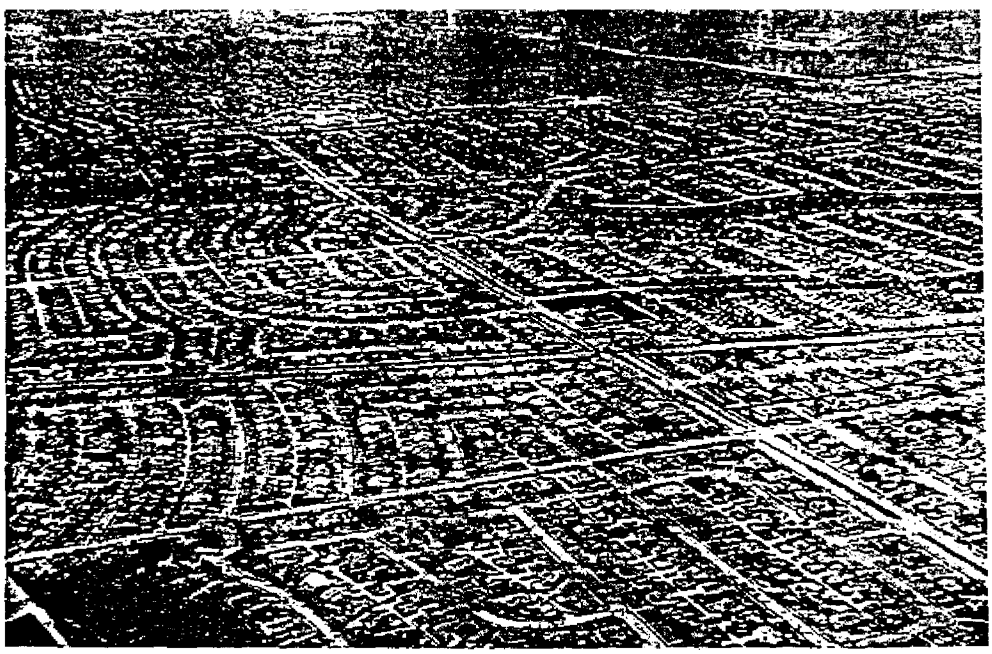
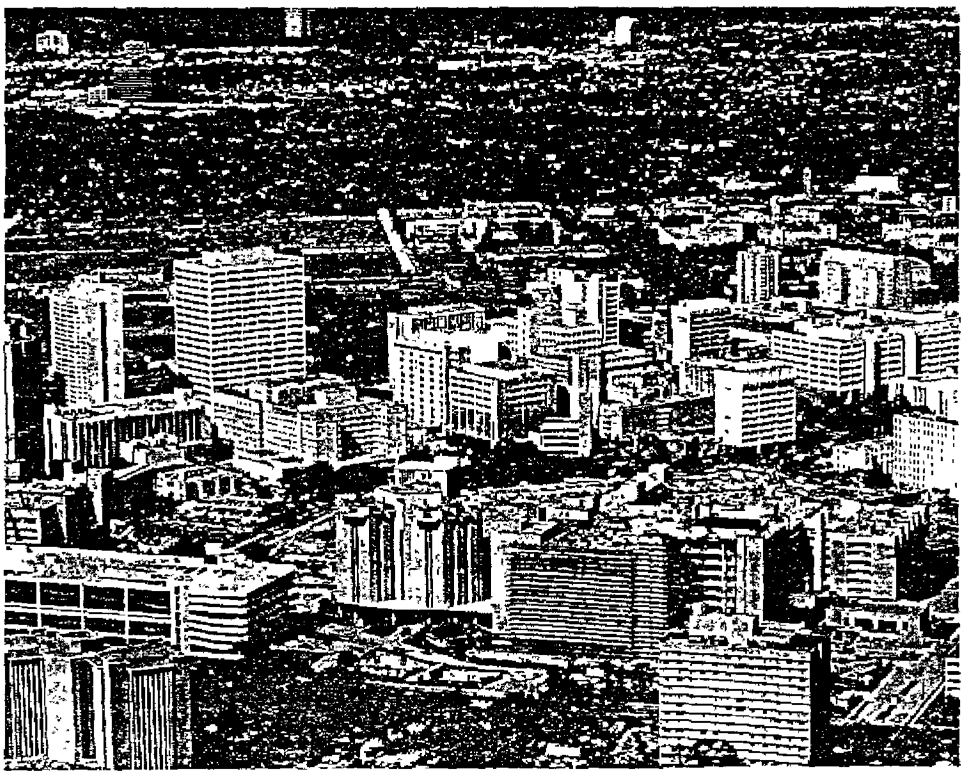
Exposure A: Large city center with at least 50% of the buildings having a height in excess of 70 ft. The subject building must have this terrain upwind for at least one-half mile or 10 times the height of the building, whichever is greater.



