Chapter 2

MINIMUM DESIGN LOADS

NATIONAL STRUCTURAL CODE OF THE PHILIPPINES
VOLUME I
BUILDINGS, TOWERS AND OTHER VERTICAL STRUCTURES

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SECTION 201
GENERAL REQUIREMENTS

201.1 Scope

This chapter provides minimum design load requirements for the design of buildings, towers and other vertical structures. Loads and appropriate load combinations which have been developed to be used together for strength design and allowable stress design are set forth.

SECTION 202
DEFINITIONS

The following terms are defined for use in this section:

ACCESS FLOOR SYSTEM is an assembly consisting of panels mounted on pedestals to provide an under-floor space for the installation of mechanical, electrical, communication or similar systems or to serve as an air-supply or return-air plenum.

AGRICULTURAL BUILDING is a structure designed and constructed to house farm implements, hay, grain, poultry, livestock or other horticultural products. The structure shall not be a place of human habitation or a place of employment where agricultural products are processed, treated, or packaged, nor shall it be a place used by the public.

ALLOWABLE STRESS DESIGN (ASD) is a method of proportioning and designing structural members such that elastically computed stresses produced in the members by nominal loads do not exceed specified allowable stresses (also called working stress design).

ASSEMBLY BUILDING is a building or portion of a building for the gathering together of 50 or more persons for such purposes as deliberation, education, instruction, worship, entertainment, amusement, drinking or dining, or awaiting transportation.

AWNING is an architectural projection that provides weather protection, identity, or decoration and is wholly supported by the building to which it is attached.

BALCONY, EXTERIOR, is an exterior floor system projecting from and supported by a structure without additional independent supports.

BASE is the level at which the earthquake motions are considered to be imparted to the structure or the level at which the structure, as a dynamic vibrator, is supported.

BASE SHEAR is the total design lateral force or shear at the base of a structure.

BASIC WIND SPEED is a three-second gust speed at 10 m above the ground in Exposure C (see Section 207A.7.3) as determined in accordance with Section 207A.5.1 and associated with an annual probability of 0.02, (i.e. 50-year mean recurrence interval).

BEARING WALL SYSTEM is a structural system that does not have a complete vertical load-carrying space frame. See Section 208.4.6.1.

BOUNDARY ELEMENT is an element at edges of openings or at perimeters of shear walls or diaphragms.

BRACED FRAME is essentially a vertical truss system of the concentric or eccentric type that is provided to resist lateral forces.

BUILDING FRAME SYSTEM is essentially a complete space frame that provides support for gravity loads. See Section 208.4.6.2.

BRACED WALL LINE is a series of braced wall panels in a single storey that meets the requirements of Section 620.10.3.

BRACED WALL PANEL is a section of wall braced in accordance with Section 620.10.3.

BUILDING, ENCLOSED is a building that does not comply with the requirements for open or partially enclosed buildings.

BUILDING ENVELOPE refers to cladding, roofing, exterior wall, glazing, door assemblies, window assemblies, skylight assemblies, and other components enclosing the building.

BUILDING, FLEXIBLE refers to slender buildings that have a fundamental natural frequency less than 1.0 Hz.

BUILDING, LOW-RISE is an enclosed or partially enclosed building that complies with the following conditions:

1. Mean roof height, $\boldsymbol{h}$, less than or equal to 18m, and
2. Mean roof height, $\boldsymbol{h}$, does not exceed least horizontal dimension.

BUILDING, OPEN refers to a building having each wall at least 80 percent open. This condition is expressed for each wall by the equation $A_o \geq 0.8A_g$. See symbols and notations.

BUILDING, PARTIALLY ENCLOSED is a building that complies with both of the following conditions:

1. the total area of openings in a wall that receives positive external pressure exceeds the sum of the areas of openings in the balance of the building envelope (walls and roof) by more than 10%; and
2. The total area of openings in a wall that receives positive external pressure exceeds 0.5 m² or 1 percent of the area of that wall, whichever is smaller, and the percentage of openings in the balance of the building envelope does not exceed 20 percent.

These conditions are expressed by the following equations:

1. $A_o > 1.10A_{oi}$
2. $A_o >$ smaller of $(0.5\ \mathrm{m}^2$ or $0.01A_g)$
3. $A_{oi}/A_{gi} \leq 0.20$

See symbols and notations.

BUILDING OR OTHER STRUCTURE, REGULAR-SHAPED refers to a building or other structure having no unusual geometrical irregularity in spatial form.

BUILDING OR OTHER STRUCTURES, RIGID refer to a building or other structure whose fundamental frequency is greater than or equal to 1.0 Hz.

BUILDING, SIMPLE DIAPHRAGM refers to a building in which both windward and leeward wind loads are transmitted through floor and roof diaphragms to the same vertical MWFRS (e.g., no structural separations).

CANTILEVERED COLUMN ELEMENT is a column element in a lateral-force-resisting system that cantilevers from a fixed base and has minimal moment capacity at the top, with lateral forces applied essentially at the top.

COLLECTOR is a member or element provided to transfer lateral forces from a portion of a structure to vertical elements of the lateral-force-resisting system.

COMPONENT is a part or element of an architectural, electrical, mechanical or structural system.

COMPONENT, EQUIPMENT is a mechanical or electrical component or element that is part of a mechanical and/or electrical system.

COMPONENT, FLEXIBLE is a component, including its attachments, having a fundamental period greater than 0.06 s.

COMPONENT, RIGID is a component, including its attachments, having a fundamental period less than or equal to 0.06s.

COMPONENTS AND CLADDING refers to elements of the building envelope that do not qualify as part of the MWFRS.

CONCENTRICALLY-BRACED FRAME is a braced frame in which the members are subjected primarily to axial forces.

CONVENTIONAL LIGHT-FRAME CONSTRUCTION is a type of construction in which the primary structural elements are formed by a system of repetitive wood framing members.

COVERING, IMPACT-RESISTANT is a covering designed to protect impact-resistant glazing.

CRIPPLE WALL is a framed stud wall extending from the top of the foundation to the underside of floor framing for the lowest occupied level.

DEAD LOADS consist of the weight of all materials and fixed equipment incorporated into the building or other structure.

DECK is an exterior floor system supported on at least two opposing sides by an adjacent structure and/or posts, piers, or other independent supports.

DESIGN BASIS GROUND MOTION is that ground motion that has a 10 percent chance of being exceeded in 50 years as determined by a site-specific hazard analysis or may be determined from a hazard map.

DESIGN FORCE is the equivalent static force to be used in the determination of wind loads for open buildings and other structures.

DESIGN RESPONSE SPECTRUM is an elastic response spectrum for 5 percent equivalent viscous damping used to represent the dynamic effects of the Design Basis Ground Motion for the design of structures in accordance with Sections 208.5 and 208.5.3.

DESIGN SEISMIC FORCE is the minimum total strength design base shear, factored and distributed in accordance with Section 208.5.

DESIGN PRESSURE is the equivalent static pressure to be used in the determination of wind loads for buildings.

DIAPHRAGM is a horizontal or nearly horizontal system acting to transmit lateral forces to the vertical resisting elements. The term "diaphragm" includes horizontal bracing systems.

DIAPHRAGM, BLOCKED is a diaphragm in which all sheathing edges not occurring on framing members are supported on and connected to blocking.

DIAPHRAGM CHORD or SHEAR WALL CHORD is the boundary element of a diaphragm or shear wall that is assumed to take axial stresses analogous to the flanges of a beam.

DIAPHRAGM STRUT (drag strut, tie, and collector) is the element of a diaphragm parallel to the applied load that collects and transfers diaphragm shear to the vertical resisting elements or distributes loads within the diaphragm. Such members may take axial tension or compression.

DIAPHRAGM, UNBLOCKED is a diaphragm that has edge nailing at supporting members only. Blocking between supporting structural members at panel edges is not included.

DRIFT or STOREY DRIFT is the lateral displacement of one level relative to the level above or below.

DUAL SYSTEM is a combination of moment-resisting frames and shear walls or braced frames designed in accordance with the criteria of Section 208.4.6.4.

EAVE HEIGHT is the distance from the ground surface adjacent to the building to the roof eave line at a particular wall. If the height of the eave varies along the wall, the average height shall be used.

ECCENTRICALLY BRACED FRAME (EBF) is a steel-braced frame designed in conformance with Section 528.

EFFECTIVE WIND AREA is the area used to determine GC_p. For cladding fasteners, the effective wind area shall not be greater than the area that is tributary to an individual fastener.

ELASTIC RESPONSE PARAMETERS are forces and deformations determined from an elastic dynamic analysis using an unreduced ground motion representation, in accordance with Section 208.5.3.

ESCARPMENT, also known as scarp, with respect to topographic effect in Section 207A.8, is a cliff or steep slope generally separating two levels or gently sloping areas (see Figure 207A-8-1).

ESSENTIAL FACILITIES are buildings, towers and other vertical structures that are intended to remain operational in the event of extreme environmental loading from wind or earthquakes.

FACTORED LOAD is the product of a load specified in Sections 204 through 208 and a load factor. See Section 203.3 for combinations of factored loads.

FIBERBOARD is a fibrous, homogeneous panel made from lignocellulosic fibers (usually wood or sugar cane bagasse) and having a density of less than 50 kg/m^3 but more than 160 kg/m^3.

FLEXIBLE ELEMENT or **SYSTEM** is one whose deformation under lateral load is significantly larger than adjoining parts of the system. Limiting ratios for defining specific flexible elements are set forth in Section 208.5.1.3.

FOREST PRODUCTS RESEARCH AND DEVELOPMENT INSTITUTE (FPRDI) is the Department of Science and Technology's (DOST's) research and development arm on forest products utilization. It is mandated to conduct basic and applied research to help the wood-using industries disseminate information and technologies on forest products to end users.

FREE ROOF is a roof with a configuration generally conforming to those shown in Figures 207B.4-4 through 207B.4-6 (monoslope, pitched, or troughed) in an open building with no enclosing walls underneath the roof surface.

GARAGE is a building or portion thereof in which motor vehicle containing flammable or combustible liquids or gas in its tank is stored, repaired or kept.

GARAGE, PRIVATE, is a building or a portion of a building, not more than 90m^2 in area, in which only motor vehicles used by the tenants of the building or buildings on the premises are kept or stored.

GLAZING is a glass or transparent or translucent plastic sheet used in windows, doors, skylights, or curtain walls.

GLAZING, IMPACT-RESISTANT is a glazing that has been tested in accordance with ASTM E1886 and ASTM E1996 or other approved test methods to withstand the impact of wind-borne missiles likely to be generated in wind-borne debris regions during design winds.

GLUED BUILT-UP MEMBERS are structural elements, the section of which is composed of built-up lumber, wood structural panels or wood structural panels in combination with lumber, all parts bonded together with structural adhesives.

GRADE (LUMBER) is the classification of lumber in regard to strength and utility in accordance with the grading rules of an approved lumber grading agency.

HARDBOARD is a fibrous-felted, homogeneous panel made from lignocellulosic fibers consolidated under heat and pressure in a hot press to a density not less than 50kg/m^3.

HILL, with respect to topographic effects in Section 207A.8, is a land surface characterized by strong relief in any horizontal direction (Figure 207A.8-2).

HORIZONTAL BRACING SYSTEM is a horizontal truss system that serves the same function as a diaphragm.

IMPACT-RESISTANT COVERING, is a covering designed to protect glazing, which has been shown by testing in accordance with ASTM E1886 and ASTM E1996 of other approved test methods to withstand the impact or wind-borne debris missiles likely to be generated in wind-borne debris regions during design winds.

IMPORTANCE FACTOR is a factor that accounts for the degree of hazard to human life and damage to property.

INTERMEDIATE MOMENT RESISTING FRAME (IMRF) is a concrete frame designed in accordance with Section 412.

LATERAL-FORCE-RESISTING SYSTEM is that part of the structural system designed to resist the Design Seismic Forces.

LIMIT STATE is a condition beyond which a structure or member becomes unfit for service and is judged to be no longer useful for its intended function (serviceability limit state) or to be unsafe (strength limit state).

LIVE LOADS are those loads produced by the use and occupancy of the building or other structure and do not include dead load, construction load, or environmental loads.

LOADS are forces or other actions that result from the weight of all building materials, occupants and their possessions, environmental effects, differential movements, and restrained dimensional changes. Permanent loads are those loads in which variations over time are rare or of small magnitude. All other loads are variable loads.

LOAD AND RESISTANCE FACTOR DESIGN (LRFD) METHOD is a method of proportioning and designing structural elements using load and resistance factors such that no applicable limit state is reached when the structure is subjected to all appropriate load combinations. The term "LRFD" is used in the design of steel structures.

MACHINE-GRADED LUMBER (MGL) is a lumber evaluated by a machine using a non-destructive test and sorted into different stress grades.

MAIN WIND-FORCE RESISTING SYSTEM (MWFRS) is an assemblage of structural elements assigned to provide support and stability for the overall structure. The system generally receives wind loading from more than one surface.

MARQUEE is a permanent roofed structure attached to and supported by the building and projecting over public right-of-way.

MEAN ROOF HEIGHT is the average of the roof eave height and the height to the highest point on the roof surface, except that, for roof angles of less than or equal to 10°, the mean roof height shall be the roof eave height.

MOISTURE CONTENT (MC) is the amount of moisture in wood, usually measured as the percentage of water to the oven dry weight of the wood.

MOMENT-RESISTING FRAME is a frame in which members and joints are capable of resisting forces primarily by flexure.

MOMENT-RESISTING WALL FRAME (MRWF) is a masonry wall frame especially detailed to provide ductile behavior and designed in conformance with Section 708.2.6.

NOMINAL LOADING is a design load that stressed a member or fastening to the full allowable stress tabulated in this chapter. This loading may be applied for approximately 10 years, either continuously or cumulatively, and 90 percent of this load may be applied for the remainder of the life of the member or fastening.

NOMINAL SIZE (Lumber) refers to the commercial size designation of width and depth, in standard sawn lumber and glued laminated lumber grades; somewhat larger than the standard net size of dressed lumber.

OPENINGS are apertures or holes in the building envelope that allow air to flow through the building envelope and that are designed as "open" during design winds as defined by these provisions.

ORDINARY BRACED FRAME (OBF) is a steel-braced frame designed in accordance with the provisions of Section 527 or 528 or concrete-braced frame designed in accordance with Section 421.

ORDINARY MOMENT-RESISTING FRAME (OMRF) is a moment-resisting frame not meeting special detailing requirements for ductile behavior.

ORTHOGONAL EFFECTS are the earthquake load effects on structural elements simultaneously occurring to the lateral-force-resisting systems along two orthogonal axes.

OVERSTRENGTH is a characteristic of structures where the actual strength is larger than the design strength. The degree of over-strength is material-and system-dependent.

PARTICLEBOARD is a manufactured panel product consisting of particles of wood or combinations of wood particles and wood fibers bonded together with synthetic resins or other suitable bonding system by a bonding process, in accordance with approved nationally recognized standard.

PLYWOOD is a panel of laminated veneers conforming to Philippine National Standards (PNS 196) "Plywood Specifications".

***P*Δ EFFECT** is the secondary effect on shears, axial forces and moments of frame members induced by the horizontal displacement of vertical loads from various loading, when a structure is subjected to lateral forces.

RECOGNIZED LITERATURE are published research findings and technical papers that are approved.

RIDGE, with respect to topographic effects in Section 207A.8, is an elongated crest of a hill characterized by strong relief in two directions (see Figure 207A.8-1).

ROTATION is the torsional movement of a diaphragm about a vertical axis.

SHEAR WALL is a wall designed to resist lateral forces parallel to the plane of the wall (sometimes referred to as vertical diaphragm or structural wall).

SHEAR WALL-FRAME INTERACTIVE SYSTEM uses combinations of shear walls and frames designed to resist lateral forces in proportion to their relative rigidities, considering interaction between shear walls and frames on all levels.

SHEATHING is a layer of boards or of other wood or fiber materials applied to the outer studs, joists, and rafters of a building to strengthen structures and serve as a base for an exterior weatherproof cladding.

SHEATHING, WALL is a layer of boards or of other wood or fiber materials used to cover the wall studding.

STRUCTURAL GLUED-LAMINATED TIMBER is any member comprising an assembly of laminations of lumber in which the grain of all laminations is approximately parallel longitudinally, in which the laminations are bonded with adhesives.

SUBDIAPHRAGM is a portion of a diaphragm used to transfer wall anchorage forces to diaphragm cross ties. It also refers to a portion of a larger wood diaphragm designed to anchor and transfer local forces to primary diaphragm struts and the main diaphragm.

SOFT STOREY is one in which the lateral stiffness is less than 70 percent of the stiffness of the storey above. See Table 208-9.

SPACE FRAME is a three-dimensional structural system, without bearing walls, composed of members interconnected so as to function as a complete self-contained unit with or without the aid of horizontal diaphragms or floor-bracing systems.

SPECIAL CONCENTRICALLY BRACED FRAME (SCBF) is a steel-braced frame designed in conformance with the provisions of Section 526.

SPECIAL MOMENT-RESISTING FRAME (SMRF) is a moment-resisting frame specially detailed to provide ductile behavior and comply with the requirements given in Chapter 4 or 5.

SPECIAL TRUSS-MOMENT FRAME (STMF) is a moment-resisting frame specially detailed to provide ductile behavior and comply with the provisions of Section 525.

STOREY is the space between levels. Storey x is the storey below level x.

STOREY DRIFT RATIO is the storey drift divided by the storey height.

STOREY SHEAR, V_x, is the summation of design lateral forces above the storey under consideration.

STRENGTH is the capacity of an element or a member to resist factored load as specified in Chapters 2, 3, 4, 5 and 7.

STRUCTURE is an assemblage of framing members designed to support gravity loads and resist lateral forces. Structures may be categorized as building structures or nonbuilding structures.

STRENGTH DESIGN is a method of proportioning and designing structural members such that the computed forces produced in the members by the factored load do not exceed the member design strength. The term strength design is used in the design of concrete structures.

TOWERS AND OTHER STRUCTURES are nonbuilding structures including poles, masts and billboards that are not typically occupied by persons but are also covered by this code.

TREATED WOOD is wood treated with an approved preservative under treating and quality control procedures.

VERTICAL LOAD-CARRYING FRAME is a space frame designed to carry vertical gravity loads.

WALL ANCHORAGE SYSTEM is the system of elements anchoring the wall to the diaphragm and those elements within the diaphragm required to develop the anchorage forces, including sub-diaphragms and continuous ties, as specified in Sections 208.7.2.7 and 208.7.2.8.

WALL, BEARING is any wall meeting either of the following classifications:

1. Any metal or wood stud wall that supports more than 1.45 kN/m of vertical load in addition to its own weight.

2. Any masonry or concrete wall that supports more than 2.90 kN/m of vertical load in addition to its own weight.

WALL, EXTERIOR is any wall or element of a wall, or any member or group of members, that defines the exterior boundaries or courts of a building and that has a slope of 60 degrees or greater with the horizontal plane.

WALL, NONBEARING is any wall that is not a bearing wall.

WALL, PARAPET is that part of any wall entirely above the roof line.

WALL, RETAINING is a wall designed to resist the lateral displacement of soil or other materials.

WEAK STOREY is one in which the storey strength is less than 80 percent of the storey above. See Table 208-9.

WIND-BORNE DEBRIS REGIONS are areas within typhoon prone regions located at:

1. Within 1.6 km of the coastal mean high water line where the basic wind speed is equal to or greater than 200 kph, or
2. In areas where the basic wind speed is equal to or greater than 250 kph.

WOOD OF NATURAL RESISTANCE TO DECAY OR TERMITES is the heartwood of the species set forth below. Corner sapwood is permitted on 5 percent of the pieces provided 90 percent or more of the width of each side on which it occurs is heartwood. Recognized species are:

- Decay resistant: Narra, Kamagong, Dao, Tangile.
- Termite resistant: Narra, Kamagong.

WOOD STRUCTURAL PANEL is a structural panel product composed primarily of wood and meeting the UBC Standard 23-2 and 23-3 or equivalent requirements of Philippine National Standards (PNS). Wood structural panels include all-veneer plywood, composite panels containing a combination of veneer and wood-based material, and mat-formed panel such as oriented stranded board and wafer board.

WYTHE is the portion of a wall which is one masonry unit in thickness. A collar joint is not considered a wythe.

SECTION 203
COMBINATIONS OF LOADS

203.1 General

Buildings, towers and other vertical structures and all portions thereof shall be designed to resist the load combinations specified in Section 203.3, 203.4 and 203.5.

The most critical effect can occur when one or more of the contributing loads are not acting. All applicable loads shall be considered, including both earthquake and wind, in accordance with the specified load combinations.

203.2 Symbols and Notations

D = dead load
E = earthquake load set forth in Section 208.6.1
E_m = estimated maximum earthquake force that can be developed in the structure as set forth in Section 208.6.1
F = load due to fluids with well-defined pressures and maximum heights
H = load due to lateral pressure of soil and water in soil
L = live load, except roof live load, including any permitted live load reduction
L_r = roof live load, including any permitted live load reduction
P = ponding load
R = rain load on the undeflected roof
T = self-straining force and effects arising from contraction or expansion resulting from temperature change, shrinkage, moisture change, creep in component materials, movement due to differential settlement, or combinations thereof
W = load due to wind pressure

203.3 Load Combinations using Strength Design or Load and Resistance Factor Design

203.3.1 Basic Load Combinations

Where strength design or load and resistance factor design is used, structures and all portions thereof shall resist the most critical effects from the following combinations of factored loads:

$$1.4(D + F) \quad (203\text{-}1)$$

$$1.2(D + F + T) + 1.6(L + H) + 0.5(L_r \text{ or } R) \quad (203\text{-}2)$$

$$1.2D + 1.6(L_r \text{ or } R) + (f_1L \text{ or } 0.5W) \quad (203\text{-}3)$$

$$1.2D + 1.0W + f_1L + 0.5(L_r \text{ or } R) \quad (203\text{-}4)$$

$$1.2D + 1.0E + f_1L \quad (203\text{-}5)$$

$$0.9D + 1.0W + 1.6H \quad (203\text{-}6)$$

$$0.9D + 1.0E + 1.6H \quad (203\text{-}7)$$

where

f_1 = 1.0 for floors in places of public assembly, for live loads in excess of 4.8 kPa, and for garage live load, or
= 0.5 for other live loads

203.3.2 Other Loads

Where P is to be considered in design, the applicable load shall be added to Section 203.3.1 factored as $1.2P$.

203.4 Load Combinations Using Allowable Stress or Allowable Strength Design

203.4.1 Basic Load Combinations

Where allowable stress or allowable strength design is used, structures and all portions thereof shall resist the most critical effects resulting from the following combinations of loads:

$$D + F \quad (203\text{-}8)$$

$$D + H + F + L + T \quad (203\text{-}9)$$

$$D + H + F + (L_r \text{ or } R) \quad (203\text{-}10)$$

$$D + H + F + 0.75[L + T(L_r \text{ or } R)] \quad (203\text{-}11)$$

$$D + H + F + \left(0.6W \text{ or } \frac{E}{1.4}\right) \quad (203\text{-}12)$$

No increase in allowable stresses shall be used with these load combinations except as specifically permitted by Section 203.4.2.

203.4.2 Alternate Basic Load Combinations

In lieu of the basic load combinations specified in Section 203.4.1, structures and portions thereof shall be permitted to be designed for the most critical effects resulting from the following load combinations. When using these alternate basic load combinations, a one-third increase shall be permitted in allowable stresses for all combinations, including W or E.

$$D + H + F + 0.75\left[L + L_r\left(0.6W \text{ or } \frac{E}{1.4}\right)\right] \quad (203\text{-}13)$$

$$0.6D + 0.6W + H \quad (203\text{-}14)$$

$$0.6D + \frac{E}{1.4} + H \quad (203\text{-}15)$$

$$D + L + (L_r \text{ or } R) \quad (203\text{-}16)$$

$$D + L + 0.6W \quad (203\text{-}17)$$

$$D + L + \frac{E}{1.4} \quad (203\text{-}18)$$

Exception:

Crane hook loads need not be combined with roof live load or with more than one-half of the wind load.

203.4.3 Other Loads

Where P is to be considered in design, each applicable load shall be added to the combinations specified in Sections 203.4.1 and 203.4.2.

203.5 Special Seismic Load Combinations

For both allowable stress design and strength design for concrete, and Load and Resistance Factor Design (LRFD) and Allowable Strength Design (ASD) for steel, the following special load combinations for seismic design shall be used as specifically required by Section 208, or by Chapters 3 through 7.

$$1.2D + f_1L + 1.0E_m \quad (203\text{-}19)$$

$$0.9D \pm 1.0E_m \quad (203\text{-}20)$$

where

f_1 = 1.0 for floors in places of public assembly, for live loads in excess of 4.8 kPa, and for garage live load, or

= 0.5 for other live loads

E_m = the maximum effect of horizontal and vertical forces as set forth in Section 208.6.1

SECTION 204
DEAD LOADS

204.1 General

Dead loads consist of the weight of all materials of construction incorporated into the building or other structure, including but not limited to walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, cladding and other similarly incorporated architectural and structural items, and fixed service equipment, including the weight of cranes.

204.2 Weights of Materials and Constructions

The actual weights of materials and constructions shall be used in determining dead loads for purposes of design. In the absence of definite information, it shall be permitted to use the minimum values in Tables 204-1 and 204-2.

204.3 Partition Loads

Floors in office buildings and other buildings where partition locations are subject to change shall be designed to support, in addition to all other loads, a uniformly distributed dead load equal to 1.0 kPa.

Exception:

Access floor systems shall be designed to support, in addition to all other loads, a uniformly distributed dead load not less than 0.5 kPa.

Table 204-1 Minimum Densities for Design Loads from Materials (kN/m^3)

Material	Density
Aluminum	26.7
Bituminous products	
Asphaltum	12.7
Graphite	21.2
Paraffin	8.8
Petroleum, crude	8.6
Petroleum, refined	7.9
Petroleum, benzine	7.2
Petroleum, gasoline	6.6
Pitch	10.8
Tar	11.8
Brass	82.6
Bronze	86.7
Cast-stone masonry (cement, stone, sand)	22.6
Cement, portland, loose	14.1
Ceramic tile	23.6
Charcoal	1.9
Cinder fill	9.0
Cinders, dry, in bulk	7.1
Coal	
Anthracite, piled	8.2
Bituminous, piled	7.4
Lignite, piled	7.4
Peat, dry, piled	3.6
Concrete, plain	
Cinder	17.0
Expanded-slag aggregate	15.7
Haydite, burned-clay aggregate	14.1
Slag	20.7
Stone	22.6
Vermiculite and perlite aggregate, nonload-bearing	3.9-7.9
Other light aggregate, load bearing	11.0-16.5
Concrete, reinforced	
Cinder	17.4
Slag	21.7
Stone, including gravel	23.6
Copper	87.3
Cork, compressed	2.2
Earth, not submerged	
Clay, dry	9.9
Clay, damp	17.3
Clay and gravel, dry	15.7
Silt, moist, loose	12.3
Silt, moist, packed	15.1
Silt, flowing	17.0
Sand and gravel, dry, loose	15.7
Sand and gravel, dry, packed	17.3
Sand and gravel, wet	18.9
Earth, submerged	
Clay	12.6
Soil	11.0
River mud	14.1
Sand or gravel	9.4
Sand or gravel and clay	10.2
Glass	25.1
Gravel, dry	16.3
Gypsum, loose	11.0
Gypsum, wallboard	7.9
Ice	9.0
Iron	
Cast	70.7
Wrought	75.4
Lead	111.5
Lime	
Hydrated, loose	5.0
Hydrated, compacted	7.1
Masonry, Ashlar Stone	
Granite	25.9
Limestone, crystalline	25.9
Limestone, oolitic	21.2
Marble	27.2
Sandstone	22.6
Masonry, Brick	
Hard, low absorption	20.4
Medium, medium absorption	18.1
Soft, high absorption	15.7
Masonry, Concrete (solid portion)	
Lightweight units	16.5
Medium weight units	19.6
Normal weight units	21.2
Masonry grout	22.0
Masonry, Rubble Stone	
Granite	24.0
Limestone, crystalline	23.1
Limestone, oolitic	21.7
Marble	24.5
Sandstone	21.5
Mortar, cement or lime	20.4
Particle board	7.1
Plywood	5.7
Riprap, not submerged	
Limestone	13.0
Sandstone	14.1
Sand	
Clean and dry	14.1
River, dry	16.7
Slag	
Bank	11.0
Bank screenings	17.0
Machine	15.1
Sand	8.2
Slate	27.0
Steel, cold-drawn	77.3
Stone, quarried, piled	
Basalt, granite, gneiss	15.1
Limestone, marble, quartz	14.9
Sandstone	12.9
Shale	14.5
Greenstone, hornblende	16.8
Terracotta, architectural	
Voids filled	18.9
Voids unfilled	11.3
Tin	72.1
Water	
Fresh	9.8
Sea	10.1
Wood (see Chapter 6 for relative densities for Philippine wood)	
Zinc, rolled sheet	70.5

Table 204-2 Minimum Design Dead Loads (kPa)

Component	Load
CEILINGS	
Acoustical fiber board	0.05
Gypsum board (per mm thickness)	0.008
Mechanical duct allowance	0.20
Plaster on tile or concrete	0.24
Plaster on wood lath	0.38
Suspended steel channel system	0.10
Suspended metal lath and cement plaster	0.72
Suspended metal lath and gypsum plaster	0.48
Wood furring suspension system	0.12
COVERINGS, Roof and Wall	
Asphalt shingles	0.10
Cement tile	0.77
Clay tile (for mortar add 0.48 kPa)	
Book tile, 50 mm	0.57
Book tile, 75 mm	0.96
Ludowici	0.48
Roman	0.57
Spanish	0.91
Composition:	
Three-ply ready roofing	0.05
Four-ply felt and gravel	0.26
Five-ply felt and gravel	0.29
Copper or tin	0.05
Corrugated asbestos-cement roofing	0.19
Deck, metal 20 gage	0.12
Deck, metal, 18 gage	0.14
Fiberboard, 13mm	0.04
Gypsum sheathing, 13 mm	0.10
Insulation, roof boards (per mm thickness)	
Cellular glass	0.0013
Fibrous glass	0.0021
Fiberboard	0.0028
Perlite	0.0015
Polystyrene foam	0.0004
Urethane foam with skin	0.0009
Plywood (per mm thickness)	0.0060
Rigid insulation, 13 mm	0.04
Skylight, metal frame, 10mm wire glass	0.38
Slate, 5 mm	0.34
Slate, 6 mm	0.48
Waterproofing membranes:	
Bituminous, gravel-covered	0.26
Bituminous, smooth surface	0.07
Liquid, applied	0.05
Single-ply, sheet	0.03
Wood sheathing (per mm thickness)	0.0057
Wood shingles	0.14

Component	Load
FLOOR FILL	
Cinder concrete, per mm	0.017
Lightweight concrete, per mm	0.015
Sand, per mm	0.015
Stone concrete, per mm	0.023
FLOOR AND FLOOR FINISHES	
Asphalt block (50 mm), 13 mm mortar	1.44
Cement finish (25 mm) on stone-concrete fill	1.53
Ceramic or quarry tile (20 mm) on 13 mm mortar bed	0.77
Ceramic or quarry tile (20 mm) on 25 mm mortar bed	1.10
Concrete fill finish (per mm thickness)	0.023
Hardwood flooring, 22 mm	0.19
Linoleum or asphalt tile, 6mm	0.05
Marble and mortar on stone-concrete fill	1.58
Slate (per mm thickness)	0.028
Solid flat tile on 25-mm mortar base	1.10
Subflooring, 19 mm	0.14
Terrazzo (38 mm) directly on slab	0.91
Terrazzos (25 mm) on stone-concrete fill	1.53
Terrazzo (25 mm) on 50-mm stone concrete	1.53
Wood block (75 mm) on mastic, no fill	0.48
Wood block (75 mm) on 13-mm mortar base	0.77
FRAME PARTITIONS	
Movable partitions	0.24
Movable partitions (steel)	0.19
Wood or steel studs, 13 mm gypsum board each side	0.38
Wood studs, 50 x 100, unplastered	0.19
Wood studs 50 x 100, plastered one side	0.57
Wood studs 50 x 100, plastered two side	0.96

Component	Load
FRAME WALLS	
Exterior stud walls:	
50x100 @ 400mm, 15 mm gypsum, insulated, 10 mm siding	0.53
50x150 @ 400mm, 15 mm gypsum, insulated, 10 mm siding	0.57
Exterior stud wall with brick veneer	2.30
Windows, glass, frame and sash	0.38
Clay brick wythes:	
100 mm	1.87
200 mm	3.74
300 mm	5.51
400 mm	7.48

CONCRETE MASONRY UNITS

Hollow Concrete Masonry Units Unplastered. Add 0.24 kPa for each face plastered

Grout Spacing	Wythe thickness (mm) 100	150	200
16.5-kN/m^3 Density of Unit			
No grout	1.05	1.15	1.48
800	1.40	1.53	2.01
600	1.50	1.63	2.20
400	1.79	1.92	2.54
Full	2.50	2.63	3.59
19.6-kN/m^3 Density of Unit			
No grout	1.24	1.34	1.72
800	1.59	1.72	2.25
600	1.69	1.87	2.44
400	1.98	2.11	2.82
Full	2.69	2.82	3.88
21.2-kN/m^3 Density of Unit			
No grout	1.39	1.44	1.87
800	1.74	1.82	2.39
600	1.83	1.96	2.59
400	2.13	2.2	2.92
Full	2.84	2.97	3.97

SECTION 205
LIVE LOADS

205.1 General

Live loads shall be the maximum loads expected by the intended use or occupancy but in no case shall be less than the loads required by this section.

205.2 Critical Distribution of Live Loads

Where structural members are arranged to create continuity, members shall be designed using the loading conditions, which would cause maximum shear and bending moments. This requirement may be satisfied in accordance with the provisions of Section 205.3.2 or 205.4.2, where applicable.

205.3 Floor Live Loads

205.3.1 General

Floors shall be designed for the unit live loads as set forth in Table 205-1. These loads shall be taken as the minimum live loads of horizontal projection to be used in the design of buildings for the occupancies listed, and loads at least equal shall be assumed for uses not listed in this section but that creates or accommodates similar loadings.

Where it can be determined in designing floors that the actual live load will be greater than the value shown in Table 205-1, the actual live load shall be used in the design of such buildings or portions thereof. Special provisions shall be made for machine and apparatus loads.

205.3.2 Distribution of Uniform Floor Loads

Where uniform floor loads are involved, consideration may be limited to full dead load on all spans in combination with full live load on adjacent spans and alternate spans.

205.3.3 Concentrated Loads

Floors shall be designed to support safely the uniformly distributed live loads prescribed in this section or the concentrated load given in Table 205-1 whichever produces the greatest load effects. Unless otherwise specified the indicated concentration shall be assumed to be uniformly distributed over an area 750-mm square and shall be located so as to produce the maximum load effects in the structural member.

Provision shall be made in areas where vehicles are used or stored for concentrated loads, ***L***, consisting of two or more loads spaced 1.5m nominally on center without uniform live loads. Each load shall be 40 percent of the gross weight of the maximum size vehicle to be accommodated. Parking garages for the storage of private or pleasure-type motor vehicles with no repair or refueling shall have a floor system designed for a concentrated load of not less than 9 kN acting on an area of 0.015 m^2 without uniform live loads. The condition of concentrated or uniform live load, combined in accordance with Section 203.3 or 203.4 as appropriate, producing the greatest stresses shall govern.

205.3.4 Special Loads

Provision shall be made for the special vertical and lateral loads as set forth in Table 205-2.

Table 205-1 Minimum Uniform and Concentrated Live Loads

Use or Occupancy		Uniform Load[1]	Concentrated Load
Category	**Description**	kPa	kN
1. Access floor systems	Office use	2.4	9.0[2]
	Computer use	4.8	9.0[2]
2. Armories	--	7.2	0
3. Theaters, assembly areas[3] and auditoriums	Fixed seats	2.9	0
	Movable seats	4.8	0
	Lobbies and platforms	4.8	0
	Stage areas	7.2	0
4. Bowling alleys, poolrooms and similar recreational areas	--	3.6	0
5. Catwalk for maintenance access	--	1.9	1.3
6. Cornices and marquees	--	3.6[4]	0
7. Dining rooms and restaurants	--	4.8	0
8. Exit facilities[5]	--	4.8	0[6]
9. Parking Garages and Ramps	General storage and/or repair	4.8	--[7]
	Public parking and ramps	4.8	--[7]
	Private (residential) or pleasure-type motor vehicle storage	2.4	--[7]
10. Hospitals	Wards and rooms	1.9	4.5[2]
	Laboratories and operating rooms	2.9	4.5[2]
	Corridors above ground floor	3.8	4.5
11. Libraries	Reading rooms	2.9	4.5[2]
	Stack rooms	7.2	4.5[2]
	Corridors above ground floor	3.8	4.5
12. Manufacturing	Light	6.0	9.0[2]
	Heavy	12.0	13.4[2]
	Building corridors above ground floor	3.8	9.0

Table 205-1 Minimum Uniform and Concentrated Live Loads (*continued*)

Use or Occupancy		Uniform Load [1]	Concentrated Load
Category	**Description**	kPa	kN
13. Office	Call centers and business processing offices	2.9	9.0
	Lobbies and ground floor corridors	4.8	9.0
	Other offices	2.4	9.0 [2]
14. Printing plants	Press rooms	7.2	11.0 [2]
	Composing and linotype rooms	4.8	9.0 [2]
15. Residential [8]	Basic floor area	1.9	0 [6]
	Exterior balconies	2.9 [4]	0
	Decks	1.9 [4]	0
	Storage	1.9	0
16. Restrooms [9]	--	--	--
17. Reviewing stands, grandstands, bleachers, and folding and telescoping seating	--	4.8	0
18. Roof decks	Same as area served or occupancy	--	--
19. Schools	Classrooms	1.9	4.5 [2]
	Corridors above ground floor	3.8	4.5
	Ground floor corridors	4.8	4.5
20. Sidewalks and driveways	Public access	12.0	-- [7]
21. Storage	Light	6.0	--
	Heavy	12.0	--
22. Stores	Retail	4.8	4.5 [2]
	Wholesale	6.0	13.4 [2]
23. Pedestrian bridges and walkways	--	4.8	--

Notes for Table 205-1

[1] *See Section 205.5 for live load reductions.*

[2] *See Section 205.3.3, first paragraph, for area of load application.*

[3] *Assembly areas include such occupancies as dance halls, drill rooms, gymnasiums, playgrounds, plazas, terraces and similar occupancies that are generally accessible to the public.*

[4] *For special-purpose roofs, see Section 205.4.4.*

[5] *Exit facilities shall include such uses as corridors serving an occupant load of 10 or more persons, exterior exit balconies, stairways, fire escapes and similar uses.*

[6] *Individual stair treads shall be designed to support a 1.3 N concentrated load placed in a position that would cause maximum stress. Stair stringers may be designed for the uniform load set forth in the table.*

[7] *See Section 205.3.3, second paragraph, for concentrated loads. See Table 205-2 for vehicle barriers.*

[8] *Residential occupancies include private dwellings, apartments and hotel guest rooms.*

[9] *Restroom loads shall not be less than the load for the occupancy with which they are associated, but need not exceed 2.4 kPa.*

Table 205-2 Special Loads[1]

Use or Occupancy		Vertical Load	Lateral Load
Category	Description	kPa	kPa
1. Construction, public access at site (live load)	Walkway	7.2	-
	Canopy	7.2	-
2. Grandstands, reviewing stands, bleachers, and folding and telescoping seating (live load)	Seats and footboards	1.75 [2]	*See Note 3*
3. Stage accessories (live load)	Catwalks	1.9	-
	Follow spot, projection and control rooms	2.4	-
4. Ceiling framing (live load)	Over stages	1.0	-
	All uses except over stages	0.5 [4]	-
5. Partitions and interior walls,	-	-	0.25
6. Elevators and dumbwaiters (dead and live loads)	-	2*total load	-
7. Cranes (dead and live loads)	Total load including impact increase	1.25*total load[5]	0.10*total load[6]
8. Balcony railings and guardrails	Exit facilities serving an occupant load greater than 50 persons	-	0.75 kN/m [7]
	Other than exit facilities	-	0.30 kN/m [7]
	Components	-	1.2 [8]
9. Vehicle barriers	-	-	27 kN[9]
10. Handrails	-	*See Note 10*	*See Note 10*
11. Storage racks	Over 2.4 m high	Total loads[11]	*See Table 208-13*
12. Fire sprinkler structural support	-	1.1kN plus weight of water-filled pipe[12]	*See Table 208-13*

Notes for Table 205-2

1 *The tabulated loads are minimum loads. Where other vertical loads required by the design would cause greater stresses, they shall be used. Loads are in kPa unless otherwise indicated in the table.*

2 *Units is kN/m.*

3 *Lateral sway bracing loads of 350 N/m parallel and 145 N/m perpendicular to seat and footboards.*

4 *Does not apply to ceilings that have sufficient access from below, such that access is not required within the space above the ceiling. Does not apply to ceilings if the attic areas above the ceiling are not provided with access. This live load need not be considered as acting simultaneously with other live loads imposed upon the ceiling framing or its supporting structure.*

5 *The impact factors included are for cranes with steel wheels riding on steel rails. They may be modified if substantiating technical data acceptable to the building official is submitted. Live loads on crane support girders and their connections shall be taken as the maximum crane wheel loads. For pendant-operated traveling crane support girders and their connections, the impact factors shall be 1.10.*

6 *This applies in the direction parallel to the runway rails (longitudinal). The factor for forces perpendicular to the rail is 0.20 * the transverse traveling loads (trolley, cab, hooks and lifted loads). Forces shall be applied at top of rail and may be distributed among rails of multiple rail cranes and shall be distributed with due regard for lateral stiffness of the structures supporting these rails.*

7 *A load per lineal meter (kN/m) to be applied horizontally at right angles to the top rail.*

8 *Intermediate rails, panel fillers and their connections shall be capable of withstanding a load of 1.2 kPa applied horizontally at right angles over the entire tributary area, including openings and spaces between rails. Reactions due to this loading need not be combined with those of Note 7.*

9 *A horizontal load applied at right angles to the vehicle barrier at a height of 450 mm above the parking surface. The force may be distributed over a 300-mm square.*

10 *The mounting of handrails shall be such that the completed handrail and supporting structure are capable of withstanding a load of at least 890 N applied in any direction at any point on the rail. These loads shall not be assumed to act cumulatively with Note 9.*

11 *Vertical members of storage racks shall be protected from impact forces of operating equipment, or racks shall be designed so that failure of one vertical member will not cause collapse of more than the bay or bays directly supported by that member.*

[12] *The 1.1-kN load is to be applied to any single fire sprinkler support point but not simultaneously to all support joints.*

205.4 Roof Live Loads

205.4.1 General

Roofs shall be designed for the unit live loads, L_r, set forth in Table 205-3. The live loads shall be assumed to act vertically upon the area projected on a horizontal plane.

