30	−1·0	−0·5	−0·8	−0·7	−1·5			
	40	−0·2	−0·5	−0·8	−0·7	−1·0			
	50	+0·2	−0·5	−0·8	−0·7				
	60	+0·5	−0·5	−0·8	−0·7				

Table 14

Table 4.1 — Terrain categories and terrain parameters

	Terrain category	z_0 m	z_{min} m
0	Sea or coastal area exposed to the open sea	0,003	1
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
III	Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5
IV	Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10
The terrain categories are illustrated in Annex A.1.			

Table 15

Table 7.4a — External pressure coefficients for duopitch roofs

Pitch Angle α	Zone for wind direction $\Theta = 0°$									
	F		G		H		I		J	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-0,6		-0,6		-0,8		-0,7		-1,0	-1,5
-30°	-1,1	-2,0	-0,8	-1,5	-0,8		-0,6		-0,8	-1,4
-15°	-2,5	-2,8	-1,3	-2,0	-0,9	-1,2	-0,5		-0,7	-1,2
-5°	-2,3	-2,5	-1,2	-2,0	-0,8	-1,2	+0,2		+0,2	
							-0,6		-0,6	
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-0,6		+0,2	
	+0,0		+0,0		+0,0				-0,6	
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-0,4		-1,0	-1,5
	+0,2		+0,2		+0,2		+0,0		+0,0	+0,0
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-0,4		-0,5	
	+0,7		+0,7		+0,4		+0,0		+0,0	
45°	-0,0		-0,0		-0,0		-0,2		-0,3	
	+0,7		+0,7		+0,6		+0,0		+0,0	
60°	+0,7		+0,7		+0,7		-0,2		-0,3	
75°	+0,8		+0,8		+0,8		-0,2		-0,3	

Table 16

Table 7.4b — External pressure coefficients for duopitch roofs

Pitch angle α	Zone for wind direction $\Theta = 90°$							
	F		G		H		I	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
-45°	-1,4	-2,0	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-30°	-1,5	-2,1	-1,2	-2,0	-1,0	-1,3	-0,9	-1,2
-15°	-1,9	-2,5	-1,2	-2,0	-0,8	-1,2	-0,8	-1,2
-5°	-1,8	-2,5	-1,2	-2,0	-0,7	-1,2	-0,6	-1,2
5°	-1,6	-2,2	-1,3	-2,0	-0,7	-1,2	-0,6	
15°	-1,3	-2,0	-1,3	-2,0	-0,6	-1,2	-0,5	
30°	-1,1	-1,5	-1,4	-2,0	-0,8	-1,2	-0,5	
45°	-1,1	-1,5	-1,4	-2,0	-0,9	-1,2	-0,5	
60°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	
75°	-1,1	-1,5	-1,2	-2,0	-0,8	-1,0	-0,5	

Table 17

Table A6.2 Flat terrain categories

	Category	Condition at construction site and upwind region
Smooth	I	Open, no significant obstruction, sea, lake
↑	II	Open, few obstructions, grassland, agricultural field
	III	Suburban, wooded terrain, few tall buildings (4 to 9-story)
↓	IV	City, tall buildings (4 to 9-story)
Rough	V	City, heavy concentration of tall buildings (higher than 10-story)

Table 18

ii) Roof

<table>
<tr><th colspan="6">zone R_U (windward roof)</th></tr>
<tr><th rowspan="2"></th><th rowspan="2">roof angle
θ (°)</th><th colspan="2">$D/H \le 1$</th><th colspan="2">$D/H > 1$</th></tr>
<tr><th>$B/H \le 2$</th><th>$B/H \ge 6$</th><th>$B/H \le 2$</th><th>$B/H \ge 6$</th></tr>
<tr><td rowspan="3">Positive</td><td>$\theta < 10$</td><td colspan="4">not necessary to evaluate</td></tr>
<tr><td>$10 \le \theta < 15$</td><td colspan="4">0</td></tr>
<tr><td>$15 \le \theta \le 45$</td><td colspan="4">$0.014(\theta - 15)$</td></tr>
<tr><td rowspan="5">Negative</td><td>$\theta < 10$</td><td colspan="4">same value as zone R (roof)</td></tr>
<tr><td>$10 \le \theta < 30$</td><td rowspan="2">$-0.84\tan(70-2\theta)$</td><td rowspan="4">$-0.81\tan(72-1.6\theta)$</td><td>$0.04(\theta-30)$</td><td rowspan="3">$-0.5\tan(80-2\theta)$</td></tr>
<tr><td>$30 \le \theta < 35$</td><td rowspan="3">0</td></tr>
<tr><td>$35 \le \theta < 40$</td><td rowspan="2">0</td></tr>
<tr><td>$40 \le \theta \le 45$</td><td>0</td></tr>
</table>

* Linear interpolation is permitted for $2 < B/H < 6$.