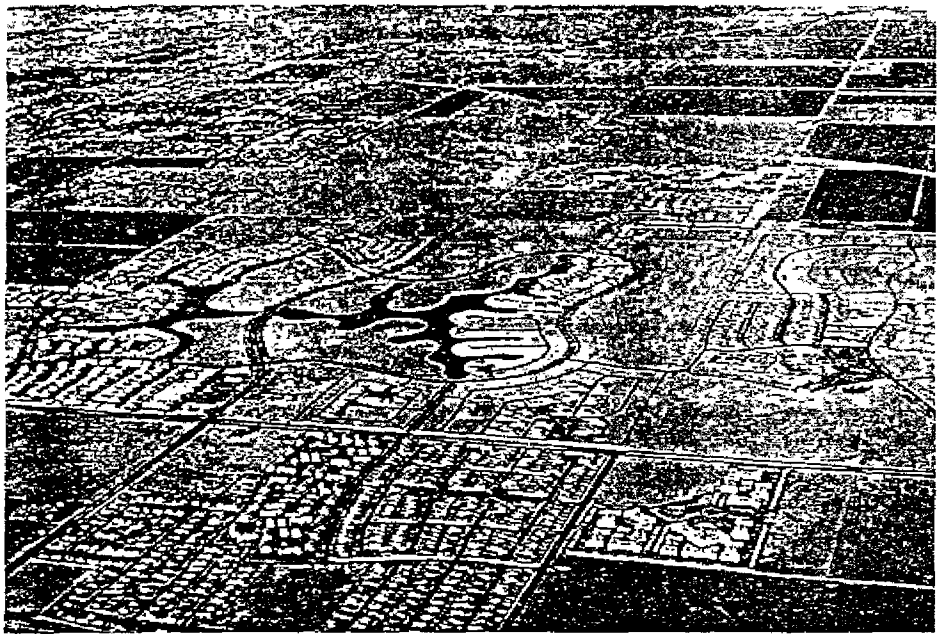
Exposure B: Suburban residential area with mostly single family dwellings. Structures in the center of the photograph have an Exposure B terrain greater than 1500 ft. or ten times the height of the structure, whichever is greater, in any wind direction.

Exposure B: Urban area with numerous closely spaced obstructions having the size of single family dwellings or larger For all structures shown, terrain representative of Exposure B extends more than 10 times the height of the structure or 1500 ft., whichever is greater, in the upwind direction.

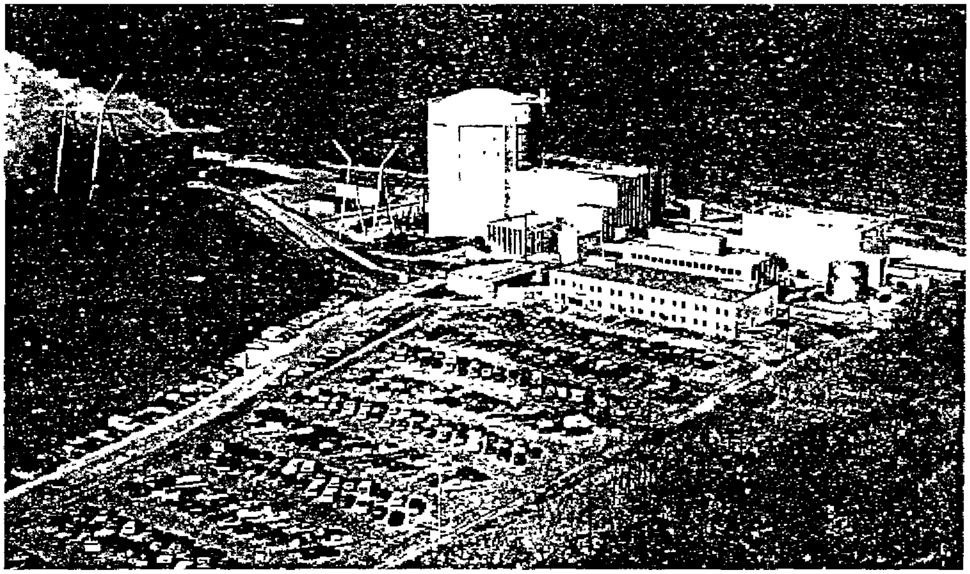


Exposure B: Structures in the foreground are subjected to an Exposure B terrain Structures in the center top of the photograph adjacent to the clearing to the left, which is greater than 600 feet in length, are subjected to Exposure C when wind comes from the left over the clearing

Exposure C: Flat open grassland with scattered obstructions having heights generally less than 30 ft.