205.4.2 Distribution of Loads

Where uniform roof loads are involved in the design of structural members arranged to create continuity, consideration may be limited to full dead loads on all spans in combination with full roof live loads on adjacent spans and on alternate spans.

Exception:

Alternate span loading need not be considered where the uniform roof live load is 1.0 kPa or more.

For those conditions where light-gage metal preformed structural sheets serve as the support and finish of roofs, roof structural members arranged to create continuity shall be considered adequate if designed for full dead loads on all spans in combination with the most critical one of the following superimposed loads:

1. The uniform roof live load, L_r, set forth in Table 205-3 on all spans.

2. A concentrated gravity load, L_r, of 9 kN placed on any span supporting a tributary area greater than 18 m^2 to create maximum stresses in the member, whenever this loading creates greater stresses than those caused by the uniform live load. The concentrated load shall be placed on the member over a length of 0.75 m along the span. The concentrated load need not be applied to more than one span simultaneously.

3. Water accumulation as prescribed in Section 206.7.

205.4.3 Unbalanced Loading

Unbalanced loads shall be used where such loading will result in larger members or connections. Trusses and arches shall be designed to resist the stresses caused by unit live loads on one-half of the span if such loading results in reverse stresses, or stresses greater in any portion than the stresses produced by the required unit live load on the entire span. For roofs whose structures are composed of a stressed shell, framed or solid, wherein stresses caused by any point loading are distributed throughout the area of the shell, the requirements for unbalanced unit live load design may be reduced 50 percent.

205.4.4 Special Roof Loads

Roofs to be used for special purposes shall be designed for appropriate loads as approved by the building official. Greenhouse roof bars, purlins and rafters shall be designed to carry a 0.45 kN concentrated load, L_r, in addition to the uniform live load

205.5 Reduction of Live Loads

The design live load determined using the unit live loads as set forth in Table 205-1 for floors and Table 205-3, Method 2, for roofs may be reduced on any member supporting more than 15 m^2, including flat slabs, except for floors in places of public assembly and for live loads greater than 4.8 kPa, in accordance with the following equation:

$$R = r(A - 15) \qquad (205\text{-}1)$$

The reduction shall not exceed 40 percent for members receiving load from one level only, 60 percent for other members or R, as determined by the following equation:

$$R = 23.1(1 + D/L) \qquad (205\text{-}2)$$

where

A = area of floor or roof supported by the member, m^2
D = dead load per square meter of area supported by the member, kPa
L = unit live load per square meter of area supported by the member, kPa
R = reduction in percentage,
r = rate of reduction equal to 0.08 for floors. See Table 205-3 for roofs

For storage loads exceeding 4.8 kPa, no reduction shall be made, except that design live loads on columns may be reduced 20 percent.

The live load reduction shall not exceed 40 percent in garages for the storage of private pleasure cars having a capacity of not more than nine passengers per vehicle.

205.6 Alternate Floor Live Load Reduction

As an alternate to Equation 205-1, the unit live loads set forth in Table 205-1 may be reduced in accordance with Equation 205-3 on any member, including flat slabs, having an influence area of 40 m² or more.

$$L = L_0\left[0.25 + 4.57\left(\frac{1}{\sqrt{A_I}}\right)\right] \qquad (205\text{-}3)$$

where

A_I = influence area, m²
L = reduced design live load per square meter of area supported by the member
L_o = unreduced design live load per square meter of area supported by the member (Table 205-1)

The influence area A_I is four times the tributary area for a column, two times the tributary area for a beam, equal to the panel area for a two-way slab, and equal to the product of the span and the full flange width for a precast T-beam.

The reduced live load shall not be less than 50 percent of the unit live load L_o for members receiving load from one level only, nor less than 40 percent of the unit live load L_o for other members.

Table 205-3 Minimum Roof Live Loads [1]

ROOF SLOPE	Method 1			Method 2		
	Tributary Area (m²)			Uniform Load [2] (kPa)	Rate of Reduction, *r*	Maximum Reduction ***R*** (percentage)
	0 to 20	20 to 60	Over 60			
	Uniform Load (kPa)					
1. Flat [3] or rise less than 1-unit vertical in 3-unit horizontal (33.3% slope). Arch and dome with rise less than 1/8 of span.	1.00	0.75	0.60	1.00	0.08	40
2. Rise 1-unit vertical to less than 3-unit vertical in 3-unit horizontal (33.3% to less than 100% slope). Arch and dome with rise 1/8 of span to less than 3/8 of span.	0.75	0.70	0.60	0.75	0.06	25
3. Rise 1-unit vertical in 1-unit horizontal (100% slope) and greater. Arch or dome with rise 3/8 of span or greater.	0.60	0.60	0.60	0.60	*No reduction permitted*	
4. Awnings except cloth covered. [4]	0.25	0.25	0.25	0.25		
5. Greenhouses, lath houses and agricultural buildings. [5]	0.50	0.50	0.50	0.50		

[1] *For special-purpose roofs, see Section 205.4.4.*

[2] *See Sections 205.5 and 205.6 for live-load reductions. The rate of reduction **r** in Equation 205-1 shall be as indicated in the table. The maximum reduction, **R**, shall not exceed the value indicated in the table.*

[3] *A flat roof is any roof with a slope less than 1-unit vertical in 48-unit horizontal (2% slope). The live load for flat roofs is in addition to the ponding load required by Section 206.7.*

[4] *See definition in Section 202.*

[5] *See Section 205.4.4 for concentrated load requirements for greenhouse roof members.*

SECTION 206
OTHER MINIMUM LOADS

206.1 General

In addition to the other design loads specified in this chapter, structures shall be designed to resist the loads specified in this section and the special loads set forth in Table 205-2. See Section 207 for design wind loads and Section 208 for design earthquake loads.

206.2 Other Loads

Buildings and other structures and portions thereof shall be designed to resist all loads due to applicable fluid pressures, ***F***, lateral soil pressures, ***H***, ponding loads, ***P***, and self-straining forces, ***T***. See Section 206.7 for ponding loads for roofs.

206.3 Impact Loads

The live loads specified in Sections 205.3 shall be assumed to include allowance for ordinary impact conditions. Provisions shall be made in the structural design for uses and loads that involve unusual vibration and impact forces. See Section 206.9.3 for impact loads for cranes, and Section 206.10 for heliport and helistop landing areas.

206.3.1 Elevators

All elevator loads shall be increased by 100% for impact.

206.3.2 Machinery

For the purpose of design, the weight of machinery and moving loads shall be increased as follows to allow for impact:

1. Elevator machinery 100%
2. Light machinery, shaft- or motor-driven 20%
3. Reciprocating machinery or power-driven units 50%
4. Hangers for floors and balconies 33%

All percentages shall be increased where specified by the manufacturer.

206.4 Anchorage of Concrete and Masonry Walls

Concrete and masonry walls shall be anchored as required by Section 104.3.3. Such anchorage shall be capable of resisting the load combinations of Section 203.3 or 203.4 using the greater of the wind or earthquake loads required by this chapter or a minimum horizontal force of 4 kN/m of wall, substituted for ***E***.

206.5 Interior Wall Loads

Interior walls, permanent partitions and temporary partitions that exceed 1.8 m in height shall be designed to resist all loads to which they are subjected but not less than a load, ***L***, of 0.25 kPa applied perpendicular to the walls. The 0.25 kPa load need not be applied simultaneously with wind or seismic loads. The deflection of such walls under a load of 0.25 kPa shall not exceed 1/240 of the span for walls with brittle finishes and 1/120 of the span for walls with flexible finishes. See Table 208-13 for earthquake design requirements where such requirements are more restrictive.

Exception:

Flexible, folding or portable partitions are not required to meet the load and deflection criteria but must be anchored to the supporting structure to meet the provisions of this code.

206.6 Retaining Walls

Retaining walls shall be designed to resist loads due to the lateral pressure of retained material in accordance with accepted engineering practice. Walls retaining drained soil, where the surface of the retained soil is level, shall be designed for a load, ***H***, equivalent to that exerted by a fluid weighing not less than 4.7 kPa per meter of depth and having a depth equal to that of the retained soil. Any surcharge shall be in addition to the equivalent fluid pressure.

Retaining walls shall be designed to resist sliding by at least 1.5 times the lateral force and overturning by at least 1.5 times the overturning moment, using allowable stress design loads.

206.7 Water Accumulation

All roofs shall be designed with sufficient slope or camber to ensure adequate drainage after the long-term deflection from dead load or shall be designed to resist ponding load, ***P***, combined in accordance with Section 203.3 or 203.4. Ponding load shall include water accumulation from any source due to deflection.

206.8 Uplift on Floors and Foundations

In the design of basement floors and similar approximately horizontal elements below grade, the upward pressure of water, where applicable, shall be taken as the full hydrostatic pressure applied over the entire area. The hydrostatic load shall be measured from the underside of the construction. Any other upward loads shall be included in the design.

Where expansive soils are present under foundations or slabs-on-ground, the foundations, slabs, and other components shall be designed to tolerate the movement or resist the upward loads caused by the expansive soils, or the expansive soil shall be removed or stabilized around and beneath the structure.

206.9 Crane Loads

206.9.1 General

The crane load shall be the rated capacity of the crane. Design loads for the runway beams, including connections and support brackets of moving bridge cranes and monorail cranes shall include the maximum wheel loads of the crane and the vertical impact, lateral, and longitudinal forces induced by the moving crane.

206.9.2 Maximum Wheel Load

The maximum wheel loads shall be the wheel loads produced by the weight of the bridge, as applicable, plus the sum of the rated capacity and the weight of the trolley with the trolley positioned on its runway where the resulting load effect is maximum.

206.9.3 Vertical Impact Force

The maximum wheel loads of the crane shall be increased by the percentages shown below to determine the induced vertical impact or vibration force:

1.	Monorail cranes (powered)	25%
2.	Cab-operated or remotely operated bridge cranes (powered)	25%
3.	Pendant-operated bridge cranes (powered)	10%
4.	Bridge cranes or monorail cranes with hand-geared ridge, trolley and hoist	0%

206.9.4 Lateral Force

The lateral force on crane runway beams with electrically powered trolleys shall be calculated as 20% of the sum of the rated capacity of the crane and the weight of the hoist and trolley. The lateral force shall be assumed to act horizontally at the traction surface of a runway beam, in either direction perpendicular to the beam, and shall be distributed with due regard to the lateral stiffness of the runway beam and supporting structure.

206.9.5 Longitudinal Forces

The longitudinal force on crane runway beams, except for bridge cranes with hand-geared bridges, shall be calculated as 10% of the maximum wheel loads of the crane. The longitudinal force shall be assumed to act horizontally at the traction surface of a runway beam, in either direction parallel to the beam.

206.10 Heliport and Helistop Landing Areas

In addition to other design requirements of this chapter, heliport and helistop landing or touchdown areas shall be designed for the following loads, combined in accordance with Section 203.3 or 203.4:

1. Dead load plus actual weight of the helicopter.

2. Dead load plus a single concentrated impact load, ***L***, covering 0.10 m^2 of 0.75 times the fully loaded weight of the helicopter if it is equipped with hydraulic-type shock absorbers, or 1.5 times the fully loaded weight of the helicopter if it is equipped with a rigid or skid-type landing gear.

The dead load plus a uniform live load, ***L***, of 4.8 kPa. The required live load may be reduced in accordance with Section 205.5 or 205.6.

SECTION 207
WIND LOADS

207.1 Specifications

Buildings and other vertical structures shall be designed and constructed to resist wind loads as specified and presented in Sections 207A through 207F.

Antenna towers and antenna supporting structures shall be designed and constructed to resist wind loads as specified and presented in ANSI/TIA-222-G-2005, entitled as "*Structural Standards for Steel Antenna Towers and Antenna Supporting Structures and* ANSI/TIA-222-G-1-2007, entitled as "*Structural Standards for Steel Antenna Towers and Antenna Supporting Structures – Addendum 1.*

207A General Requirements

Commentary:

The format and layout of the wind load provisions in this code have been significantly revised from NSCP 2001 and NSCP 2010 editions. The goal was to improve the organization, clarity, and use of the wind load provisions by creating individual sub-sections organized according to the applicable major subject areas. The wind load provisions are now presented in Sections 207A through 207F as opposed to prior editions, where the provisions were contained in a single section.

- *Section 207A provides the basic wind design parameters that are applicable to the various wind load determination methodologies outlined in Sections 207B through 207F. Items covered in Section 207A include definitions, basic wind speed, exposure categories, internal pressures, enclosure classification, gust-effects, and topographic factors, among others. A general description of each section is provided below:*

- *Section 207B discusses about Directional Procedure for Enclosed, Partially Enclosed, and Open Buildings of All Heights: The procedure is the former "buildings of all heights method" in NSCP 2010 (ASCE 7-05), Method 2. A simplified procedure, based on the Directional Procedure, is provided for buildings up to 48m in height.*

- *Section 207C discusses about Envelope Procedure for Enclosed and Partially Enclosed Low-Rise Buildings: This procedure is the former "low-rise buildings method" in NSCP 2010 (ASCE 7-05) Method 2. This section also incorporates NSCP 2010 (ASCE 7-05) Method 1 for MWFRS applicable to the MWFRS of enclosed simple diaphragm buildings less than 18 m in height.*

- *Section 207D discusses Other Structures and Building Appurtenances: A single section is dedicated to determining wind loads on non-building structures such as signs, rooftop structures, and towers.*

- *Section 207E discusses about Components and Cladding. This code addresses the determination of component and cladding loads in a single section. Analytical and simplified methods are provided based on the building height. Provisions for open buildings and building appurtenances are also addressed.*

- *Section 207F discusses about Wind Tunnel Procedure.*

207A.1 Procedures

207A.1.1 Scope

Buildings and other structures, including the Main Wind-Force Resisting System (MWFRS) and all components and cladding (C&C) thereof, shall be designed and constructed to resist the wind loads determined in accordance with Section 207A through 207F. The provisions of this section define basic wind parameters for use with other provisions contained in this code.

Commentary:

The procedures specified in this code provide wind pressures and forces for the design of MWFRS and for the design of components and cladding (C&C) of buildings and other structures. The procedures involve the determination of wind directionality and velocity pressure, the selection or determination of an appropriate gust effect factor, and the selection of appropriate pressure or force coefficients. The procedure allows for the level of structural reliability required, the effects of differing wind exposures, the speed-up effects of certain topographic features such as hills and escarpments, and the size and geometry of the building or other structure under consideration. The procedure differentiates between rigid and flexible buildings and other structures, and the results generally envelop the most critical load conditions for the design of MWFRS as well as C&C.

The pressure and force coefficients provided in Sections 207B, 207C, 207D, and 207E have been assembled from the latest boundary-layer wind-tunnel and full-scale tests and from previously available literature. Because 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.*

207A.1.2 Permitted Procedures

The design wind loads for buildings and other structures, including the MWFRS and C&C elements thereof, shall be determined using one of the procedures as specified in this article. An outline of the overall process for the determination of the wind loads, including section references, is provided in Figure 207A.1-1.

Commentary:

The design wind loads for buildings and other structures, including the MWFRS and C&C elements thereof, shall be determined using one of the procedures as specified in this article. An outline of the overall process for the determination of the wind loads, including section references, is provided in Figure 207A.1-1.

This version of the wind load standard provides several procedures (as illustrated in Table 207A.1-1) from which the designer can choose.

For MWFRS:

1. *Directional Procedure for Buildings of All Heights (Section 207B)*
2. *Envelope Procedure for Low-Rise Buildings (Section 207C)*
3. *Directional Procedure for Building Appurtenances and Other Structures (Section 207D)*
4. *Wind Tunnel Procedure for All Buildings and Other Structures (Section 207F)*

For Components and Cladding:

1. *Analytical Procedure for Buildings and Building Appurtenances (Section 207E)*
2. *Wind Tunnel Procedure for All Buildings and Other Structures (Section 207F)*

A "simplified method" for which the designer can select wind pressures directly from a table without any calculation, when the building meets all the requirements for application of the method, is provided for designing buildings using the Directional Procedure (Section 207B, Part 2), the Envelope Procedure (Section 207C, Part 2) and the Analytical Procedure for Components and Cladding (Section 207E).

Limitations. *The provisions given under Section 207A.1.2 apply to the majority of site locations and buildings and structures, but for some projects, these provisions may be inadequate. Examples of site locations and buildings and structures (or portions thereof) that may require other approved standards, special studies using applicable recognized literature pertaining to wind effects, or using the wind tunnel procedure of Section 207F include:*

1. *Site locations that have channeling effects or wakes from upwind obstructions. Channeling effects can be caused by topographic features (e.g., a mountain gorge) or buildings (e.g., a neighboring tall building or a cluster of tall buildings). Wakes can be caused by hills or by buildings or other structures.*
2. *Buildings with unusual or irregular geometric shape, including barrel vaults, and other buildings whose shape (in plan or vertical cross-section) differs significantly from the shapes in Figures 207B.4-1, 207B.4-2, 207B.4-7, 207C.4-1, and 207E.4-1 to 207E.4-7. Unusual or irregular geometric shapes include buildings with multiple setbacks, curved facades, or irregular plans resulting from significant indentations or projections, openings through the building, or multi-tower buildings connected by bridges.*
3. *Buildings with response characteristics that result in substantial vortex-induced and/or torsional dynamic effects, or dynamic effects resulting from aero-elastic instabilities such as flutter or galloping. Such dynamic effects are difficult to anticipate, being dependent on many factors, but should be considered when any one or more of the following apply:*

    i. *The height of the building is over 120 m.*

    ii. *The height of the building is greater than 4 times its minimum effective width B_{min}, as defined below.*

    iii. *The lowest natural frequency of the building is less than $n_1 = 0.25$ Hz.*

    iv. *The reduced velocity*

$$\frac{\bar{V}_z}{n_1 B_{min}} > 5$$

where

$\bar{z}$ = $0.6h$
$\bar{V}_z$ = *the mean hourly velocity at height* $\bar{z}$

The minimum effective width B_{min} *is defined as the minimum value of* $\sum h_i B_i / \sum h_i$ *considering all wind directions. The summations are performed over the height of the building for each wind direction,* h_i, *is the height above grade of level i, and* B_i *is the width at level i normal to the wind direction.*

4. *Bridges, cranes, electrical transmission lines, guyed masts, highway signs and lighting structures, telecommunication towers, and flagpoles.*

When undertaking detailed studies of the dynamic response to wind forces, the fundamental frequencies of the structure in each direction under consideration should be established using the structural properties and deformational characteristics of the resisting elements in a properly substantiated analysis, and not utilizing approximate equations based on height.

Shielding. *Due to the lack of reliable analytical procedures for predicting the effects of shielding provided by buildings and other structures or by topographic features, reductions in velocity pressure due to shielding are not permitted under the provisions of this chapter. However, this does not preclude the determination of shielding effects and the corresponding reductions in velocity pressure by means of the wind tunnel procedure in Section 207F.*

207A.1.2.1 Main Wind-Force Resisting System (MWFRS)

Wind loads for MWFRS shall be determined using one of the following procedures:

1. Directional Procedure for buildings of all heights as specified in Section 207B for buildings meeting the requirements specified therein;

2. Envelope Procedure for low-rise buildings as specified in Section 207C for buildings meeting the requirements specified therein;

3. Directional Procedure for Building Appurtenances (rooftop structures and rooftop equipment) and Other Structures (such as solid freestanding walls and solid freestanding signs, chimneys, tanks, open signs, lattice frameworks, and trussed towers) as specified in Section207D; or

4. Wind Tunnel Procedure for all buildings and all other structures as specified in Section 207F.

207A.1.2.2 Components and Cladding

Wind loads on components and cladding on all buildings and other structures shall be designed using one of the following procedures:

1. Analytical Procedures provided in Parts 1 through 6, as appropriate, of Section 207E; or

2. Wind Tunnel Procedure as specified in Section 207F.

207A.2 Definitions

The following definitions apply to the provisions of Section 207:

APPROVED is an acceptable to the authority having jurisdiction.

BASIC WIND SPEED, *V* is a three-second gust speed at 10m above the ground in Exposure C (see Section 207A.7.3) as determined in accordance with Section 207A.5.1.

BUILDING, ENCLOSED is a building that does not comply with the requirements for open or partially enclosed buildings.

BUILDING ENVELOPE is a cladding, roofing, exterior walls, glazing, door assemblies, window assemblies, skylight assemblies, and other components enclosing the building.

BUILDING AND OTHER STRUCTURE, FLEXIBLE are slender buildings and other structures that have a fundamental natural frequency less than 1 Hz.

BUILDING, LOW-RISE are enclosed or partially enclosed buildings that comply with the following conditions:

1. Mean roof height h less than or equal to 18m.

2. Mean roof height h does not exceed least horizontal dimension.

BUILDING, OPEN is a building having each wall at least 80 percent open. This condition is expressed for each wall by the equation $A_o \geq 0.8A_g$.

where:

A_o = total area of openings in a wall that receives positive external pressure, in m^2

A_g = the gross area of that wall in which A_o is identified, in m^2

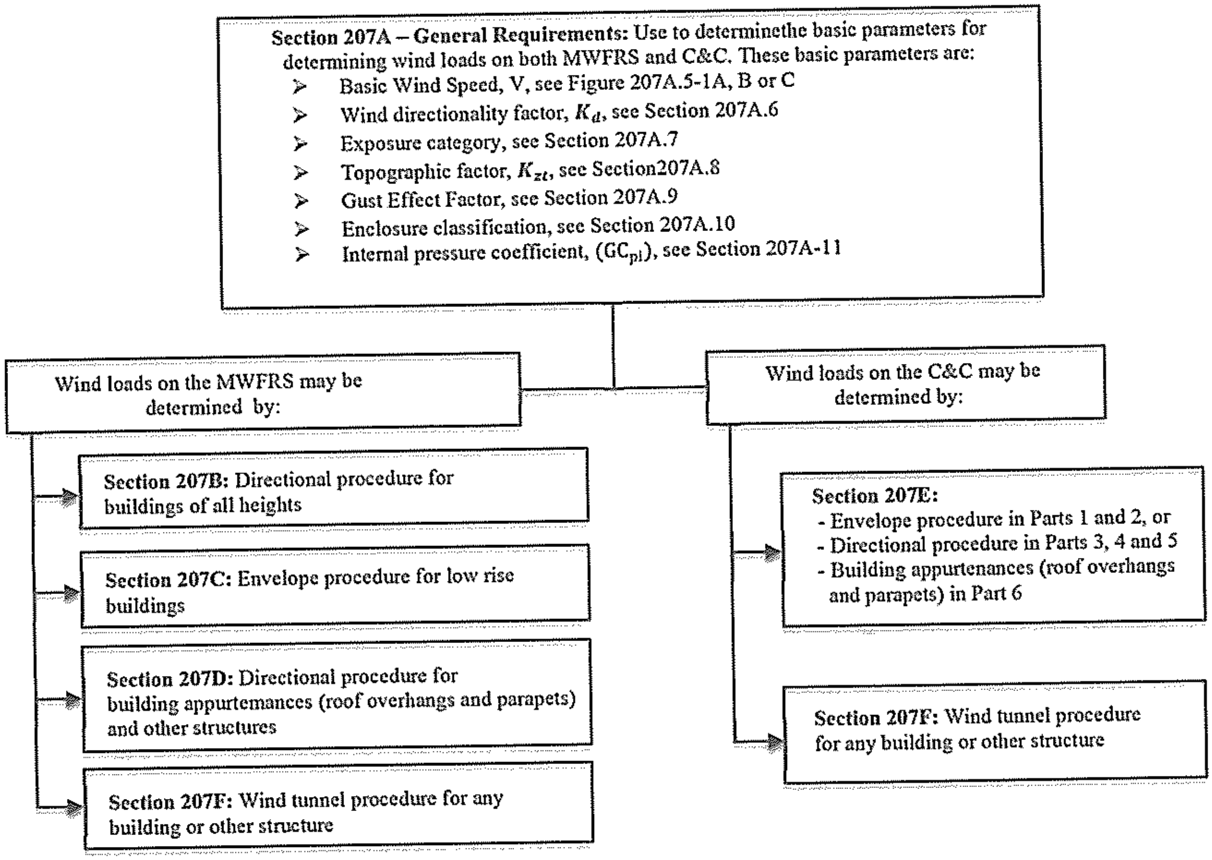


Figure 207A.1-1

Outline of Process for Determining Wind Loads. Additional Outlines and User Notes are Provided at the Beginning of each Chapter for more Detailed Step-By-Step Procedures for Determining the Wind Loads

BUILDING, PARTIALLY ENCLOSED is a building that complies with both of the following conditions:

1. The total area of openings in a wall that receives positive external pressure exceeds the sum of the areas of openings in the balance of the building envelope (walls and roof) by more than 10 percent.

2. The total area of openings in a wall that receives positive external pressure exceeds 0.37 m^2.

or 1 percent of the area of that wall, whichever is smaller, and the percentage of openings in the balance of the building envelope does not exceed 20 percent.

These conditions are expressed by the following equations:

1. $A_o > 1.10A_{oi}$

2. $A_o > 0.37$ m^2 or $0.01A_g$, whichever is smaller, and $A_{oi}/A_{gi} \leq 0.20$

where:

A_o, A_g = are as defined for Open Building

A_{oi} = the sum of the areas of openings in the building envelope (walls and roof) not including A_o, in m^2

A_{gi} = the sum of the gross surface areas of the building envelope (walls and roof) not including A_g, in m^2

Components can be part of the MWFRS when they act as shear walls or roof diaphragms, but they may also be loaded as individual components. The engineer needs to use appropriate loadings for design of components, which may require certain components to be designed for more than one type of loading, for example, long-span roof trusses should be designed for loads associated with MWFRS, and individual members of trusses should also be designed for component and cladding loads (*Mehta and Marshall 1998*). Examples of cladding include wall coverings, curtain walls, roof coverings, exterior windows (fixed and operable) and doors, and overhead doors.

DIAPHRAGM in wind load applications has been added in ASCE 7-10. This definition, for the case of untopped steel decks, differs somewhat from the definition used in Section 12.3 of ASCE 7-10 because diaphragms under wind loads are expected to remain essentially elastic.

EFFECTIVE WIND AREA, A is an effective wind area is the area of the building surface used to determine (GC_p). This area does not necessarily correspond to the area of the building surface contributing to the force being considered. Two cases arise. In the usual case, the effective wind area does correspond to the area tributary to the force component being considered. For example, for a cladding panel, the effective wind area may be equal to the total area of the panel. For a cladding fastener, the effective wind area is the area of cladding secured by a single fastener. A mullion may receive wind from several cladding panels. In this case, the effective wind area is the area associated with the wind load that is transferred to the mullion.

The second case arises where components such as roofing panels, wall studs, or roof trusses are spaced closely together. The area served by the component may become long and narrow. To better approximate the actual load distribution in such cases, the width of the effective wind area used to evaluate (GC_p) need not be taken as less than one-third the length of the area. This increase in effective wind area has the effect of reducing the average wind pressure acting on the component. Note, however, that this effective wind area should only be used in determining the (GC_p) in Figures 207E.4-1 through 207E.4-6 and 207E.4-8. The induced wind load should be applied over the actual area tributary to the component being considered.

For membrane roof systems, the effective wind area is the area of an insulation board (or deck panel if insulation is not used) if the boards are fully adhered (or the membrane is adhered directly to the deck). If the insulation boards or membrane are mechanically attached or partially adhered, the effective wind area is the area of the board or membrane secured by a single fastener or individual spot or row of adhesive.

For typical door and window systems supported on three or more sides, the effective wind area is the area of the door or window under consideration. For simple spanning doors (e.g., horizontal spanning section doors or coiling doors), large specialty constructed doors (e.g., aircraft hangar doors), and specialty constructed glazing systems, the effective wind area of each structural component composing the door or window system should be used in calculating the design wind pressure.

MAIN WIND-FORCE RESISTING SYSTEM (MWFRS) can consist of a structural frame or an assemblage of structural elements that work together to transfer wind loads acting on the entire structure to the ground. Structural elements such as cross-bracing, shear walls, roof trusses, and roof diaphragms are part of the Main Wind-Force Resisting System (MWFRS) when they assist in transferring overall loads (*Mehta and Marshall 1998*).

WIND-BORNE DEBRIS REGIONS are defined to alert the designer to areas requiring consideration of missile impact design. These areas are located within tropical cyclone prone regions where there is a high risk of glazing failure due to the impact of wind-borne debris.

207A.3 Symbols and Notations

The following symbols and notation apply only to the provisions of Section 207A through 207F:

A	=	effective wind area, in m^2
A_f	=	area of open buildings and other structures either normal to the wind direction or projected on a plane normal to the wind direction, in m^2
A_g	=	the gross area of that wall in which A_o is identified, in m^2
A_{gi}	=	the sum of the gross surface areas of the building envelope (walls and roof) not including A_g, in m^2
A_o	=	total area of openings in a wall that receives positive external pressure, in m^2
A_{oi}	=	the sum of the areas of openings in the building envelope (walls and roof) not including A_o, in m^2
A_{og}	=	total area of openings in the building envelope in m^2
A_s	=	gross area of the solid freestanding wall or solid sign, in m^2
a	=	width of pressure coefficient zone, in m

B = horizontal dimension of building measured normal to wind direction, in m

$\bar{b}$ = mean hourly wind speed factor in Equation 207A.9-16 from Table 207A.9-1

$\hat{b}$ = 3-s gust speed factor from Table 207A.9-1

C_f = force coefficient to be used in determination of wind loads for other structures

C_N = net pressure coefficient to be used in determination of wind loads for open buildings

C_p = external pressure coefficient to be used in determination of wind loads for buildings

c = turbulence intensity factor in Equation 207A.9-7 from Table 207A.9-1

D = diameter of a circular structure or member, in m

D' = depth of protruding elements such as ribs and spoilers, in m

F = design wind force for other structures, in N

G = gust-effect factor

G_f = gust-effect factor for MWFRS of flexible buildings and other structures

(GC_r) = product of external pressure coefficient and gust-effect factor to be used in determination of wind loads for rooftop structures

(GC_p) = product of external pressure coefficient and gust-effect factor to be used in determination of wind loads for buildings

(GC_{pf}) = product of the equivalent external pressure coefficient and gust-effect factor to be used in determination of wind loads for MWFRS of low-rise buildings

(GC_{pi}) = product of internal pressure coefficient and gust-effect factor to be used in determination of wind loads for buildings

(GC_{pn}) = combined net pressure coefficient for a parapet

g_Q = peak factor for background response in Equations 207A.9-6 and 207A.9-10

g_R = peak factor for resonant response in Equation 207A.9-10

g_v = peak factor for wind response in Equations 207A.9-6 and 207A.9-10

H = height of hill or escarpment in Figure 207A.8-1, in m

h = mean roof height of a building or height of other structure, except that eave height shall be used for roof angle θ less than or equal to 10°, in m

h_e = roof eave height at a particular wall, or the average height if the eave varies along the wall

h_p = height to top of parapet in Figure 207B.6-4 and 207E.7-1

I_z = intensity of turbulence from Equation 207A.9-7

K_1, K_2, K_3 = multipliers in Figure 207A.8-1 to obtain K_{zt}

K_d = wind directionality factor in Table 207A.6-1

K_h = velocity pressure exposure coefficient evaluated at height $z = h$

K_z = velocity pressure exposure coefficient evaluated at height z

K_{zt} = topographic factor as defined in Section 207A.8

L = horizontal dimension of a building measured parallel to the wind direction, in m

L_h = distance upwind of crest of hill or escarpment in Figure 207A.8-1 to where the difference in ground elevation is half the height of the hill or escarpment, in m

L_r = horizontal dimension of return corner for a solid freestanding wall or solid sign from Figure 207D.4-1, in m

L_z = integral length scale of turbulence, in m

ℓ = integral length scale factor from Table 207A.9-1, m

N_1 = reduced frequency from Equation 207A.9-14

n_a = approximate lower bound natural frequency (Hz) from Section 207A.9.2

n_1 = fundamental natural frequency, Hz

p = design pressure to be used in determination of wind loads for buildings, in N/m²

P_L = wind pressure acting on leeward face in Figure 207B.4-8, in N/m²

p_{net} = net design wind pressure from Equation 207E.5-1, in N/m²

p_{net10} = net design wind pressure for Exposure B at $h = 10$ m and $I = 1.0$ from Figure 207E.5-1, in N/m²

p_p = combined net pressure on a parapet from Equation 207B.4-5, in N/m²

p_s = net design wind pressure from Equation 207C.6-1, in N/m²

p_{s10} = simplified design wind pressure for Exposure B at $h = 10$ m and $I = 1.0$ from Figure 207C.6-1, in N/m²

p_W = wind pressure acting on windward face in Figure 207B.4-8, in N/m²

Q = background response factor from Equation 207A.9-8

q = velocity pressure, in N/m²

q_h = velocity pressure evaluated at height $z = h$, in N/m²

q_i = velocity pressure for internal pressure determination, in N/m²

q_p = velocity pressure at top of parapet, in N/m²

q_z = velocity pressure evaluated at height z above ground, in N/m²

R = resonant response factor from Equation 207A.9-12

R_h, R_L = values from Equations 207A.9-15

R_i = reduction factor from Equation 207A.11-1

R_n = value from Equation 207A.9-13

s = vertical dimension of the solid freestanding wall or solid sign from Figure 207D.4-1, in m

r = rise-to-span ratio for arched roofs

v = height-to-width ratio for solid sign

V = basic wind speed obtained from Figure 207A.5-1A through 207A.5-1C, in m/s. The basic wind speed corresponds to a 3-s gust speed at 10 m above the ground in Exposure Category C

V_i = unpartitioned internal volume, m³

$\bar{V}_{\bar{z}}$ = mean hourly wind speed at height $\bar{z}$ m/s

W = width of building in Figures 207E.4-3 and 207E.4-5A and 207E.4-5B and width of span in Figures 207E.4-4 and 207E.4-6, in m

x = distance upwind or downwind of crest in Figure 207A.8-1, in m

z = height above ground level, in m

$\bar{z}$ = equivalent height of structure, in m

z_g = nominal height of the atmospheric boundary layer used in this code. Values appear in Table 207A.9-1

z_{min} = exposure constant from Table 207A.9-1

α = 3-s gust-speed power law exponent from Table 207A.9-1

$\hat{\alpha}$ = reciprocal of α from Table 207A.9-1

$\bar{\alpha}$ = mean hourly wind-speed power law exponent in Equation 207A.9-16 from Table 207A.9-1

β = damping ratio, percent critical for buildings or other structures

ϵ = ratio of solid area to gross area for solid freestanding wall, solid sign, open sign, face of a trussed tower, or lattice structure

$\bar{\epsilon}$ = integral length scale power law exponent in Equation 207A.9-9 from Table 207A.9-1

λ = adjustment factor for building height and exposure from Figures. 207C.6-1 and 207E.5-1

η = value used in Equation 207A.9-15 (see Section 207A.9.4)

θ = angle of plane of roof from horizontal, in degrees

207A.4 General

207A.4.1 Sign Convention

Positive pressure acts toward the surface and negative pressure acts away from the surface.

207A.4.2 Critical Load Condition

Values of external and internal pressures shall be combined algebraically to determine the most critical load.

207A.4.3 Wind Pressures Acting on Opposite Faces of Each Building Surface

In the calculation of design wind loads for the MWFRS and for components and cladding for buildings, the algebraic sum of the pressures acting on opposite faces of each building surface shall be taken into account.

Commentary:

Section 207A.4.3 is included in the code to ensure that internal and external pressures acting on a building surface are taken into account by determining a net pressure from the algebraic sum of those pressures. For additional information on the application of the net components and cladding wind pressure acting across a multilayered building envelope system, including air-permeable cladding, refer to Section C207E.1.5.

207A.5 Wind Hazard Map

207A.5.1 Basic Wind Speed

The basic wind speed, V, used in the determination of design wind loads on buildings and other structures shall be determined from Figure 207A.5-1 as follows, except as provided in Section 207A.5.2 and 207A.5.3:

For Occupancy Category III, IV and V buildings and other structures – use Figure 207A.5-1A.

For Occupancy Category II buildings and other structures – use Figure 207A.5-1B.

For Occupancy Category I buildings and other structures – use Figure 207A.5-1C.

The wind shall be assumed to come from any horizontal direction. The basic wind speed shall be increased where records or experience indicate that the wind speeds are higher than those reflected in Figure 207A.5-1.

Commentary:

This edition of NSCP departs from prior editions by providing wind maps that are directly applicable for determining pressures for strength design approaches. Rather than using a single map with importance factors and a load factor for each building occupancy category, in this edition there are different maps for different categories of building occupancies. The updated maps are based on a new and more complete analysis of tropical cyclone characteristics (Vickery et al. 2008a, 2008b and 2009) performed over the past 10 years.