Table 19

ROOFS—EXTERNAL PRESSURE COEFFICIENTS ($C_{p,e}$) FOR RECTANGULAR ENCLOSED BUILDINGS—FOR UPWIND SLOPE (U) AND DOWNWIND SLOPE, (D) FOR $\alpha < 10°$ AND FOR (R) FOR GABLE ROOFS

Roof type and slope		Horizontal distance from windward edge of roof	External pressure coefficient ($C_{p,e}$)	
Crosswind slopes for gable roofs, (R)	**Upwind slope, (U), Downwind slope, (D)**		**$h/d \le 0.5$ (see Note 1)**	**$h/d \ge 1.0$ (see Note 1)**
All α	$\alpha < 10°$	0 to $0.5h$	−0.9, −0.4	−1.3, −0.6
		0.5 to $1h$	−0.9, −0.4	−0.7, −0.3
		$1h$ to $2h$	−0.5, 0	(−0.7), (−0.3)
		$2h$ to $3h$	−0.3, 0.1	see Note 2
		$> 3h$	−0.2, 0.2	

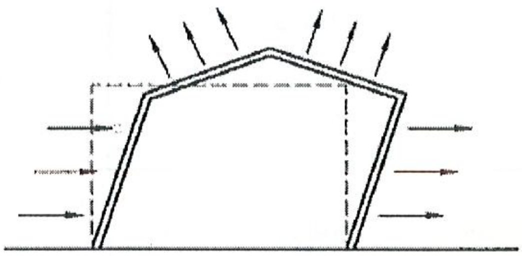
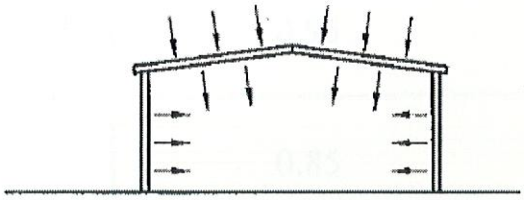
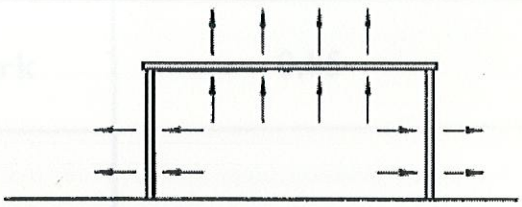
Table 20

AREA REDUCTION FACTOR (K_a)

Tributary area (A), m^2 (see Note)	Area reduction factor (K_a)
≤ 10	1.0
25	0.9
≥ 100	0.8

Table 21

ACTION COMBINATION FACTORS FOR WIND PRESSURE CONTRIBUTING FROM TWO OR MORE BUILDING SURFACES TO EFFECTS ON MAJOR STRUCTURAL ELEMENTS

	Design case	Combination factor (K_c)	Example diagrams
(a)	Where wind action from any single surface contributes 75 percent or more to an action effect	1.0	—
(b)	Pressures from windward and leeward walls in combination with positive or negative roof pressures	0.8	
(c)	Positive pressures on roofs in combination with negative internal pressures (from a wall opening)	0.8	
(d)	Negative pressures on roofs or walls in combination with positive internal pressures	0.95	
(e)	All other cases	1.0	—

NOTE: The action combination factors less than 1.0 can be justified because wind pressures are highly fluctuating and do not occur simultaneously on all building surfaces.