Exposure C: Open terrain with scattered obstructions having heights generally less than 30 ft. For most wind directions, all structures in the photograph are less than 1500 feet or 10 times the height of the structure, whichever is greater, from an open field which prevents the use of Exposure B.



Exposure D: A building at the shoreline (excluding shorelines in hurricane prone regions) with wind flowing over open water for a distance of at least one mile. Shorelines in Exposure D include inland waterways, the Great Lakes, and coastal areas of California, Oregon, Washington, and Alaska wind loads) from any wind direction is required for use in design of component and cladding elements However, in the design of the main wind force resisting system using Figure 6-3, the designer may consider one or more wind directions and assign a terrain exposure to each direction for use in calculating wind loads for that direction For example the designer may select a terrain exposure for each 90 degree quadrant and calculate wind loads for each quadrant. It is common in wind tunnel studies to consider 36 ten degree sectors

C6.5.6.4 Velocity pressure exposure coefficient. The velocity pressure exposure coefficient K_z can be obtained using the equation:

$$K_z = \begin{cases} 2.01\left(\dfrac{z}{z_g}\right)^{2/\alpha} & \text{for } 15 \text{ ft} \le z \le z_g \qquad \text{(C6-3a)} \\ 2.01\left(\dfrac{15}{z_g}\right)^{2/\alpha} & \text{for } z < 15 \text{ ft} \qquad \text{(C6-3b)} \end{cases}$$

in which values of α and z_g are given in Table 6-4. These equations are now given in Table 6-5 to aid the user.

The values of the gradient height, z_g, listed in Table 6-4 are consistent with those values used in ASCE 7-93. However, because the shape of the wind speed profiles changes when the reference wind speed is changed from fastest mile to the 3-second gust speed, it was necessary to modify the values of α in the power-law representation of the wind speed profile The new values of α in Table 6-4 are based on a comprehensive review of existing data and representations of gust speed profiles. Correspondingly, the multiplier in Eq C6-3 for the exposure coefficient, K_z, changes from 2 58 to 2 01. Values of K_z are assumed to be constant for heights less than 15, and for heights greater than the gradient height. For Case 1 in exposures A and B, the value of K_z has been truncated at 100 ft. and 30 ft., respectively (refer to Table 6-5).

The new values of α (Table 6-4) make the wind speed profiles flatter than they are in ASCE 7-93; this is consistent with theory as wind speed averaging time is changed from fastest-mile to 3-second gust speed [67], [68]. Field data collected recently in flat terrain in 1992 on a 160 ft high tower with anemometers at several levels also indicated that α value changes as averaging time of wind speed is varied. In order to determine α values related to 3-second gust speed for exposure categories A, B, C and D, a published atmospheric boundary layer turbulence model [67] was used. Mean velocity profiles, defined using power-law exponent from ASCE 7-93, were combined with the turbulence profiles to produce profiles of peak gust speed. Mean velocity profile power law exponents consistent with the gust profiles are listed in Table 6-4 for reference. In the profile calculations, boundary layer heights are the same ones used for ASCE 7-93 as indicated in Table C6-2 of that standard The gust profile was fitted to determine α values. As an additional check, log-law profiles were fitted with power-law profiles in the bottom 500 ft (152.4m) to obtain α values. The roughness length z_o selected to represent exposure categories A, B, C and D were 0.3, 0.1, 0.01, and 0.003 m consistent with gust speed [68]. The α values are rounded for use in the standard The α values of Table 6-4 increase K_z values for exposure categories A and B while decreasing the values for exposure category D as compared to values K_z in ASCE 7-93. In addition, differences in K_z values between exposure categories are reduced; e.g. for exposure category B at 30 ft (9m) the values of $K_z = 0.7$ in Table 6-5 as compared to the value of $K_z = 0.5$ in ASCE 7-93. The new values of K_z in Table 6-5 are very close to the values specified in the Australian Standard [34], which also uses the 3-second gust speed format; this agreement lends credence to the new values of in Table 6-4.

C6.5.7 Wind Speed-Up over Hills and Escarpments. As an aid to the designer, this section has been rewritten to specify when topographic effects need to be applied to a particular structure rather than when they do not as in the previous version In addition, the upwind distance to consider has been lengthened from 50 times to 100 times the height of the topographic feature (100 H) and from one mile to two miles. In an effort to exclude situations where little or no topographic effect exists, condition (2) has been added to include the fact that the topographic feature should protrude significantly above (by a factor of two or more) upwind terrain features before it becomes a factor For example, if a significant upwind terrain feature has a height of 35 feet above its base elevation and has a top elevation of 100 feet above mean sea level then the topographic feature (hill, ridge or escarpment) must have at least the H specified and extend to elevation 170 mean sea level (100 ft + 2 x 35 ft) within the two mile radius specified.