The decision to move to multiple-strength design maps in conjunction with a wind load factor of 1.0 instead of using a single map used with an importance and a load factor of 1.6 relied on several factors important to an accurate wind specification:

1. *A strength design wind speed map brings the wind loading approach in line with that used for seismic loads in that they both essentially eliminate the use of a load factor for strength design.*
2. *Multiple maps remove inconsistencies in the use of importance factors that actually should vary with location and between tropical cyclone-prone and non-tropical cyclone-prone regions for Occupancy Category III, IV and V structures and acknowledge that the demarcation between tropical cyclone and non-tropical cyclone winds change with the recurrence interval.*
3. *The new maps establish uniformity in the return period for the design-basis winds, and they more clearly convey that information.*
4. *The new maps, by providing the design wind speed directly, more clearly inform owners and their consultants about the storm intensities for which designs are performed.*

Selection of Return Periods. *In the development of the design wind speed map used in Section 207 NSCP 2010, the Wind Load Subcommittee evaluated the wind importance factor, I_w, that had been in use since 1982. The task committee recognized that using a uniform value of the wind importance factor probably was not appropriate because risk varies with location along the coast.*

To determine the return periods to be used in the new mapping approach, the task committee needed to meet with PAGASA scientists, gather historical records and evaluate representative return periods for wind speeds determined in accordance with Section 207 NSCP 2010 and earlier, wherein determination of pressures appropriate for strength design started with mapped wind speeds, but involved multiplication by importance factors and a wind load factor to achieve pressures that were appropriate for strength design. Furthermore, it was assumed that the variability of the wind speed dominates the calculation of the wind load factor. The strength design wind load, W_T, is given as:

$$W_T = C_F(V_{50}I)^2 W_{LF} \qquad (C207A.5\text{-}1)$$

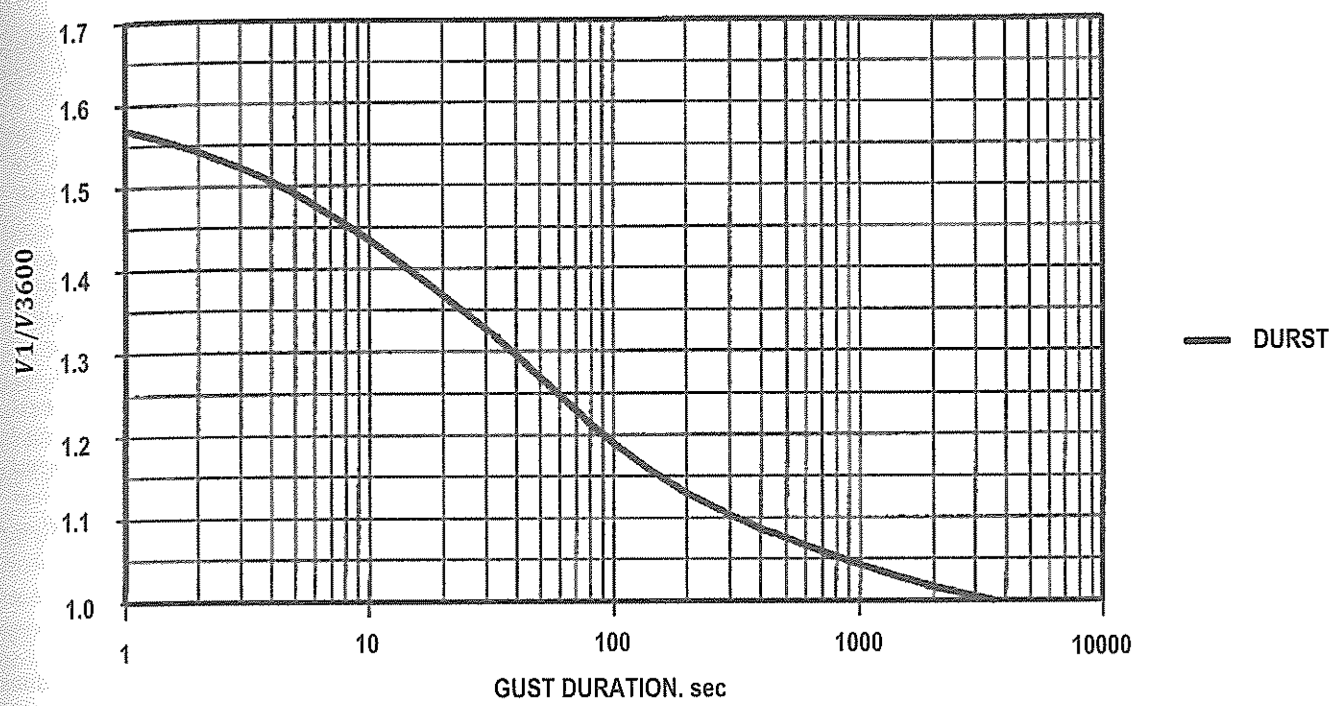


Figure C207A.5-1
Maximum Speed Averaged over t s to Hourly Mean Speed

where C_F *is a building, component, or structure specific coefficient that includes the effects of things like building height, building geometry, terrain, and gust factor as computed using the procedures outlined in NSCP 2010.* V_{50} *is the 50-year return period design wind speed,* W_{LF} *is the wind load factor, and* I *is the importance factor.*

Starting with the nominal return period of 50 years, the ratio of the wind speed for any return period to the 50-year return period wind speed can be computed from Peterka and Shahid (1998):

$$V_T/V_{50} = [0.36 + 0.11n(12T)] \qquad (C207A.5\text{-}2)$$

where T *is the return period in years and* V_T *is the* T*-year return period wind speed. The strength design wind load,* W_T*, occurs when:*

$$W_T = C_F V_T^2 = C_F V_{50}^2 W_{LF} \qquad (C207A.5\text{-}3)$$

Thus,

$$V_T/V_{50} = [0.36 + 0.11n(12T)] = \sqrt{W_{LF}} \qquad (C207A.5\text{-}4)$$

and from Equation C207A.5-4, the return period T *associated with the strength design wind speed is:*

$$T = 0.00228\, exp(10\sqrt{W_{LF}}) \qquad (C207A.5\text{-}5)$$

Using the wind load factor of 1.6 as specified in Section 207 NSCP 2010, from Equation C207A.5-5 we get $T = 709$ *years, and therefore* $V_{design} = V_{709}/\sqrt{W_{LF}} \approx V_{700}/\sqrt{W_{LF}}$*. Thus for Occupancy Category IV structures, the basic wind speed is associated with a return period of 700 years, or an annual exceedance probability of 0.0014.*

The importance factor used in Section 207 NSCP 2010 and earlier for the computation of wind loads for the design of Occupancy Category I and II structures is defined so that the nominal 50-year return period non-tropical cyclone wind speed is increased to be representative of a 100-year return period value. Following the approach used above to estimate the resulting effective strength design return period associated with a 50-year basic design speed, in the case of the 100-year return period basic wind speed in the non-tropical cyclone-prone regions, we find that:

$$T = 00228\, exp\left[10(V_{100}/V_{50})\sqrt{W_{LF}}\right] \qquad (C207A.5\text{-}6)$$

where for V_{100}/V_{50} *computed from Equation C207A.5-4 with* W_{LF} *= 1.6, we find* T *= 1,697 years. In the development of Equation C207A.5-6, the term* $(V_{100}/V_{50})W_{LF}$ *replaces the* W_{LF} *used in Equation C207A.5-5, effectively resulting in a higher load factor for Occupancy Category I, II and III structures equal to* $W_{LF}(V_{100}/V_{50})^2$*. Thus for Occupancy Category I and II structures, the basic wind speed is associated with a return period of 1,700 years, or an annual exceedance probability of 0.000588. Similarly, the 25-year return period wind speed associated with Occupancy Category III, IV and V buildings equates to a 300-year return period wind speed with a wind load factor of 1.0.*

Wind Speeds. *The wind speed maps of Figure 207A.5-1 present basic wind speeds for the entire archipelago of the Philippines. The wind speeds correspond to 3-sec gust speeds at 10 m above ground for exposure category C.*

Serviceability Wind Speeds. *For applications of serviceability, design using maximum likely events, or other applications, it may be desired to use wind speeds associated with mean recurrence intervals other than those given in Figures 207A.5-1A to 207A.5-1C. To accomplish this, previous editions of NSCP 2010 provided tables with factors that enabled the user to adjust the basic design wind speed (previously having a return period of 50 years to wind speeds associated with other return periods.*

For applications of serviceability, design using maximum likely events, or other applications, Appendix C presents maps of peak gust wind speeds at 10 m above ground in Exposure C conditions for return periods of 10, 25, 50, and 100 years.

The probability P_n *that the wind speed associated with a certain annual probability* P_a *will be equaled or exceeded at least once during an exposure period of n years is given by:*

$$P_n = 1 - (1 - P_a)^n \qquad (C207A.5\text{-}7)$$

As an example, if a wind speed is based upon P_a *= 0.02 (50-year mean recurrence interval), there exists a probability of 0.40 that this speed will be equaled or exceeded during a 25-year period, and a 0.64 probability of being equaled or exceeded in a 50-year period.*

Similarly, if a wind speed is based upon P_a *= 0.00143 (700-year mean recurrence interval), there exists a 3.5% probability that this speed will be equaled or exceeded during a 25-year period, and a 6.9% probability of being equaled or exceeded in a 50-year period.*

Some products have been evaluated and test methods have been developed based on design wind speeds that are consistent with the unfactored load effects typically used in Allowable Stress Design. Table C207A.5-6 provides conversion from the strength design-based design wind speeds used in the ASCE 7-10 design wind speed maps and the Section 207 NSCP 2010 design wind speeds used in these product evaluation reports and test methods. A column of values is also provided to allow coordination with ASCE 7-93 design wind speeds.

207A.5.2 Special Wind Regions

Mountainous terrain, gorges, and special wind regions shown in Figure 207A.5-1 shall be examined for unusual wind conditions. The authority having jurisdiction shall, if necessary, adjust the values given in Figure 207A.5-1 to account for higher local wind speeds. Such adjustment shall be based on meteorological information and an estimate of the basic wind speed obtained in accordance with the provisions of Section 207A.5.3.

Commentary:

Although the wind speed map of Figure 207A.5-1 is valid for most regions of the country, there are special regions in which wind speed anomalies are known to exist. Some of these special regions are noted in Figure 207A.5-1. Winds blowing over mountain ranges or through gorges or river valleys in these special regions can develop speeds that are substantially higher than the values indicated on the map. When selecting basic wind speeds in these special regions, use of regional climatic data and consultation with a wind engineer or meteorologist is advised.

It is also possible that anomalies in wind speeds exist on a micrometeorological scale. For example, wind speed-up over hills and escarpments is addressed in Section 207A.8. Wind speeds over complex terrain may be better determined by wind-tunnel studies as described in Section 207F. Adjustments of wind speeds should be made at the micrometeorological scale on the basis of wind engineering or meteorological advice and used in accordance with the provisions of Section 207A.5.3 when such adjustments are warranted. Due to the complexity of mountainous terrain and valley gorges in Hawaii, there are topographic wind speed-up effects that cannot be *addressed solely by Figure 207A.8-1 (Applied Research Associates 2001).*

207A.5.3 Estimation of Basic Wind Speeds from Regional Climatic Data

In areas outside tropical cyclone-prone regions, regional climatic data shall only be used in lieu of the basic wind speeds given in Figure 207A.5-1 when (1) approved extreme-value statistical-analysis procedures have been employed in reducing the data; and (2) the length of record, sampling error, averaging time, anemometer height, data quality, and terrain exposure of the anemometer have been taken into account. Reduction in basic wind speed below that of Figure 207A.5-1 shall be permitted.

In tropical cyclone-prone regions, wind speeds derived from simulation techniques shall only be used in lieu of the basic wind speeds given in Figure 207A.5-1 when approved simulation and extreme value statistical analysis procedures are used.

In areas outside tropical cyclone-prone regions, when the basic wind speed is estimated from regional climatic data, the basic wind speed shall not be less than the wind speed associated with the specified mean recurrence interval, and the estimate shall be adjusted for equivalence to a 3-s gust wind speed at 10m above ground in Exposure C. The data analysis shall be performed in accordance with this section.

Commentary:

When using regional climatic data in accordance with the provisions of Section 207A.5.3 and in lieu of the basic wind speeds given in Figure 207A.5-1, the user is cautioned that the gust factors, velocity pressure exposure coefficients, gust effect factors, pressure coefficients, and force coefficients of this code are intended for use with the 3-s gust speed at 10m above ground in open country. It is necessary, therefore, that regional climatic data based on a different averaging time, for example, hourly mean or fastest mile, be adjusted to reflect peak gust speeds at 10m above ground in open country.

In using local data, it should be emphasized that sampling errors can lead to large uncertainties in specification of the wind speed. Sampling errors are the errors associated with the limited size of the climatological data samples (years of record of annual extremes). It is possible to have a 8.9m/s error in wind speed at an individual station with a record length of 30 years. While local records of limited extent often must be used to define wind speeds in special wind areas, care and conservatism should be exercised in their use.

If meteorological data are used to justify a wind speed lower than 177-km/h 700-yr peak gust at 10 m, an analysis of sampling error is required to demonstrate that the wind record could not occur by chance. This can be accomplished by showing that the difference between predicted speed and 177 km/h contains two to three standard deviations of sampling error (Simiu and Scanlan 1996). Other equivalent methods may be used.

207A.5.4 Limitation

Tornadoes have not been considered in developing the basic wind-speed distributions.

207A.6 Wind Directionality

The wind directionality factor, K_d, shall be determined from Table 207A.6-1. This directionality factor shall only be included in determining wind loads when the load combinations specified in Sections 2.3 and 2.4 are used for the design. The effect of wind directionality in determining wind loads in accordance with Section 207F shall be based on an analysis for wind speeds that conforms to the requirements of Section 207A.5.3.

Commentary:

The wind load factor 1.3 in ASCE 7-95 included a "wind directionality factor" of 0.85 (Ellingwood 1981 and Ellingwood et al. 1982). This factor accounts for two effects: (1) The reduced probability of maximum winds coming from any given direction and (2) the reduced probability of the maximum pressure coefficient occurring for any given wind direction. The wind directionality factor (identified as K_d in the code) is tabulated in Table 207A.6-1 for different structure types. As new research becomes available, this factor can be directly modified. Values for the factor were established from references in the literature and collective committee judgment. The K_d value for round chimneys, tanks, and similar structures is given as 0.95 in recognition of the fact that the wind load resistance may not be exactly the same in all directions as implied by a value of 1.0. A value of 0.85 might be more appropriate if a triangular trussed frame is shrouded in a round cover. A value of 1.0 might be more appropriate for a round chimney having a lateral load resistance equal in all directions. The designer is cautioned by the footnote to Table 207A.6-1 and the statement in Section 207A.6, where reference is made to the fact that this factor is only to be used in conjunction with the load combinations specified in Sections 2.3 and 2.4 of ASCE 7-10.

207A.7 Exposure

For each wind direction considered, the upwind exposure shall be based on ground surface roughness that is determined from natural topography, vegetation, and constructed facilities.

Commentary:

The descriptions of the surface roughness categories and exposure categories in Section 207A.7 have been expressed as far as possible in easily understood verbal terms that are sufficiently precise for most practical applications. Upwind surface roughness conditions required for Exposures B and D are shown schematically in Figures C207A.7-1 and C207A.7-2, respectively. For cases where the designer wishes to make a more detailed assessment of the surface roughness category and exposure category, the following more mathematical description is offered for guidance (Irwin 2006). The ground surface roughness is best measured in terms of a roughness length parameter called z_0*. Each of the surface roughness categories B through D correspond to a range of values of this parameter, as does the even rougher category A used in previous versions of the code in heavily built-up urban areas but removed in the present edition. The range of* z_0 *in meters (m) for each terrain category is given in Table C207A.7-1. Exposure A has been included in Table C207A.7-1 as a reference that may be useful when using the Wind Tunnel Procedure. Further information on values of* z_0 *in different types of terrain can be found in Simiu and Scanlan (1996) and Table C207A.7-2 based on Davenport et al. (2000) and Wieringa et al. (2001). The roughness classifications in Table C207A.7-2 are not intended to replace the use of exposure categories as required in the code for structural design purposes. However, the terrain roughness classifications in Table C207A.7-2 may be related to ASCE 7 exposure categories by comparing* z_0 *values between Table C207A.7-1 and C207A.7-2. For example, the* z_0 *values for Classes 3 and 4 in Table C207A.7-2 fall within the range of* z_0 *values for Exposure C in Table C207A.7-1. Similarly, the* z_0 *values for Classes 5 and 6 in Table C207A.7-2 fall within the range of* z_0 *values for Exposure B in Table C207A.7-1.*

Research described in Powell et al. (2003), Donelan et al. (2004), and Vickery et al. (2008b) showed that the drag coefficient over the ocean in high winds in tropical cyclones did not continue to increase with increasing wind speed as previously believed (e.g., Powell 1980). These studies showed that the sea surface drag coefficient, and hence the aerodynamic roughness of the ocean, reached a maximum at mean wind speeds of about 30m/s. There is some evidence that the drag coefficient actually decreases (i.e., the sea surface becomes aerodynamically smoother) as the wind speed increases further (Powell et al. 2003) or as the tropical cyclone radius decreases (Vickery et al. 2008b). The consequences of these studies are that the surface roughness over the ocean in a tropical cyclone is consistent with that of exposure D rather than exposure C. Consequently, the use of exposure D along the tropical cyclone coastline is now required.

For Exposure B the tabulated values of K_z *correspond to* z_0 *= 0.2 m, which is below the typical value of 0.3 m, whereas for Exposures C and D they correspond to the typical value of* z_0*. The reason for the difference in Exposure B is that this category of terrain, which is applicable to suburban areas, often contains open patches, such as highways, parking lots, and playing fields. These cause local increases in the wind speeds at their edges. By using an exposure coefficient corresponding to a lower than typical value of* z_0*, some allowance is made for this. The alternative would be to introduce a number of exceptions to use of Exposure B in suburban areas, which would add an undesirable level of complexity.*

The value of z_0 *for a particular terrain can be estimated from the typical dimensions of surface roughness elements and their spacing on the ground area using an empirical relationship, due to Lettau (1969), which is:*

$$z_0 = 0.5H_{ob}\frac{S_{ob}}{A_{ob}} \qquad \text{(C207A.7-1)}$$

H_{ob} = *the average height of the roughness in the upwind terrain*

S_{ob} = *the average vertical frontal area per obstruction presented to the wind*

A_{ob} = *the average area of ground occupied by each obstruction, including the open area surrounding it*

Vertical frontal area is defined as the area of the projection of the obstruction onto a vertical plane normal to the wind direction. The area S_{ob} *may be estimated by summing the approximate vertical frontal areas of all obstructions within a selected area of upwind fetch and dividing the sum by the number of obstructions in the area. The average height* H_{ob} *may be estimated in a similar way by averaging the individual heights rather than using the frontal areas. Likewise* A_{ob} *may be estimated by dividing the size of the selected area of upwind fetch by the number of obstructions in it.*

As an example, if the upwind fetch consists primarily of single family homes with typical height H_{ob} = *6m, vertical frontal area (including some trees on each lot) of 100m², and ground area per home of 1,000m², then* z_0 *is calculated to be* $z_0 = 0.5 \times 20 \times 100/1{,}000 =$ *0.3m, which falls into exposure category B according to Table C207A.7-1.*

Trees and bushes are porous and are deformed by strong winds, which reduce their effective frontal areas (ESDU, 1993). For conifers and other evergreens no more than 50 percent of their gross frontal area can be taken to be effective in obstructing the wind. For deciduous trees and bushes no more than 15 percent of their gross frontal area can be taken to be effective in obstructing the wind. Gross frontal area is defined in this context as the projection onto a vertical plane (normal to the wind) of the area enclosed by the envelope of the tree or bush.

Ho (1992) estimated that the majority of buildings (perhaps as much as 60 percent to 80 percent) have an exposure category corresponding to Exposure B. While the relatively simple definition in the code will normally suffice for most practical applications, oftentimes the designer is in need of additional information, particularly with regard to the effect of large openings or clearings (e.g., large parking lots, freeways, or tree clearings) in the otherwise "normal" ground surface roughness B. The following is offered as guidance for these situations:

The simple definition of Exposure B given in the body of the code, using the surface roughness category definition, is shown pictorially in Figure C207A.7-1. This definition applies for the surface roughness B condition prevailing 800 m upwind with insufficient "open patches" as defined in the following text to disqualify the use of Exposure B.

An opening in the surface roughness B large enough to have a significant effect on the exposure category determination is defined as an "open patch." An open patch is defined as an opening greater than or equal to approximately 50 m on each side (i.e., greater than 50 m by 50 m). Openings smaller than this need not be considered in the determination of the exposure category.

The effect of open patches of surface roughness C or D on the use of exposure category B is shown pictorially in Figures C207A.7-3 and C207A.7-4. Note that the plan location of any open patch may have a different effect for different wind directions.

Aerial photographs, representative of each exposure type, are included in the commentary to aid the user in establishing the proper exposure for a given site. Obviously, the proper assessment of exposure is a matter of good engineering judgment. This fact is particularly true in light of the possibility that the exposure could change in one or more wind directions due to future demolition and/or development.

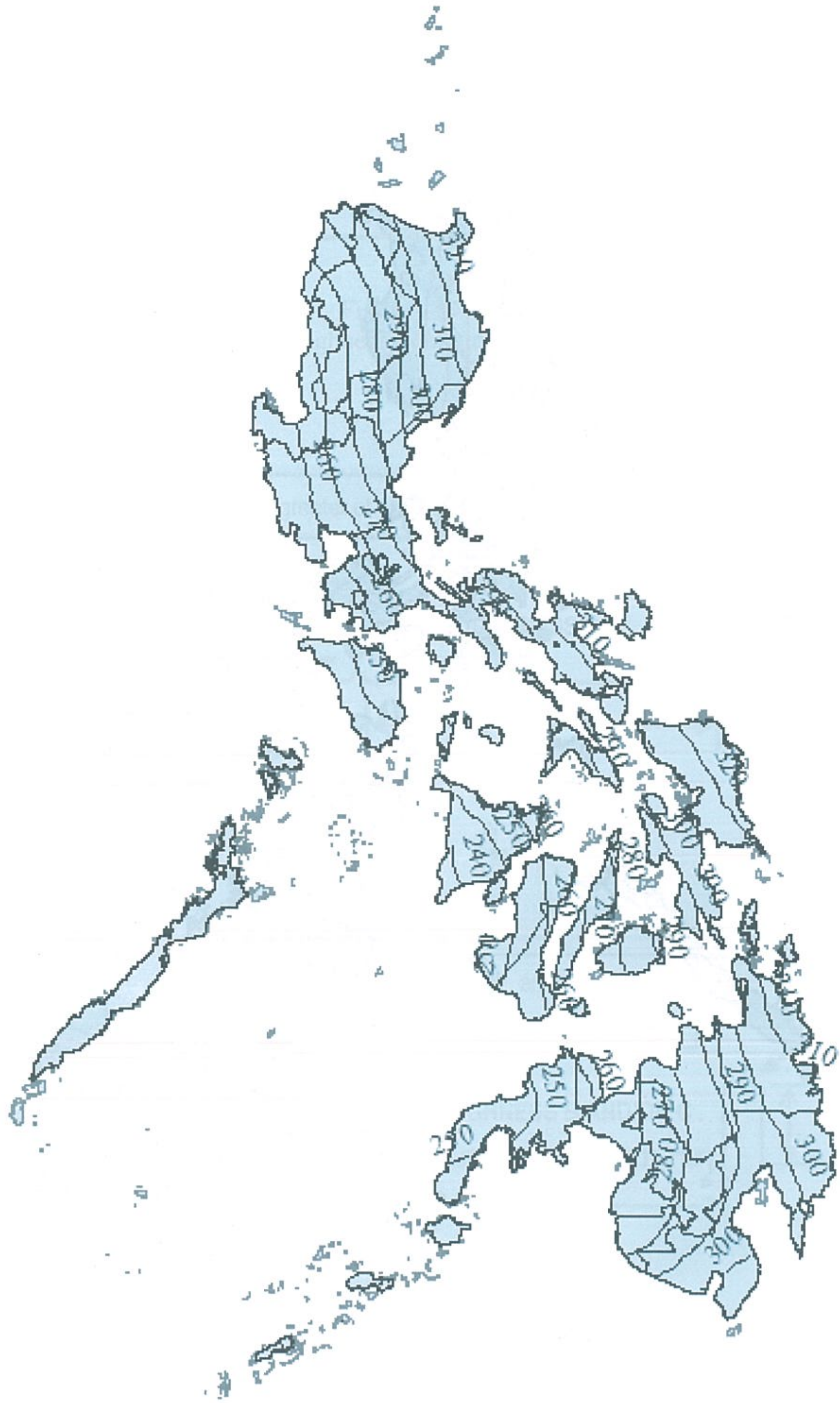
207A.7.1 Wind Directions and Sectors

For each selected wind direction at which the wind loads are to be determined, the exposure of the building or structure shall be determined for the two upwind sectors extending 45° either side of the selected wind direction. The exposure in these two sectors shall be determined in accordance with Sections 207A.7.2 and 207A.7.3, and the exposure whose use would result in the highest wind loads shall be used to represent the winds from that direction.

Notes:

1. Values are nominal design 3-second gust wind speeds in kilometers per hour at 10 m above ground for Exposure C category.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 15% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00333, MRI = 300 years).
6. Results are from PAGASA.

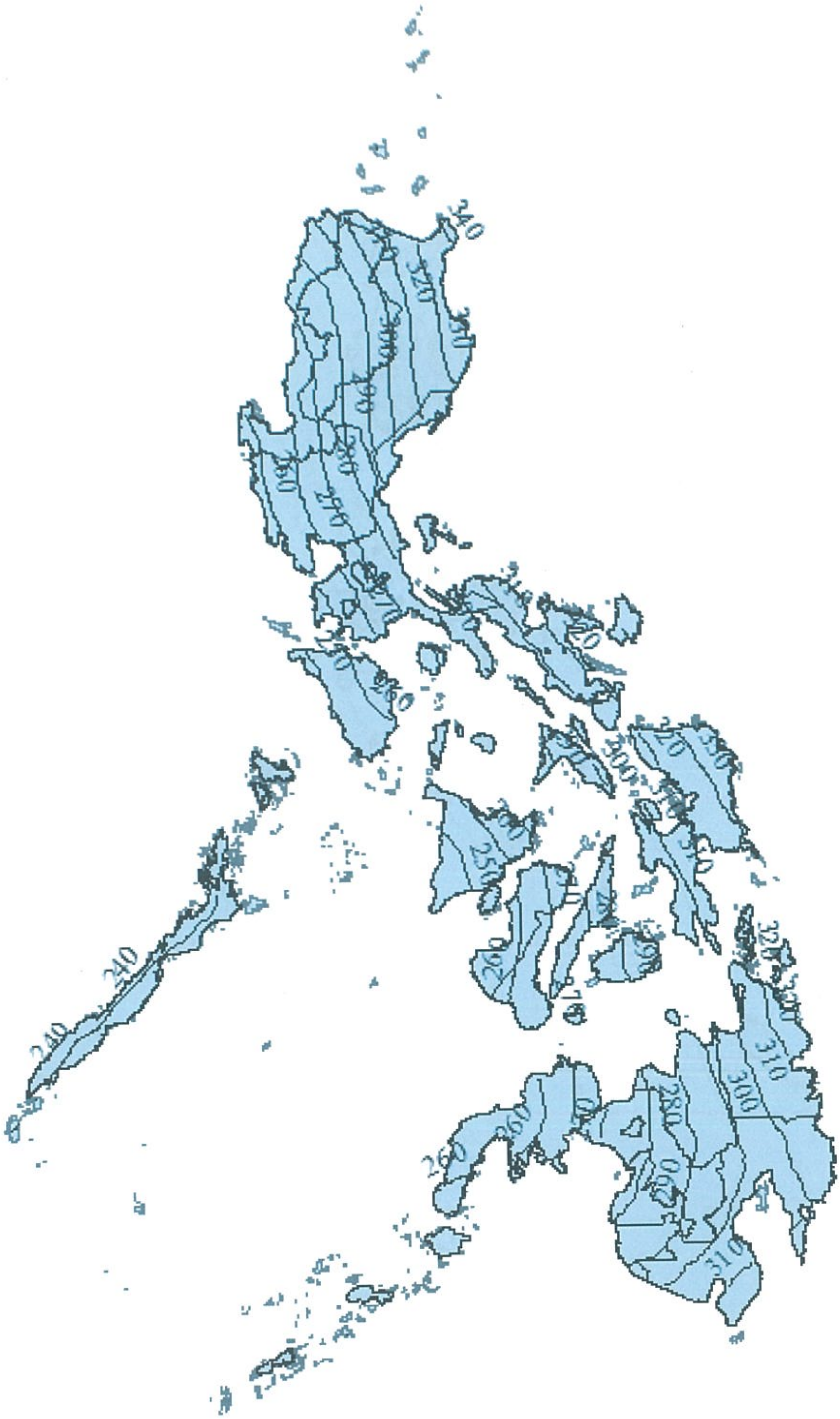
Figure 207A.5-1A Basic Wind Speeds for Occupancy Category III, IV and V Buildings and Other Structures



Notes:

1. Values are nominal design 3-second gust wind speeds in kilometers per hour at 10 m above ground for Exposure C category.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 7% probability of exceedance in 50 years (Annual Exceedance Probability = 0.00143, MRI = 700 years).
6. Results are from PAGASA.

Figure 207A.5-1B Basic Wind Speeds for Occupancy Category II Buildings and Other Structures



Notes:

1. Values are nominal design 3-second gust wind speeds in kilometers per hour at 10 m above ground for Exposure C category.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.
5. Wind speeds correspond to approximately a 3% probability of exceedance in 50 years (Annual Exceedance Probability = 0.000588, MRI = 1700 years).
6. Results are from PAGASA.

Figure 207A.5-1C Basic Wind Speeds for Occupancy Category I Buildings and Other Structures

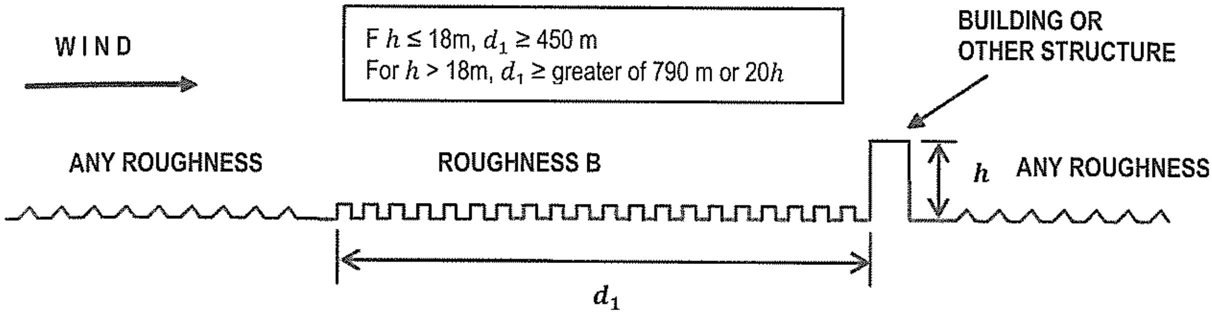


Figure C207A.7-1
Upwind Surface Roughness Conditions Requires for Exposure B.

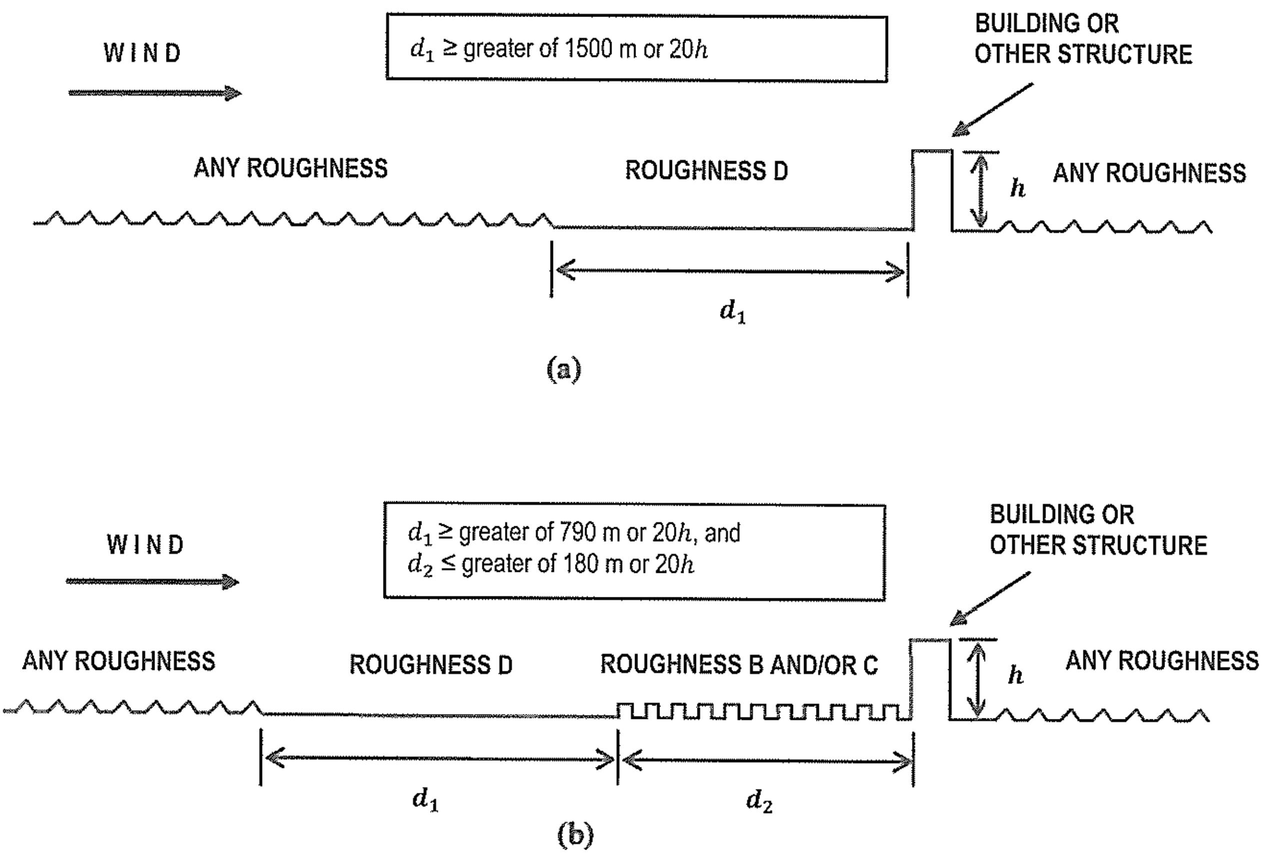


Figure C207A.7-2
Upwind Surface Roughness Conditions Required for Exposure D, for the Cases with
(a) Surface Roughness D Immediately Upwind of the Building, and (b) Surface Roughness B and/or C Immediately Upwind of the Building

Table 207A.6-1
Wind Directionality Factor, K_d

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 Freestanding Walls and Solid Freestanding and Attached Signs	0.85
Open Signs and Lattice Framework	0.85
Trussed Towers	
Triangular, square, rectangular	0.85
All other cross sections	0.95

**Directionality Factor K_d has been calibrated with combinations of loads specified in Section 203. This factor shall only be applied when used in conjunction with load combinations specified in Sections 203.3 and 203.4.*

207A.7.2 Surface Roughness Categories

A ground Surface Roughness within each 45° sector shall be determined for a distance upwind of the site as defined in Section 207A.7.3 from the categories defined in the following text, for the purpose of assigning an exposure category as defined in Section 207A.7.3.

Surface Roughness B: Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.

Surface Roughness C: Open terrain with scattered obstructions having heights generally less than 9 m. This category includes flat open country and grasslands.

Surface Roughness D: Flat, unobstructed areas and water surfaces. This category includes smooth mud flats, salt flats, and unbroken ice.

207A.7.3 Exposure Categories

Exposure B: For buildings with a mean roof height of less than or equal to 9 m, Exposure B shall apply where the ground surface roughness, as defined by Surface Roughness B, prevails in the upwind direction for a distance greater than 450 m. For buildings with a mean roof height greater than 9 m, Exposure B shall apply where Surface Roughness B prevails in the upwind direction for a distance greater than 790 m or 20 times the height of the building, whichever is greater.

Exposure C: Exposure C shall apply for all cases where Exposures B or D do not apply.

Exposure D: Exposure D shall apply where the ground surface roughness, as defined by Surface Roughness D, prevails in the upwind direction for a distance greater than 1500 m or 20 times the building height, whichever is greater. Exposure D shall also apply where the ground surface roughness immediately upwind of the site is exposure B or C, and the site is within a distance of 180 m or 20 times the building height, whichever is greater, from an Exposure D condition as defined in the previous sentence.

For a site located in the transition zone between exposure categories, the category resulting in the largest wind forces shall be used.

Exception:

An intermediate exposure between the preceding categories is permitted in a transition zone provided that it is determined by a rational analysis method defined in the recognized literature.

207A.7.4 Exposure Requirements

Commentary:

The provision in Section 207A.5.1 requires that a structure be designed for winds from all directions. A rational procedure to determine directional wind loads is as follows. Wind load for buildings using Section 207B.4.1 and Figures 207B.4-1, 207B.4-2 or 207B.4-3 are determined for eight wind directions at 45° intervals, with four falling along primary building axes as shown in Figure C207A.7-5. For each of the eight directions, upwind exposure is determined for each of two 45° sectors, one on each side of the wind direction axis. The sector with the exposure giving highest loads will be used to define wind loads for that direction. For example, for winds from the north, the exposure from sector one or eight, whichever gives the higher load, is used. For wind from the east, the exposure from sector two or three, whichever gives the highest load, is used. For wind coming from the northeast, the most exposed of sectors one or two is used to determine full $\mathbf{x}$ *and* $\mathbf{y}$ *loading individually, and then 75 percent of these loads are to be applied in each direction at the same time according to the requirements of Section 207B.4.6 and Figure 207B.4-8. The procedure defined in this section for determining wind loads in each design direction is not to be confused with the determination of the wind directionality factor* K_d. *The* K_d *factor determined from Section 207A.6 and Table 207A.6-1 applies for all design wind directions. See Section C207A.6.*

Wind loads for cladding and low-rise buildings elements are determined using the upwind exposure for the single surface roughness in one of the eight sectors of Figure C207A.7-5 that gives the highest cladding pressures.