Table 22

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

Table 23

Height above ground level, z		Exposure (Note 1)					
		A		B		C	D
ft	(m)	Case 1	Case 2	Case 1	Case 2	Cases 1 & 2	Cases 1 & 2
0-15	(0-4.6)	0.68	0.32	0.70	0.57	0.85	1.03
20	(6.1)	0.68	0.36	0.70	0.62	0.90	1.08
25	(7.6)	0.68	0.39	0.70	0.66	0.94	1.12
30	(9.1)	0.68	0.42	0.70	0.70	0.98	1.16
40	(12.2)	0.68	0.47	0.76	0.76	1.04	1.22
50	(15.2)	0.68	0.52	0.81	0.81	1.09	1.27
60	(18)	0.68	0.55	0.85	0.85	1.13	1.31
70	(21.3)	0.68	0.59	0.89	0.89	1.17	1.34
80	(24.4)	0.68	0.62	0.93	0.93	1.21	1.38
90	(27.4)	0.68	0.65	0.96	0.96	1.24	1.40
100	(30.5)	0.68	0.68	0.99	0.99	1.26	1.43
120	(36.6)	0.73	0.73	1.04	1.04	1.31	1.48
140	(42.7)	0.78	0.78	1.09	1.09	1.36	1.52
160	(48.8)	0.82	0.82	1.13	1.13	1.39	1.55
180	(54.9)	0.86	0.86	1.17	1.17	1.43	1.58
200	(61.0)	0.90	0.90	1.20	1.20	1.46	1.61
250	(76.2)	0.98	0.98	1.28	1.28	1.53	1.68
300	(91.4)	1.05	1.05	1.35	1.35	1.59	1.73
350	(106.7)	1.12	1.12	1.41	1.41	1.64	1.78
400	(121.9)	1.18	1.18	1.47	1.47	1.69	1.82
450	(137.2)	1.24	1.24	1.52	1.52	1.73	1.86
500	(152.4)	1.29	1.29	1.56	1.56	1.77	1.89

Notes:

1. **Case 1:** a. All components and cladding.
   b. Main wind force resisting system in low-rise buildings designed using Figure 6-4.

   Case 2: a. All main wind force resisting systems in buildings except those in low-rise buildings designed using Figure 6-4.
   b. All main wind force resisting systems in other structures.

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

   For 15 ft. $\le z \le z_g$ — $K_z = 2.01\,(z/z_g)^{2/\alpha}$

   For $z < 15$ ft. — $K_z = 2.01\,(15/z_g)^{2/\alpha}$

   Note: z shall not be taken less than 100 feet for Case 1 in exposure A or less than 30 feet for Case 1 in exposure B.

3. α and z_g are tabulated in Table 6-4.
4. Linear interpolation for intermediate values of height z is acceptable.
5. Exposure categories are defined in 6.5.6.

Table 24

Exposure	α	z_g (ft)	$\hat{a}$	$\hat{b}$	$\bar{\alpha}$	$\bar{b}$	c	ℓ (ft)	$\bar{\epsilon}$	z_{min} (ft)*
A	5.0	1500	1/5	0.64	1/3.0	0.30	0.45	180	1/2.0	60
B	7.0	1200	1/7	0.84	1/4.0	0.45	0.30	320	1/3.0	30
C	9.5	900	1/9.5	1.00	1/6.5	0.65	0.20	500	1/5.0	15
D	11.5	700	1/11.5	1.07	1/9.0	0.80	0.15	650	1/8.0	7

*z_{min} = minimum height used to ensure that the equivalent height $\bar{z}$ is greater of 0.6h or z_{min}. For buildings with h ≤ z_{min}, $\bar{z}$ shall be taken as z_{min}.