A recent wind tunnel study [81] and observation of actual wind damage has shown that the affected height H is less than previously specified. Accordingly, condition (5) has been changed to 15 feet in Exposure C.

Buildings sited on the upper half of an isolated hill or escarpment may experience significantly higher wind speeds than buildings situated on level ground. To account for these higher wind speeds, the velocity pressure exposure coefficients in Table 6-5 are multiplied by a topographic factor, K_{zt}, defined in Eq. 6-13 of 6.5.10 The topographic feature (2-D ridge or escarpment, or 3-D axisymmetrical hill) is described by two parameters, H and L_h. H is the height of the hill or difference in elevation between the crest and that of the upwind terrain. L_h is the distance upwind of the crest to where the ground elevation is equal to half the height of the hill. K_{zt} is determined from three multipliers, K_1, K_2 and K_3, which are obtained from Fig 6-2, respectively. K_1 is related to the shape of the topographic feature and the maximum speed-up near the crest. K_2 accounts for the reduction in speed-up with distance upwind or downwind of the crest, and K_3 accounts for the reduction in speed-up with height above the local ground surface

The multipliers listed in Figure 6-2 are based on the assumption that the wind approaches the hill along the direction of maximum slope, causing the greatest speed-up near the crest The average maximum upwind slope of the hill is approximately $H/2L_h$, and measurements have shown that hills with slopes of less than about 0 10 ($H/L_h < 0\ 20$) are unlikely to produce significant speed-up of the wind. For values of $H/L_h > 0.5$ the speed-up effect is assumed to be independent of slope. The speed-up principally affects the mean wind speed rather than the amplitude of the turbulent fluctuations and this fact has been accounted for in the values of K_1. K_2 and K_3 given in Figure 6-2. Therefore, values of K_{zt} obtained from Table 6-2 are intended for use with velocity pressure exposure coefficients. K_h and K_z, which are based on gust speeds.

It is not the intent of Section 6.5 7 to address the general case of wind flow over hilly or complex terrain for which engineering judgment, expert advice, or wind tunnel tests as described in 6 6 may be required Background material on topographic speed-up effects may be found in the literature [18], [21], [56].

The designer is cautioned that, at present, the standard contains no provision for vertical wind speed up because of a topographic effect, even though this phenomenon is known to exist and can cause additional uplift on roofs Additional research is required to quantify this effect before it can be incorporated into the standard

C6.5.8 Gust Effect Factors. ASCE 7-98 contains a single gust effect factor of 0 85 for rigid buildings. As an option, the designer can incorporate specific features of the wind environment and building size to more accurately calculate a gust effect factor. One such procedure, previously contained in the commentary, is now located in the body of the standard [63, 64] A suggested procedure is also included for calculating the gust effect factor for flexible structures. The rigid structure gust factor is typically 0-4 percent higher than in ASCE 7-95 and is 0-10 percent lower than the simple, but conservative, value of 0.85 permitted in the standard without calculation The procedures for both rigid and flexible structures have been changed from the previous version to 1) keep the rigid gust factor calculation within a few percent of the previous model, 2) provide a superior model for flexible structures which displays the peak factors g_Q and g_R, and 3) causes the flexible structure value to match the rigid structure as resonance is removed (an advantage not included in the previous version) A designer is free to use any other rational procedure in the approved literature, as stated in 6.5 8 3.

The gust effect factor accounts for the loading effects in the along-wind direction due to wind turbulence-structure interaction It also accounts for along-wind loading effects due to dynamic amplification for flexible buildings and structures. It does not include allowances for across-wind loading effects, vortex shedding, instability due to galloping or flutter, or dynamic torsional effects For structures susceptible to loading effects that are not accounted for in the gust effect factor, information should be obtained from recognized literature [60]-[65] *or from* wind tunnel tests.

Along-wind Response. Based on the preceding definition of the gust effect factor, predictions of along-wind response, e g., maximum displacement, rms and peak acceleration, can be made. These response components are needed for survivability and serviceability limit states. In the following, expressions for evaluating these along-wind response components are given.