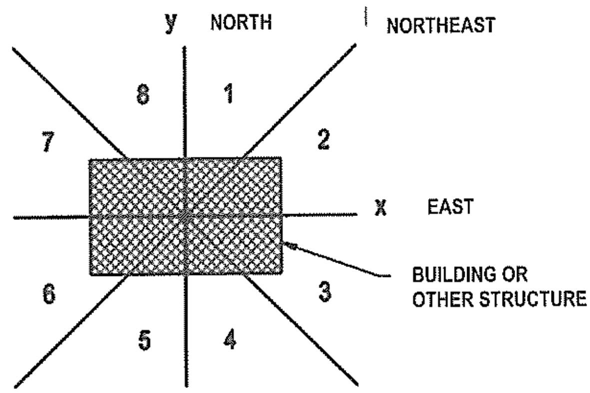
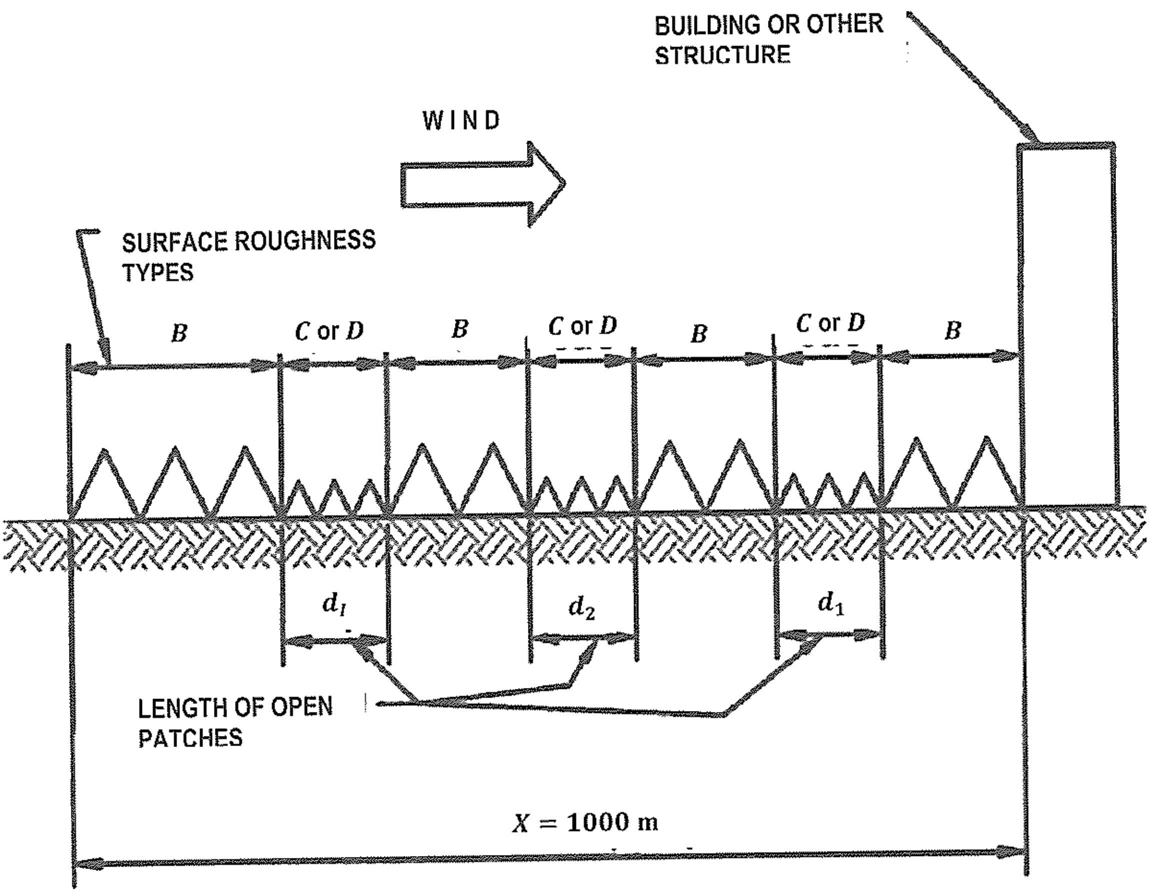


Figure C207A.7-5
Determination of Wind Loads
from Different Directions



"OPEN PATCHES" – OPENINGS ≥ 50 m x 50 m
$d_1, d_2, \_, d_i \geq 50$ m
$d_1 + d_2 + \_ + d_i \leq 200$ m
TOTAL LENGTH OF SURFACE ROUGHNESS $B \geq 800$ m
WITHIN 1000 m OF UPWIND FETCH DISTANCE

Figure C207A.7-3
Exposure B with Upwind Open Patches

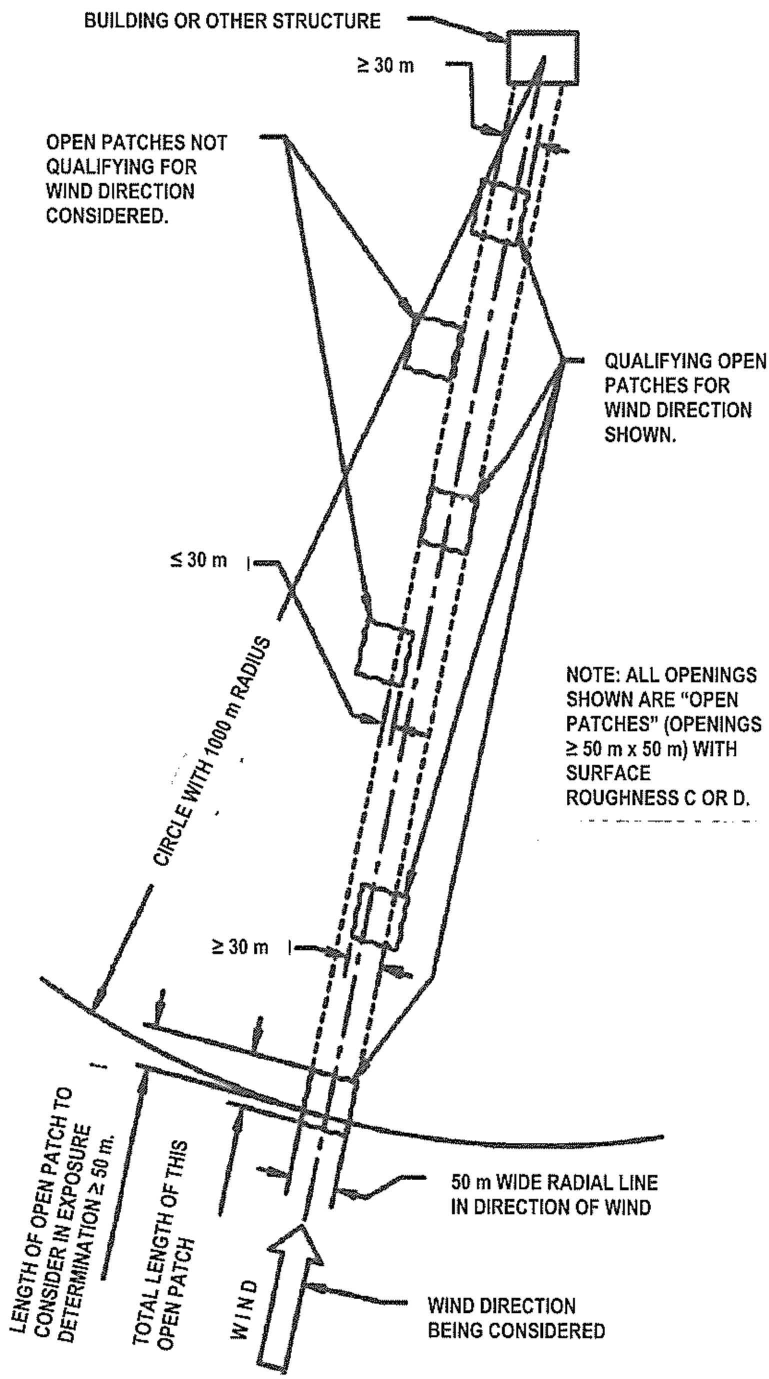


Figure C207A.7-4
Exposure B with Open Patches

207A.7.4.1 Directional Procedure (Section 207B)

For each wind direction considered, wind loads for the design of the MWFRS of enclosed and partially enclosed buildings using the Directional Procedure of Section 207B shall be based on the exposures as defined in Section 207A.7.3. Wind loads for the design of open buildings with monoslope, pitched, or troughed free roofs shall be based on the exposures, as defined in Section 207A.7.3, resulting in the highest wind loads for any wind direction at the site.

207A.7.4.2 Envelope Procedure (Section 207C)

Wind loads for the design of the MWFRS for all low-rise buildings designed using the Envelope Procedure of Section 207C shall be based on the exposure category resulting in the highest wind loads for any wind direction at the site.

207A.7.4.3 Directional Procedure for Building Appurtenances and Other Structures (Section 207D)

Wind loads for the design of building appurtenances (such as rooftop structures and equipment) and other structures (such as solid freestanding walls and freestanding signs, chimneys, tanks, open signs, lattice frameworks, and trussed towers) as specified in Section 207D shall be based on the appropriate exposure for each wind direction considered.

207A.7.4.4 Components and Cladding (Section 207E)

Design wind pressures for components and cladding shall be based on the exposure category resulting in the highest wind loads for any wind direction at the site.

207A.8 Topographic Effects

Commentary:

As an aid to the designer, this section was rewritten in ASCE 7-98 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 an effort to exclude situations where little or no topographic effect exists, Condition (2) was 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 10 m above its base elevation and has a top elevation of 30 m above mean sea level then the topographic feature (hill, ridge, or escarpment) must have at least the H specified and extend to elevation 52 m mean sea level (30.5 m + [3.22 × 10.7 m]) within the 3.22-km radius specified.

*A wind tunnel study by Means et al. (1996) and observation of actual wind damage has shown that the affected height **H** is less than previously specified. Accordingly, Condition (5) was changed to 4.5 m 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 Tables 207B.3-1, 207C.3-1, 207D.3-1, and 207E.3-1 are multiplied by a topographic factor, K_{zt}, *determined by Equation 207A.8-1. 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 Figure 207A.8-1, 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 207A.8-1 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 207A.8-1. Therefore, values of* K_{zt} *obtained from Figure 207A.8-1 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 207A.8 to address the general case of wind flow over hilly or complex terrain for which engineering judgment, expert advice, or the Wind Tunnel Procedure as described in Section 207F may be required. Background material on topographic speed-up effects may be found in the literature (Jackson and Hunt 1975, Lemelin et al. 1988, and Walmsley et al. 1986).

The designer is cautioned that, at present, the code 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 code.

207A.8.1 Wind Speed-Up over Hills, Ridges, and Escarpments

Wind speed-up effects at isolated hills, ridges, and escarpments constituting abrupt changes in the general topography, located in any exposure category, shall be included in the design when buildings and other site conditions and locations of structures 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 3.2 km, whichever is less. This distance shall be measured horizontally from the point at which the height H of the hill, ridge, or escarpment is determined.
2. The hill, ridge, or escarpment protrudes above the height of upwind terrain features within a 3.2-km radius in any quadrant by a factor of two or more.
3. The structure is located as shown in Figure 207A.8-1 in the upper one-half of a hill or ridge or near the crest of an escarpment.
4. $H/L_h \geq 0.2$.
5. H is greater than or equal to 4.5 m for Exposure C and D and 18 m for Exposure B.

207A.8.2 Topographic Factor

The wind speed-up effect shall be included in the calculation of design wind loads by using the factor K_{zt}:

$$K_{zt} = (1 + K_1 + K_2 + K_3)^2 \qquad (207A.8\text{-}1)$$

where K_1, K_2, and K_3 are given in Figure 207A.8-1.

If site conditions and locations of structures do not meet all the conditions specified in Section 207A.8.1 then $K_{zt} = 1.0$.

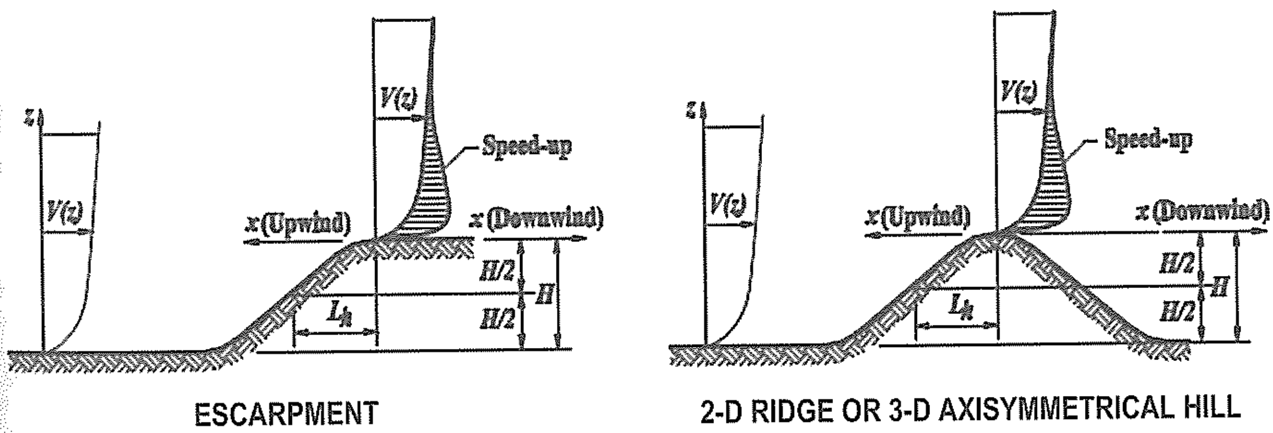


Figure 207A.8-1
Topographic Factor, K_{zt}

Table 207A.8-1
Topographic Multipliers for Exposure C

H/L_h	K_1 Multiplier			x/L_h	K_2 Multiplier		z/L_h	K_3 Multiplier		
	2-D Ridge	2-D Escarp.	3-D Axisym. Hill		2-D Escarp.	All Other Cases		2-D Ridge	2-D Escarp.	3-D Axisym. Hill
0.20	0.29	0.17	0.21	0.00	1.00	1.00	0.00	1.00	1.00	1.00
0.25	0.36	0.21	0.26	0.50	0.88	0.67	0.10	0.74	0.78	0.67
0.30	0.43	0.26	0.32	1.00	0.75	0.33	0.20	0.55	0.61	0.45
0.35	0.51	0.30	0.37	1.50	0.63	0.00	0.30	0.41	0.47	0.30
0.40	0.58	0.34	0.42	2.00	0.50	0.00	0.40	0.30	0.37	0.20
0.45	0.65	0.38	0.47	2.50	0.38	0.00	0.50	0.22	0.29	0.14
0.50	0.72	0.43	0.53	3.00	0.25	0.00	0.60	0.17	0.22	0.09
				3.50	0.13	0.00	0.70	0.12	0.17	0.06
				4.00	0.00	0.00	0.80	0.09	0.14	0.04
							0.90	0.07	0.11	0.03
							1.00	0.05	0.08	0.02
							1.50	0.01	0.02	0.00
							2.00	0.00	0.00	0.00

Notes:

1. For values of H/L_h, x/L_h and z/L_h other than those shown, linear interpolation is permitted.
2. For $\frac{H}{L_h} > 0.50$, assume $\frac{H}{L_h} = 0.50$ for evaluating K_1 and substitute $2H$ for L_h for evaluating K_2 and K_3.
3. Multipliers are based on the assumption that wind approaches the hill or escarpment along the direction of maximum slope.
4. Notation:

H = Height of hill or escarpment relative to the upwind terrain, in meters.
L_h = Distance upwind of crest to where the difference in ground elevation is half the height of hill or escarpment, in meters.
K_1 = Factor to account for shape of topographic feature and maximum speed-up effect.
K_2 = Factor to account for reduction in speed-up with distance upwind or downwind of crest.
K_3 = Factor to account for reduction in speed-up with height above local terrain.
x = Distance (upwind or downwind) from the crest to the building site, in meters.
z = Height above ground surface at building site, in meters.
μ = Horizontal attenuation factor.
γ = Height attenuation factor.

Equations:

$K_{zt} = (1 + K_1 + K_2 + K_3)^2$
K_1 determined from table below
$K_2 = \left(1 - \frac{|x|}{\mu L_h}\right)$
$K_3 = e^{-\gamma z/L_h}$

Hill Shape	$K_1/(H/L_h)$ Exposure B	$K_1/(H/L_h)$ Exposure C	$K_1/(H/L_h)$ Exposure D	γ	μ Upwind of Crest	μ Downwind of Crest
2-dimensional ridges (or valleys with negative) H in $K_1/(H/L_h)$	1.30	1.45	1.55	3.00	1.50	1.50
2-dimensional escarpments	0.75	0.85	0.95	2.50	1.50	4.00
3-dimensional axisymmetrical hill	0.95	1.05	1.15	4.00	1.50	1.50

Figure 207A.8-2
Parameters for Speed-Up Over Hills and Escarpments

207A.9 Gust Effects

Commentary:

NSCP 2001 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 is located in the body of the standard (Solari 1993a and 1993b). A procedure is also included for calculating the gust effect factor for flexible structures. The rigid structure gust factor is 0 percent to 10 percent lower than the simple, but conservative, value of 0.85 permitted in the code without calculation. The procedures for both rigid and flexible structures (1) provide a superior model for flexible structures that displays the peak factors g_Q *and* g_R *and (2) cause the flexible structure value to match the rigid structure as resonance is removed. A designer is free to use any other rational procedure in the approved literature, as stated in Section 207A.9.5.*

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 (Kareem 1992 and 1985, Gurley and Kareem 1993, Solari 1993a and 1993b, and Kareem and Smith 1994) or from wind tunnel tests.

Along-Wind Response. Based on the preceding definition of the gust effect factor, predictions of along wind response, for example, maximum displacement, root-mean-square (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 Along-Wind Displacement. *The maximum along-wind displacement* $X_{max}(z)$ *as a function of height above the ground surface is given by:*

$$X_{max}(z) = \frac{\phi(z)\rho BhC_{fx}\hat{V}_{\bar{z}}^2}{2m_1(2\pi n_1)^2}KG \qquad (C207A.9\text{-}1)$$

where

$\phi(z)$ = *the fundamental model shape*
= $(z/h)^{\xi}$
ξ = the mode exponent
ρ = air density
C_{fx} = mean along-wind force coefficient
m_1 = modal mass
= $\int_0^h \mu(z)\phi^2(z)dz$
$\mu(z)$ = mass per unit height
K = $(1.65)^{\alpha}/(\hat{\alpha}+\xi+1)$

and $\hat{V}_{\bar{z}}$ *is the 3-s gust speed at height* $\bar{z}$. *This can be evaluated by* $\hat{V}_{\bar{z}} = \hat{b}(z/33)^{\hat{\alpha}}V$, *where* V *is the 3-s gust speed in Exposure C at the reference height (obtained from Figure 207A.5-1);* $\hat{b}$ *and* $\hat{\alpha}$ *are given in Table 207A.9-1.*

RMS Along-Wind Acceleration. *The rms along-wind acceleration* $\sigma_{\ddot{x}}(z)$ *as a function of height above the ground surface is given by:*

$$\sigma_{\ddot{x}}(z) = \frac{0.85\phi(z)\rho BhC_{fx}\bar{V}_{\bar{z}}^2}{m_1}I_{\bar{z}}KR \qquad (C207A.9\text{-}2)$$

where $\bar{V}_{\bar{z}}$ *is the mean hourly wind speed at height* $\bar{z}$, *m/s:*

$$\bar{V}_{\bar{z}} = \bar{b}\left(\frac{z}{33}\right)^{\bar{\alpha}}V \qquad (C207A.9\text{-}3)$$

where $\bar{b}$ *and* $\bar{\alpha}$ *are defined in Table 207A.9-1.*

Maximum Along-Wind Acceleration. *The maximum along-wind acceleration as a function of height above the ground surface is given by:*

$$\ddot{X}_{max}(z) = g_{\ddot{x}}\sigma_{\ddot{x}}(z) \qquad (C207A.9\text{-}4)$$

$$g_{\ddot{x}} = \sqrt{2\,ln(n_1T)} + \frac{0.5772}{\sqrt{2\,ln(n_1T)}} \qquad (C207A.9\text{-}5)$$

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

Approximate Fundamental Frequency. To estimate the dynamic response of structures, knowledge of the fundamental frequency (lowest natural frequency) of the structure is essential. This value would also assist in determining if the dynamic response estimates are necessary. Most computer codes used in the analysis of *structures would provide estimates of the natural frequencies of the structure being analyzed. However, for the preliminary design stages some empirical relationships for building period* T_a ($T_a = 1/n_1$) *are available in the earthquake chapters of ASCE 7. However, it is noteworthy that these expressions are based on recommendations for earthquake design with inherent bias toward higher estimates of fundamental frequencies (Goel and Chopra 1997 and 1998). For wind design applications these values may be unconservative because an estimated frequency higher than the actual frequency would yield lower values of the gust effect factor and concomitantly a lower design wind pressure. However, Goel and Chopra (1997 and 1998) also cite lower bound estimates of frequency that are more suited for use in wind applications. These lower-bound expressions are now given in Section 207A.9.2; graphs of these expressions are shown in Figure C207A.9-1. Because these expressions are based on regular buildings, limitations based on height and slenderness are required. The effective length* L_{eff}, *uses a height-weighted average of the along-wind length of the building for slenderness evaluation. The top portion of the building is most important; hence the height-weighted average is appropriate. This method is an appropriate first-order equation for addressing buildings with setbacks. Explicit calculation of gust effect factor per the other methods given in Section 207A.9 can still be performed.*

Observation from wind tunnel testing of buildings where frequency is calculated using analysis software reveals the following expression for frequency, appropriate for buildings less than about 120 m in height, applicable to all buildings in steel or concrete:

$n_1 = 100/H$ *(m) average value* (C207A.9-6)

$n_1 = 75/H$ *(m) lower bound value* (C207A.9-7)

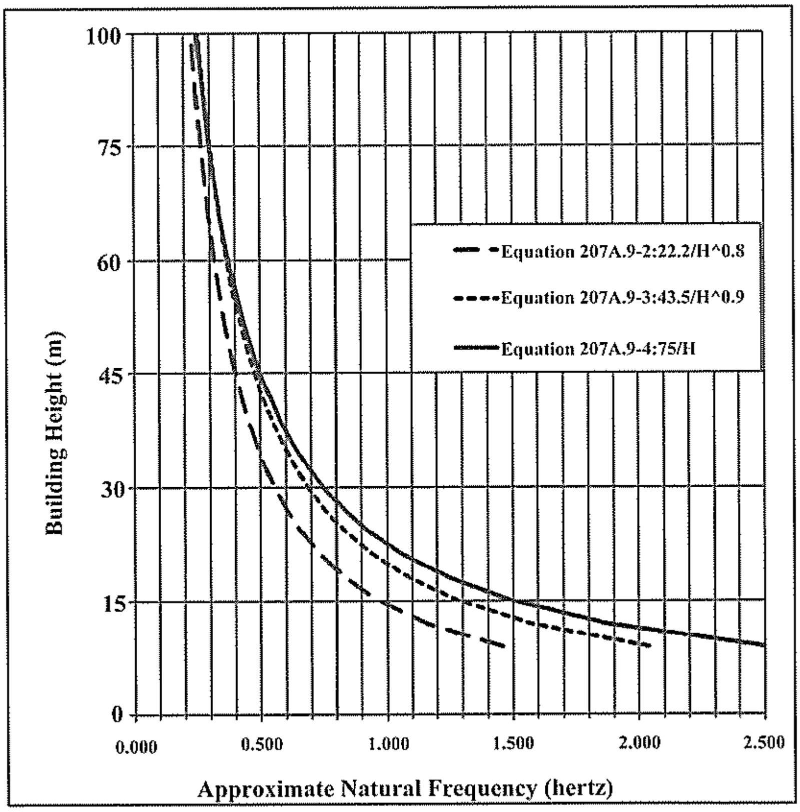


Figure C207A.9-1
Equations for Approximate Natural Frequency vs. Building Height

Equation C207A.9-7 for the lower bound value is provided in Section 207A.9.2.

Based on full-scale measurements of buildings under the action of wind, the following expression has been proposed for wind applications (Zhou and Kareem 2001, Zhou, Kijewski, and Kareem 2002):

$$f_{n1} = 150/H \qquad (C207A.9\text{-}8)$$

This frequency expression is based on older buildings and overestimates the frequency common in U.S. construction for smaller buildings less than 120 m in height, but becomes more accurate for tall buildings greater than 120 m in height. The Australian and New Zealand Standard AS/NZS 1170.2, Eurocode ENV1991-2-4, Hong Kong Code of Practice on Wind Effects (2004), and others have adopted Equation C207A.9-8 for all building types and all heights.

Recent studies in Japan involving a suite of buildings under low-amplitude excitations have led to the following expressions for natural frequencies of buildings (Sataka et al. 2003):

$$n_1 = 220/H(m)\text{(concrete buildings)} \qquad (C207A.9\text{-}9)$$

$$n_1 = 164/H(m)\text{ (steel buildings)} \qquad (C207A.9\text{-}10)$$

The expressions based on Japanese buildings result in higher frequency estimates than those obtained from the general expression given in Equations C207A.9-6 through C207A.9-8, particularly since the Japanese data set has limited observations for the more flexible buildings sensitive to wind effects and Japanese construction tends to be stiffer.

For cantilevered masts or poles of uniform cross-section (in which bending action dominates):

$$n_1 = (0.56/h^2)\sqrt{(EI/m)} \qquad (C207A.9\text{-}11)$$

where EI is the bending stiffness of the section and m is the mass/unit height. (This formula may be used for masts with a slight taper, using average value of EI and m) (ECCS 1978).

An approximate formula for cantilevered, tapered, circular poles (ECCS 1978) is:

$$n_1 = [\lambda/(2\pi h^2)]\sqrt{(EI/m)} \qquad (C207A.9\text{-}12)$$

where h is the height, and E, I, and m are calculated for the cross-section at the base. λ depends on the wall thicknesses at the tip and base, e_t and e_b, and external diameter at the tip and base, d_t and d_b, according to the following formula:

$$\lambda = \left[1.9exp\left(\frac{-4d_t}{d_b}\right)\right] + \left[\frac{6.65}{0.9 + \left(\frac{e_t}{e_b}\right)^{0.666}}\right] \qquad (C207A.9\text{-}13)$$

Equation C207A.9-12 reduces to Equation C207A.9-11 for uniform masts. For free-standing lattice towers (without added ancillaries such as antennas or lighting frames) (Standards Australia 1994):

$$n_1 = 1500w_a/h^2 \qquad (C207A.9\text{-}14)$$

where w_a is the average width of the structure in m and h is tower height. An alternative formula for lattice towers (with added ancillaries) (Wyatt 1984) is:

$$n_1 = \left(\frac{L_N}{H}\right)^{2/3}\left(\frac{w_b}{H}\right)^{1/2} \qquad (C207A.9\text{-}15)$$

where w_b = tower base width and L_N = 270 m for square base towers, or 230 m for triangular base towers.

Structural Damping. *Structural damping is a measure of energy dissipation in a vibrating structure that results in bringing the structure to a quiescent state. The damping is defined as the ratio of the energy dissipated in one oscillation cycle to the maximum amount of energy in the structure in that cycle. There are as many structural damping mechanisms as there are modes of converting mechanical energy into heat. The most important mechanisms are material damping and interfacial damping.*

In engineering practice, the damping mechanism is often approximated as viscous damping because it leads to a linear equation of motion. This damping measure, in terms of the damping ratio, is usually assigned based on the construction material, for example, steel or concrete. The calculation of dynamic load effects requires damping ratio as an input. In wind applications, damping ratios of 1 percent and 2 percent are typically used in the United States for steel and concrete buildings at serviceability levels, respectively, *while ISO (1997) suggests 1 percent and 1.5 percent for steel and concrete, respectively. Damping values for steel support structures for signs, chimneys, and towers may be much lower than buildings and may fall in the range of 0.15 percent to 0.5 percent. Damping values of special structures like steel stacks can be as low as 0.2 percent to 0.6 percent and 0.3 percent to 1.0 percent for unlined and lined steel chimneys, respectively (ASME 1992 and CICIND 1999). These values may provide some guidance for design. Damping levels used in wind load applications are smaller than the 5 percent damping ratios common in seismic applications because buildings subjected to wind loads respond essentially elastically whereas buildings subjected to design level earthquakes respond inelastically at higher damping levels.*

Because the level of structural response in the serviceability and survivability states is different, the damping values associated with these states may differ. Further, due to the number of mechanisms responsible for damping, the limited full-scale data manifest a dependence on factors such as material, height, and type of structural system and foundation. The Committee on Damping of the Architectural Institute of Japan suggests different damping values for these states based on a large damping database described in Sataka et al. (2003).

In addition to structural damping, aerodynamic damping may be experienced by a structure oscillating in air. In general, the aerodynamic damping contribution is quite small compared to the structural damping, and it is positive in low to moderate wind speeds. Depending on the structural shape, at some wind velocities, the aerodynamic damping may become negative, which can lead to unstable oscillations. In these cases, reference should be made to recognized literature or a wind tunnel study.

Alternate Procedure to Calculate Wind Loads. *The concept of the gust effect factor implies that the effect of gusts can be adequately accounted for by multiplying the mean wind load distribution with height by a single factor. This is an approximation. If a more accurate representation of gust effects is required, the alternative procedure in this section can be used. It takes account of the fact that the inertial forces created by the building's mass, as it moves under wind action, have a different distribution with height than the mean wind loads or the loads due to the direct actions of gusts (ISO 1997 and Sataka et al. 2003). The alternate formulation of the equivalent static load distribution utilizes the peak base bending moment and expresses it in terms of inertial forces at different building levels. A base bending moment, instead of the base shear as in earthquake engineering, is used for the wind loads, as it is less sensitive to deviations from a linear mode shape while still providing a gust effect factor generally equal to the gust factor calculated by the Section 207 NSCP 2010 standard. This equivalence occurs only for structures with linear mode shape and uniform mass distribution, assumptions tacitly implied in the previous formulation of the gust effect factor, and thereby permits a smooth transition from the existing procedure to the formulation suggested here. For a more detailed discussion on this wind loading procedure, see ISO (1997) and Sataka et al. (2003).*

Along-Wind Equivalent Static Wind Loading. *The equivalent static wind loading for the mean, background, and resonant components is obtained using the procedure outlined in the following text.*

Mean wind load component $\bar{P}_j$ at the J^{th} floor level is given by:

$$\bar{P}_j = q_j \times C_p \times A_j \times \bar{G} \qquad \text{(C207A.9-16)}$$

where

j = *floor level*
z_j = *height of the J^{th} floor above the ground level*
q_j = *velocity pressure at height z_j*
C_p = *external pressure coefficient*
G = $0.925(1+1.7g_v I_{\bar{z}})^{-1}$ *is the gust velocity factor*

Peak background wind load component $\hat{P}_{Bj}$ at the J^{th} floor level is given similarly by:

$$\hat{P}_{Bj} = \bar{P}_j\left(\frac{G_B}{\bar{G}}\right) \qquad \text{(C207A.9-17)}$$

where

$$G_B = 0.925\left(\frac{1.7 I_{\bar{z}}\, g_Q Q}{1+1.7 g_v I_{\bar{z}}}\right)$$

= *is the background component of the gust effect factor.*

Peak resonant wind load component $\hat{P}_{Rj}$ at the J^{th} floor level is obtained by distributing the resonant base bending moment response to each level

$$\hat{P}_{Rj} = C_{Mj}\hat{M}_R \qquad \text{(C207A.9-18)}$$

$$C_{Mj} = \frac{w_j \phi_j}{\sum w_j \phi_j z_j} \qquad (C207A.9\text{-}19)$$

$$\widehat{M}_R = \frac{\overline{M} G_R}{\overline{G}} \qquad (C207A.9\text{-}20)$$

$$\overline{M} = \sum_{j=1,n} \overline{P}_j z_j \qquad (C207A.9\text{-}21)$$

where

C_{Mj}	=	*vertical load distribution factor*
M_R	=	*peak resonant component of the base bending moment response*
w_j	=	*portion of the total gravity load of the building located or assigned to level* j
n	=	*total stories of the building*
ϕ_j	=	*first structural mode shape value at level* j
$\overline{M}$	=	*mean base bending produced by mean wind load*
G_R	=	$0.925\left(\frac{1.7 I_{\bar{z}}\, g_R R}{1 + 1.7 g_v I_{\bar{z}}}\right)$
	=	*is the resonant component of the gust effect factor.*

Along-Wind Response. *Through a simple static analysis the peak-building response along-wind direction can be obtained by:*

$$\hat{r} = \overline{r} + \sqrt{\hat{r}_B^2 + \hat{r}_R^2} \qquad (C207A.9\text{-}22)$$

where $\overline{r}$, $\hat{r}_B$, *and* $\hat{r}_R$ = *mean, peak background, and resonant response components of interest, for example, shear forces, moment, or displacement. Once the equivalent static wind load distribution is obtained, any response component including acceleration can be obtained using a simple static analysis. It is suggested that caution must be exercised when combining the loads instead of response according to the preceding expression, for example,*

$$\widehat{P}_j = \overline{P}_j + \sqrt{\widehat{P}_{Bj}^2 + \widehat{P}_{Rj}^2} \qquad (C207A.9\text{-}23)$$

because the background and the resonant load components have normally different distributions along the building height. Additional background can be found in ISO (1997) and Sataka et al. (2003).

Example: The following example is presented to illustrate the calculation of the gust effect factor. Table C207A.9-1 uses the given information to obtain values from Table 207A.9-1. Table C207A.9-2 presents the calculated values. Table C207A.9-3 summarizes the calculated displacements and accelerations as a function of the height, $\mathbf{z}$.

Given Values:

Basic wind speed at reference height in exposure C	=	*150 km/h*
C_{fx}	=	*1.3*
Damping ratio	=	*0.01*
Mode exponent	=	*1.0*
Type of exposure	=	*B*
Building height $\mathbf{h}$	=	*183 m*
Building width $\boldsymbol{B}$	=	*30.5 m*
Building depth $\mathbf{L}$	=	*30.5 m*
Building natural frequency $\boldsymbol{n_1}$	=	*0.2 Hz*
Building density	=	*12 lb/ft³*
		192.0817 kg/m³
Air density	=	*1.2369 kg/m³*

Table C207A.9-1

Calculated Values

$\mathbf{z_{min}}(m)^*$	=	*9.14 ft*
$\overline{\epsilon}$	=	*1/3*
$\mathbf{c}$	=	*0.3*
$\overline{\boldsymbol{b}}$	=	*0.45*
$\overline{\boldsymbol{a}}$	=	*0.25*
$\widehat{\boldsymbol{b}}$	=	*0.84*
$\widehat{\boldsymbol{a}}$	=	*1/7*
$\boldsymbol{l}$	=	*97.54 m*
$\boldsymbol{\xi}$	=	*1*

Table C207A.9-2
Calculated Values

V	*40.23 m/s*	R_B	*0.610*
$\bar{z}$	*109.73 m*	η	*5.113*
$I_{\bar{z}}$	*0.201*	R_h	*0.176*
$L_{\bar{z}}$	*216.75 m*	η	*2.853*
Q^2	*0.616*	R_L	*0.289*
$\bar{V}_{\bar{z}}$	*32.95 m/s*	R^2	*0.813*
$\hat{V}_{\bar{z}}$	*47.59 m/s*	G_f	*1.062*
N_1	*1.31*	K	*0.501*
R_n	*0.113*	m_1	*10.88x10⁶ kg*
η	*0.852*	g_R	*3.787*

Table 207A.9-3
Along-wind Response - Example

Floor	$z_j\ (m)$	ϕ_j	$X_{max\,j}$	*RMS Acc.* (m/s²)*	*RMS Acc.* (mg)*	*Max Acc.* (m/s²)*	*Max Acc.* (mg)*
0	0	0	0	0	0	0	0
5	18.29	0.10	0.03	0.00	0.41	0.02	1.6
10	36.58	0.20	0.06	0.01	0.83	0.03	3.1
15	54.86	0.30	0.09	0.01	1.24	0.05	4.7
20	73.15	0.40	0.13	0.02	1.66	0.06	6.3
25	91.44	0.50	0.16	0.02	2.07	0.08	7.8
30	109.73	0.60	0.19	0.02	2.49	0.09	9.4
35	128.02	0.70	0.22	0.03	2.90	0.11	11.0
40	146.3	0.80	0.25	0.03	3.32	0.12	12.6
45	164.59	0.80	0.28	0.04	3.73	0.14	14.1
50	182.88	1.00	0.31	0.04	4.14	0.15	15.7

Aerodynamic Loads on Tall Buildings—An Interactive Database. *Under the action of wind, tall buildings oscillate simultaneously in the along-wind, across-wind, and torsional directions. While the along-wind loads have been successfully treated in terms of gust loading factors based on quasi-steady and strip theories, the across-wind and torsional loads cannot be treated in this manner, as these loads cannot be related in a straightforward manner to fluctuations in the approach flow. As a result, most current codes and standards provide little guidance for the across-wind and torsional response ISO (1997) and Sataka et al. (2003).*

To provide some guidance at the preliminary design stages of buildings, an interactive aerodynamic loads database for assessing dynamic wind-induced loads on a suite of generic isolated buildings is introduced. Although the analysis based on this experimental database is not intended to replace wind tunnel testing in the final design stages, it provides users a methodology to approximate the previously untreated across-wind and torsional responses in the early design stages. The database consists of high frequency base balance measurements involving seven rectangular building models, with side ratio $\boldsymbol{D/B}$*, where* $\boldsymbol{D}$ *is the depth of the building section along the oncoming wind direction) from 1/3 to 3, three aspect ratios for each building model in two approach flows, namely,* $\boldsymbol{BL_1(\bar{\alpha} = 0.16)}$ *and* $\boldsymbol{BL_2(\bar{\alpha} = 0.35)}$ *corresponding to an open and an urban environment. The data are accessible with a user-friendly Java-based applet through the worldwide Internet community at http://aerodata.ce.nd.edu/interface/interface.html.*

Through the use of this interactive portal, users can select the geometry and dimensions of a model building from the available choices and specify an urban or suburban condition. Upon doing so, the aerodynamic load spectra for the along-wind, across-wind, or torsional directions is displayed with a Java interface permitting users to specify a reduced frequency (building frequency × building dimension/ wind velocity) of interest and automatically obtain the *corresponding spectral value. When coupled with the supporting Web documentation, examples, and concise analysis procedure, the database provides a comprehensive tool for computation of wind-induced response of tall buildings, suitable as a design guide in the preliminary stages.*

Example: An example tall building is used to demonstrate the analysis using the database. The building is a square steel tall building with size $H \times W_1 \times W_2$ *= 200 × 40 × 40 m and an average radius of gyration of 18 m.*

The three fundamental mode frequencies, f_1*, are 0.2, 0.2, and 0.35 Hz in X, Y, and Z directions, respectively; the mode shapes are all linear, or* β *is equal to 1.0, and there is no modal coupling. The building density is equal to 250 kg/ m³. This building is located in Exposure A or close to the* BL_2 *test condition of the Internet-based database (Zhou et al. 2002). In this location (Exposure A), the reference 3-sec design gust speed at a 50-year recurrence interval is 63 m/s [ASCE 7-98], which is equal to 18.9 m/s upon conversion to 1-h mean wind speed with 50-yr MRI (207 × 0.30 = 62 m/s). For serviceability requirements, 1-h mean wind speed with 10-yr MRI is equal to 14 m/s (207 × 0.30 × 0.74 = 46). For the sake of illustration only, the first mode critical structural damping ratio,* ζ_1*, is to be 0.01 for both survivability and serviceability design.*

Using these aerodynamic data and the procedures provided on the Web and in ISO (1997), the wind load effects are evaluated and the results are presented in Table C207A.9-4. This table includes base moments and acceleration response in the along-wind direction obtained by the procedure in ASCE 7-02. Also the building experiences much higher across-wind load effects when compared to the along-wind response for this example, which reiterates the significance of wind loads and their effects in the across-wind direction.

207A.9.1 Gust Effect Factor

The gust-effect factor for a rigid building or other structure is permitted to be taken as 0.85.

207A.9.2 Frequency Determination

To determine whether a building or structure is rigid or flexible as defined in Section 207A.2, the fundamental natural frequency, n_1, shall be established using the structural properties and deformational characteristics of the resisting elements in a properly substantiated analysis. Low-Rise Buildings, as defined in 207A.2, are permitted to be considered rigid.

207A.9.2.1 Limitations for Approximate Natural Frequency

As an alternative to performing an analysis to determine n_1, the approximate building natural frequency, n_1, shall be permitted to be calculated in accordance with Section 207A.9.3 for structural steel, concrete, or masonry buildings meeting the following requirements:

1. The building height is less than or equal to 91 m, and

2. The building height is less than 4 times its effective length, L_{eff}.

The effective length, L_{eff}, in the direction under consideration shall be determined from the following equation:

$$L_{eff} = \frac{\sum_{i=1}^{n} h_i L_i}{\sum_{i=1}^{n} h_i} \qquad (207A.9\text{-}1)$$

The summations are over the height of the building

where

h_i = is the height above grade of level i
L_i = is the building length at level i parallel to the wind direction

207A.9.3 Approximate Natural Frequency

The approximate lower-bound natural frequency (n_a), in Hertz, of concrete or structural steel buildings meeting the conditions of Section 207A.9.2.1, is permitted to be determined from one of the following equations:

For structural steel moment-resisting-frame buildings:

$$n_a = 22.2/h^{0.8} \qquad (207A.9\text{-}2)$$

For concrete moment-resisting frame buildings:

$$n_a = 43.5/h^{0.9} \qquad (207A.9\text{-}3)$$

For structural steel and concrete buildings with other lateral-force-resisting systems:

$$n_a = 75/h \qquad (207A.9\text{-}4)$$

For concrete or masonry shear wall buildings, it is also permitted to use:

$$n_a = 385(C_w)^{0.5}/h \qquad (207A.9\text{-}5)$$

where

$$C_w = \frac{100}{A_B}\sum_{i=1}^{n}\left(\frac{h}{h_i}\right)^2 \frac{A_i}{\left[1+0.83\left(\frac{h_i}{D_i}\right)^2\right]}$$

where

h = mean roof height (m)
n = number of shear walls in the building effective in resisting lateral forces in the direction under consideration
A_B = base area of the structure (m²)
A_i = horizontal cross-section area of shear wall "i" (m²)
D_i = length of shear wall "i" (m)
h_i = height of shear wall "i" (m)

207A.9.4 Rigid Buildings or Other Structures

For rigid buildings or other structures as defined in Section 207A.2, the gust-effect factor shall be taken as 0.85 or calculated by the formula:

$$G = 0.925\left(\frac{1+1.7g_Q I_z Q}{1+1.7g_v I_z}\right) \qquad (207A.9\text{-}6)$$

$$I_{\bar{z}} = c\left(\frac{33}{\bar{z}}\right)^{1/6} \qquad (207A.9\text{-}7)$$

In SI:

$$I_{\bar{z}} = c\left(\frac{10}{\bar{z}}\right)^{1/6}$$

where $I_{\bar{z}}$ is the intensity of turbulence at height $\bar{z}$

where $\bar{z}$ is the equivalent height of the structure defined as $0.6h$, but not less than z_{min} for all building heights h. z_{min} and c are listed for each exposure in Table 207A.9-1; g_Q and g_v shall be taken as 3.4. The background response Q is given by:

$$Q = \sqrt{\frac{1}{1+0.63\left(\frac{B+h}{L_z}\right)^{0.63}}} \qquad (207A.9\text{-}8)$$

where B and h are defined in Section 207A.3 and $L_{\bar{z}}$ is the integral length scale of turbulence at the equivalent height given by:

$$L_{\bar{z}} = \ell\left(\frac{\bar{z}}{33}\right)^{\bar{\epsilon}} \qquad (207A.9\text{-}9)$$

In SI:

$$L_{\bar{z}} = \ell\left(\frac{\bar{z}}{10}\right)^{\bar{\epsilon}}$$

In which ℓ and $\bar{\epsilon}$ are constants listed in Table 207A.9-1.