Figure 11

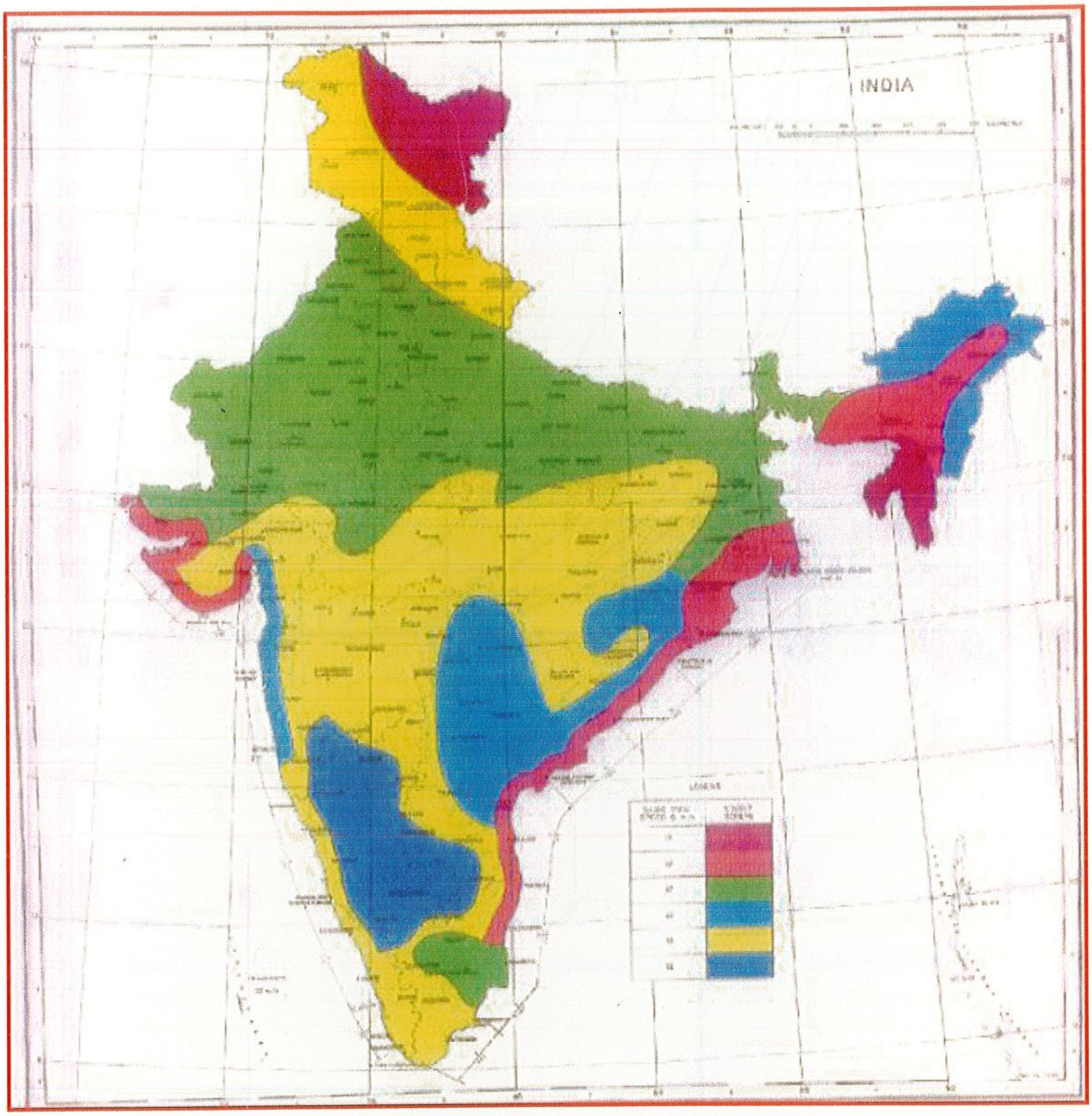


Figure 12

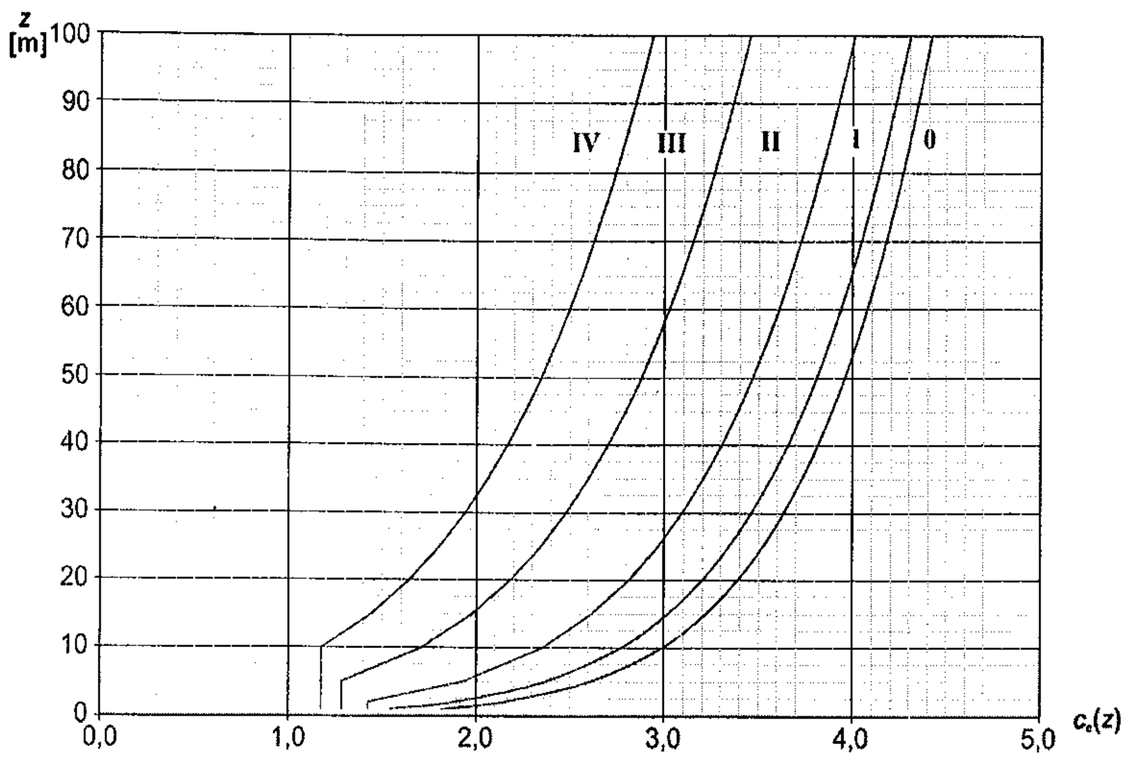