Maximum Alongwind Displacement. The maximum along-wind displacement $X_{max}(z)$ as a function of height above the ground surface is given by

$$X_{\max}(z) = \frac{\phi(z)\rho B h C_{fx} \hat{V}_{\bar{z}}^2}{2 m_1 (2\pi n_1)^2} KG \qquad \text{(C6-4)}$$

where·

$\phi(z)$	=	the fundamental model shape
	=	$(z/h)^{\xi}$
ξ	=	the mode exponent
ρ	=	air density
C_{fx}	=	mean alongwind force coefficient
m_1	=	modal mass

$$= \int_0^h \mu(z)\phi^2(z)\, dz \qquad \text{(C6-5)}$$

$\mu(z)$	=	mass per unit height

$$K = (1.65)^{\hat{\alpha}} / (\hat{\alpha} + \xi + 1) \qquad \text{(C6-6)}$$

$\hat{V}_{\bar{z}}$ is the 3-sec gust speed at height $\bar{z}$ This can be evaluated $\hat{V}_{\bar{z}} = \hat{b}\,(\bar{z}/33)^{\hat{\alpha}} V$, where V is the 3-sec gust speed in exposure C at the reference height (obtained from Fig. 6-1); $\hat{b}$ and $\hat{\alpha}$ are given in Table 6-4.

RMS Alongwind Acceleration. The rms alongwind acceleration $\sigma_{\ddot{x}}(z)$ as a function of height above the ground surface is given by

$$\sigma_x(z) = \frac{0.85\phi(z)\,\rho B h C_{fx} \bar{V}_{\bar{z}}^2}{m_1} I_{\bar{z}} K R \qquad \text{(C6-7)}$$

where $\bar{V}_{\bar{z}}$ is the mean hourly wind speed at height $\bar{z}$, ft/sec

$$\bar{V}_{\bar{z}} = \bar{b}\left(\frac{\bar{z}}{33}\right)^{\bar{\alpha}} V \qquad \text{(C6-8)}$$

where $\hat{b}$ and $\hat{\alpha}$ are defined in Table 6-4.

Maximum Alongwind Acceleration. The maximum alongwind acceleration as a function of height above the ground surface is given by

$$\ddot{X}_{\max}(z) = g_x \sigma_{\ddot{x}}(z) \qquad \text{(C6-9)}$$

$$g_x = \sqrt{2\ln(n_1 T)} + \frac{0.5772}{\sqrt{2\ln(n_1 T)}} \qquad \text{(C6-10)}$$

where T = the length of time over which the minimum acceleration is computed, usually taken to be 3,600 sec to represent 1 hour.

Example:

The following example is presented to illustrate the calculation of the gust effect factor

Table C6-4 uses the given information to obtain values from Table 6-4. Table C6-5 presents the calculated values. Table C6-6 summarizes the calculated displacements and accelerations as a function of the height, z.

Given Values:

- Basic wind speed at reference height in exposure C =90 mph
- Type of exposure = A
- Building height h = 600 ft
- Building width B = 100 ft
- Building depth L = 100 ft
- Building natural frequency n_1 = 0.2 Hz
- Damping ratio = 0.01
- C_{fx} = 1.3
- Mode exponent = 1.0
- Building density = 12 lb/cu ft = 0.3727 slugs/cu ft
- Air density = 0 0024 slugs/cu ft

C6.5.9 Enclosure Classifications. The magnitude and sense of internal pressure is dependent upon the magnitude and location of openings around the building envelope with respect to a given wind direction. Accordingly, the standard requires that a determination be made of the amount of openings in the envelope in order to assess enclosure classification (enclosed, partially enclosed, or open). "Openings" are specifically defined in this version of the standard as "apertures or holes in the building envelope which allow air to flow through the building envelope and which are designed as "open" during design winds " Examples include doors, operable windows, air intake exhausts for air conditioning and/or ventilation systems, gaps around doors, deliberate gaps in cladding and flexible and operable louvers. Once the enclosure classification is known, the designer enters Table 6-7 to select the appropriate internal pressure coefficient.

This version of the standard creates four new definitions applicable to enclosure. "wind borne debris regions," "glazing" "impact resistant glazing," and "impact resistant covering." "Wind borne debris regions" are defined to alert the designer to areas requiring consideration of missile impact design and potential openings in the building envelope. "Glazing" is defined as "any glass or transparent or translucent plastic sheet used in windows, doors, or skylights " "Impact resistant glazing" is specifically defined as "glazing which has been shown by a test method, acceptable to the authority having jurisdiction, to withstand impact of wind borne missiles likely to be generated in wind borne debris regions during design winds " "Impact resistant coverings" over glazing can be shutters or screens designed for wind borne debris impact While impact resistance can now be tested using the new ASTM Standard E 1886 [70], no ASTM specification yet exists (one is currently under development) for defining specific missiles and impact speeds that can be referenced in the body of the standard. The designer can refer to SBCCI SSTD 12 [71] which does define specific missiles and corresponding impact speeds. Origins of missile impact provisions contained in these test standards are summarized in references [72], [80].