207A.9.5 Flexible or Dynamically Sensitive Buildings or Other Structures

For flexible or dynamically sensitive buildings or other structures as defined in Section 207A.2, the gust-effect factor shall be calculated by:

$$G_f = 0.925\left(\frac{1+1.7I_{\bar{z}}\sqrt{g_Q^2 Q^2 + g_R^2 R^2}}{1+1.7g_v I_{\bar{z}}}\right) \qquad (207A.9\text{-}10)$$

g_Q and g_v shall be taken as 3.4 and g_R is given by:

$$g_R = \sqrt{2\ln(3600n_1)} + \frac{0.577}{\sqrt{2\ln(3600n_1)}} \qquad (207A.9\text{-}11)$$

R, the resonant response factor, is given by:

$$R = \sqrt{\frac{1}{\beta}R_n R_h R_B(0.53+0.47R_L)} \qquad (207A.9\text{-}12)$$

$$R_n = \frac{7.47N_i}{(1+10.3N_i)^{5/3}} \qquad (207A.9\text{-}13)$$

$$N_1 = \frac{n_1 L_{\bar{z}}}{V_{\bar{z}}} \qquad (207A.9\text{-}14)$$

$$R_\ell = \frac{1}{\eta} - \frac{1}{2\eta^2}(1 - e^{-2\eta}) \qquad \text{for } \eta > 0 \quad (207A.9\text{-}15a)$$

$$R_\ell = 1 \qquad \text{for } \eta = 0 \quad (207A.9\text{-}15b)$$

where the subscript ℓ in Equation 207A.9-15 shall be taken as h, B, and L, respectively, where h, B, and L are defined in Section 207A.3.

n_1 = fundamental natural frequency
R_ℓ = R_h setting $\eta = 4.6n_1h/\bar{V}_z$
R_ℓ = R_B setting $\eta = 4.6n_1B/\bar{V}_z$
R_ℓ = R_L setting $\eta = 15.4n_1L/\bar{V}_z$
β = damping ratio, percent of critical (i.e. for 2% use 0.02 in the equation)
$\bar{V}_z$ = mean hourly wind speed (m/s) at height $\bar{z}$ determined from Equation 207A.9-16:

$$\bar{V}_z = \bar{b}\left(\frac{\bar{z}}{33}\right)^{\bar{\alpha}}\left(\frac{88}{60}\right)V \qquad (207A.9\text{-}16)$$

In SI:

$$\bar{V}_z = \bar{b}\left(\frac{\bar{z}}{10}\right)^{\bar{\alpha}} V$$

where $\bar{b}$ and $\bar{\alpha}$ are constants listed in Table 207A.9-1 and V is the basic wind speed in km/h.

207A.9.6 Rational Analysis

In lieu of the procedure defined in Sections 207A.9.3 and 207A.9.4, determination of the gust-effect factor by any rational analysis defined in the recognized literature is permitted.

207A.9.7 Limitations

Where combined gust-effect factors and pressure coefficients (GC_p), (GC_{pi}), and (GC_{pf}) are given in figures and tables, the gust-effect factor shall not be determined separately.

207A.10 Enclosure Classification

Commentary:

Accordingly, the code requires that a determination be made of the amount of openings in the envelope to assess enclosure classification (enclosed, partially enclosed, or open). "Openings" are specifically defined in this version of the code 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 207A.11-1 to select the appropriate internal pressure coefficient.

This version of the code has four terms applicable to enclosure: wind-borne debris regions, glazing, impact-resistant glazing, and impact protective system. "Wind-borne debris regions" are specified 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, skylights, or curtain walls." "Impact resistant glazing" is specifically defined as "glazing that has been shown by testing to withstand the impact of test missiles." "Impact protective systems" over glazing can be shutters or screens designed to withstand wind-borne debris impact. Impact resistance of glazing and protective systems can be tested using the test method specified in ASTM E1886-2005 (2005), with missiles, impact speeds, and pass/fail criteria specified in ASTM E1996-2009 (2009). Other approved test methods are acceptable. Origins of missile impact provisions contained in these standards are summarized in Minor (1994) and Twisdale et al. (1996).

Attention is drawn to Section 207A.10.3, which requires glazing in Category I, II, III, and IV buildings in wind-borne debris regions to be protected with an impact protective system or to be made of impact resistant glazing. The option of unprotected glazing was eliminated for most buildings in the 2005 edition of the standard to reduce the amount of wind and water damage to buildings during design wind storm events.

Table 207A.9-1
Terrain Exposure Constants

Exposure	α	z_g	$\hat{a}$	$\hat{b}$	$\bar{a}$	$\bar{b}$	c	ℓ(m)	$\bar{\epsilon}$	z_{min}(m)*
B	7.0	365.76	1/7	0.84	1/4.0	0.45	0.30	97.54	1/3.0	9.14
C	9.5	274.32	1/9.5	1.00	1/6.5	0.65	0.20	152.4	1/5.0	4.57
D	11.5	213.36	1/11.5	1.07	1/9.0	0.80	0.15	198.12	1/8.0	2.13

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

Prior to the 2002 edition of the standard, glazing in the lower 18 m of Category II, III, or IV buildings sited in wind-borne debris regions was required to be protected with an impact protective system, or to be made of impact-resistant glazing, or the area of the glazing was assumed to be open. Recognizing that glazing higher than 18 m above grade may be broken by wind-borne debris when a debris source is present, a new provision was added in 2002. With that new provision, aggregate surfaced roofs on buildings within 450 m of the new building need to be evaluated. For example, roof aggregate, including gravel or stone used as ballast that is not protected by a sufficiently high parapet should be considered as a debris source. Accordingly, the glazing in the new building, from 9 m above the source building to grade would need to be protected with an impact protective system or be made of impact-resistant glazing. If loose roof aggregate is proposed for the new building, it too should be considered as a debris source because aggregate can be blown off the roof and be propelled into glazing on the leeward side of the building. Although other types of wind-borne debris can impact glazing higher than 18 m above grade, at these higher elevations, loose roof aggregate has been the predominate debris source in previous wind events. The requirement for protection 9 m above the debris source is to account for debris that can be lifted during flight. The following references provide further information regarding debris damage to glazing: Beason et al. (1984), Minor (1985 and 1994), Kareem (1986), and Behr and Minor (1994).

Although wind-borne debris can occur in just about any condition, the level of risk in comparison to the postulated debris regions and impact criteria may also be lower than that determined for the purpose of standardization. For example, individual buildings may be sited away from likely debris sources that would generate significant risk of impacts similar in magnitude to pea gravel (i.e., as simulated by 2 gram steel balls in impact tests) or butt-on 2 × 4 impacts as required in impact testing criteria. This situation describes a condition of low vulnerability only as a result of limited debris sources within the vicinity of the building. In other cases, potential sources of debris may be present, but extenuating conditions can lower the risk. These extenuating conditions include the type of materials and surrounding construction, the level of protection offered by surrounding exposure conditions, and the design wind speed. Therefore, the risk of impact may differ from those postulated as a result of the conditions specifically enumerated in the code and the referenced impact standards. The committee recognizes that there are vastly differing opinions, even within the standards committee, regarding the significance of these parameters that are not fully considered in developing standardized debris regions or referenced impact criteria.

Recognizing that the definition of the wind-borne debris regions given in NSCP 2001 (ASCE 7-98) through NSCP 2010 (ASCE 7-05) was largely based on engineering judgment rather than a risk and reliability analysis, the definition of the wind-borne debris regions in ASCE 7-10 for Occupancy Category III and IV buildings and structures has been chosen such that the coastal areas included in the wind-borne debris regions defined with the new wind speed maps are approximately consistent with those given in the prior editions for this risk category. Thus, the new wind speed contours that define the wind-borne debris regions in Section 207A.10.3.1 are not direct conversions of the wind speed contours that are defined in NSCP 2010 (ASCE 7-05) as shown in Table C207A.5-6. As a result of this shift, adjustments are needed to the Wind Zone designations in ASTM E 1996 for the determination of the appropriate missile size for the impact test because the Wind Zones are based on the NSCP 2010 (ASCE 7-05) wind speed maps. Chapter 6.2.2 of ASTM E 1996 should be as follows:

6.2.2 Unless otherwise specified, select the wind zone based on the basic wind speed as follows:

6.2.2.1 Wind Zone 1 – 210 kph ≤ basic wind speed < 225 kph.

6.2.2.2 Wind Zone 2 – 225 kph ≤ basic wind speed < 240 kph at greater than 1.6 km from the coastline. The coastline shall be measured from the mean high water mark.

6.2.2.3 Wind Zone 3 - basic wind speed ≥ 240 kph, or basic wind speed ≥ 225 kph and within 1.6 km of the coastline. The coastline shall be measured from the mean high water mark.

However, While the coastal areas included in the wind-borne debris regions defined in the new wind speed maps for Risk Category II are approximately consistent with those given in NSCP 2010 (ASCE 7-05), significant reductions in the wind-borne debris regions for this risk category occur in the area around Jacksonville, Florida, in the Florida Panhandle, and inland from the coast of North Carolina.

The introduction of separate risk-based maps for different risk categories provides a means for achieving a more risk-consistent approach for defining wind-borne debris regions. The approach selected was to link the geographical definition of the wind-borne debris regions to the wind speed contours in the maps that correspond to the particular risk category. The resulting expansion of the wind-borne debris region for Occupancy Category I and II buildings and structures (wind-borne debris regions in Figure 207A.5-1C that are not part of the wind-borne debris regions defined in Figure 207A.5-1B) was considered appropriate for the types of buildings included in Occupancy Category I and II. A review of the types of buildings and structures currently included in Occupancy Category III suggests that life safety issues would be most important, in the expanded wind-borne debris region, for health care facilities. Consequently, the committee chose to apply the expanded wind-borne debris protection requirement to this type of Occupancy Category III facilities and not to all Occupancy Category III buildings and structures.

207A.10.1 General

For the purpose of determining internal pressure coefficients, all buildings shall be classified as enclosed, partially enclosed, or open as defined in Section 207A.2.

207A.10.2 Openings

A determination shall be made of the amount of openings in the building envelope for use in determining the enclosure classification.

207A.10.3 Protection of Glazed Openings

Glazed openings in Occupancy Category I, II, III or IV buildings located in tropical cyclone-prone regions shall be protected as specified in this Section.

207A.10.3.1 Wind-borne Debris Regions

Glazed openings shall be protected in accordance with Section 207A.10.3.2 in the following locations:

1. Within 1.6 km of the coastal mean high water line where the basic wind speed is equal to or greater than 58 m/s, or

2. In areas where the basic wind speed is equal to or greater than 63 m/s.

For Occupancy Category III and IV buildings and structures, except health care facilities, the wind-borne debris region shall be based on Figure 207A.5-1A. For Occupancy Category III health care facilities and Occupancy Category II buildings and structures, the wind-borne debris region shall be based on Figure 207A.5-1B. Occupancy Categories shall be determined in accordance with Section 103.

Exception:

Glazing located over 18 m above the ground and over 9 m above aggregate-surfaced-roofs, including roofs with gravel or stone ballast, located within 450 m of the building shall be permitted to be unprotected.

207A.10.3.2 Protection Requirements for Glazed Openings

Glazing in buildings requiring protection shall be protected with an impact-protective system or shall be impact-resistant glazing.

Impact-protective systems and impact-resistant glazing shall be subjected to missile test and cyclic pressure differential tests in accordance with ASTM E1996 as applicable. Testing to demonstrate compliance with ASTM E1996 shall be in accordance with ASTM E1886. Impact-resistant glazing and impact protective systems shall comply with the pass/fail criteria of Section 7 of ASTM E1996 based on the missile required by Table 3 or Table 4 of ASTM E1996.

Exception:

Other testing methods and/or performance criteria are permitted to be used when approved.

ızing and impact-protective systems in buildings and ıctures classified as Occupancy Category I in ordance with Section 103 shall comply with the hanced protection" requirements of Table 3 of ASTM)96. Glazing and impact-protective systems in all other ıctures shall comply with the "basic protection" uirements of Table 3 of ASTM E1996.

> *ser Note:*
>
> *'he wind zones that are specified in ASTM E1996 for ;e in determining the applicable missile size for the ıpact test, have to be adjusted for use with the wind ɪeed maps of this code and the corresponding wind- ɔrne debris regions, see Section C207A.10.3.2.*

'A.10.4 Multiple Classifications

ı building by definition complies with both the "open" l "partially enclosed" definitions, it shall be classified as "open" building. A building that does not comply with ıer the "open" or "partially enclosed" definitions shall classified as an "enclosed" building.

'A.11 Internal Pressure Coefficient

nmentary:

? internal pressure coefficient values in ɔle 207A.11-1 were obtained from wind tunnel tests :athopoulos et al. 1979) and full-scale data (Yeatts and ·hta 1993). Even though the wind tunnel tests were ıducted primarily for low-rise buildings, the internal ·ssure coefficient values are assumed to be valid for 'ldings of any height. The values (GC_{pi}) *= +0.18 and 18 are for enclosed buildings. It is assumed that the 'lding has no dominant opening or openings and that the all leakage paths that do exist are essentially uniformly tributed over the building's envelope. The internal ·ssure coefficient values for partially enclosed buildings :ume that the building has a dominant opening or ɜnings. For such a building, the internal pressure is 'tated by the exterior pressure at the opening and is 'ically increased substantially as a result. Net loads, that the combination of the internal and exterior pressures, ? therefore also significantly increased on the building 'faces that do not contain the opening. Therefore, higher* $C_{pi})$ *values of +0.55 and −0.55 are applicable to this ;e. These values include a reduction factor to account · the lack of perfect correlation between the internal ·ssure and the external pressures on the building 'faces not containing the opening (Irwin 1987 and Beste d Cermak 1996). Taken in isolation, the internal pressure coefficients can reach values of ±0.8 (or possibly even higher on the negative side).*

For partially enclosed buildings containing a large unpartitioned space, the response time of the internal pressure is increased, and this increase reduces the ability of the internal pressure to respond to rapid changes in pressure at an opening. The gust factor applicable to the internal pressure is therefore reduced. Equation 207A.11-1, which is based on Vickery and Bloxham (1992) and Irwin and Dunn (1994), is provided as a means of adjusting the gust factor for this effect on structures with large internal spaces, such as stadiums and arenas.

Because of the nature of tropical cyclone winds and exposure to debris hazards (Minor and Behr 1993), glazing located below 18 m above the ground level of buildings sited in wind-borne debris regions has a widely varying and comparatively higher vulnerability to breakage from missiles, unless the glazing can withstand reasonable missile loads and subsequent wind loading, or the glazing is protected by suitable shutters. (See Section C207A.10 for discussion of glazing above 18 m. When glazing is breached by missiles, development of higher internal pressure may result, which can overload the cladding or structure if the higher pressure was not accounted for in the design. Breaching of glazing can also result in a significant amount of water infiltration, which typically results in considerable damage to the building and its contents (Surry et al. 1977, Reinhold 1982, and Stubbs and Perry 1993).

The influence of compartmentalization on the distribution of increased internal pressure has not been researched. If the space behind breached glazing is separated from the remainder of the building by a sufficiently strong and reasonably airtight compartment, the increased internal pressure would likely be confined to that compartment. However, if the compartment is breached (e.g., by an open corridor door or by collapse of the compartment wall), the increased internal pressure will spread beyond the initial compartment quite rapidly. The next compartment may contain the higher pressure, or it too could be breached, thereby allowing the high internal pressure to continue to propagate. Because of the great amount of air leakage that often occurs at large hangar doors, designers of hangars should consider utilizing the internal pressure coefficients for partially enclosed buildings in Table 207A.11-1.

207A.11.1 Internal Pressure Coefficients

Internal pressure coefficients, (GC_{pi}), shall be determined from Table 207A.11-1 based on building enclosure classifications determined from Section 207A.10.

Table 207A.11-1
Internal Pressure Coefficient, (GC_{pi})

Main Wind Force Resisting System and Components and Cladding	**All Heights**
Enclosed, Partially Enclosed, and Open Buildings	**Walls & Roofs**
Enclosure Classification	(GC_{pi})
Open Buildings	0.00
Partially Enclosed Buildings	+0.55 -0.55
Enclosed Buildings	+0.18 -0.18

Notes:

1. Plus and minus signs signify pressures acting toward and away from the internal surfaces, respectively.
2. Values of (GC_{pi}) shall be used with q_z or q_h as specified.
3. Two cases shall be considered to determine the critical load requirements for the appropriate condition:
   i. a positive value of (GC_{pi}) applied to all internal surfaces
   ii. a negative value of (GC_{pi}) applied to all internal surfaces

207A.11.1.1 Reduction Factor for Large Volume Buildings, R_i

For a partially enclosed building containing a single, unpartitioned large volume, the internal pressure coefficient, (GC_{pi}), shall be multiplied by the following reduction factor, R_i:

$R_i = 1.0$ or

$$R_i = 0.5\left(1 + \frac{1}{\sqrt{1 + \frac{V_i}{7\,A_{og}}}}\right) < 1.0 \qquad (207A.11\text{-}1)$$

where

A_{og} = total area of openings in the building envelope (walls and roof), in m^2
V_i = unpartitioned internal volume, in m^3

207B Wind Loads On Buildings—MWFRS (Directional Procedure)

Commentary:

The Directional Procedure is the former "buildings of all heights" provision in Method 2 of NSCP 2010 (ASCE 7-05) for MWFRS. A simplified method based on this Directional Procedure is provided for buildings up to 49 m in height. The Directional Procedure is considered the traditional approach in that 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.

207B.1 Scope

207B.1.1 Building Types

This chapter applies to the determination of MWFRS wind loads on enclosed, partially enclosed, and open buildings of all heights using the Directional Procedure.

1. Part 1 applies to buildings of all heights where it is necessary to separate applied wind loads onto the windward, leeward, and side walls of the building to properly assess the internal forces in the MWFRS members.

2. Part 2 applies to a special class of buildings designated as enclosed simple diaphragm buildings, as defined in Section 207A.2, with $h \leq 48$ m.

207B.1.2 Conditions

A building whose design wind loads are determined in accordance with this chapter shall comply with all of the following conditions:

1. The building is a regular-shaped building or structure as defined in Section 207A.2.

2. The building does not have response characteristics making it subject to across-wind loading, vortex shedding, instability due to galloping or flutter; or it does not have a site location for which channeling effects or buffeting in the wake of upwind obstructions warrant special consideration.

207B.1.3 Limitations

The provisions of this chapter take into consideration the load magnification effect caused by gusts in resonance with along-wind vibrations of flexible buildings. Buildings not meeting the requirements of Section 207B.1.2, or having unusual shapes or response characteristics shall be designed using recognized literature documenting such wind load effects or shall use the wind tunnel procedure specified in Section 207F.

207B.1.4 Shielding

There shall be no reductions in velocity pressure due to apparent shielding afforded by buildings and other structures or terrain features.

Part 1: Enclosed, Partially Enclosed, and Open Buildings of All Heights

207B.2 General Requirements

The steps to determine the wind loads on the MWFRS for enclosed, partially enclosed and open buildings of all heights are provided in Table 207B.2-1.

User Note:

Use Part 1 of Section 207B to determine wind pressures on the MWFRS of enclosed, partially enclosed or an open building with any general plan shape, building height or roof geometry that matches the figures provided. These provisions utilize the traditional "all heights" method (Directional Procedure) by calculating wind pressures using specific wind pressure equations applicable to each building surface.

207B.2.1 Wind Load Parameters Specified in Section 207A

The following wind load parameters shall be determined in accordance with Section 207A:

- Basic Wind Speed, V (Section 207A.5)
- Wind directionality factor, K_d (Section 207A.6)
- Exposure category (Section 207A.7)
- Topographic factor, K_{zt} (Section 207A.8)
- Gust-effect factor (Section 207A.9)
- Enclosure classification (Section 207A.10)
- Internal pressure coefficient, (GC_{pi}) (Section 207A.11)

207B.3 Velocity Pressure

207B.3.1 Velocity Pressure Exposure Coefficient

Based on the exposure category determined in Section 207A.7.3, a velocity pressure exposure coefficient K_z or K_h, as applicable, shall be determined from Table 207B.3-1. For a site located in a transition zone between exposure categories that is near to a change in ground surface roughness, intermediate values of K_z or K_h, between those shown in Table 207B.3-1 are permitted provided that they are determined by a rational analysis method defined in the recognized literature.

Table 207B.2-1
Steps to Determine MWFRS Wind Loads for Enclosed, Partially Enclosed and Open Buildings of All Heights

Step 1:	Determine risk category of building or other structure, see Table 103-1
Step 2:	Determine the basic wind speed, V, for the applicable risk category, see Figure 207A.5-1A, B or C
Step 3:	Determine wind load parameters: ➢ Wind directionality factor, K_d , see Section 207A.6 and Table 207A.6-1 ➢ Exposure category, see Section 207A.7 ➢ Topographic factor, K_{zt}, see Section 207A.8 and Table 207A.8-1 ➢ Gust Effect Factor, G, see Section 207A.9 ➢ Enclosure classification, see Section 207A.10 ➢ Internal pressure coefficient, (GC_{pi}), see Section 207A.11 and Table 207A.11-1
Step 4:	Determine velocity pressure exposure coefficient, K_z or K_h, see Table 207B.3-1
Step 5:	Determine velocity pressure q_z or q_h Equation 207B.3-1
Step 6:	Determine external pressure coefficient, C_p or C_N ➢ Figure 207B.4-1 for walls and flat, gable, hip, monoslope or mansard roofs ➢ Figure 207B.4-2 for domed roofs ➢ Figure 207B.4-3 for arched roofs ➢ Figure 207B.4-4 for monoslope roof, open building ➢ Figure 207B.4-5 for pitched roof, open building ➢ Figure 207B.4-6 for troughed roof, open building ➢ Figure 207B.4-7 for along-ridge/valley wind load case for monoslope, pitched or troughed roof, open building
Step 7:	Calculate wind pressure, p, on each building surface ➢ Equation 207B.4-1 for rigid buildings ➢ Equation 207B.4-2 for flexible buildings ➢ Equation 207B.4-3 for open buildings

Commentary:

The velocity pressure exposure coefficient K_z can be obtained using the equation:

$$K_z = \begin{cases} 2.01\left(\dfrac{z}{z_g}\right)^{2/\alpha} & \text{For } 4.57m \leq z \leq z_g \quad \text{(C207B.3-1)} \\ 2.01\left(\dfrac{4.57}{z_g}\right)^{2/} & \text{For } z < 4.57\,m \quad \text{(C207B.3-2)} \end{cases}$$

in which values of α and z_g are given in Table 207A.9-1. These equations are now given in Tables 207B.3-1, 207C.3-1, 207D.3-1, and 207E.3-1 to aid the user.

Changes were implemented in NSCP 2001 (ASCE 7-98), including truncation of K_z values for Exposures A and B below heights of 30 m and 9 m, respectively, applicable to Components and Cladding and the Envelope Procedure. Exposure A was eliminated in the 2002 edition of ASCE 7.

In the NSCP 2010 (ASCE 7-05) standard, the K_z expressions were unchanged from NSCP 2001 (ASCE 7-98). However, the possibility of interpolating between the standard exposures using a rational method was added in the NSCP 2010 (ASCE 7-05) edition. One rational method is provided in the following text.

To a reasonable approximation, the empirical exponent α and gradient height z_g in the preceding expressions (Equations C207B.3-1 and C207B.3-2) for exposure coefficient K_z may be related to the roughness length z_O (where z_O is defined in Section C207A.7) by the relations

$$\alpha = c_1 z_O^{-0.133} \qquad \text{(C207B.3-3)}$$

and

$$z_g = c_2 z_O^{0.125} \qquad \text{(C207B.3-4)}$$

where

Units of z_O, z_g	c_1	c_2
m	*5.65*	*450*

The preceding relationships are based on matching the ESDU boundary layer model (Harris and Deaves 1981 and ESDU 1990 and 1993) empirically with the power law relationship in Equations C207B.3-1 and C207B.3-2, the ESDU model being applied at latitude 35° with a gradient *wind of 75 m/s. If z_0 has been determined for a particular upwind fetch, Equations C207B.3-1 through C207B.3-4 can be used to evaluate K_z. The correspondence between z_0 and the parameters α and z_g implied by these relationships does not align exactly with that described in the commentary to ASCE 7-95 and 7-98. However, the differences are relatively small and not of practical consequence. The ESDU boundary layer model has also been used to derive the following simplified method (Irwin 2006) of evaluating K_z following a transition from one surface roughness to another. For more precise estimates the reader is referred to the original ESDU model (Harris and Deaves 1981 and ESDU 1990 and 1993).*

In uniform terrain, the wind travels a sufficient distance over the terrain for the planetary boundary layer to reach an equilibrium state. The exposure coefficient values in Table 207B.3-1 are intended for this condition. Suppose that the site is a distance x miles downwind of a change in terrain. The equilibrium value of the exposure coefficient at height z for the terrain roughness downwind of the change will be denoted by K_{zd}, and the equilibrium value for the terrain roughness upwind of the change will be denoted by K_{zu}. The effect of the change in terrain roughness on the exposure coefficient at the site can be represented by adjusting K_{zd} by an increment ΔK, thus arriving at a corrected value K_z for the site.

$$K_z = K_{zd} + \Delta K \qquad (C207B.3\text{-}5)$$

In this expression ΔK is calculated using:

$$\Delta K = \left(K_{33,u} - K_{33,d}\right)\frac{K_{zd}}{K_{33,d}} F_{\Delta K}(x) \qquad (C207B.3\text{-}6)$$

$$|\Delta K| \le |K_{zu} - K_{zd}|$$

where $K_{33,d}$ and $K_{33,u}$ are respectively the downwind and upwind equilibrium values of exposure coefficient at 10 m height, and the function $F_{\Delta K}(x)$ is given by:

$$F_{\Delta K}(x) = log_{10}\left(\frac{x_1}{x}\right) \Big/ log_{10}\left(\frac{x_1}{x_0}\right) \qquad (C207B.3\text{-}7)$$

For $x_0 < x < x_1$

$F_{\Delta K}(x) \quad = \quad 1 \quad$ *for* $x < x_0$

$F_{\Delta K}(x) \quad = \quad 0 \quad$ *for* $x > x_1$

In the preceding relationships

$$x_0 = c_3 \times 10^{-(K_{33,d} - K_{33,u})^2 - 2.3} \qquad (C207B.3\text{-}8)$$

The constant c_3 = 1.0 km. The length x_1 = 10 km for $K_{33,d} < K_{33,u}$ (wind going from smoother terrain upwind to rougher terrain downwind) or x_1 = 100 km) for $K_{33,d} > K_{33,u}$ (wind going from rougher terrain upwind to smoother terrain downwind).

The above description is in terms of a single roughness change. The method can be extended to multiple roughness changes. The extension of the method is best described by an example. Figure C207B.3-1 shows wind with an initial profile characteristic of Exposure D encountering an expanse of B roughness, followed by a further expanse of D roughness and then some more B roughness again before it arrives at the building site. This situation is representative of wind from the sea flowing over an outer strip of land, then a coastal waterway, and then some suburban roughness before arriving at the building site. The above method for a single roughness change is first used to compute the profile of K_z at station 1 in Figure C207B.3-1. Call this profile $K_z^{(1)}$. The value of ΔK for the transition between stations 1 and 2 is then determined using the equilibrium value of $K_{33,u}$ for the roughness immediately upwind of station 1, i.e., as though the roughness upwind of station 1 extended to infinity. This value of ΔK is then added to the equilibrium value $K_z^{(2)}$ of the exposure coefficient for the roughness between stations 1 and 2 to obtain the profile of K_z at station 2, which we will call $K_z^{(2)}$. Note however, that the value of $K_z^{(2)}$ in this way cannot be any lower than $K_z^{(1)}$. The process is then repeated for the transition between stations 2 and 3. Thus, ΔK for the transition from station 2 to station 3 is calculated using the value of $K_{33,u}$ for the equilibrium profile of the roughness immediately upwind of station 2, and the value of $K_{33,d}$ for the equilibrium profile of the roughness downwind of station 2. This value of ΔK is then added to $K_z^{(2)}$ to obtain the profile $K_z^{(3)}$ at station 3, with the limitation that the value of $K_z^{(3)}$ cannot be any higher than $K_z^{(2)}$.

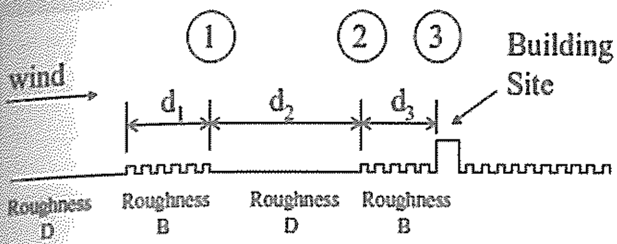


Figure C207B.3-1
Multiple Roughness Changes Due to Coastal Waterway

Example 1, single roughness change: Suppose the building is 20 m high and its local surroundings are suburban with a roughness length z_0 *= 0.3 m. However, the site is 0.6 km downwind of the edge of the suburbs, beyond which the open terrain is characteristic of open country with* z_0 *= 0.02 m. From Equations C207B.3-1, C207B.3-3, and C207B.3-4, for the open terrain*

$$\alpha = c_1 z_0^{-0.133} = 6.62 \times 0.066^{-0.133} = 9.5$$

$$z_g = c_2 z_0^{0.125} = 1{,}273 \times 0.066^{0.125} = 276\ m$$

Therefore, applying Equation C207B.3-1 at 20 m and 10 m heights,

$$K_{zu} = 2.01\left(\frac{66}{906}\right)^{2/9.5} = 1.16 \text{ and}$$

$$K_{33,u} = 2.01\left(\frac{33}{906}\right)^{2/9.5} = 1.0$$

Similarly, for the suburban terrain

$$\alpha = c_1 z_0^{-0.133} = 6.62 \times 1.0^{-0.133} = 6.62$$

$$z_g = c_2 z_0^{0.125} = 1{,}273 \times 1.0^{0.125} = 388\ m$$

Therefore

$$K_{zd} = 2.01\left(\frac{66}{1{,}273}\right)^{2/6.19} = 0.77 \text{ and}$$

$$K_{33,d} = 2.01\left(\frac{33}{1{,}273}\right)^{2/6.62} = 0.67$$

From Equation C207B.3-8

$$x_0 = c_3 \times 10^{-(K_{33,d}-K_{33,u})^2-2.3}$$

$$= 0.621 \times 10^{-(0.62-1.00)^2-2.3}$$

$$= 0.00241\ mi$$

From Equation C207B.3-7

$$F_{\Delta K}(x) = \log_{10}\left(\frac{6.21}{0.36}\right) \Big/ \log_{10}\left(\frac{6.21}{0.00241}\right) = 0.36$$

Therefore from Equation C207B.3-6

$$\Delta K = (1.00 - 0.67)\frac{0.82}{0.67}0.36 = 0.15$$

Note that because $|\Delta K|$ *is 0.15, which is less than the 0.38 value of* $|K_{33,u} - K_{33,d}|$*, 0.15 is retained. Finally, from Equation C207B.3-5, the value of* K_z *is:*

$$K_z = K_{zd} + \Delta K = 0.82 + 0.15 = 0.97$$

Because the value 0.97 for K_z *lies between the values 0.88 and 1.16, which would be derived from Table 207B.3-1 for Exposures B and C respectively, it is an acceptable interpolation. If it falls below the Exposure B value, then the Exposure B value of* K_z *is to be used. The value* K_z *= 0.97 may be compared with the value 1.16 that would be required by the simple 792 m fetch length requirement of Section 207A.7.3.*

The most common case of a single roughness change where an interpolated value of K_z *is needed is for the transition from Exposure C to Exposure B, as in the example just described. For this particular transition, using the typical values of* z_0 *of 0.02 m and 0.3 m, the preceding formulae can be simplified to:*

$$K_z = K_{zd}\left(1 + 0.146\log_{10}\left(\frac{6.21}{x}\right)\right) \qquad \text{(C207B.3-9)}$$

$$K_{zB} \le K_z \le K_{zC}$$

where x *is in miles, and* K_{zd} *is computed using* α *= 6.62.* K_{zB} *and* K_{zC} *are the exposure coefficients in the standard Exposures C and B. Figure C207B.3-2 illustrates the transition from terrain roughness C to terrain roughness B from this expression. Note that it is acceptable to use the typical* z_0 *rather than the lower limit for Exposure B in deriving this formula because the rate of transition of the wind profiles is dependent on average roughness over significant distances, not local roughness anomalies. The potential effects of local roughness anomalies, such as* *parking lots and playing fields, are covered by using the standard Exposure B value of exposure coefficient,* K_{zB}*, as a lower limit to the calculated value of* K_z*.*

Example 2: Multiple Roughness Change Suppose we have a coastal waterway situation as illustrated in Figure C207B.3-1, where the wind comes from open sea with roughness type D, for which we assume $z_0 = 0.003\ m$*, and passes over a strip of land 1.61 km wide, which is covered in buildings that produce typical B type roughness, i.e.* $z_0 = 0.3\ m$*. It then passes over a 3.22-km wide strip of coastal waterway where the roughness is again characterized by the open water value* $z_0 = 0.003\ m$*. It then travels over 0.16 km of roughness type B (*z_0 *= 0.3 m before arriving at the site, station 3 in Figure C207B.3-1, where the exposure coefficient is required at the 15-m height. The exposure coefficient at station 3 at 15 m height is calculated as shown in Table C207B.3-1.*

The value of the exposure coefficient at 15 m at station 3 is seen from the table to be 1.067. This is above that for Exposure B, which would be 0.81, but well below that for Exposure D, which would be 1.27, and similar to that for Exposure C, which would be 1.09.

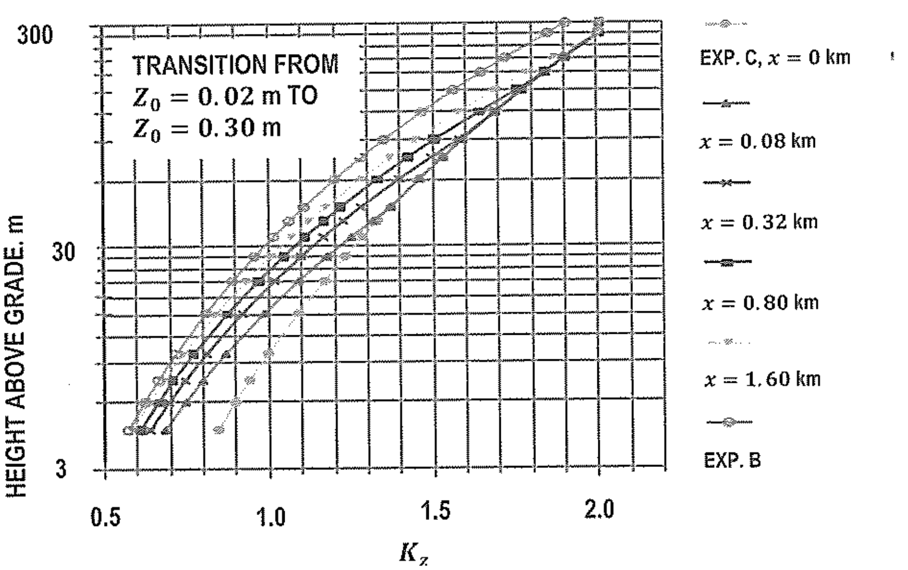


Figure C207B.3-2
Transition from Terrain Roughness C to Terrain Roughness B, Equation C207B.3.1-9

Table C207B.3-1
Tabulated Exposure Coefficients

Transition from sea to station 1	$K_{10,u}$ 1.215	$K_{10,d}$ 0.667	$K_{15,d}$ 0.758	$F_{\Delta K}$ 0.220	ΔK_{15} 0.137	$K_z^{(1)}$ 0.895
Transition from sea to station 2	$K_{10,u}$ 0.667	$K_{10,d}$ 1.215	$K_{15,d}$ 1.215	$F_{\Delta K}$ 0.324	ΔK_{15} -0.190	$K_z^{(2)}$ 1.111
Transition from sea to station 3	$K_{10,u}$ 1.215	$K_{10,d}$ 0.667	$K_{15,d}$ 0.667	$F_{\Delta K}$ 0.498	ΔK_{15} 0.310	$K_z^{(3)}$ 1.067

Note: *The equilibrium values of the exposure coefficients, $K_{10,u}$, $K_{10,d}$ and $K_{15,d}$ (downwind value of K_z at 15 m), were calculated from Equation C207B-1 using α and z_g values obtained from Equations C207B-3 and C207B-4 with the roughness values given. Then $F_{\Delta K}$ is calculated using Equations C207B-7 and C207B-8, and then the value of ΔK at 15 m height, ΔK_{15}, is calculated from Equation C207B-6. Finally, the exposure coefficient at 15 m at station i, $K_{15}^{(i)}$, is obtained from Equation C207B-5.*

207B.3.2 Velocity Pressure

Velocity pressure, q_z, evaluated at height z shall be calculated by the following equation:

$$q_z = 0.613 K_z K_{zt} K_d V^2 (\text{N/m}^2); V \text{ in m/s} \qquad (207\text{B}.3\text{-}1)$$

where

- K_d = wind directionality factor, see Section 207A.6
- K_z = velocity pressure exposure coefficient, see Section 207B.3.1
- K_{zt} = topographic factor defined, see Section 207A.8.2
- V = basic wind speed, see Section 207A.5
- q_z = velocity pressure calculated using Equation 207B.3-1 at height z
- q_{zt} = velocity pressure calculated using Equation 207B.3-1 at mean roof height h

The numerical coefficient 0.613 shall be used except where sufficient climatic data are available to justify the selection of a different value of this coefficient for a design application.

Commentary:

The basic wind speed is converted to a velocity pressure q_z in (N/m²) at height z by the use of Equation 207B.3-1.

The constant 0.613 reflects the mass density of air for the standard atmosphere, that is, temperature of 15 °C and sea level pressure of 101.325 kPa, and dimensions associated with wind speed in m/s. The constant is obtained as follows:

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

207B.4 Wind Loads—Main Wind Force-Resisting System

207B.4.1 Enclosed and Partially Enclosed Rigid Buildings

Design wind pressures for the MWFRS of buildings of all heights shall be determined by the following equation:

$$p = qGC_p - q_i(GC_{pi}) \text{ (N/m}^2\text{)} \qquad (207B.4\text{-}1)$$

where

q = q_z for windward walls evaluated at height z above the ground

q = q_h for leeward walls, side walls, and roofs, evaluated at height h

q_i = q_h for windward walls, side walls, leeward walls, and roofs of enclosed buildings and for negative internal pressure evaluation in partially enclosed buildings

q_i = q_z for positive internal pressure evaluation in partially enclosed buildings where height z is defined as the level of the highest opening in the building that could affect the positive internal pressure. For buildings sited in wind-borne debris regions, glazing that is not impact resistant or protected with an impact resistant covering shall be treated as an opening in accordance with Section 207A.10.3.

For positive internal pressure evaluation, q_i may conservatively be evaluated at height $h(q_i = q_h)$

G = gust-effect factor, see Section 207A.9

C_p = external pressure coefficient from Figures 207B.4-1, 207B.4-2 and 207B.4-3

(GC_{pi}) = internal pressure coefficient from Table 207A.11-1

q and q_i shall be evaluated using exposure defined in Section 207A.7.3. Pressure shall be applied simultaneously on windward and leeward walls and on roof surfaces as defined in Figures 207B.4-1, 207B.4-2 and 207B.4-3.

The numerical constant of 0.613 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 C207B.3-2.

Table 207B.3-1
Velocity Pressure Exposure Coefficients, K_h and K_z
Main Wind Force Resisting System – Part 1

Height above ground level, z	Exposure		
(m)	B	C	D
0 - 4.5	057	0.85	1.03
6.0	0.62	0.90	1.08
7.5	0.66	0.94	1.12
9.0	0.70	0.98	1.16
12.0	0.76	1.04	1.22
15.0	0.81	1.09	1.27
18.0	0.85	1.13	1.31
21.0	0.89	1.17	1.34
24.0	0.93	1.21	1.38
27.0	0.96	1.24	1.40
30.0	0.99	1.26	1.43
36.0	1.04	1.31	1.48
42.0	1.09	1.36	1.52
48.0	1.13	1.39	1.55
54.0	1.17	1.43	1.58
60.0	1.20	1.46	1.61
75.0	1.28	1.53	1.68
90.0	1.35	1.59	1.73
105.0	1.41	1.64	1.78
120.0	1.47	1.69	1.82
135.0	1.52	1.73	1.86
150.0	1.56	1.77	1.89

Notes:

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

   For $4.5 \text{ m} \le z \le z_g$ $\qquad$ For $z < 4.5$ m

   $$K_z = 2.01(z/z_g)^{2/\alpha} \qquad K_z = 2.01(4.5/z_g)^{2/\alpha}$$

2. α and z_g are tabulated in Table 207A.9.1.
3. Linear interpolation for intermediate values of height z is acceptable.
4. Exposure categories are defined Section 207A.7.