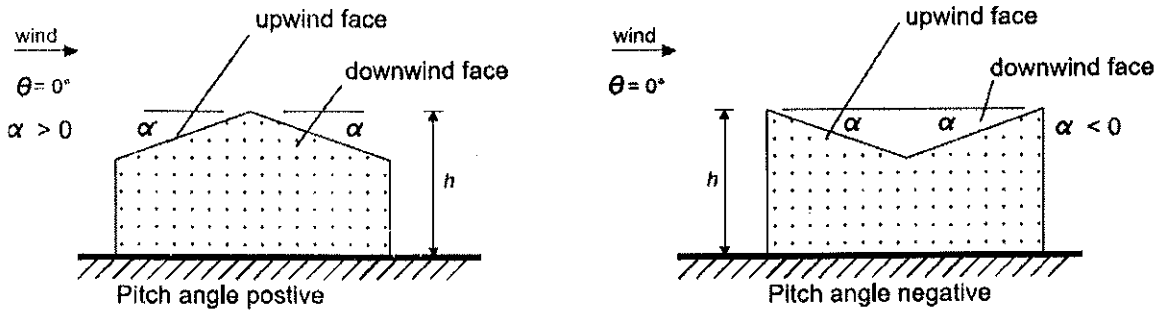
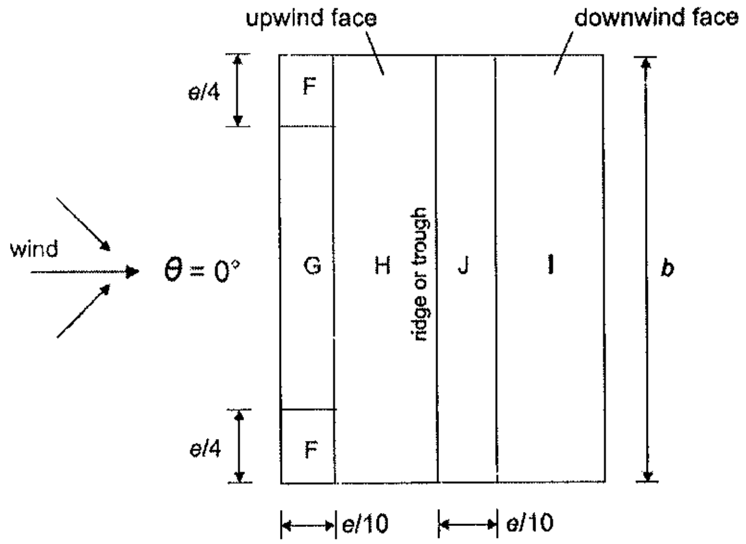