Attention is made to 6.5.9.3 which requires the designer to assume glazing not designed to be impact resistant glazing or protected by an impact resistant covering on surfaces receiving positive pressure in wind borne debris regions to be treated as openings when assessing enclosure classification

C6.5.10 Velocity Pressure. The basic wind speed is converted to a velocity pressure q_z in pounds per square foot (newtons per square meter) at height z by the use of equation 6-13.

The constant 0.00256 (or 0.613 in SI) reflects the mass density of air for the standard atmosphere, i.e., temperature of 59°F (15°C) and sea level pressure of 29.92 inches of mercury (101.325 kPa), and dimensions associated with wind speed in miles-per-hour (meters per second). The constant is obtained as follows:

$$\text{constant} = 1/2[(0.0765 \text{ lb/cu ft})/(32.2 \text{ ft/s}^2)] \times [(\text{mi/h})(5280 \text{ ft/mi}) \times (1 \text{ h}/3600 \text{ s})]^2 \quad \text{(C6-11)}$$
$$= 0.00256$$

$$\text{constant} = 1/2[(1.225 \text{ kg/m}^3)/(9.81 \text{ m/s}^2)] \times [(\text{m/s})]^2 [9.81 \text{ N/kg}]$$
$$= 0.613$$

The numerical constant of 0.00256 should be used except where sufficient weather data are available to justify a different value of this constant for a specific design application. The mass density of air will vary as a function of altitude, latitude, temperature, weather, and season. Average and extreme values of air density are given in Table C6-1.

C6.5.11 Pressure and Force Coefficients. The pressure and force coefficients provided in Figs. 6-3 through 6-8 and in Tables 6-4 through 6-10 have been assembled from the latest boundary-layer wind-tunnel and full-scale tests and from previously available literature. Since the boundary-layer wind tunnel results were obtained for specific types of building such as low- or high-rise buildings and buildings having specific types of structural framing systems, the designer is cautioned against indiscriminate interchange of values among the figures and tables.

Loads on Main Wind-Force Resisting Systems:

Figures 6-3 and 6-4. The pressure coefficients for main wind-force resisting systems are separated into two categories:

1. Buildings of all heights (Fig. 6-3), and
2. Low-rise buildings having a height less than or equal to 60 ft (18 m) (Fig. 6-4).

In generating these coefficients, two distinctly different approaches were used. For the pressure coefficients given in Fig. 6-3, the more traditional approach was followed and the pressure coefficients reflect the actual loading on each surface of the building as a function of wind direction; namely, winds perpendicular or parallel to the ridge line.

For low-rise buildings having a height less than or equal to 60 ft (18 m), however, the values of GC_{pf} represent "pseudo" loading conditions (Case A and Case B) which, when applied to the building, envelope the desired structural actions (bending moment, shear, thrust) independent of wind direction and exposure. To capture all appropriate structural actions, the building must be designed for all wind directions by considering in turn each corner of the building as the windward corner shown in the sketches of Fig. 6-4. Note also that for all roof slopes, load case A and load case B must be considered individually in order to determine the critical loading for a given structural assemblage or component thereof. These two separate loading conditions are required for each of the windward corners to generate the wind actions, including torsion, to be resisted by the structural systems. Note that the building "end zones" must be aligned in accordance with the assumed windward corner (see Fig. C6-2).

To develop the appropriate "pseudo" values of GC_{pf}, investigators at the University of Western Ontario [11] used an approach which consisted essentially of permitting the building model to rotate in the wind tunnel through a full 360 degrees while simultaneously monitoring the loading conditions on each of the surfaces (see Fig. C6-3). Both exposures B and C were considered. Using influence coefficients for rigid frames, it was possible to spatially average and time average the surface pressures to ascertain the maximum induced external force components to be resisted. More specifically, the following structural actions were evaluated:

1. total uplift
2. total horizontal shear
3. bending moment at knees (2-hinged frame)
4. bending moment at knees (3-hinged frame), and
5. bending moment at ridge (2-hinged frame)

The next step involved developing sets of "pseudo" pressure coefficients to generate loading conditions which would envelope the maximum induced force components to be resisted for all possible wind directions and exposures. Note, for example, that the wind azimuth producing the maximum bending moment at the knee would not necessarily produce the maximum total uplift. The maximum induced external force components determined for each of the above five categories were used to develop the coefficients. The end result was a set of coefficients which represent fictitious loading conditions, but which conservatively envelope the maximum induced force components (bending moment, shear, and thrust) to be resisted, independent of wind direction.

The original set of coefficients was generated for the framing of conventional pre-engineered buildings, i.e., single story moment-resisting frames in one of the principal directions and bracing in the other principal direction. The approach was later extended to single story moment-resisting frames with interior columns [19].