Commentary:

Loads on Main Wind-Force Resisting Systems: In Equations 207B.4-1 and 207B.4-2, a velocity pressure term qi appears that is defined as the "velocity pressure for internal pressure determination." The positive internal pressure is dictated by the positive exterior pressure on the windward face at the point where there is an opening. The positive exterior pressure at the opening is governed by the value of q *at the level of the* *opening, not* q_h. *For positive internal pressure evaluation,* q_i *may conservatively be evaluated at height* $h(q_i = q_h)$. *For low buildings this does not make much difference, but for the example of a 90-m tall building in Exposure B with a highest opening at 18 m, the difference between* q_{90} *and* q_{18} *represents a 59 percent increase in internal pressure. This difference is unrealistic and represents an unnecessary degree of conservatism. Accordingly,* $q_i = q_h$ *for positive internal pressure evaluation in partially enclosed buildings where height* **z** *is defined as the level of the highest opening in the building that could affect the positive internal pressure. For buildings sited in wind-borne debris regions, with glazing that is not impact resistant or protected with an impact protective system,* q_i *should be treated on the assumption there will be an opening.*

Figure 207B.4-1. *The pressure coefficients for MWFRSs are separated into two categories:*

1. *Directional Procedure for buildings of all heights (Figure 207B.4-1) as specified in Section 207B for buildings meeting the requirements specified therein.*

2. *Envelope Procedure for low-rise buildings having a height less than or equal to 18 m (Figure 207C.4-1) as specified in Section 207C for buildings meeting the requirements specified therein.*

In generating these coefficients, two distinctly different approaches were used. For the pressure coefficients given in Figure 207B.4-1, 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. Observations in wind tunnel tests show that areas of very low negative pressure and even slightly positive pressure can occur in all roof structures, particularly as the distance from the windward edge increases and the wind streams reattach to the surface. These pressures can occur even for relatively flat or low slope roof structures. Experience and judgment from wind tunnel studies have been used to specify either zero or slightly negative pressures (-0.18) depending on the negative pressure coefficient. These values require the designer to consider a zero or slightly positive net wind pressure in the load combinations of Section 203.

Table C207B.3-2
Ambient Air Density Values for Various Altitudes

Altitude	***Ambient Air Temperature***		
Meters	***Minimum*** ***(kg/m³)***	***Average*** ***(kg/m³)***	***Maximum*** ***(kg/m³)***
0	1.1392	1.2240	1.3152
305	1.1088	1.1872	1.2720
610	1.0800	1.1520	1.2288
914	1.0512	1.1184	1.1888
1000	1.0432	1.1088	1.1776
1219	1.0240	1.0848	1.1488
1524	0.9984	1.0544	1.1120
1829	0.9728	1.0224	1.0752
2000	0.9584	1.0064	1.0560
2134	0.9472	0.9920	1.0400
2438	0.9232	0.9632	1.0048
2743	0.8976	0.9344	0.9712
3000	0.8784	0.9104	0.9456
3048	0.8752	0.9072	0.9408

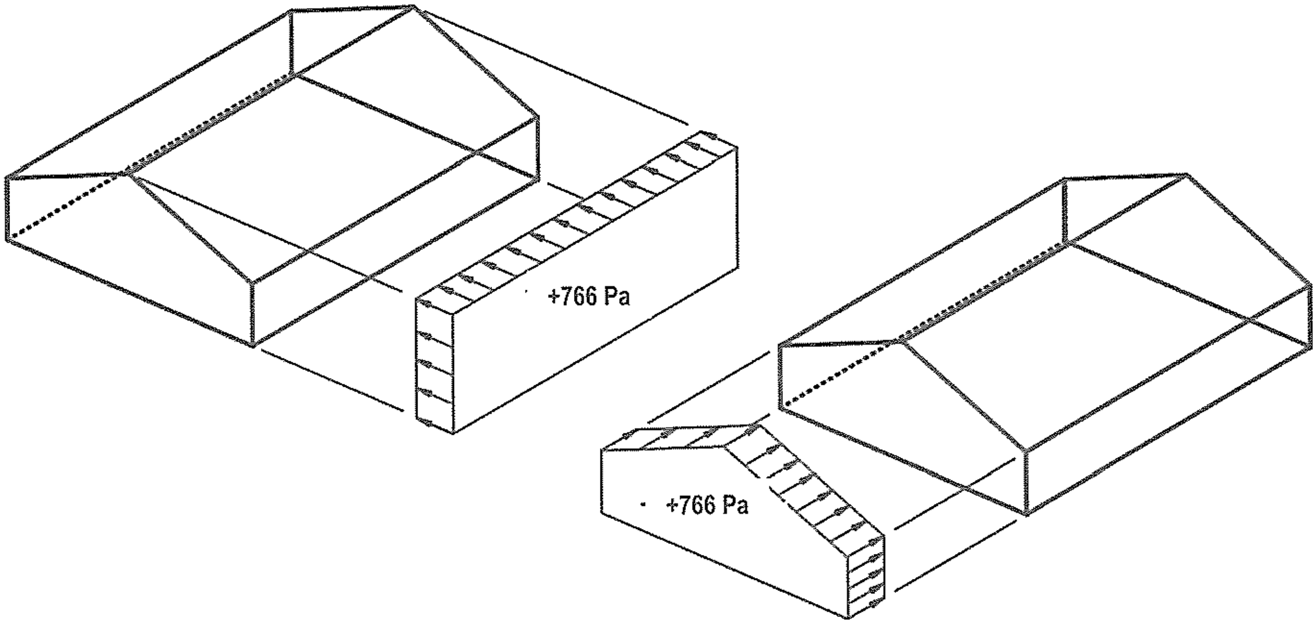


Figure C207B.4-1
Application of Minimum Wind Load

Figure 207B.4-2. *Frame loads on dome roofs are adapted from the Eurocode (1995). The loads are based on data obtained in a modeled atmospheric boundary-layer flow that does not fully comply with requirements for wind-tunnel testing specified in this code (Blessman 1971). Loads for three domes* $(h_D/D = 0.5, f/D = 0.5)$, $(h_D/D = 0, f/D = 0.5)$, *and* $(hD/D = 0, f/D = 0.33)$ *are roughly consistent with data of Taylor (1991), who used an atmospheric boundary layer as required in this code. Two load cases are defined, one of which has a linear variation of pressure from A to B as in the Eurocode (1995) and one in which the pressure at A is held constant from 0° to 25°; these two cases are based on comparison of the Eurocode provisions with Taylor (1991). Case A (the Eurocode calculation) is necessary in many cases to define maximum uplift. Case B is necessary to properly define positive pressures for some cases, which cannot be isolated with current information, and which result in maximum base shear. For domes larger than 60 m in diameter the designer should consider use of wind-tunnel testing. Resonant response is not considered in these provisions. Wind-tunnel testing should be used to consider resonant response. Local bending moments in the dome shell may be larger than predicted by this method due to the difference between instantaneous local pressure distributions and those predicted by Figure 207B.4-2. If the dome is supported on vertical walls directly below, it is appropriate to consider the walls as a "chimney" using Figure 207D.5-1.*

Figure 207B.4-3. *The pressure and force coefficient values in these tables are unchanged from ANSI A58.1-1972. The coefficients specified in these tables are based on wind-tunnel tests conducted under conditions of uniform flow and low turbulence, and their validity in turbulent boundary-layer flows has yet to be completely established. Additional pressure coefficients for conditions not specified herein may be found in SIA (1956) and ASCE (1961).*

207B.4.2 Enclosed and Partially Enclosed Flexible Buildings

Design wind pressures for the MWFRS of flexible buildings shall be determined from the following equation:

$$p = qG_fC_p - q_i(GC_{pi}) \text{ (N/m}^2\text{)} \qquad (207\text{B}.4\text{-}2)$$

where q, q_i, C_p, and (GC_{pi}) are as defined in Section 207B.4.1 and G_f (gust-effect factor) is determined in accordance with Section 207A.9.5.

207B.4.3 Open Buildings with Monoslope, Pitched, or Troughed Free Roofs

The net design pressure for the MWFRS of open buildings with monoslope, pitched, or troughed roofs shall be determined by the following equation:

$$p = q_h G C_N \quad (\text{N/m}^2) \qquad (207\text{B}.4\text{-}3)$$

where

q_h = velocity pressure evaluated at mean roof height h using the exposure as defined in Section 207A.7.3 that results in the highest wind loads for any wind direction at the site

G = gust-effect factor from Section 207A.9

C_N = net pressure coefficient determined from Figures 207B.4-4 through 207B.4-7

Net pressure coefficients, C_N, include contributions from top and bottom surfaces. All load cases shown for each roof angle shall be investigated. Plus and minus signs signify pressure acting toward and away from the top surface of the roof, respectively.

For free roofs with an angle of plane of roof from horizontal θ less than or equal to 5° and containing fascia panels, the fascia panel shall be considered an inverted parapet. The contribution of loads on the fascia to the MWFRS loads shall be determined using Section 207B.4.5 with q_p equal to q_h.

Commentary:

Figures 207B.4-4 through 207B.4-6 and 207E.8-1 through 207E.8-3 are presented for wind loads on MWFRSs and components and cladding of open buildings with roofs as shown, respectively. This work is based on the Australian Standard AS1170.2-2000, Part 2: Wind Actions, with modifications to the MWFRS pressure coefficients based on recent studies (Altman and Uematsu and Stathopoulos 2003).

Two load cases, A and B, are given in Figures 207B.4-4 through 207B.4-6. These pressure distributions provide loads that envelop the results from detailed wind-tunnel measurements of simultaneous normal forces and moments. Application of both load cases is required to envelop the combinations of maximum normal forces and moments that are appropriate for the particular roof shape and blockage configuration.

The roof wind loading on open building roofs is highly dependent upon whether goods or materials are stored under the roof and restrict the wind flow. Restricting the flow can introduce substantial upward acting pressures on the bottom surface of the roof, thus increasing the resultant uplift load on the roof. Figures 207B.4-4 through 207B.4-6 and 207E.8-1 through 207E.8-3 offer the designer two options. Option 1 (clear wind flow) implies little (less than 50 percent) or no portion of the cross-section below the roof is blocked. Option 2 (obstructed wind flow) implies that a significant portion (more than 75 percent is typically referenced in the literature) of the cross-section is blocked by goods or materials below the roof. Clearly, values would change from one set of coefficients to the other following some sort of smooth, but as yet unknown, relationship. In developing the provisions included in this code, the 50 percent blockage value was selected for Option 1, with the expectation that it represents a somewhat conservative transition. If the designer is not clear about usage of the space below the roof or if the usage could change to restrict free air flow, then design loads for both options should be used.

207B.4.4 Roof Overhangs

The positive external pressure on the bottom surface of windward roof overhangs shall be determined using $C_p = 0.8$ and combined with the top surface pressures determined using Figure 207B.4-1.

207B.4.5 Parapets

The design wind pressure for the effect of parapets on MWFRS of rigid or flexible buildings with flat, gable, or hip roofs shall be determined by the following equation:

$$p_p = q_p (GC_{pn}) \; (\text{N/m}^2) \qquad 207\text{B}.4\text{-}4$$

where

p_p = combined net pressure on the parapet due to the combination of the net pressures from the front and back parapet surfaces. Plus (and minus) signs signify net pressure acting toward (and away from) the front (exterior) side of the parapet

q_p = velocity pressure evaluated at the top of the parapet

(GC_{pn}) = combined net pressure coefficient
= +1.5 for windward parapet
= −1.0 for leeward parapet

207B.4.6 Design Wind Load Cases

The MWFRS of buildings of all heights, whose wind loads have been determined under the provisions of this chapter, shall be designed for the wind load cases as defined in Figure 207B.4-8.

Exception:

Buildings meeting the requirements of Section D1.1 of Appendix D, ASCE 7-10 need only be designed for Case 1 and Case 3 of Figure 207B.4-8.

The eccentricity e for rigid structures shall be measured from the geometric center of the building face and shall be considered for each principal axis (e_X, e_Y). The eccentricity e for flexible structures shall be determined from the following equation and shall be considered for each principal axis (e_X, e_Y):

$$e = \frac{e_Q + 1.71 I_{\bar{z}} \sqrt{(g_Q Q e_Q)^2 + (g_R R e_R)^2}}{1.71 I_{\bar{z}} \sqrt{(g_Q Q e_Q)^2 + (g_R R e_R)^2}} \qquad \text{207B.4-5}$$

where

e_Q = eccentricity e as determined for rigid structures in Figure 207B.4-8

e_R = distance between the elastic shear center and center of mass of each floor

$I_{\bar{z}}$, g_Q, Q, g_R, and R shall be as defined in Section 207A.9

The sign of the eccentricity e shall be plus or minus, whichever causes the more severe load effect.

Commentary:

Wind tunnel research (Isyumov 1983, Boggs et al. 2000, Isyumov and Case 2000, and Xie and Irwin 2000) has shown that torsional load is caused by non-uniform pressure on the different faces of the building from wind flow around the building, interference effects of nearby buildings and terrain, and by dynamic effects on more flexible buildings. Load Cases 2 and 4 in Figure 207B.4-8 specifies the torsional loading to 15 percent eccentricity under 75 percent of the maximum wind shear for Load Case 2. Although this is more in line with wind tunnel experience on square and rectangular buildings with aspect ratios up to about 2.5, it may not cover all cases, even for symmetric and common building shapes where larger torsions have been observed. For example, wind tunnel studies often show an eccentricity of 5 percent or more under full (not reduced) base shear. The designer may wish to apply this level of eccentricity at full wind loading for certain more critical buildings even though it is not required by the code. The present more moderate torsional load requirements can in part be justified by the fact that the design wind forces tend to be upper-bound for most common building shapes.

In buildings with some structural systems, more severe loading can occur when the resultant wind load acts diagonally to the building. To account for this effect and the fact that many buildings exhibit maximum response in the across-wind direction (the standard currently has no analytical procedure for this case), a structure should be capable of resisting 75 percent of the design wind load applied simultaneously along each principal axis as required by Case 3 in Figure 207B.4-8.

For flexible buildings, dynamic effects can increase torsional loading. Additional torsional loading can occur because of eccentricity between the elastic shear center and the center of mass at each level of the structure. Equation 207B.4-5 accounts for this effect.

It is important to note that significant torsion can occur on low-rise buildings also (Isyumov and Case 2000) and, therefore, the wind loading requirements of Section 207B.4.6 are now applicable to buildings of all heights.

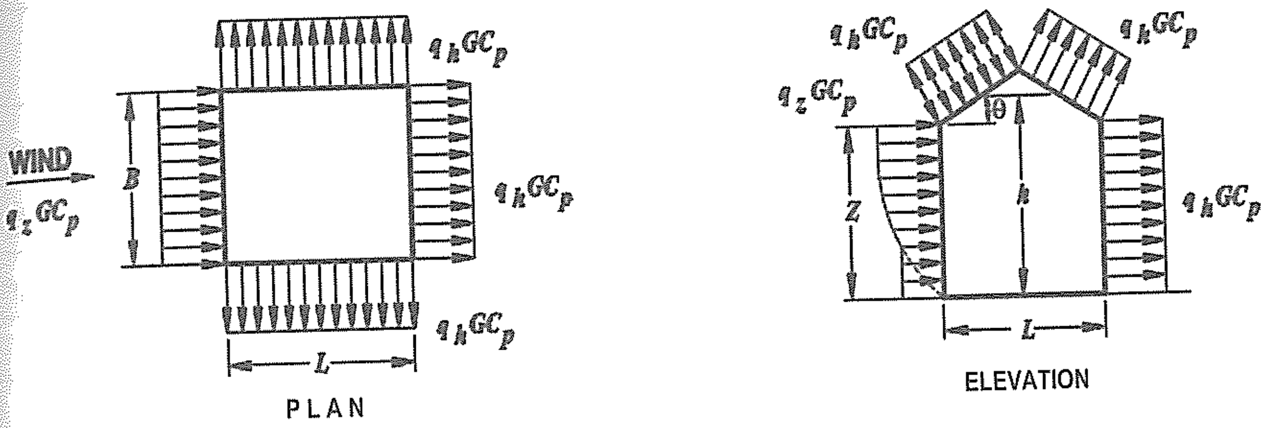
As discussed in Section 207F, the wind tunnel procedure should always be considered for buildings with unusual shapes, rectangular buildings with larger aspect ratios, and dynamically sensitive buildings. The effects of torsion can more accurately be determined for these cases and for the more normal building shapes using the wind tunnel procedure.

207B.4.7 Minimum Design Wind Loads

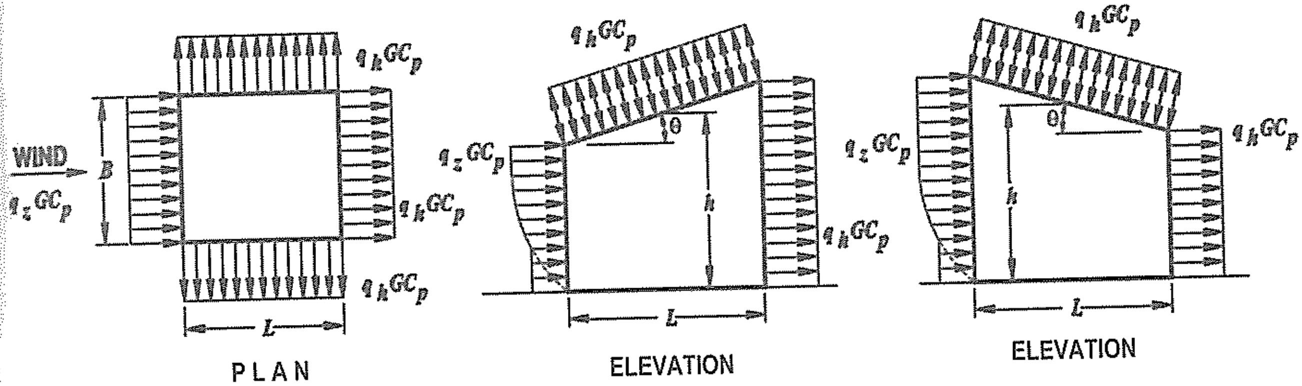
The wind load to be used in the design of the MWFRS for an enclosed or partially enclosed building shall not be less than 0.77 kN/m² multiplied by the wall area of the building and 0.38 kN/m² multiplied by the roof area of the building projected onto a vertical plane normal to the assumed wind direction. Wall and roof loads shall be applied simultaneously. The design wind force for open buildings shall be not less than 0.77 kN/m² multiplied by the area A_f.

Commentary:

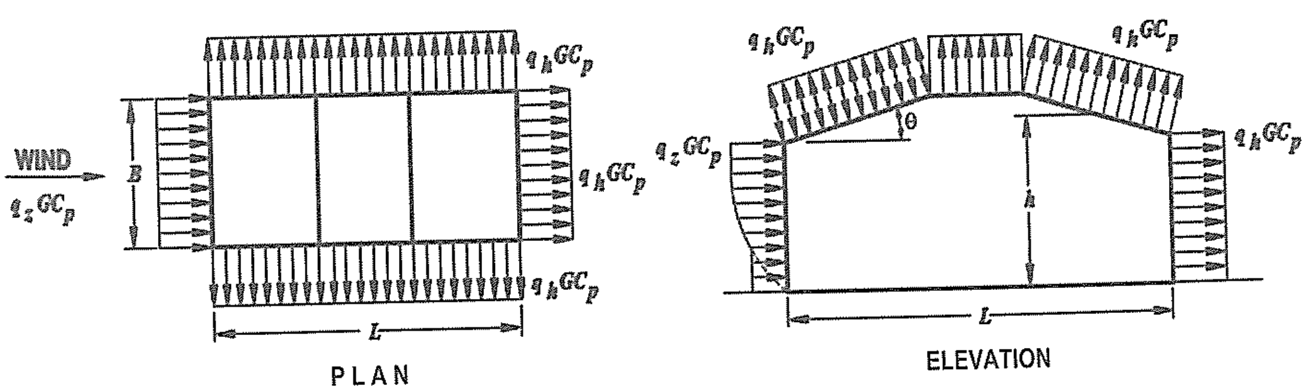
This section specifies a minimum wind load to be applied horizontally on the entire vertical projection of the building as shown in Figure C207B.4-1. This load case is to be applied as a separate load case in addition to the normal load cases specified in other portions of this chapter.



GABLE, HIP ROOF



MONOSLOPE ROOF (NOTE 4)



MANSARD ROOF (NOTE 8)

Figure 207B.4-1
External Pressure Coefficients, C_p, Walls and Roofs Enclosed, Partially Enclosed Buildings

Wall Pressure Coefficients, C_p			
Surface	L/B	C_p	**Use With**
Windward Wall	All values	0.8	q_z
Leeward Wall	0-1	-0.5	q_h
	2	-0.3	
	≥ 4	-0.2	
Side Wall	All values	-0.7	q_h

Roof Pressure Coefficients, C_p, for use with q_h												
Wind Direction	Windward									Leeward		
	Angle, θ (degrees)									Angle, θ (degrees)		
	h/L	10	15	20	25	30	35	45	≥ 60	10	15	≥ 20
Normal to Ridge for $\theta \geq$ **10^o**	≤ 0.25	-0.7 -0.18	-0.5 0.0*	-0.3 0.2	-0.2 0.3	-0.2 0.3	0.0* 0.4	0.4	0.01θ	-0.3	-0.5	-0.6
	0.5	-0.9 -0.18	-0.7 -0.18	-0.4 0.0*	-0.3 0.2	-0.2 0.2	-0.2 0.3	0.0* 0.4	0.01θ	-0.5	-0.5	-0.6
	≥ 10	-1.3** -0.18	-1.0 -0.18	-0.7 -0.18	-0.5 0.0*	-0.3 0.2	-0.2 0.2	0.0* 0.3	0.01θ	-0.7	-0.6	-0.6

Wind Direction	h/L	Horizontal distance from windward edge	C_p
Normal to Ridge for $\theta <$ **10^o** and Parallel to ridge for all θ	≤ 0.5	**0 to $h/2$**	-0.9, -0.18
		$h/2$ to h	-0.9, -0.18
		h to 2 h	-0.5, -0.18
		$> 2h$	-0.3, -0.18
	≥ 1.0	**0 to $h/2$**	-1.3**, -0.18
		$> h/2$	-0.7, -0.18

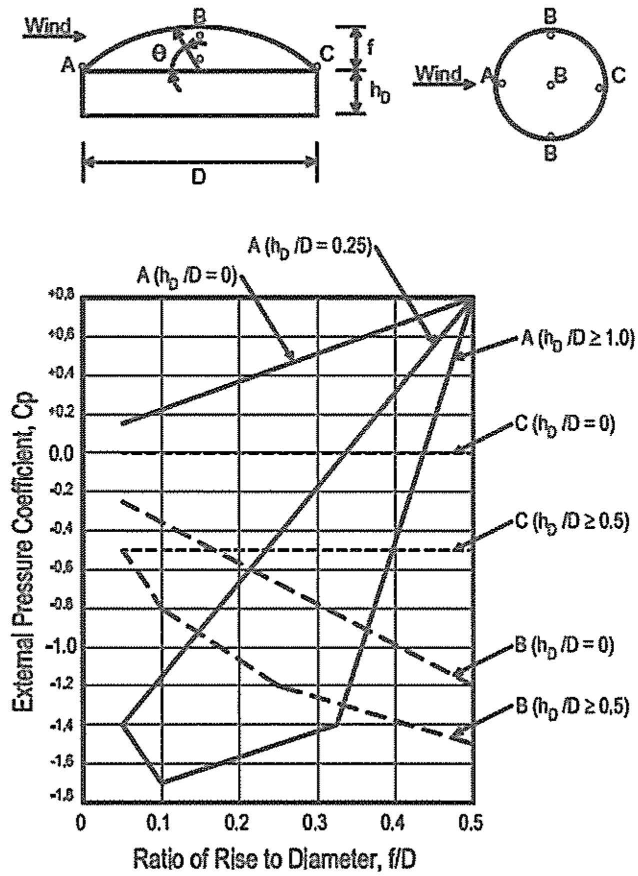
*Value is provided for interpolation purposes

**Value can be reduced linearly with area over which it is applicable as follows

Area (m^2)	**Reduction Factor**
≤ 9.3 m^2	1.0
23.2 m^2	0.9
≥ 92.9 m^2	0.8

Notes:

1. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
2. Linear interpolation is permitted for values of L/B, h/L and θ other than shown. Interpolation shall only be carried out between values of the same sign. Where no value of the same sign is given, assume 0.0 for interpolation purposes.
3. Where two values of C_p are listed, this indicates that the windward roof slope is subjected to either positive or negative pressures and the roof structure shall be designed for both conditions. Interpolation for intermediate ratios of h/L in this case shall only be carried out between C_p values of like sign.
4. For monoslope roofs, entire roof surface is either a windward or leeward surface.
5. For flexible buildings use appropriate G_f as determined by Section 207B.9.4.
6. Refer to Figure 207B.4-2 for domes and Figure 207B.4-3 for arched roofs.
7. Notation:
   - B = horizontal dimension of building, m, measured normal to wind direction.
   - L = horizontal dimension of building, m, measured parallel to wind direction.
   - h = mean roof height in meters, except that eave height shall be used for $\theta \leq 10°$
   - z = height above ground, m
   - G = gust effect factor.
   - q_z, q_h = velocity pressure, (N/m^2), evaluated at respective height.
   - θ = Angle of plane of roof from horizontal, °
8. For mansard roofs, the top horizontal surface and leeward inclined surface shall be treated as leeward surfaces from the table.
9. Except for MWFRS at the roof consisting of moment resisting frames, the total horizontal shear shall not be less than that determined by neglecting wind forces on roof surfaces.
10. For roof slopes greater than 80°, use $C_p = 0.8$



External Pressure Coefficients for Domes with a Circular Base
(Adapted from Eurocode, 1995)

Notes:

1. Two load cases shall be considered:

   Case A: C_p values between A and B and between B and C shall be determined by linear interpolation along arcs on the dome parallel to the wind direction;

   Case B: C_p shall be the constant value of A for $\theta \leq 25°$, and shall be determined by linear interpolation from 25° to B and from B to C.

2. Values denote C_p to be used with $q_{(hD+f)}$ where $hD + f$ is the height at the top of the dome.
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. C_p is constant on the dome surface for arcs of circles perpendicular to the wind direction; for example, the arc passing through B-B-B and all arcs parallel to B-B-B.
5. For values of hD/D between those listed on the graph curves, linear interpolation shall be permitted.
6. $\theta = 0°$ on dome spring line, $\theta = 90°$ at dome center top point. f is measured from spring line to top.
7. The total horizontal shear shall not be less than that determined by neglecting wind forces on roof surfaces.
8. For f/D values less than 0.05, use Figure 207B.4-1.

Figure 207B.4-2
External Pressure Coefficients, C_p, Domed Roofs Enclosed, Partially Enclosed Buildings

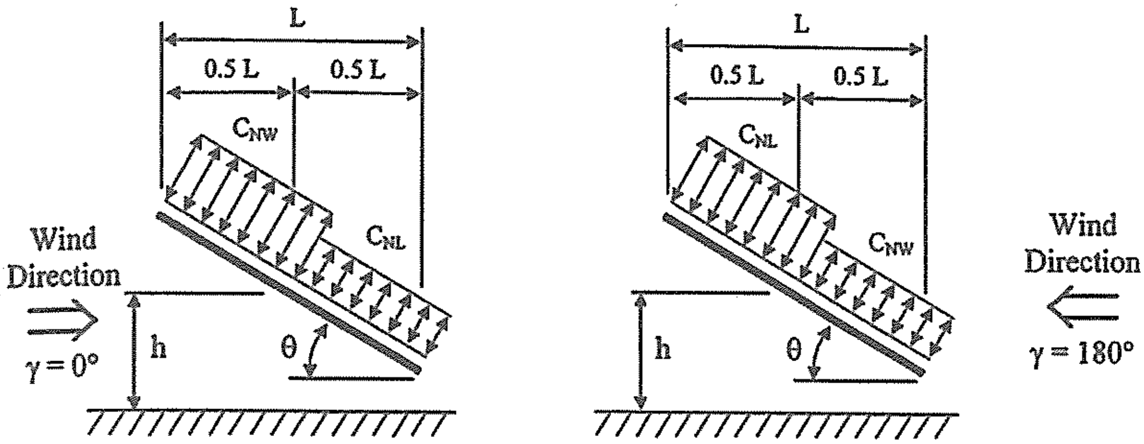
Conditions	**Rise-to-span ratio, r**	C_p		
		Windward quarter	**Center half**	**Leeward quarter**
Roof on elevated structure	$0 < r < 0.2$	-0.9	$-0.7-r$	-0.5
	$0.2 \leq r < 0.3$ *	$1.5r - 0.3$	$-0.7-r$	-0.5
	$0.3 \leq r \leq 0.6$	$2.75r - 0.7$	$-0.7-r$	-0.5
Roof springing from ground level	$0 < r \leq 0.6$	$1.4r$	$-0.7-r$	-0.5

**When the rise-to-span ratio is* $\mathbf{0.2 \leq r \leq 0.3}$*, alternate coefficients given by* $\mathbf{6r - 2.1}$ *shall also be used for the windward quarter.*

Notes:

1. Values listed are for the determination of average loads on main wind force resisting systems.
2. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
3. For wind directed parallel to the axis of the arch, use pressure coefficients from Figure 207B.4-1 with wind directed parallel to ridge.
4. For components and cladding: (1) At roof perimeter, use the external pressure coefficients in Figure 207E.4-2A, B and C with θ based on spring-line slope and (2) for remaining roof areas, use external pressure coefficients of this table multiplied by 0.87.

Figure 207B.4-3
External Pressure Coefficients, C_p, Arched Roofs, $0.25 \leq h/L \leq 1.0$
Enclosed, Partially Enclosed Buildings



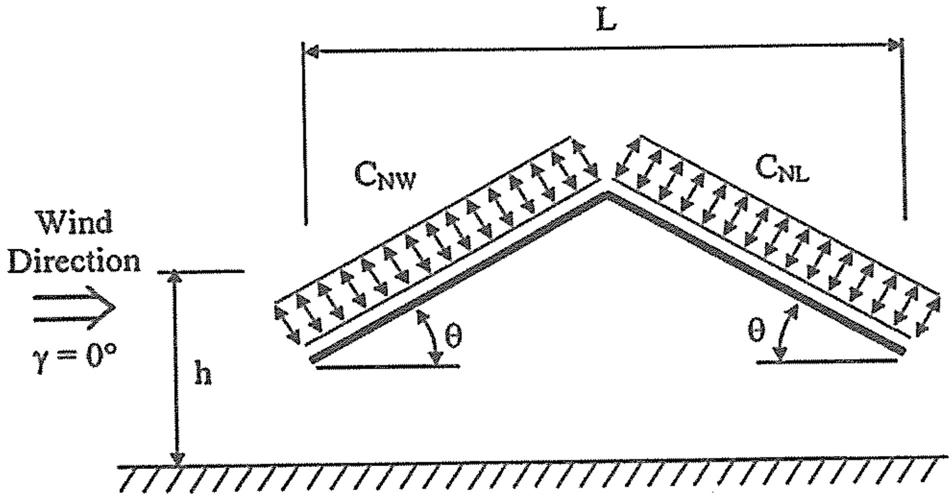
Roof Angle θ	Load Case	Wind Direction, $\gamma = 0^o$				Wind Direction, $\gamma = 180^o$			
		Clear Wind Flow		Obstructed Wind Flow		Clear Wind Flow		Obstructed Wind Flow	
		C_{NW}	C_{NL}	C_{NW}	C_{NL}	C_{NW}	C_{NL}	C_{NW}	C_{NL}
0^o	A	1.2	0.3	-0.5	-1.2	-1.2	0.3	-0.5	-1.2
	B	-1.1	-0.1	-1.1	-0.6	-1.1	-0.1	-1.1	-0.6
7.5^o	A	-0.6	-1	-1	-1.5	0.9	1.5	-0.2	-1.2
	B	-1.4	0	-1.7	-0.8	1.6	0.3	0.8	-0.3
15^o	A	-0.9	-1.3	-1.1	-1.5	1.3	1.6	0.4	-1.1
	B	-1.9	0	-2.1	-0.6	1.8	0.6	1.2	-0.3
22.5^o	A	-.15	-1.6	-1.5	-1.7	1.7	1.8	0.5	-1
	B	-2.4	-0.3	-2.3	-0.9	2.2	0.7	1.3	0
30^o	A	-1.8	-1.8	-1.5	-1.8	2.1	2.1	0.6	-1
	B	-2.5	-0.5	-2.3	-1.1	2.6	1	1.6	0.1
37.5^o	A	-1.8	-1.8	-1.5	-1.8	2.1	2.2	0.7	-0.9
	B	-2.4	-0.6	-2.2	-1.1	2.7	1.1	1.9	0.3
45^o	A	-1.6	-1.8	-1.3	-1.8	2.2	2.5	0.8	-0.9
	B	-2.3	-0.7	-1.9	-1.2	2.6	1.4	2.1	0.4

Notes:

1. C_{NW} and C_{NL} denote net pressures (contributions from top and bottom surfaces) for windward and leeward half of roof surfaces, respectively.
2. Clear wind flow denotes relatively unobstructed wind flow with blockage less than or equal to **50%**. Obstructed wind flow denotes objects below roof inhibiting wind flow (> 50% blockage).
3. For values of θ between 7.5° and 45°, linear interpolation is permitted. For values of θ less than 7.5°, use load coefficients for 0°.
4. Plus and minus signs signify pressures acting towards and away from the top roof surface, respectively.
5. All load cases shown for each roof angle shall be investigated.
6. Notation:

L = horizontal dimension of roof, measured in the along wind direction, m
h = mean roof height, m
γ = direction of wind, °
θ = angle of plane of roof from horizontal, °

Figure 207B.4-4
Net Pressure Coefficient, C_N Monoslope Free Roofs $\theta \leq 45^o$, $\gamma = 0^o, 180^o$
$0.25 \leq h/L \leq 1.0$ Open Buildings



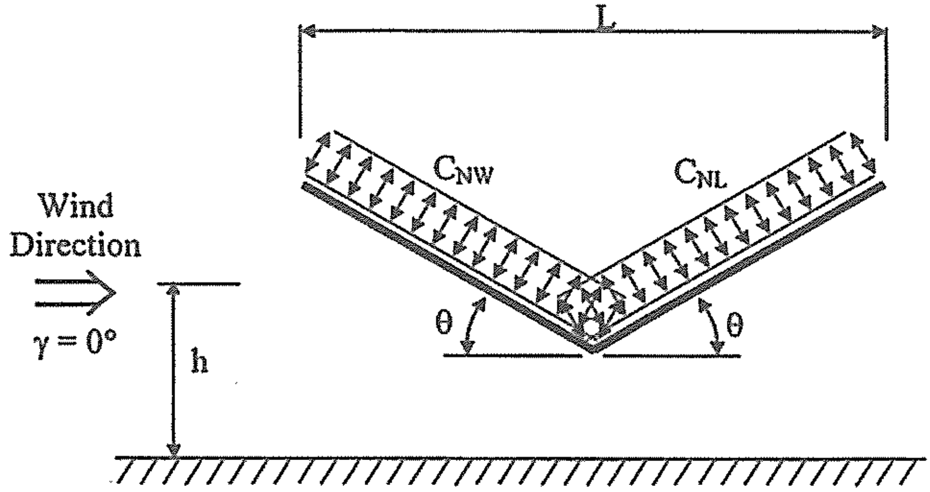
Roof Angle θ	Load Case	Wind Direction, $\gamma = 0^o, 180^o$			
		Clear Wind Flow		Obstructed Wind Flow	
		C_{NW}	C_{NL}	C_{NW}	C_{NL}
7.5^o	A	1.1	-0.3	-1.6	-1
	B	0.2	-1.2	-0.9	-1.7
15^o	A	1.1	-0.4	-1.2	-1
	B	0.1	-1.1	-0.6	-1.6
22.5^o	A	1.1	0.1	-1.2	-1.2
	B	-0.1	-0.8	-0.8	-1.7
30^o	A	1.3	0.3	-0.7	-0.7
	B	-0.1	-0.9	-0.2	-1.1
37.5^o	A	1.3	0.6	-0.6	-0.6
	B	-0.2	-0.6	-0.3	-0.9
45^o	A	1.1	0.9	-0.5	-0.5
	B	-0.3	-0.5	-0.3	-0.7

Notes:

1. C_{NW} and C_{NL} denote net pressures (contributions from top and bottom surfaces) for windward and leeward half of roof surfaces, respectively.
2. Clear wind flow denotes relatively unobstructed wind flow with blockage less than or equal to **50%**. Obstructed wind flow denotes objects below roof inhibiting wind flow (> 50% blockage).
3. For values of θ between 7.5° and 45°, linear interpolation is permitted. For values of θ less than 7.5°, use monoslope roof load coefficients.
4. Plus and minus signs signify pressures acting towards and away from the top roof surface, respectively.
5. All load cases shown for each roof angle shall be investigated.
6. Notation:

L = horizontal dimension of roof, measured in the along wind direction, m
h = mean roof height, m
γ = direction of wind, °
θ = angle of plane of roof from horizontal, °

Figure 207B.4-5
Net Pressure Coefficient, C_N Pitched Free Roofs $\theta \leq 45^o, \gamma = 0^o, 180^o$
$0.25 \leq h/L \leq 1.0$ Open Buildings



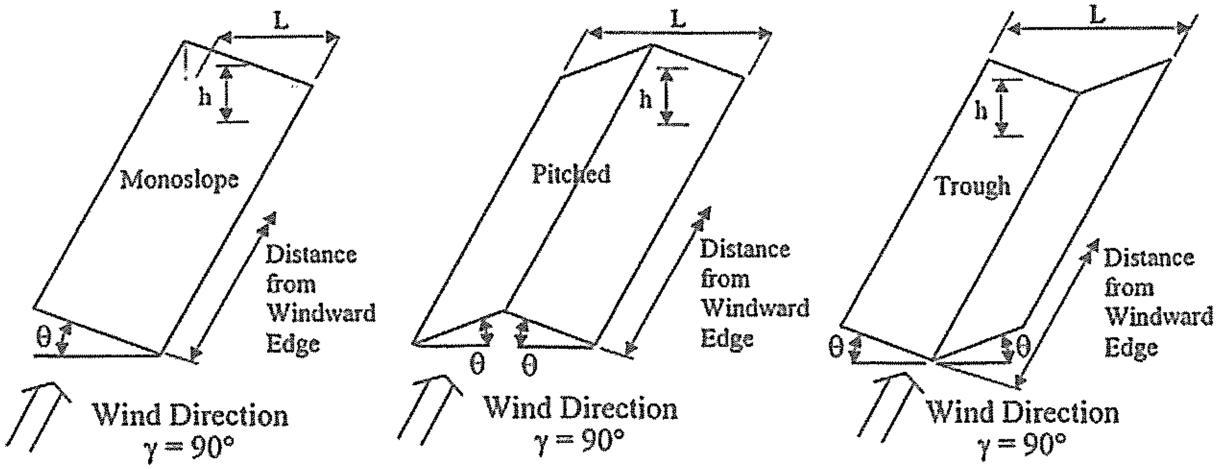
Roof Angle θ	Load Case	Wind Direction, $\gamma = 0^o, 180^o$			
		Clear Wind Flow		Obstructed Wind Flow	
		C_{NW}	C_{NL}	C_{NW}	C_{NL}
7.5^o	A	-1.1	0.3	-1.6	-0.5
	B	-0.2	1.2	-0.9	-0.8
15^o	A	-1.1	0.4	-1.2	-0.5
	B	0.1	1.1	-0.6	-0.8
22.5^o	A	-1.1	-0.1	-1.2	-0.6
	B	-0.1	0.8	-0.8	-0.8
30^o	A	-1.3	-0.3	-1.4	-0.4
	B	-0.1	0.9	-0.2	-0.5
37.5^o	A	-1.3	-0.6	-1.4	-0.3
	B	0.2	0.6	-0.3	-0.4
45^o	A	-1.1	-0.9	-1.2	-0.3
	B	0.3	0.5	-0.3	-0.4

Notes:

1. C_{NW} and C_{NL} denote net pressures (contributions from top and bottom surfaces) for windward and leeward half of roof surfaces, respectively.
2. Clear wind flow denotes relatively unobstructed wind flow with blockage less than or equal to **50%**. Obstructed wind flow denotes objects below roof inhibiting wind flow (> 50% blockage).
3. For values of θ between 7.5° and 45°, linear interpolation is permitted. For values of θ less than 7.5°, use monoslope roof load coefficients.
4. Plus and minus signs signify pressures acting towards and away from the top roof surface, respectively.
5. All load cases shown for each roof angle shall be investigated.
6. Notation:

L = horizontal dimension of roof, measured in the along wind direction, m
h = mean roof height, m
γ = direction of wind, °
θ = angle of plane of roof from horizontal, °

Figure 207B.4-6
Net Pressure Coefficient, C_N Troughed Free Roofs $\theta \leq 45^o, \gamma = 0^o, 180^o$
$0.25 \leq h/L \leq 1.0$ Open Buildings



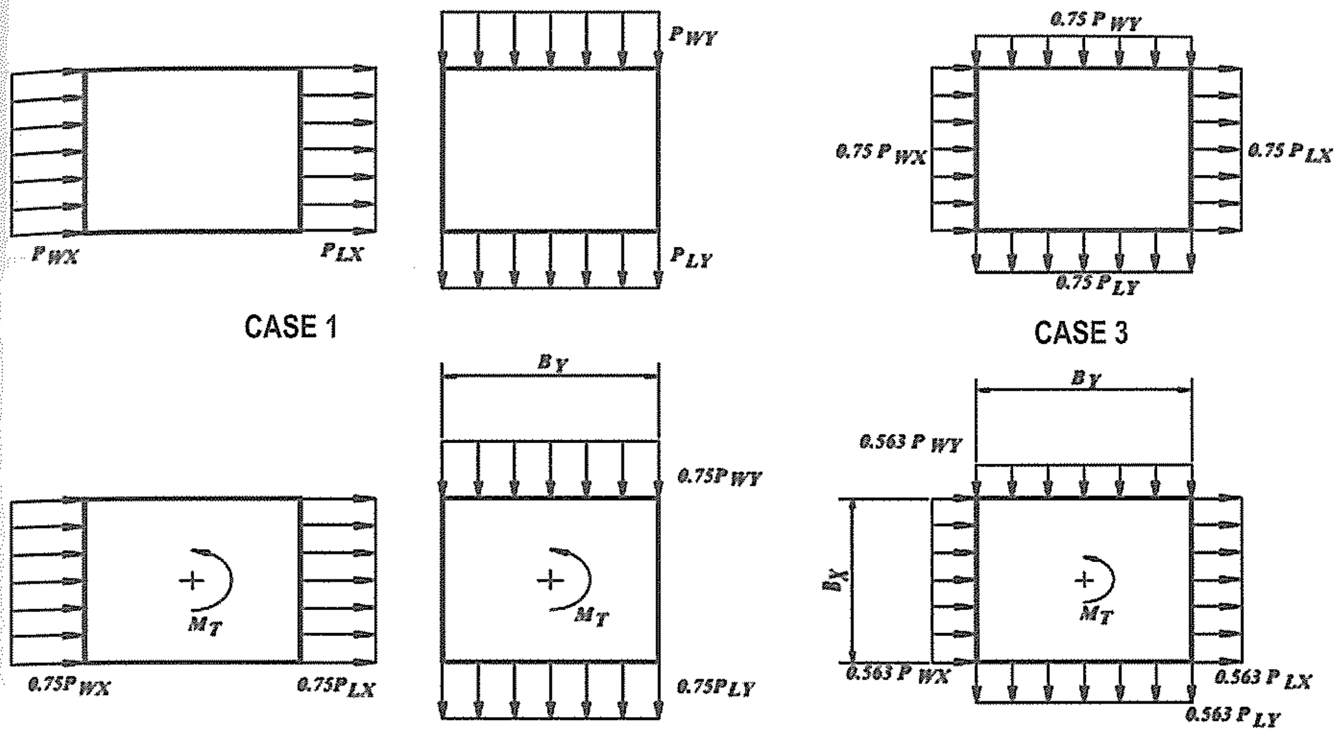
Horizontal Distance from Windward Edge	Roof Angle θ	Load Case	Clear Wind Flow C_{NW}	Obstructed Wind Flow C_{NL}
$\leq h$	All Shapes	A	-0.8	1.2
	$\theta \leq 45^o$	B	0.8	0.5
$> h, \leq 2h$	All Shapes	A	-0.6	-0.9
	$\theta \leq 45^o$	B	0.5	0.5
$> 2h$	All Shapes	A	-0.3	-0.6
	$\theta \leq 45^o$	B	0.3	0.3

Notes:

1. CN denotes net pressures (contributions from top and bottom surfaces).
2. Clear wind flow denotes relatively unobstructed wind flow with blockage less than or equal to **50%**. Obstructed wind flow denotes objects below roof inhibiting wind flow (> 50% blockage).
3. Plus and minus signs signify pressures acting towards and away from the top roof surface, respectively.
4. All load cases shown for each roof angle shall be investigated.
5. For monoslope roofs with theta less than 5 degrees, C_N values shown apply also for cases where gamma = 0 degrees and 0.05 less than or equal to h/L less than or equal to 0.25. See Figure 207B.4-4 for other h/L values.
6. Notation:

L = horizontal dimension of roof, measured in the along wind direction, m
h = mean roof height, m. See Figures 207B.4-4, 207B.4-5 or 207B.4-6 for a graphical depiction of this dimension.
γ = direction of wind, °
θ = angle of plane of roof from horizontal, °

Figure 207B.4-7
Net Pressure Coefficient, C_N Free Roofs $\theta \leq 45^o, \gamma = 90^o, 270^o$
$0.25 \leq h/L \leq 1.0$ Open Buildings



$M_T = 0.75\ (P_{WX}+P_{LX})B_X e_X$ $\quad$ $M_T = 0.75\ (P_{WY}+P_{LY})B_Y e_Y$ $\quad$ $M_T = 0.563\ (P_{WX}+P_{LX})B_X e_X + 0.563\ (P_{WY}+P_{LY})B_Y e_Y$

$e_X = \pm\ 0.15\ B_X$ $\quad$ $e_Y = \pm\ 0.15\ B_Y$ $\quad$ $e_X = \pm\ 0.15\ B_X$ $\quad$ $e_Y = \pm\ 0.15\ B_Y$

CASE 2 CASE 4

Case 1: Full design wind pressure acting on the projected area perpendicular to each principal axis of the structure, considered separately along each principal axis.