Figure 13



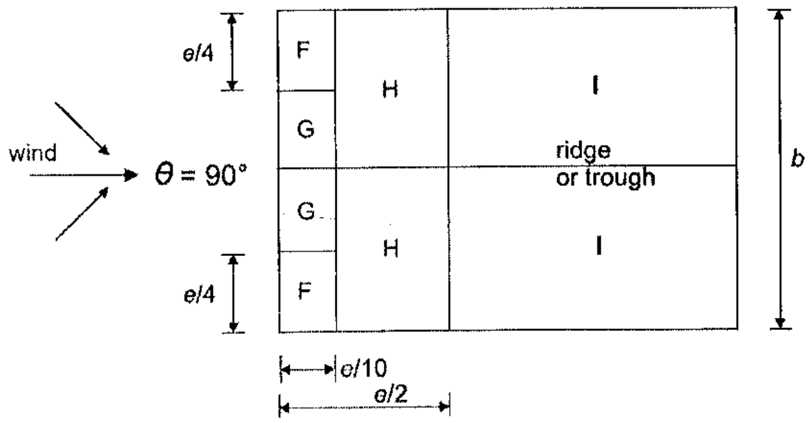
(a) general



(b) wind direction $\theta = 0°$

$e = b$ or $2h$
whichever is smaller

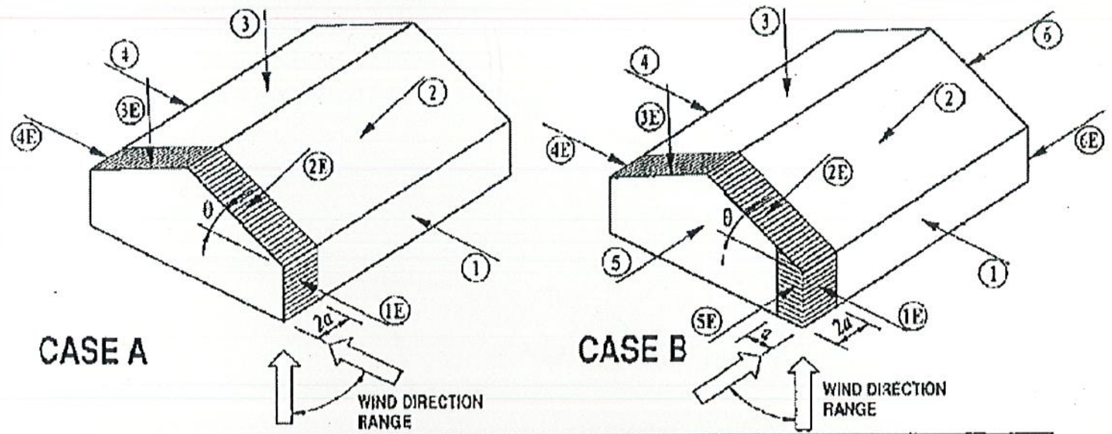
b : crosswind dimension



(c) wind direction $\theta = 90°$

Figure 14

Main Wind Force Resisting System		h ≤ 60 ft.
Figure 6-4	External Pressure Coefficients, GC_{pf}	**Walls & Gable Roof**
Enclosed, Partially Enclosed Buildings		



Roof Angle θ (degrees)	CASE A							
	Building Surface							
	1	2	3	4	1E	2E	3E	4E
0-5	0.40	-0.69	-0.37	-0.29	0.61	-1.07	-0.53	-0.43
20	0.53	-0.69	-0.48	-0.43	0.80	-1.07	-0.69	-0.64
30-45	0.56	0.21	-0.43	-0.37	0.69	0.27	-0.53	-0.48
90	0.56	0.56	-0.37	-0.37	0.69	0.69	-0.48	-0.48

Roof Angle θ (degrees)	CASE B											
	Building Surface											
	1	2	3	4	5	6	1E	2E	3E	4E	5E	6E
0-90	-0.45	-0.69	-0.37	-0.45	0.40	-0.29	-0.48	-1.07	-0.53	-0.48	0.61	-0.43

Notes:

1. Case A and Case B are required as two separate loading conditions to generate the wind actions, including torsion, to be resisted by the main wind-force resisting system.
2. To obtain the critical wind actions, the building shall be rotated in 90° degree increments so that each corner in turn becomes the windward corner while the loading patterns in the sketches remain fixed. For the design of structural systems providing lateral resistance in the direction parallel to the ridge line, Case A shall be based on $\theta = 0°$.
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. For Case A loading the following restrictions apply:
   a. The roof pressure coefficient GC_{pf}, when negative in Zone 2, shall be applied in Zone 2 for a distance from the edge of roof equal to 0.5 times the horizontal dimensions of the building measured perpendicular to the eave line or $2.5h$, whichever is less; the remainder of Zone 2 extending to the ridge line shall use the pressure coefficient GC_{pf} for Zone 3.
   b. Except for moment-resisting frames, the total horizontal shear shall not be less than that determined by neglecting wind forces on roof surfaces.
5. Combinations of external and internal pressures (see Table 6-7) shall be evaluated as required to obtain the most severe loadings.
6. For values of θ other than those shown, linear interpolation is permitted.
7. Notation:
   a: 10 percent of least horizontal dimension or 0.4h, whichever is smaller, but not less than either 4% of least horizontal dimension or 3 ft (1 m).
   h: Mean roof height, in feet (meters), except that eave height shall be used for $\theta \leq 10°$.
   θ: Angle of plane of roof from horizontal, in degrees.