Subsequent wind tunnel studies [69] have shown that the GC_{pf} values of Figure 6-4 are also applicable to low-rise buildings with structural systems other than moment-resisting frames. That work examined the instantaneous wind pressures on a low-rise building with a 4:12 pitched gable roof and the resulting wind-induced forces on its main wind-force resisting system. Two (2) different main wind-force resisting systems were evaluated. One consisted of shear walls and roof trusses at different spacings The other had moment resisting frames in one direction. positioned at the same spacings as the roof trusses, and diagonal wind bracing in the other direction. Wind tunnel tests were conducted for both Exposures B and C. The findings of this study showed that the GC_{pf} values of Figure 6-4 provided satisfactory estimates of the wind forces for both types of structural systems. This work confirms the validity of Figure 6-4, which reflects the combined action of wind pressures on different external surfaces of a building and thus take advantage of spatial averaging

In the original wind tunnel experiments, both B and C exposure terrains were checked In these early experiments, B exposure did not include nearby buildings. In general, the force components, bending moments, etc. were found comparable in both exposures, although GC_{pf} values associated with Exposure B Terrain would be higher than that for Exposure C terrain because of reduced velocity pressure in Exposure B terrain. The GC_{pf} values given in Figure 6-4 (also in Figures 6-5, 6-6 and 6-7) are derived from wind tunnel studies modeled with Exposure C terrain. However, they may also be used in other exposures when the velocity pressure representing the appropriate exposure is used

In recent comprehensive wind tunnel studies conducted by [66] at the University of Western Ontario, it was determined that when low buildings (h < 60 ft) are embedded in suburban terrain (Exposure B which included nearby buildings), the pressures in most cases are lower than those currently used in existing standards and codes, although the values show a very large scatter because of high turbulence and many variables. The results seem to indicate that some reduction in pressures for buildings located in Exposure B is justified. The Task Committee on Wind Loads believes it is desirable to design buildings for the exposure conditions consistent with the exposure designations defined in the standard. In the case of low buildings, the effect of the increased intensity of turbulence in rougher terrain (i.e., Exposure A or B vs C) increases the local pressure coefficients. In ASCE 7-95 this effect was accounted for by allowing the designer of a building situated in Exposure A or B to use the loads calculated as if the building were located in Exposure C, but to reduce the loads by 15%. In ASCE 7-98 the effect of the increased turbulence intensity on the loads is treated with the truncated profile. Using this approach, the actual building exposure is used and the profile truncation corrects for the underestimate in the loads that would be obtained otherwise. The resulting wind loads on components and cladding obtained using this approach are much closer to the true values than those obtained using Exposure C loads combined with a 15% reduction in the resulting pressures.

Figure 6-4 is most appropriate for low buildings with width greater than twice their height and a mean roof height that does not exceed 33 ft (10m) The original data base included low buildings with *width no greater than 5 times* their eave height, and eave height did not exceed 33 ft (10m). In the absence of more appropriate data, Figure 6-4 may also be used for buildings with mean roof height which does not exceed the least horizontal dimension and is less than or equal to 60 ft (18m). Beyond these extended limits, Figure 6-3 should be used

Internal pressure coefficients (GC_{pi}) to be used for loads on main wind-force resisting systems are given in Table 6-4. The internal pressure load can be critical in one-story moment resisting frames and in the top story of a building where the main wind-force resisting system consists of moment resisting frames. Loading cases with positive and negative internal pressures should be considered. The internal pressure load cancels out in the determination of total lateral load and base shear. The designer can use judgment in the use of internal pressure loading for the main wind-force resisting system of high rise buildings

Loads on Components and Cladding. In developing the set of pressure coefficients applicable for the design of components and cladding as given in Figs. 6-5, 6-6 and 6-7, an envelope approach was followed but using different methods than for the main wind-force resisting systems of Fig. 6-4. Because of the small effective area which may be involved in the design of a particular component (consider, for example, the effective area associated with the design of a fastener), the point-wise pressure fluctuations may be highly correlated over the effective area of interest. Consider the local purlin loads shown in Fig. C6-2. The approach involved spatial averaging and time averaging of the point pressures over the effective area transmitting loads to the purlin while the building model was permitted to rotate in the wind tunnel through 360 degrees. As the induced localized pressures may also vary widely as a function of the specific location on the building, height above ground level, exposure, and more importantly, local geometric discontinuities and location of the element relative to the boundaries in the building surfaces (walls. roof lines), these factors were also enveloped in the wind tunnel tests. Thus, for the pressure coefficients given in Figs. 6-5, 6-6 and 6-7, the directionality of the wind and influence of exposure have been removed and the surfaces of the building "zoned" to reflect an envelope of the peak pressures possible for a given design application