Case 2: Three quarters of the design wind pressure acting on the projected area perpendicular to each principal axis of the structure in conjunction with a torsional moment as shown, considered separately for each principal axis.

Case 3: Wind loading as defined in Case 1, but considered to act simultaneously at 75% of the specified value.

Case 4: Wind loading as defined in Case 2, but considered to act simultaneously at 75% of the specified value.

Notes:

1. Design wind pressures for windward and leeward faces shall be determined in accordance with the provisions of 207B.4.1 and 207B.4.2 as applicable for building of all heights.
2. Diagrams show plan views of building.
3. Notation:

P_{WX},P_{WY}	=	Windward face design pressure acting in the x, y principal axis, respectively.
P_{LX},P_{LY}	=	Leeward face design pressure acting in the x, y principal axis, respectively.
$e(e_X, e_Y)$	=	Eccentricity for the x, y principal axis of the structure, respectively.
M_T	=	Torsional moment per unit height acting about a vertical axis of the building.

Figure 207B.4-8
Design Wind Load Cases All Heights

Part 2: Enclosed Simple Diaphragm Buildings with $h = 48$ m

This section has been added to ASCE 7-10 to cover the common practical cases of enclosed simple diaphragm buildings up to height $h = 48\,m$*. Two classes of buildings are covered by this method. Class 1 buildings have* $h \leq 18\,m$ *with plan aspect ratios* L/B *between 0.2 and 5.0. Cases A through F are described in Appendix D, ASCE 7-10 to allow the designer to establish the lines of resistance of the MWFRS in each direction so that the torsional load cases of Figure 207B.4-8 need not be considered. Class 2 buildings have* $18\,m < h \leq 48\,m$ *with plan aspect ratios of* L/B *between 0.5 and 2.0. Cases A through E of Appendix D, ASCE 7-10 are described to allow the designer to establish the lines of resistance of the MWFRS so that the torsional load cases of Figure 207B.4-8 need not be considered.*

For the type of buildings covered in this method, the internal building pressure cancels out and need not be considered for the design of the MWFRS. Design net wind pressures for roofs and walls are tabulated directly in Tables 207B.6-1 and 207B.6-2 using the Directional Procedure as described in Part 1. Guidelines for determining the exterior pressures on windward, leeward, and side walls are provided in footnotes to Table 207B.6-1.

The requirements in Class 2 buildings for natural building frequency $(75/h)$ *and structural damping* ($\beta =$ *1.5% critical) are necessary to ensure that the Gust Effect Factor,* G_f*, which has been calculated and built into the design procedure, is consistent with the tabulated pressures. The frequency of* $75/h$ *represents a reasonable lower bound to values found in practice. If calculated frequencies are found to be lower, then consideration should be given to stiffening the building. A structural damping value of 1.5 %, applicable at the ultimate wind speeds as defined in the new wind speed maps, is conservative for most common building types and is consistent with a damping value of 1% for the ultimate wind speeds divided by* 1.6 *as contained in the NSCP 2010 (ASCE 7-05) wind speed map. Because Class 1 buildings are limited to* $h \leq 18\,m$*, the building can be assumed to be rigid as defined in the glossary, and the Gust Effect Factor can be assumed to be 0.85. For this class of buildings frequency and damping need not be considered.*

207B.5 General Requirements

207B.5.1 Design Procedure

The procedure specified herein applies to the determination of MWFRS wind loads of enclosed simple diaphragm buildings, as defined in Section 207A.2, with a mean roof height $h \leq 48$ m. The steps required for the determination of MWFRS wind loads on enclosed simple diaphragm buildings are shown in Table 207B.5-1.

> *User Note:*
>
> *Part 2 of Section 207B is a simplified method for determining the wind pressures for the MWFRS of enclosed, simple diaphragm buildings whose height h is ≤ 4 m. The wind pressures are obtained directly from a table. The building may be of any general plan shape and roof geometry that matches the specified figures. This method is a simplification of the traditional "all heights" method (Directional Procedure) contained in Part 1 of Section 207B.*

Table 207B.5-1
Steps to Determine MWFRS Wind Loads Enclosed Simple Diaphragm Buildings
($h \leq 48$ m)

Step 1:	Determine risk category of building or other structure, see Table 103-1
Step 2:	Determine the basic wind speed, V, for the applicable risk category, see Figure 207A.5-1A, B or C
Step 3:	Determine wind load parameters: ➢ Wind directionality factor, K_d, see Section 207A.6 and Table 207A.6-1 ➢ Exposure category B, C or D, see Section 207A.7 ➢ Topographic factor, K_{zt}, see Section 207A.8 and Figure 207A.8-1 ➢ Enclosure classification, see Section 207A.10
Step 4:	Enter table to determine net pressures on walls at top and base of building respectively, p_h , p_o, Table 207B.6-1
Step 5:	Enter table to determine net roof pressures, p_z, Table 207B.6-2
Step 6:	Determine topographic factor, K_{zt}, and apply factor to wall and roof pressures (if applicable), see Section 207A.8
Step 7:	Apply loads to walls and roofs simultaneously.

207B.5.2 Conditions

In addition to the requirements in Section 207B.1.2, a building whose design wind loads are determined in accordance with this section shall meet all of the following conditions for either a Class 1 or Class 2 building (see Figure 207B.5-1):

Class 1 Buildings:

1. The building shall be an enclosed simple diaphragm building as defined in Section 207A.2.

2. The building shall have a mean roof height $h \leq$ 18 m.

3. The ratio of L/B shall not be less than 0.2 nor more than 5.0 ($0.2 \leq L/B \leq 5.0$).

4. The topographic effect factor $K_{zt} = 1.0$ or the wind pressures determined from this section shall be multiplied by K_{zt} at each height z as determined from Section 207A.8. It shall be permitted to use one value of K_{zt} for the building calculated at $0.33h$. Alternatively it shall be permitted to enter the pressure table with a wind velocity equal to $V\sqrt{K_{zt}}$ where K_{zt} is determined at a height of $0.33h$.

Class 2 Buildings:

1. The building shall be an enclosed simple diaphragm building as defined in Section 207A.2.

2. The building shall have a mean roof height 18 m (18 m < $h \leq$ 48 m).

3. The ratio of L/B shall not be less than 0.5 nor more than 2.0 ($0.5 \leq L/B \leq 2.0$).

4. The fundamental natural frequency (Hertz) of the building shall not be less $75/h$ where h is in meters.

5. The topographic effect factor $K_{zt} = 1.0$ or the wind pressures determined from this section shall be multiplied by K_{zt} at each height z as determined from Section 207A.8. It shall be permitted to use one value of K_{zt} for the building calculated at $0.33h$. Alternatively it shall be permitted to enter the pressure table with a wind velocity equal to $V\sqrt{K_{zt}}$ where K_{zt} is determined at a height of $0.33h$.

207B.5.3 Wind Load Parameters Specified in Section 207A

Refer to Section 207A for determination of Basic Wind Speed V (Section 207A.5) and exposure category (Section 207A.7) and topographic factor K_{zt} (Section 207A.8).

207B.5.4 Diaphragm Flexibility

The design procedure specified herein applies to buildings having either rigid or flexible diaphragms. The structural analysis shall consider the relative stiffness of diaphragms and the vertical elements of the MWFRS.

Diaphragms constructed of wood panels can be idealized as flexible. Diaphragms constructed of untopped metal decks, concrete filled metal decks, and concrete slabs, each having a span-to-depth ratio of 2 or less, are permitted to be idealized as rigid for consideration of wind loading.

207B.6 Wind Loads—Main Wind Force-Resisting System

207B.6.1 Wall and Roof Surfaces—Class 1 and 2 Buildings

Net wind pressures for the walls and roof surfaces shall be determined from Tables 207B.6-1 and 207B.6-2, respectively, for the applicable exposure category as determined by Section 207A.7.

For Class 1 building with L/B values less than 0.5, use wind pressures tabulated for $L/B = 0.5$. For Class 1 building with L/B values greater than 2.0, use wind pressures tabulated for $L/B = 2.0$.

Net wall pressures shall be applied to the projected area of the building walls in the direction of the wind, and exterior side wall pressures shall be applied to the projected area of the building walls normal to the direction of the wind acting outward according to Note 3 of Table 207B.6-1, simultaneously with the roof pressures from Table 207B.6-2 as shown in Figure 207B.6-1.

Where two load cases are shown in the table of roof pressures, the effects of each load case shall be investigated separately. The MWFRS in each direction shall be designed for the wind load cases as defined in Figure 207B.4-8.

Exception:

The torsional load cases in Figure 207B.4-8 (Case 2 and Case 4) need not be considered for buildings which meet the requirements of Appendix D, ASCE 7-10.

Commentary:

Wall and roof net pressures are shown in Tables 207B.6-1 and 207B.6-2 and are calculated using the external pressure coefficients in Figure 207B.4-1. Along wind net wall pressures are applied to the projected area of the building walls in the direction of the wind, and exterior sidewall pressures are applied to the projected area of the building walls normal to the direction of the wind acting outward, simultaneously with the roof pressures from Table 207B.6-2. Distribution of the net wall pressures between windward and leeward wall surfaces is defined in Note 4 of Table 207B.6-1. The magnitude of exterior sidewall pressure is determined from Note 2 of Table 207B.6-1. It is to be noted that all tabulated pressures are defined without consideration of internal pressures because internal pressures cancel out when considering the net effect on the MWFRS of simple diaphragm buildings. Where the net wind pressure on any individual wall surface is required, internal pressure must be included as defined in Part 1 of Section 207B.

The distribution of wall pressures between windward and leeward wall surfaces is useful for the design of floor and roof diaphragm elements like drag strut collector beams, as well as for MWFRS wall elements. The values defined in Note 4 of Table 207B.6-1 are obtained as follows: The external pressure coefficient for all windward walls is $C_p = 0.8$ *for all* L/B *values. The leeward wall* C_p *value is (–0.5) for* L/B *values from 0.5 to 1.0 and is (–0.3) for* $L/B = 2.0$*. Noting that the leeward wall pressure is constant for the full height of the building, the leeward wall pressure can be calculated as a percentage of the* p_h *value in the table. The percentage is 0.5/(0.8 + 0.5) × 100 = 38% for* $L/B = 0.5$ *to 1.0. The percentage is 0.3/(0.8+0.3) x 100 = 27% for* $L/B = 2.0$*. Interpolation between these two percentages can be used for* L/B *ratios between 1.0 and 2.0. The windward wall pressure is then calculated as the difference between the total net pressure from the table using the* p_h *and* p_0 *values and the constant leeward wall pressure.*

Sidewall pressures can be calculated in a similar manner to the windward and leeward wall pressures by taking a percentage of the net wall pressures. The C_p *value for sidewalls is (–0.7). Thus, for* $L/B = 0.5$ *to 1.0, the percentage is 0.7/(0.8 + 0.5) × 100 = 54%. For* $L/B = 2.0$*, the percentage is 0.7/(0.8 + 0.3) × 100 = 64%. Note that the sidewall pressures are constant up the full height of the building.*

The pressures tabulated for this method are based on simplifying conservative assumptions made to the different pressure coefficient (GC_p) *cases tabulated in Figure 207B.4-1, which is the basis for the traditional all heights building procedure (defined as the Directional Procedure in this code) that has been a part of the standard since 1972. The external pressure coefficients* C_p *for roofs have been multiplied by 0.85, a reasonable gust effect factor for most common roof framing, and then combined with an internal pressure coefficient for enclosed buildings (plus or minus 0.18) to obtain a net pressure coefficient to serve as the basis for pressure calculation. The linear wall pressure diagram has been conceived so that the applied pressures from the table produce the same overturning moment as the more exact pressures from Part 1 of Section 207B. For determination of the wall pressures tabulated, the actual gust effect factor has been calculated from Equation 207A.9-10 based on building height, wind speed, exposure, frequency, and the assumed damping value.*

207B.6.2 Parapets

The effect of horizontal wind loads applied to all vertical surfaces of roof parapets for the design of the MWFRS shall be based on the application of an additional net horizontal wind pressure applied to the projected area of the parapet surface equal to 2.25 times the wall pressures tabulated in Table 207B.6-1 for $L/B = 1.0$. The net pressure specified accounts for both the windward and leeward parapet loading on both the windward and leeward building surface. The parapet pressure shall be applied simultaneously with the specified wall and roof pressures shown in the table as shown in Figure 207B.6-2. The height h used to enter Table 207B.6-1 to determine the parapet pressure shall be the height to the top of the parapet as shown in Figure 207B.6-2 (use $h = h_p$).

Commentary:

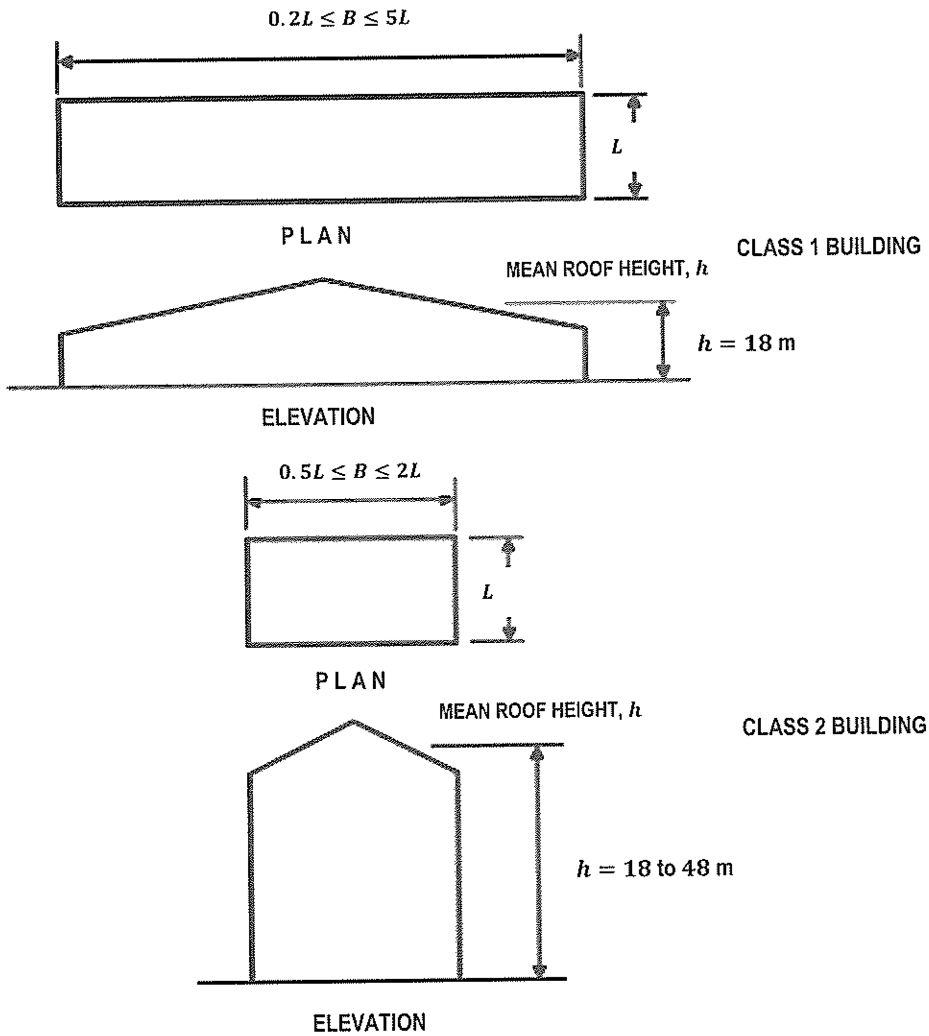
The effect of parapet loading on the MWFRS is specified in Section 207B.4.5 of Part 1. The net pressure coefficient for the windward parapet is +1.5 and for the leeward parapet is −1.0. The combined effect of both produces a net coefficient of +2.5 applied to the windward surface to account for the cumulative effect on the MWFRS in a simple diaphragm building. This pressure coefficient compares to a net pressure coefficient of $1.3G_f$ *for the tabulated horizontal wall pressure* p_h *at the top of the building. Assuming a lower-bound gust factor* $G_f = 0.85$*, the ratio of the parapet pressure to the wall pressure is 2.5/(0.85×1.3) = 2.25. Thus, a value of 2.25 is assumed as a reasonable constant to apply to the tabulated wall pressure* p_h *to account for the additional parapet loading on the MWFRS.*

207B.6.3 Roof Overhangs

The effect of vertical wind loads on any roof overhangs shall be based on the application of a positive wind pressure on the underside of the windward overhang equal to 75% of the roof edge pressure from Table 207B.6-2 for Zone 1 or Zone 3 as applicable. This pressure shall be applied to the windward roof overhang only and shall be applied simultaneously with other tabulated wall and roof pressures as shown in Figure 207B.6-3.

Commentary:

The effect of vertical wind loading on a windward roof overhang is specified in Section 207B.4.4 of Part 1. A positive pressure coefficient of +0.8 is specified. This compares to a net pressure coefficient tabulated for the windward edge zone 3 of −1.06 (derived from 0.85 × −1.3 × 0.8 − 0.18). The 0.85 factor represents the gust factor G*, the 0.8 multiplier accounts for the effective wind area reduction to the 1.3 value of* C_p *specified in Figure 207B.4-1 of Part 1, and the −0.18 is the internal pressure contribution. The ratio of coefficients is 0.8/1.06 = 0.755. Thus, a multiplier of 0.75 on the tabulated pressure for zone 3 in Table 207B.6-2 is specified.*



Note: Roof form may be flat, gable, mansard or hip

Figure 207B.5-1
Building Geometry Requirements Building Class, $h \leq 48$ m
Enclosed Simple Diaphragm Buildings

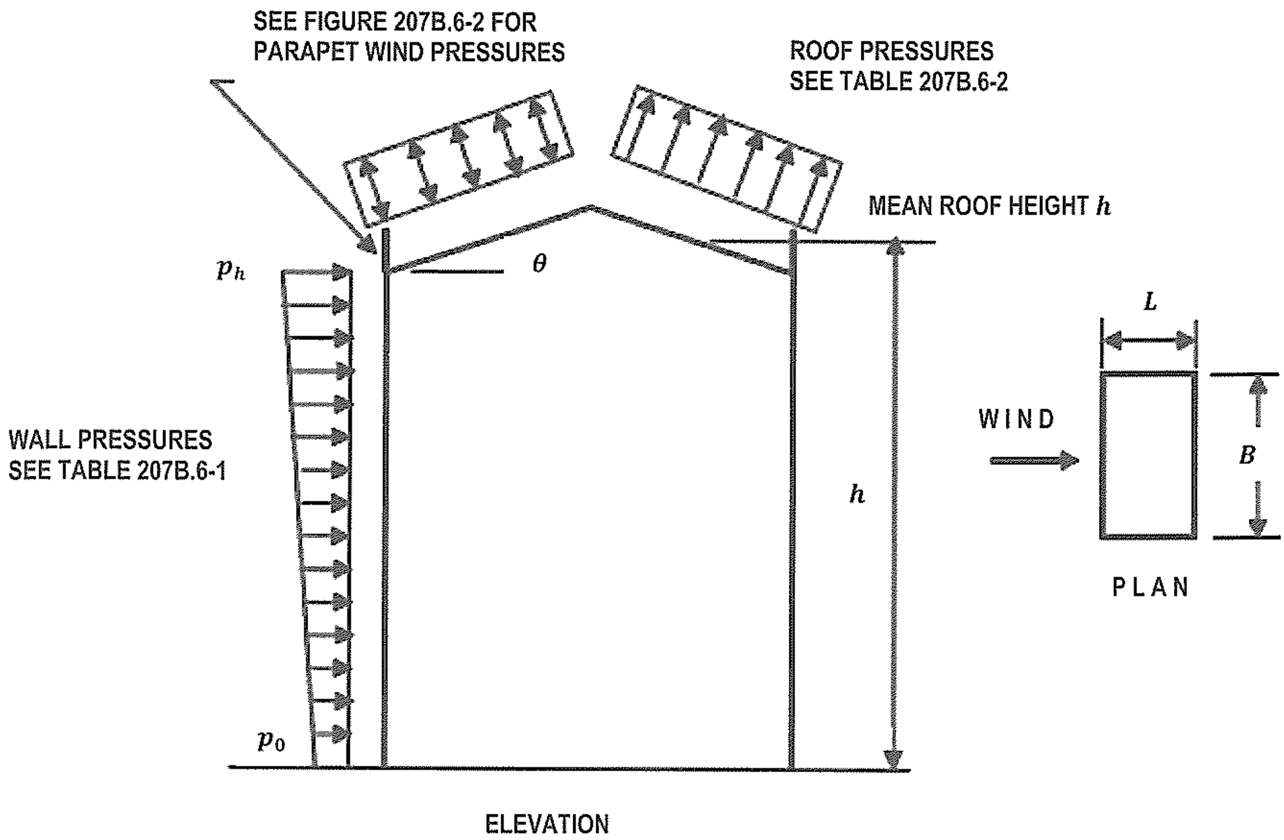


Figure 207B.6-1
Application of Wind Pressures Wind Pressures – Walls and Roof, $h \leq 48$ m
Enclosed Simple Diaphragm Buildings

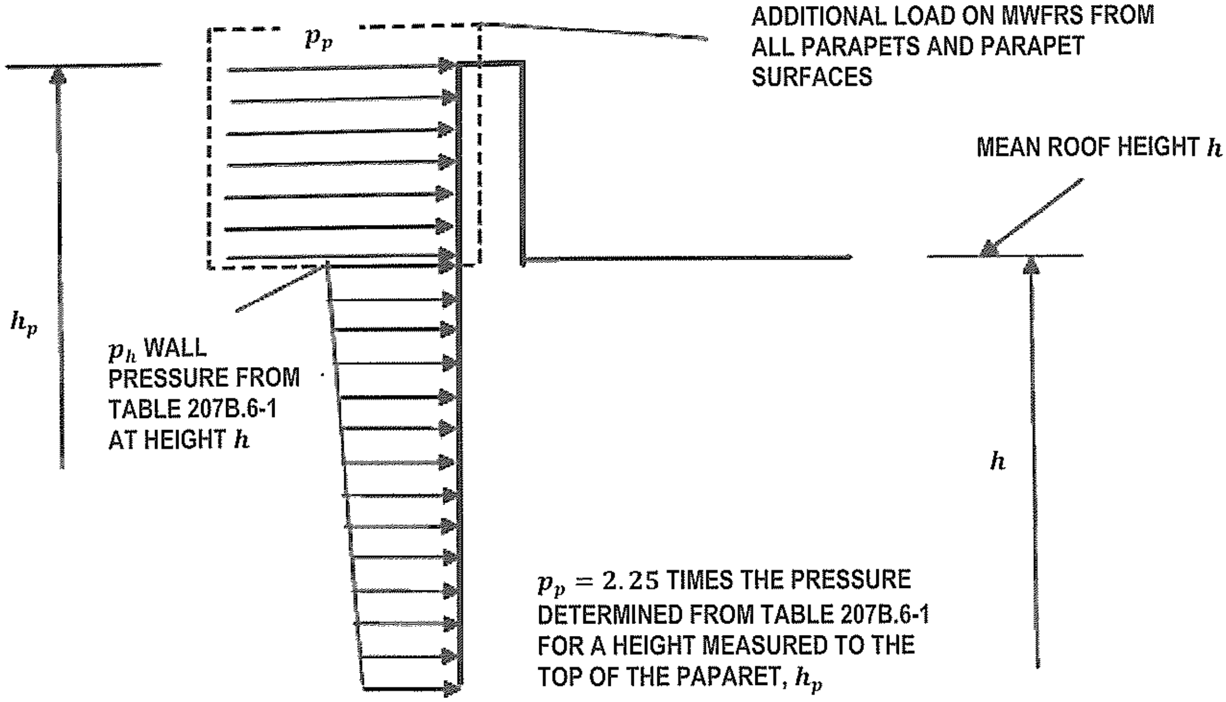


Figure 207B.6-2
Application of Parapet Wind Loads Parapet Wind Loads, $h \leq 48$ m
Enclosed Simple Diaphragm Buildings

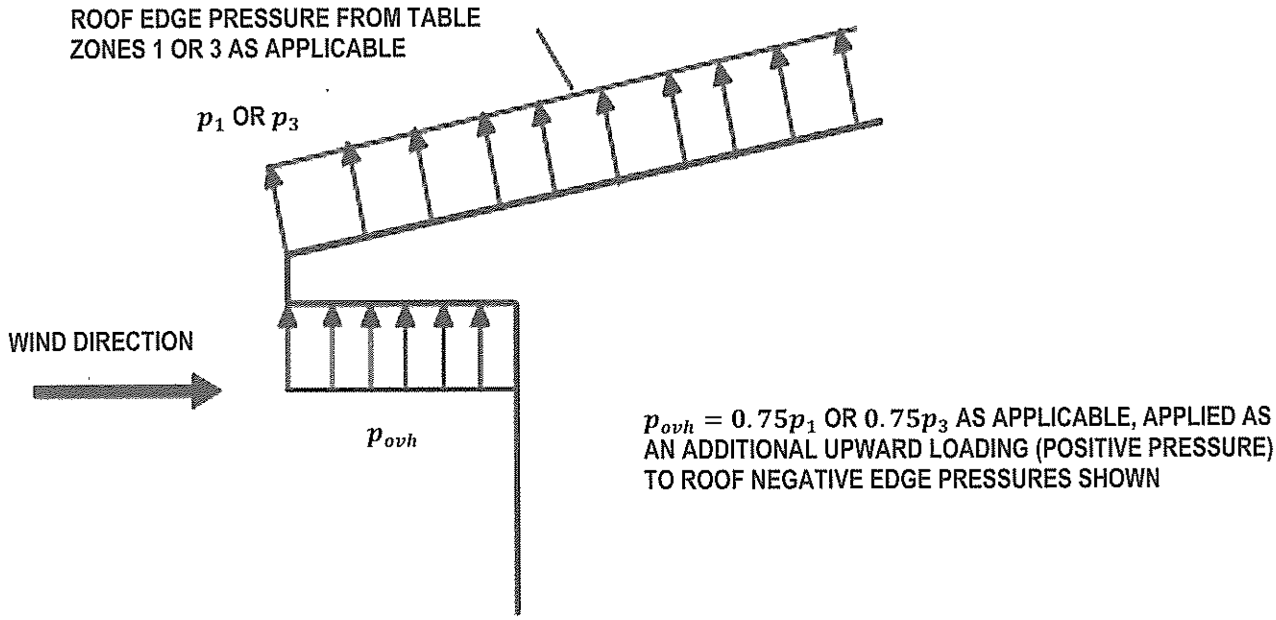
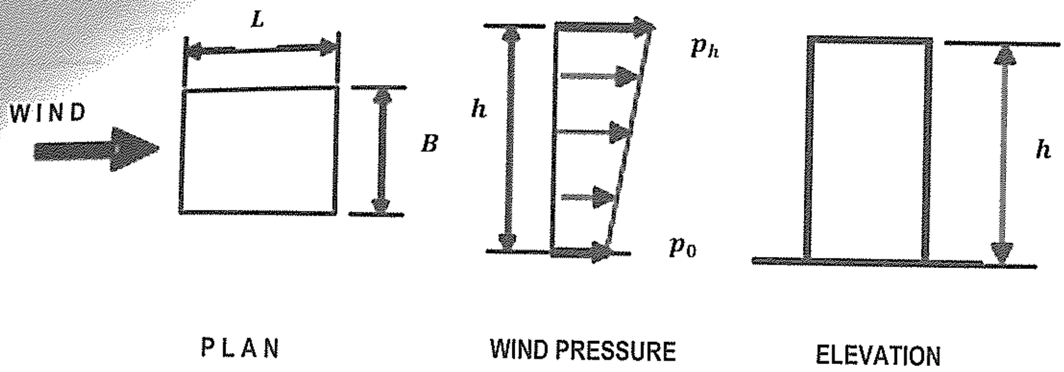


Figure 207B.6-3
Application of Roof Overhang Roof Overhang Wind Loads, $h \leq 48$ m
Enclosed Simple Diaphragm Buildings



Notes to Wall Pressure Table 207B.6-1:

1. From table for each Exposure (B, C or D), V, L/B and h, determine p_h (top number) and p_o (bottom number) horizontal along-wind net wall pressures.
2. Side wall external pressures shall be uniform over the wall surface acting outward and shall be taken as 54% of the tabulated p_h pressure for $0.2 \leq L/B \leq 1.0$ and 64% of the tabulated p_h pressure for $2.0 \leq L/B \leq 5.0$. Linear interpolation shall apply for $1.0 < L/B < 2.0$. Side wall external pressures do not include effect of internal pressure.
3. Apply along-wind net wall pressures as shown above to the projected area of the building walls in the direction of the wind and apply external side wall pressures to the projected area of the building walls normal to the direction wind, simultaneously with the roof pressures from Table 207B.6-2.
4. Distribution of tabulated net wall pressures between windward and leeward wall faces shall be based on the linear distribution of total net pressure with building height as shown above and the leeward external wall pressures assumed uniformly distributed over the leeward wall surface acting outward at 38% of p_h for $0.2 \leq L/B \leq 1.0$ and 27% of p_h for $2.0 \leq L/B \leq 5.0$. Linear interpolation shall be used for $1.0 < L/B < 2.0$. The remaining net pressure shall be applied to the windward walls as an external wall pressure acting towards the wall surface. Windward and leeward wall pressures so determined do not include effect of internal pressure.
5. Interpolation between values of V, h and L/B is permitted.