As indicated in the discussion for Figure 6-4, the wind tunnel experiments checked both B and C exposure terrains. Basically GC_p values associated with Exposure B terrain would be higher than that for Exposure C terrain because of reduced velocity pressure in Exposure B terrain. The GC_p values given in Figures 6-5, 6-6 and 6-7 are associated with Exposure C terrain as obtained in the wind tunnel However, they may be also used for any exposure when the correct velocity pressure representing the appropriate exposure is used. (See commentary discussion in Section C6.5 11 under Loads on Main Wind Force Resisting Systems)

The wind tunnel studies conducted by [66] determined that when low buildings ($h < 60$ ft) are embedded in suburban terrain (Exposure B), the pressures on components and cladding in most cases are lower than those currently used in the standards and codes, although the values show a very large scatter because of high turbulence and many variables. The results seem to indicate that some reduction in pressures for components and cladding of buildings located in Exposure B is justified.

The pressure coefficients given in Fig. 6-8 for buildings with mean height greater than 60 feet were developed following a similar approach, but the influence of exposure was not enveloped [42] Therefore, exposure categories A, B, C or D may be used with the values of GC_p in Fig. 6-8 as appropriate

Figure 6-5. The pressure coefficient values provided in this figure are to be used for buildings with a mean roof height of 60 ft (18 m) or less. The values were obtained from wind-tunnel tests conducted at the University of Western Ontario [10], [11], at the James Cook University of North Queensland [6], and at Concordia University [39], [40], [44], [45], [47]. These coefficients have been refined to reflect results of full-scale tests conducted by the National Bureau of Standards [22] and the Building Research Station, England [14]. Pressure coefficients for hemispherical domes on ground or on cylindrical structures have been reported [52] Some of the characteristics of the values in the figure are as follows:

1. The values are combined values of GC_p; the gust effect factors from these values should not be separated.
2. The velocity pressure q_h evaluated at mean roof height should be used with all values of GC_p.
3. The values provided in the figure represent the upper bounds of the most severe values for any wind direction. The reduced probability that the design wind speed may not occur in the particular direction for which the worst pressure coefficient is recorded has not been included in the values shown in the figure.
4. The wind-tunnel values, as measured, were based on the mean hourly wind speed. The values provided in the figures are the measured values divided by $(1.53)^2$ (see Fig. C6-1) to reflect the reduced pressure coefficient values associated with a three-second gust speed.

Each component and cladding element should be designed for the maximum positive and negative pressures (including applicable internal pressures) acting on it The pressure coefficient values should be determined for each component and cladding element on the basis of its location on the building and the effective area for the element. As recent research has shown [41], [43], the pressure coefficients provided generally apply to facades with architectural features such as balconies, ribs and various facade textures.

Figures 6-6 and 6-7A. These figures present values of GC_p for the design of roof components and cladding for buildings with multispan gable roofs and buildings with monoslope roofs. The coefficients are based *on wind* tunnel studies reported by [46], [47], [51]

Figure 6-7B. The values of GC_p in this figure are for the design of roof components and cladding for buildings with sawtooth roofs and mean roof height, h, less than or equal to 60 ft (18 m). Note that the coefficients for corner zones on segment A differ from those coefficients for corner zones on the segments designated as B, C, and D Also, when the roof angle is less than or equal to 10 degrees, values of GC_p for regular gables roofs (Fig 6-5B) are to be used The coefficients included in Fig. 6-7B are based on wind tunnel studies reported by [35].

Figure 6-8. The pressure coefficients shown in this figure have been revised to reflect the results obtained from comprehensive wind tunnel studies carried out by [42]. In general, the loads resulting from these coefficients are lower than those required by ASCE 7-93. However, the area averaging effect for roofs is less pronounced when compared with the requirements of ASCE 7-93 The availability of more comprehensive wind tunnel data has also allowed a simplification of the zoning for pressure coefficients; flat roofs are now divided into three zones, and walls are represented by two zones

The external pressure coefficients and zones given in Fig 6-8 were established by wind tunnel tests on isolated "box-like" buildings [2], [31]. Boundary-layer wind tunnel tests on high-rise buildings (mostly in downtown city centers) show that variations in pressure coefficients and the distribution of pressure on the different building facades are obtained [53]. These variations are due to building geometry, low attached buildings, non-rectangular cross sections, setbacks, and sloping surfaces. In addition, surrounding buildings contribute to the variations in pressure. Wind-tunnel tests indicate that pressure coefficients are not distributed symmetrically and can give rise to torsional wind loading on the building.

Boundary-layer wind tunnel tests that include modeling of surrounding buildings permit the establishment of more exact magnitudes and distributions of GC_p for buildings that are not isolated or "box-like" in shape.