Notation:

L	=	building plan dimension parallel to wind direction, m
B	=	building plan dimension perpendicular to wind direction, m
h	=	mean roof height, m
p_h, p_o	=	along-wind net wall pressure at top and base of building respectively, Pa

Figure 207B.6-1
Application of Wall Pressures Wind Pressures - Walls, $h \leq 48$ m
Enclosed Simple Diaphragm Buildings

Table 207B.6-1
MWFRS – Part 2: Wind Loads – Walls (kN/m^2)
Exposure B

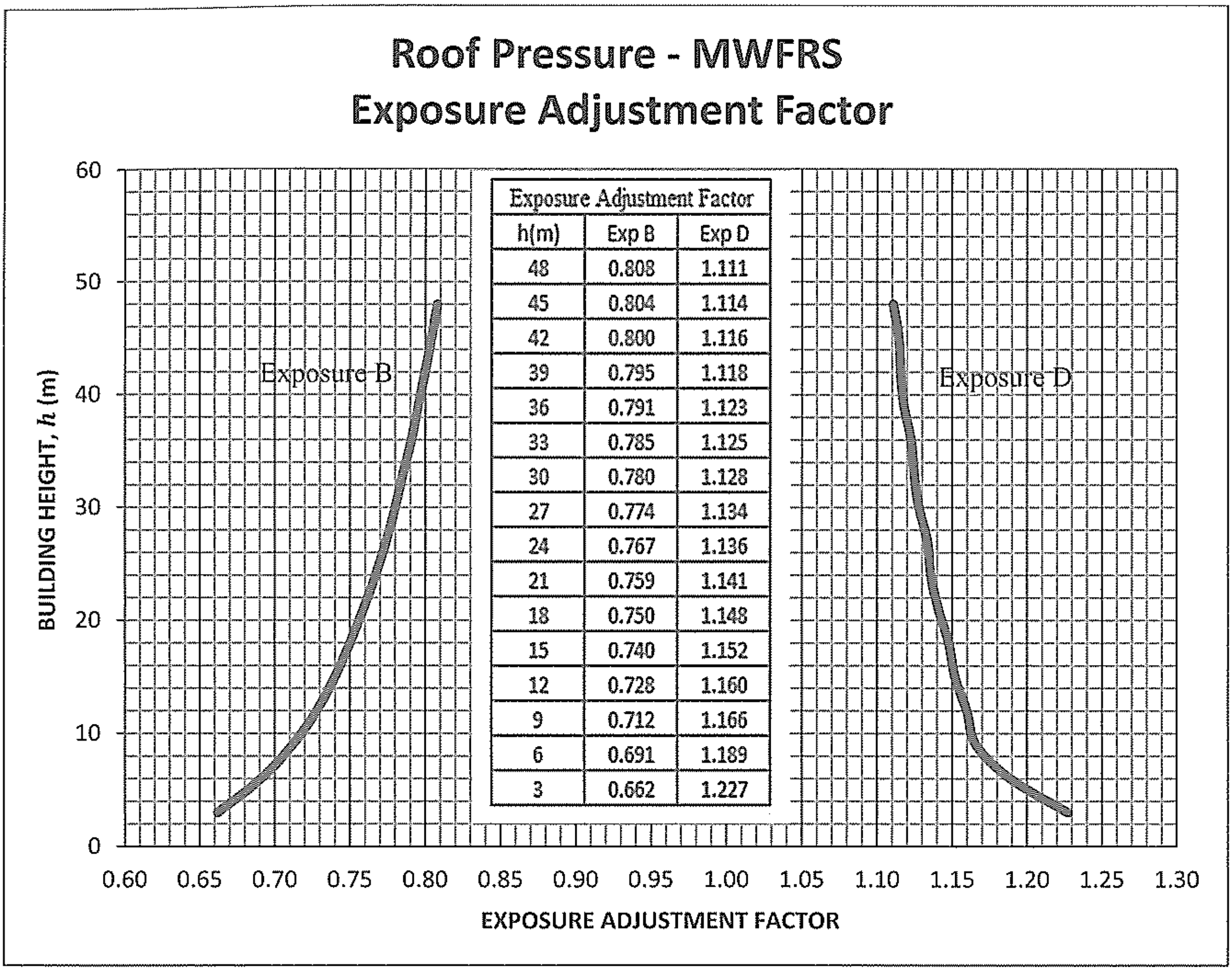
V (kph)	150			200			250			300			350		
h (m), L/B	0.5	1	2	0.5	1	2	0.5	1	2	0.5	1	2	0.5	1	2
48	1.24	1.22	1.09	2.39	2.36	2.15	4.03	3.96	3.63	6.25	6.11	5.61	9.14	8.90	8.17
	0.83	0.82	0.67	1.61	1.59	1.33	2.72	2.67	2.24	4.22	4.12	3.47	6.17	6.00	5.09
45	1.20	1.19	1.06	2.31	2.29	2.08	3.88	3.82	3.50	6.00	5.88	5.40	8.76	8.57	7.86
	0.82	0.81	0.66	1.58	1.56	1.30	2.65	2.61	2.19	4.09	4.01	3.39	5.96	5.81	4.96
42	1.16	1.15	1.03	2.23	2.21	2.00	3.73	3.68	3.37	5.75	5.64	5.19	8.38	8.17	7.51
	0.79	0.80	0.65	1.54	1.53	1.27	2.57	2.54	2.14	3.97	3.89	3.30	5.83	5.64	4.79
39	1.13	1.12	1.00	2.14	2.13	1.93	3.57	3.53	3.23	5.49	5.40	4.97	7.97	7.82	7.22
	0.78	0.79	0.64	1.50	1.49	1.25	2.50	2.47	2.09	3.84	3.78	3.21	5.58	5.47	4.66
36	1.08	1.09	0.96	2.06	2.05	1.85	3.42	3.38	3.09	5.23	5.15	4.74	7.56	7.43	6.86
	0.77	0.77	0.64	1.46	1.45	1.22	2.42	2.40	2.03	3.71	3.66	3.12	5.39	5.27	4.54
33	1.04	1.05	0.93	1.98	1.97	1.77	3.26	3.23	2.94	4.97	4.90	4.51	7.20	7.05	6.55
	0.76	0.76	0.63	1.43	1.42	1.19	2.35	2.33	1.98	3.58	3.54	3.03	5.18	5.10	4.37
30	1.01	1.00	0.89	1.90	1.88	1.69	3.10	3.08	2.80	4.70	4.65	4.27	6.79	6.64	6.15
	0.73	0.74	0.61	1.39	1.38	1.16	2.27	2.26	1.92	3.45	3.41	2.93	5.01	4.86	4.23
27	0.97	0.96	0.86	1.85	1.80	1.60	2.94	2.92	2.65	4.43	4.39	4.02	6.51	6.28	5.72
	0.73	0.72	0.60	1.35	1.34	1.13	2.20	2.19	1.86	3.32	3.28	2.83	4.75	4.62	4.08
24	0.93	0.92	0.81	1.71	1.71	1.52	2.77	2.76	2.49	4.16	4.13	3.77	5.93	5.88	5.41
	0.71	0.72	0.60	1.31	1.31	1.10	2.12	2.11	1.80	3.18	3.16	2.72	4.53	4.50	3.88
21	0.88	0.89	0.77	1.62	1.61	1.43	2.60	2.59	2.33	3.88	3.86	3.50	5.52	5.45	4.97
	0.69	0.69	0.57	1.27	1.27	1.07	2.04	2.04	1.74	3.05	3.03	2.61	4.35	4.27	3.71
18	0.83	0.85	0.73	1.52	1.52	1.34	2.43	2.42	2.16	3.60	3.58	3.23	5.07	5.03	4.59
	0.68	0.68	0.55	1.23	1.23	1.03	1.97	1.96	1.67	2.91	2.90	2.50	4.06	4.08	3.55
15	0.78	0.78	0.69	1.41	1.41	1.24	2.25	2.25	1.99	3.31	3.30	2.95	4.60	4.56	4.13
	0.65	0.65	0.56	1.19	1.19	1.00	1.89	1.89	1.61	2.78	2.77	2.39	3.89	3.85	3.34
12	0.74	0.74	0.63	1.31	1.31	1.14	2.07	2.07	1.82	3.03	3.03	2.69	4.20	4.20	3.77
	0.65	0.63	0.52	1.15	1.15	0.97	1.82	1.82	1.55	2.66	2.66	2.29	3.67	3.69	3.22
9	0.67	0.67	0.57	1.19	1.19	1.03	1.88	1.88	1.64	2.74	2.74	2.40	3.77	3.77	3.31
	0.62	0.62	0.53	1.10	1.10	0.94	1.74	1.74	1.49	2.53	2.53	2.19	3.46	3.46	3.05
6	0.59	0.59	0.51	1.07	1.07	0.93	1.68	1.68	1.46	2.43	2.43	2.12	3.33	3.33	2.93
	0.59	0.59	0.51	1.05	1.05	0.91	1.65	1.65	1.43	2.39	2.39	2.08	3.27	3.27	2.87
3	0.38	0.38	0.33	0.67	0.67	0.58	1.05	1.05	0.91	1.51	1.51	1.33	2.04	2.04	1.85
	0.38	0.38	0.33	0.67	0.67	0.58	1.05	1.05	0.91	1.51	1.51	1.33	2.04	2.04	1.85

Table 207B.6-1
MWFRS – Part 2: Wind Loads – Walls (kN/m²)
Exposure C

V (kph)	150			200			250			300			350		
h (m), L/B	0.5	1	2	0.5	1	2	0.5	1	2	0.5	1	2	0.5	1	2
48	1.58	1.58	1.42	3.10	3.06	2.75	5.21	5.11	4.62	8.04	7.85	7.10	11.72	11.40	7.10
	1.16	1.16	0.97	2.28	2.25	1.89	3.83	3.76	3.19	5.92	5.77	4.89	8.66	8.36	4.89
45	1.56	1.55	1.38	3.01	2.97	2.68	5.06	5.04	4.49	7.79	7.61	6.89	11.28	10.53	6.89
	0.68	1.16	0.96	2.24	2.21	1.87	3.75	3.74	3.13	5.78	5.65	4.81	8.90	7.84	4.81
42	1.56	1.51	1.33	2.92	2.89	2.60	4.90	4.87	4.36	7.53	7.37	6.68	10.84	10.31	6.68
	1.18	1.13	0.94	2.19	2.17	1.85	3.67	3.65	3.07	5.65	5.53	4.71	8.16	7.77	4.71
39	1.48	1.48	1.29	2.83	2.81	2.52	4.73	4.66	4.22	7.26	7.12	6.46	10.5	10.28	6.46
	1.13	1.12	0.94	2.15	2.13	1.81	3.59	3.53	3.01	5.50	5.39	4.62	7.93	7.78	4.62
36	1.43	1.43	1.27	2.74	2.72	2.44	4.56	4.50	4.07	6.98	6.85	6.23	10.09	9.85	6.23
	1.10	1.10	0.92	2.10	2.09	1.83	3.50	3.45	2.95	5.35	5.25	4.51	7.70	7.56	4.51
33	1.39	1.39	1.23	2.65	2.63	2.36	4.39	4.33	3.92	6.69	6.59	5.98	9.63	9.51	5.98
	1.08	1.09	0.90	2.06	2.04	1.97	3.41	3.37	2.89	5.20	5.11	4.41	7.50	7.29	4.41
30	1.37	1.36	1.20	2.55	2.44	2.27	4.21	4.17	3.76	6.40	6.31	5.73	9.17	8.62	5.73
	1.08	1.06	0.89	2.01	2.00	1.70	3.31	3.28	2.82	5.04	4.97	4.30	7.26	7.14	4.30
27	1.32	1.31	1.16	2.45	1.90	2.18	4.02	3.99	3.60	6.09	6.02	5.47	8.72	6.43	5.47
	1.06	1.06	0.87	1.96	1.95	1.67	3.22	3.19	2.75	4.87	4.82	4.18	6.94	6.88	4.18
24	1.26	1.27	1.11	2.35	2.34	2.08	3.83	3.81	3.42	5.78	5.72	5.19	8.28	8.11	5.19
	1.04	1.07	0.87	1.92	1.91	1.63	3.12	3.10	2.67	4.70	4.66	4.05	6.72	6.61	4.05
21	1.23	1.21	1.06	2.24	2.24	1.98	3.63	3.62	3.24	5.45	5.41	4.89	7.75	7.67	4.89
	1.02	1.26	0.84	1.90	1.86	1.59	3.02	2.99	2.59	4.53	4.34	3.92	6.58	5.60	3.92
18	1.16	1.16	1.01	2.13	2.13	1.88	3.43	3.42	3.05	5.12	5.08	4.58	7.26	7.16	4.58
	0.99	1.00	0.83	2.07	1.81	1.55	2.92	2.75	2.51	4.36	3.05	3.77	7.21	1.94	3.77
15	1.10	1.07	0.99	2.01	2.01	1.76	3.22	3.21	2.85	4.77	4.75	4.25	6.70	6.71	4.25
	0.98	0.96	0.81	1.76	1.76	1.50	2.82	2.81	2.43	4.17	4.16	3.63	5.82	5.86	3.63
12	1.05	0.56	0.91	1.89	1.89	1.64	3.01	2.99	2.63	4.41	4.39	3.90	6.09	6.62	3.90
	0.94	0.94	0.80	1.71	1.71	1.46	2.71	2.71	2.34	3.99	3.98	3.47	5.60	5.56	3.47
9	0.98	0.97	0.83	1.75	1.75	1.51	2.87	2.76	2.41	4.02	4.02	3.53	4.88	5.55	3.53
	0.92	0.92	0.78	1.65	1.65	1.41	2.60	2.60	2.25	3.80	3.79	3.30	5.28	5.24	3.30
6	1.01	0.90	0.78	1.60	1.60	1.38	2.55	2.53	2.40	3.65	3.65	3.18	4.69	4.92	3.18
	0.87	0.87	0.76	1.58	1.58	1.36	2.49	2.48	2.37	3.60	3.60	3.13	4.91	4.97	3.13
3	0.56	0.56	0.49	1.01	1.01	0.88	1.59	1.59	1.38	2.30	2.30	2.00	3.14	3.14	2.00
	0.56	0.56	0.49	1.01	1.01	0.88	1.59	1.59	1.38	2.30	2.30	2.00	3.14	3.14	2.00

Table 207B.6-1
MWFRS – Part 2: Wind Loads – Walls (kN/m^2)
Exposure D

V (kph)	150			200			250			300			350		
h (m), L/B	0.5	1	2	0.5	1	2	0.5	1	2	0.5	1	2	0.5	1	2
48	1.80	1.80	1.59	3.50	3.45	3.08	5.87	5.75	5.15	9.00	8.79	7.86	12.98	12.66	11.27
	1.39	1.36	1.16	2.70	2.66	2.25	4.52	4.43	3.76	6.93	6.77	5.74	10.01	9.78	8.24
45	1.77	1.76	1.56	3.42	3.37	3.01	5.72	5.61	5.02	8.76	8.56	7.67	12.63	12.30	11.04
	1.37	1.37	1.15	2.66	2.62	2.22	4.44	4.36	3.70	6.80	6.65	5.65	9.83	9.55	8.13
42	1.74	1.73	1.53	3.33	3.29	2.94	5.56	5.46	4.89	8.51	8.33	7.46	12.26	11.99	10.73
	1.36	1.36	1.13	2.61	2.58	2.19	4.36	4.28	3.65	6.66	6.52	5.56	9.56	9.36	7.97
39	1.69	1.69	1.49	3.24	3.21	2.86	5.40	5.31	4.76	8.24	8.08	7.25	11.83	11.61	10.39
	1.34	1.29	1.12	2.57	2.54	2.16	4.27	4.20	3.59	6.52	6.39	5.46	9.4	9.23	7.82
36	1.64	1.65	1.45	3.15	3.12	2.78	5.23	5.15	4.62	7.97	7.82	7.03	11.46	11.21	10.07
	1.31	1.17	1.13	2.52	2.49	2.12	4.18	4.12	3.52	6.37	6.25	5.36	9.17	9.07	7.67
33	1.87	1.61	1.41	3.06	3.03	2.70	5.05	4.99	4.47	7.69	7.55	6.80	10.83	10.77	9.77
	1.31	1.29	1.16	2.47	2.45	2.08	4.08	4.03	3.46	6.21	6.10	5.26	8.93	8.73	7.44
30	2.78	1.57	1.38	2.96	2.94	2.62	4.87	4.82	4.32	7.39	7.28	6.55	9.40	10.39	9.38
	1.29	1.28	1.07	2.41	2.40	2.05	3.98	3.94	3.39	6.04	5.95	5.14	8.63	8.48	7.35
27	1.53	1.52	1.34	2.86	2.84	2.52	4.68	4.64	4.16	7.08	6.99	6.29	10.15	9.96	8.94
	1.25	1.26	1.06	2.35	2.35	2.01	3.88	3.84	3.32	5.87	5.79	5.02	8.35	8.26	7.14
24	1.48	1.47	1.28	2.75	2.74	2.43	4.49	4.45	3.98	6.76	6.68	6.01	9.62	9.51	8.60
	1.25	1.24	1.05	2.31	2.30	1.97	3.78	3.75	3.24	5.69	5.62	4.89	8.07	7.94	6.95
21	1.43	1.43	1.24	2.64	2.63	2.32	4.28	4.26	3.80	6.42	6.36	5.72	9.13	8.97	8.12
	1.22	1.22	1.03	2.26	2.25	1.93	3.67	3.65	3.15	5.50	5.45	4.75	7.80	7.68	6.79
18	1.37	1.39	1.20	2.52	2.52	2.22	4.07	4.05	3.60	6.07	6.03	5.40	8.57	8.51	7.68
	1.20	1.19	1.00	2.21	2.20	1.88	3.56	3.54	3.06	5.31	5.27	4.60	7.52	7.45	6.56
15	1.31	1.32	1.14	2.40	2.40	2.10	3.85	3.83	3.39	5.70	5.67	5.06	7.99	7.98	7.16
	1.19	1.17	1.00	2.15	2.14	1.84	3.44	3.43	2.97	5.10	5.08	4.43	7.17	7.13	6.26
12	1.26	1.24	1.08	2.27	2.27	1.97	3.61	3.61	3.16	5.31	5.30	4.69	7.40	7.38	6.60
	1.16	1.14	0.98	2.09	2.09	1.79	3.36	3.32	2.87	4.89	4.88	4.26	6.60	6.82	6.00
9	1.19	1.17	1.02	2.12	2.12	1.83	3.36	3.35	2.92	4.91	4.90	4.30	6.77	6.81	5.98
	1.13	1.13	0.96	2.02	2.02	1.73	3.20	3.20	2.76	4.68	4.67	4.07	6.47	6.43	5.68
6	1.10	1.09	0.93	1.97	1.97	1.69	3.09	3.09	2.68	4.49	4.49	3.91	6.20	6.21	5.39
	1.09	1.09	0.93	1.95	1.95	1.67	3.06	3.06	2.65	4.45	4.44	3.86	6.15	6.11	5.29
3	0.70	0.70	0.60	1.25	1.25	1.08	1.96	1.96	1.70	2.83	2.83	2.47	3.86	3.86	3.40
	0.70	0.70	0.60	1.25	1.25	1.08	1.96	1.96	1.70	2.83	2.83	2.47	3.86	3.86	3.40



Exposure Adjustment Factor		
h(m)	Exp B	Exp D
48	0.808	1.111
45	0.804	1.114
42	0.800	1.116
39	0.795	1.118
36	0.791	1.123
33	0.785	1.125
30	0.780	1.128
27	0.774	1.134
24	0.767	1.136
21	0.759	1.141
18	0.750	1.148
15	0.740	1.152
12	0.728	1.160
9	0.712	1.166
6	0.691	1.189
3	0.662	1.227

Notes to Roof Pressure Table 207B.6-2:

1. From table for Exposure C, V, h and roof slope, determine roof pressure p_h for each roof zone shown in the figures for the applicable roof form. For other exposures B or D, multiply pressures from table by appropriate exposure adjustment factor as determined from figure below.
2. Where two load cases are shown, both load cases shall be investigated. Load case 2 is required to investigate maximum overturning on the building from roof pressures shown.
3. Apply along-wind net wall pressures to the projected area of the building walls in the direction of the wind and apply exterior side wall pressures to the projected area of the building walls normal to the direction of the wind acting outward, simultaneously with the roof pressures from Table 207B.6-2.
4. Where a value of zero is shown in the tables for the flat roof case, it is provided for the purpose of interpolation.
5. Interpolation between V, h and roof slope is permitted.

Figure 207B.6-2
Application of Roof Pressures Wind Pressures - Roofs, $h \leq 48$ m
Enclosed Simple Diaphragm Buildings

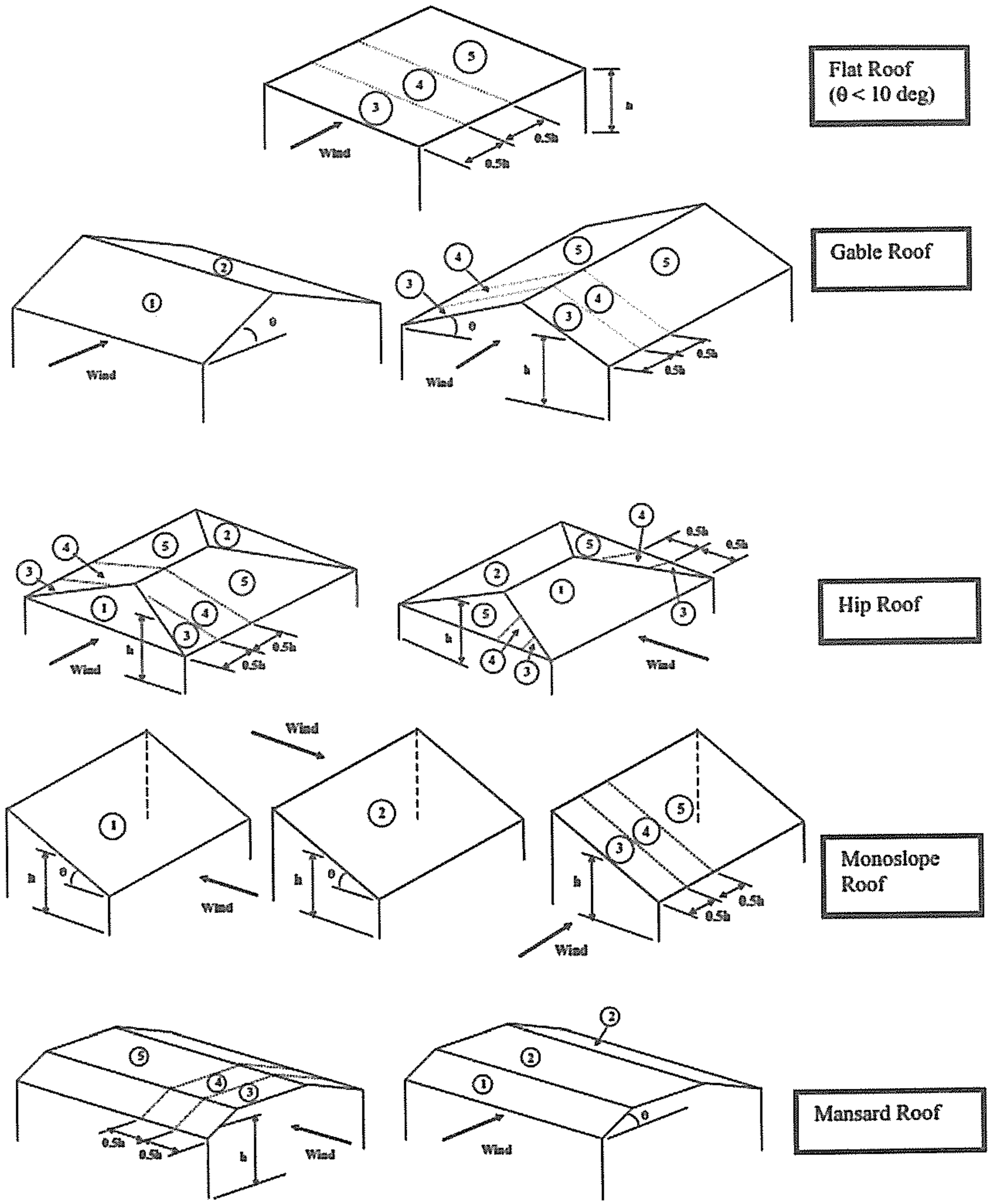


Figure 207B.6-2
Application of Roof Pressures Wind Pressures - Roofs, $h \leq 48$ m
Enclosed Simple Diaphragm Buildings

Table 207B.6-2
MWFRS - Part 2: Wind Loads – Roof (kN/m^2)
MWFRS – Roof, $V = 150 - 250$ kph, $h = 3 - 12$ m
Exposure C

V (kph)			150					200					250				
		Load Case	Zone					Zone					Zone				
h (m)	Roof Slope		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
12	Flat < 2:12 (9.46°)	1	NA	NA	-1.00	-0.89	-0.23	NA	NA	-1.78	-1.58	-1.30	NA	NA	-2.77	-2.47	-2.03
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-0.99	-0.48	-1.00	-0.89	-0.73	-1.76	-1.18	-1.78	-1.58	-1.30	-2.72	-1.91	-2.77	-2.47	-2.03
		2	0.14	-0.20	0.00	0.00	0.00	0.25	-0.35	0.00	0.00	0.00	0.39	-0.55	0.00	0.00	0.00
	4: 12 (18.4°)	1	-0.80	-0.66	-1.00	-0.89	-0.73	-1.43	-1.16	-1.78	-1.58	-1.30	-2.24	-1.81	-2.77	-2.47	-2.03
		2	0.43	-0.09	0.00	0.00	0.00	0.50	-0.49	0.00	0.00	0.00	0.77	-0.79	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.64	-0.66	-1.00	-0.89	-0.73	-1.15	-1.16	-1.78	-1.58	-1.30	-1.80	-1.81	-2.77	-2.47	-2.03
		2	0.37	-3.01	0.00	0.00	0.00	NA	-0.55	0.00	0.00	0.00	1.03	-0.86	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.52	-0.66	-1.14	-0.89	-0.73	-0.92	-1.16	-1.78	-1.58	-1.30	-1.44	-1.81	-2.77	-2.47	-2.03
		2	0.41	-0.32	0.00	0.00	0.00	0.73	-0.55	0.00	0.00	0.00	1.14	-0.86	0.00	0.00	0.00
	9:12 (36.9°)	1	2.87	-0.66	-0.98	-0.89	-0.73	-0.07	-1.16	-1.78	-1.58	-1.30	-0.83	-1.81	-2.77	-2.47	-2.03
		2	0.49	-0.32	0.00	0.00	0.00	0.87	-0.55	0.00	0.00	0.00	0.95	-0.86	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.16	-0.66	-1.00	-0.89	-0.73	-0.30	-1.16	-1.78	-1.58	-1.30	-0.47	-1.81	-2.77	-2.47	-2.03
		2	0.59	-0.32	0.00	0.00	0.00	0.87	-0.55	0.00	0.00	0.00	1.36	-0.86	0.00	0.00	0.00
9	Flat < 2:12 (9.46°)	1	NA	NA	-0.93	-0.83	6.55	NA	NA	-1.67	-1.49	-1.22	NA	NA	-2.61	-2.32	-1.90
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-0.92	-0.45	-0.93	-0.83	-0.68	-1.64	-1.11	-1.67	-1.49	-1.22	-2.56	-1.80	-2.61	-2.32	-1.90
		2	0.14	-0.19	0.00	0.00	0.00	0.24	-0.33	0.00	0.00	0.00	0.37	-0.52	0.00	0.00	0.00
	4: 12 (18.4°)	1	-0.75	-0.60	-0.93	-0.83	-0.68	-1.34	-1.08	-1.67	-1.49	-1.22	-2.10	-1.66	-2.61	-2.32	-1.90
		2	2.55	2.56	0.00	0.00	0.00	0.47	-0.31	0.00	0.00	0.00	0.73	-0.75	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.60	-0.60	-0.93	-0.83	-0.68	-1.08	-1.08	-1.67	-1.49	-1.22	-1.69	-1.70	-2.61	-2.32	-1.90
		2	0.36	-0.29	0.00	0.00	0.00	0.62	-0.52	0.00	0.00	0.00	0.97	-0.81	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.49	-0.60	-0.93	-0.83	-0.68	-0.87	-1.08	-1.67	-1.49	-1.22	-1.35	-1.70	-2.61	-2.32	-1.90
		2	0.39	-0.29	0.00	0.00	0.00	0.68	-0.52	0.00	0.00	0.00	1.07	-0.81	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.29	-0.60	-0.93	-0.83	-0.68	-0.50	-1.08	-1.67	-1.49	-1.22	-0.78	-1.70	-2.61	-2.32	-1.90
		2	0.45	-0.29	0.00	0.00	0.00	0.82	-0.52	0.00	0.00	0.00	0.90	-0.81	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.17	-0.60	-0.93	-0.83	-0.68	-0.27	-1.08	-1.67	-1.49	-1.22	-0.44	-1.67	-2.61	-2.32	-1.90
		2	1.81	-0.29	0.00	0.00	0.00	0.82	-0.52	0.00	0.00	0.00	1.28	-0.84	0.00	0.00	0.00
6	Flat < 2:12 (9.46°)	1	NA	NA	-0.87	-0.76	-0.63	NA	NA	-1.54	-1.37	-1.12	NA	NA	-2.40	-2.14	-1.63
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-0.85	-0.43	-0.87	-0.76	-0.63	-1.50	-1.02	-1.54	-1.37	-1.12	-2.35	-1.65	-2.40	-2.14	-1.63
		2	0.13	-0.17	0.00	0.00	0.00	0.22	-0.31	0.00	0.00	0.00	0.34	-0.48	0.00	0.00	0.00
	4: 12 (18.4°)	1	-0.69	-0.56	-0.87	-0.76	-0.63	-1.24	-0.94	-1.54	-1.37	-1.12	-1.93	-1.00	-2.40	-2.14	-1.63
		2	0.23	-0.24	0.00	0.00	0.00	0.43	-0.44	0.00	0.00	0.00	0.67	-0.68	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.56	-0.56	-0.87	-0.76	-0.63	-0.99	-1.00	-1.54	-1.37	-1.12	-1.55	-1.56	-2.40	-2.14	-1.63
		2	0.33	-0.26	0.00	0.00	0.00	0.57	-0.48	0.00	0.00	0.00	0.89	-0.75	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.45	-0.56	-0.87	-0.76	-0.63	-0.80	-1.00	-1.54	-1.37	-1.12	-1.25	-1.56	-2.40	-2.14	-1.63
		2	0.35	-0.26	0.00	0.00	0.00	0.63	-0.48	0.00	0.00	0.00	0.98	-0.75	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.26	-0.56	-0.87	-0.76	-0.63	-0.46	-1.00	-1.54	-1.37	-1.12	-0.72	-1.56	-2.40	-2.14	-1.63
		2	0.41	-0.26	0.00	0.00	0.00	0.75	-0.48	0.00	0.00	0.00	0.83	-0.75	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.15	-0.56	-0.87	-0.76	-0.63	-0.04	-1.00	-1.54	-1.37	-1.12	-0.40	-1.13	-2.40	-2.14	-1.63
		2	0.41	-0.26	0.00	0.00	0.00	0.75	-0.48	0.00	0.00	0.00	1.18	-1.18	0.00	0.00	0.00
3	Flat < 2:12 (9.46°)	1	NA	NA	-0.76	-0.67	-0.56	NA	NA	-1.35	-1.21	-0.99	NA	NA	-2.12	-1.89	2.22
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-0.73	-0.36	-0.76	-0.67	-0.56	-1.33	-0.91	-1.35	-1.21	-0.99	-2.08	-1.46	-2.12	-1.89	2.22
		2	0.11	-0.14	0.00	0.00	0.00	0.19	-0.27	0.00	0.00	0.00	0.30	-0.42	0.00	0.00	0.00
	4: 12 (18.4°)	1	-0.61	-0.47	-0.76	-0.67	-0.56	-1.09	0.88	-1.35	-1.21	-0.99	-1.70	-2.16	-2.12	-1.89	2.22
		2	0.22	-0.23	0.00	0.00	0.00	0.38	-0.39	0.00	0.00	0.00	0.59	-0.60	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.47	-0.47	-0.76	-0.67	-0.56	-0.87	-0.88	-1.35	-1.21	-0.99	-1.37	-1.38	-2.12	-1.89	2.22
		2	0.28	-0.25	0.00	0.00	0.00	0.51	-0.42	0.00	0.00	0.00	0.79	-0.66	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.38	-0.47	-0.76	-0.67	-0.56	-0.71	-0.88	-1.35	-1.21	-0.99	-1.10	-1.38	-2.12	-1.89	2.22
		2	0.32	-0.25	0.00	0.00	0.00	0.56	-0.42	0.00	0.00	0.00	0.87	-0.66	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.21	-0.47	-0.76	-0.67	-0.56	-0.41	-0.88	-1.35	-1.21	-0.99	-0.63	-1.38	-2.12	-1.89	2.22
		2	0.38	-0.25	0.00	0.00	0.00	0.66	-0.42	0.00	0.00	0.00	0.73	-0.66	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.12	-0.47	-0.76	-0.67	-0.56	-0.48	-0.88	-1.35	-1.21	-0.99	-0.36	-1.85	-2.12	-1.89	2.22
		2	0.38	-0.25	0.00	0.00	0.00	0.66	-0.42	0.00	0.00	0.00	1.04	-0.18	0.00	0.00	0.00

Table 207B.6-2
MWFRS - Part 2: Wind Loads – Roof (kN/m^2)
MWFRS – Roof, $V = 300 - 350$ kph, $h = 3 - 12$ m
Exposure C

V (kph)			300					350				
h (m)	Roof Slope	Load Case	Zone					Zone				
			1	2	3	4	5	1	2	3	4	5
12	Flat < 2:12 (9.46°)	1	NA	NA	-3.99	-3.56	-2.92	NA	NA	-2.38	-2.12	-1.74
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-3.92	-2.66	-3.99	-3.56	-2.92	-2.33	-1.58	-2.38	-2.12	-1.74
		2	0.56	-0.79	0.00	0.00	0.00	0.34	-0.47	0.00	0.00	0.00
	4: 12 (18.4°)	1	-3.22	-2.60	-3.99	-3.56	-2.92	-1.91	-1.55	-2.38	-2.12	-1.74
		2	1.12	-1.14	0.00	0.00	0.00	0.66	-0.68	0.00	0.00	0.00
	5:12 (22.6°)	1	-2.58	-2.60	-3.99	-3.56	-2.92	-1.54	-1.55	-2.38	-2.12	-1.74
		2	1.48	-1.24	0.00	0.00	0.00	0.88	-0.74	0.00	0.00	0.00
	6:12 (26.6°)	1	-2.07	-2.60	-3.99	-3.56	-2.92	-1.23	-1.55	-2.38	-2.12	-1.74
		2	1.64	-1.24	0.00	0.00	0.00	0.98	-0.74	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.20	-2.60	-3.99	-3.56	-2.92	-0.72	-1.55	-2.38	-2.12	-1.74
		2	1.96	-1.24	0.00	0.00	0.00	1.07	-0.68	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.68	-2.60	-3.99	-3.56	-2.92	-0.40	-1.55	-2.38	-2.12	-1.74
		2	1.96	-1.24	0.00	0.00	0.00	1.17	-0.74	0.00	0.00	0.00
9	Flat < 2:12 (9.46°)	1	NA	NA	-3.75	-3.34	-2.74	NA	NA	-2.34	-2.09	-1.71
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-3.68	-2.50	-3.75	-3.34	-2.74	-2.30	-1.56	-2.34	-2.09	-1.71
		2	0.53	-0.75	0.00	0.00	0.00	0.33	-0.47	0.00	0.00	0.00
	4: 12 (18.4°)	1	-3.03	-2.44	-3.75	-3.34	-2.74	-1.89	-1.53	-2.34	-2.09	-1.71
		2	1.05	-1.07	0.00	0.00	0.00	0.65	-0.67	0.00	0.00	0.00
	5:12 (22.6°)	1	-2.43	-2.44	-3.75	-3.34	-2.74	-1.52	-1.53	-2.34	-2.09	-1.71
		2	1.40	-1.17	0.00	0.00	0.00	0.68	-0.73	0.00	0.00	0.00
	6:12 (26.6°)	1	-1.95	-2.44	-3.75	-3.34	-2.74	-1.22	-1.53	-2.34	-2.09	-1.71
		2	1.54	-1.17	0.00	0.00	0.00	0.96	-0.73	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.13	-2.44	-3.75	-3.34	-2.74	-0.71	-1.53	-2.34	-2.09	-1.71
		2	1.84	-1.17	0.00	0.00	0.00	1.15	-0.73	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.64	-2.44	-3.75	-3.34	-2.74	-0.40	-1.53	-2.34	-2.09	-1.71
		2	1.84	-1.17	0.00	0.00	0.00	1.15	-0.73	0.00	0.00	0.00
6	Flat < 2:12 (9.46°)	1	NA	NA	-3.45	-3.08	-2.52	NA	NA	-2.31	-2.06	-1.69
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-3.38	-2.30	-3.45	-3.08	-2.52	-2.27	-1.54	-2.31	-2.06	-1.69
		2	0.49	-0.69	0.00	0.00	0.00	0.33	-0.35	0.00	0.00	0.00
	4: 12 (18.4°)	1	-2.78	-2.25	-3.45	-3.08	-2.52	-1.86	-1.50	-2.31	-2.06	-1.69
		2	0.96	-0.99	0.00	0.00	0.00	0.65	-0.66	0.00	0.00	0.00
	5:12 (22.6°)	1	-2.23	-2.25	-3.45	-3.08	-2.52	-1.49	-1.50	-2.31	-2.06	-1.69
		2	1.28	-1.07	0.00	0.00	0.00	0.24	-0.72	0.00	0.00	0.00
	6:12 (26.6°)	1	-1.79	-2.25	-3.45	-3.08	-2.52	-1.20	-1.50	-2.31	-2.06	-1.69
		2	1.42	-1.07	0.00	0.00	0.00	0.95	-0.72	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.04	-2.25	-3.45	-3.08	-2.52	-0.70	-1.50	-2.31	-2.06	-1.69
		2	1.69	-1.07	0.00	0.00	0.00	1.13	-0.72	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.58	-2.20	-3.45	-3.08	-2.52	-0.39	-1.50	-2.31	-2.06	-1.69
		2	1.69	-1.07	0.00	0.00	0.00	1.09	-0.69	0.00	0.00	0.00
3	Flat < 2:12 (9.46°)	1	NA	NA	-3.05	-2.72	-2.23	NA	NA	-2.27	-2.03	-1.66
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-2.99	-2.03	-3.05	-2.72	-2.23	-2.23	-1.52	-2.27	-2.03	-1.66
		2	0.43	-0.61	0.00	0.00	0.00	0.32	-0.07	0.00	0.00	0.00
	4: 12 (18.4°)	1	-2.46	-1.98	-3.05	-2.72	-2.23	-1.83	-1.48	-2.27	-2.03	-1.66
		2	0.85	-0.87	0.00	0.00	0.00	0.64	-0.65	0.00	0.00	0.00
	5:12 (22.6°)	1	-1.98	-1.98	-3.05	-2.72	-2.23	-1.47	-1.48	-2.27	-2.03	-1.66
		2	1.13	-0.95	0.00	0.00	0.00	0.85	-0.71	0.00	0.00	0.00
	6:12 (26.6°)	1	-1.59	-1.98	-3.05	-2.72	-2.23	-1.18	-1.48	-2.27	-2.03	-1.66
		2	1.25	-0.95	0.00	0.00	0.00	0.93	-0.71	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.92	-1.98	-3.05	-2.72	-2.23	-0.68	-1.48	-2.27	-2.03	-1.66
		2	1.49	-0.95	0.00	0.00	0.00	1.12	-0.71	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.52	-0.44	-3.05	-2.72	-2.23	-0.39	-1.48	-2.27	-2.03	-1.66
		2	1.49	-0.95	0.00	0.00	0.00	19.8	-12.5	0.0	0.0	0.0

Table 207B.6-2
MWFRS - Part 2: Wind Loads – Roof (kN/m^2)
MWFRS – Roof, $V = 150 - 250$ kph, $h = 15 - 24$ m
Exposure C

V (kph)			150					200					250				
h (m)	Roof Slope	Load Case	Zone					Zone					Zone				
			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
24	Flat < 2:12 (9.46°)	1	NA	NA	-1.16	-1.03	-0.84	NA	NA	-2.05	-1.83	-1.50	NA	NA	-3.21	-2.86	-2.34
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-1.14	-0.57	-1.16	-1.03	-0.84	-2.02	-1.37	-2.05	-1.83	-1.50	-3.15	-2.21	-3.21	-2.86	-2.34
		2	0.17	-0.23	0.00	0.00	0.00	0.29	-0.41	0.00	0.00	0.00	0.45	-0.64	0.00	0.00	0.00
	4: 12 (18.4°)	1	-8.45	-0.74	-1.16	-1.03	-0.84	-1.66	-1.34	-2.05	-1.83	-1.50	-2.59	-2.09	-3.21	-2.86	-2.34
		2	0.32	-0.33	0.00	0.00	0.00	0.57	-0.59	0.00	0.00	0.00	0.90	-0.92	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.75	-0.74	-1.16	-1.03	-0.84	-1.33	-1.34	-2.05	-1.83	-1.50	-2.08	-2.09	-3.21	-2.86	-2.34
		2	0.42	-0.36	0.00	0.00	0.00	0.76	-0.64	0.00	0.00	0.00	1.19	-1.00	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.60	-0.74	-1.16	-1.03	-0.84	-1.00	-1.34	-2.05	-1.83	-1.50	-1.67	-2.09	-3.21	-2.86	-2.34
		2	0.47	-0.36	0.00	0.00	0.00	0.84	-0.64	0.00	0.00	0.00	1.32	-1.00	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.34	-0.74	-1.16	-1.03	-0.84	-0.62	-1.34	-2.05	-1.83	-1.50	-0.97	-2.09	-3.21	-2.86	-2.34
		2	NA	-0.36	0.00	0.00	0.00	1.01	-0.64	0.00	0.00	0.00	1.11	-1.00	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.19	-0.74	-1.16	-1.03	-0.84	-0.35	-1.34	-2.05	-1.83	-1.50	-0.54	-2.09	-3.21	-2.86	-2.34
		2	0.56	-0.36	0.00	0.00	0.00	1.01	-0.64	0.00	0.00	0.00	1.57	-1.00	0.00	0.00	0.00
21	Flat < 2:12 (9.46°)	1	NA	NA	-1.13	-1.00	-0.83	NA	NA	-2.00	-1.78	-1.46	NA	NA	-3.12	-2.78	-2.28
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-1.10	-0.55	-1.13	-1.00	-0.83	-1.96	-1.33	-2.00	-1.78	-1.46	-3.06	-2.15	-3.12	-2.78	-2.28
		2	0.15	-0.22	0.00	0.00	0.00	0.28	-0.40	0.00	0.00	0.00	0.44	-0.62	0.00	0.00	0.00
	4: 12 (18.4°)	1	-0.90	-0.73	-1.13	-1.00	-0.83	-1.61	-1.30	-2.00	-1.78	-1.46	-2.51	-2.03	-3.12	-2.78	-2.28
		2	0.32	-0.33	0.00	0.00	0.00	0.56	-0.57	0.00	0.00	0.00	0.87	-0.89	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.72	-0.73	-1.13	-1.00	-0.83	-1.29	-1.30	-2.00	-1.78	-1.46	-2.02	-2.03	-3.12	-2.78	-2.28
		2	0.42	-0.36	0.00	0.00	0.00	0.74	-0.62	0.00	0.00	0.00	1.16	-0.97	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.58	-0.73	-1.13	-1.00	-0.83	-0.59	-1.30	-2.00	-1.78	-1.46	-1.62	-2.03	-3.12	-2.78	-2.28
		2	0.45	-0.36	0.00	0.00	0.00	0.82	-0.62	0.00	0.00	0.00	1.28	-0.97	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.34	-0.73	-1.13	-1.00	-0.83	-0.60	-1.30	-2.00	-1.78	-1.46	-0.94	-2.03	-3.12	-2.78	-2.28
		2	0.55	-0.36	0.00	0.00	0.00	0.98	-0.62	0.00	0.00	0.00	1.07	-0.97	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.19	-0.73	-1.13	-1.00	-0.83	-0.34	-1.30	-2.00	-1.78	-1.46	-0.53	-2.03	-3.12	-2.78	-2.28
		2	0.55	-0.36	0.00	0.00	0.00	0.98	-0.62	0.00	0.00	0.00	1.53	-0.97	0.00	0.00	0.00
18	Flat < 2:12 (9.46°)	1	NA	NA	-1.08	-0.97	-0.80	NA	NA	-1.93	-1.72	-1.41	NA	NA	-3.02	-2.69	-2.21
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-1.07	-0.53	-1.08	-0.97	-0.80	-1.90	-1.29	-1.93	-1.72	-1.41	-2.96	-2.08	-3.02	-2.69	-2.21
		2	0.16	-0.22	0.00	0.00	0.00	0.27	-0.38	0.00	0.00	0.00	0.43	-0.60	0.00	0.00	0.00
	4: 12 (18.4°)	1	-0.87	-0.70	-1.08	-0.97	-0.80	-1.56	-1.26	-1.93	-1.72	-1.41	-2.44	-1.97	-3.02	-2.69	-2.21
		2	0.31	-0.32	0.00	0.00	0.00	0.54	-0.55	0.00	0.00	0.00	0.84	-0.86	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.70	-0.70	-1.08	-0.97	-0.80	-1.25	-1.26	-1.93	-1.72	-1.41	-1.95	-1.97	-3.02	-2.69	-2.21
		2	0.40	-0.35	0.00	0.00	0.00	0.72	-0.60	0.00	0.00	0.00	1.12	-0.94	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.57	-0.70	-1.08	-0.97	-0.80	-1.00	-1.26	-1.93	-1.72	-1.41	-1.57	-1.97	-3.02	-2.69	-2.21
		2	0.45	-0.34	0.00	0.00	0.00	0.79	-0.60	0.00	0.00	0.00	1.24	-0.94	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.32	-0.70	-1.08	-0.97	-0.80	-0.58	-1.26	-1.93	-1.72	-1.41	-0.90	-1.97	-3.02	-2.69	-2.21
		2	0.54	-0.34	0.00	0.00	0.00	0.95	-0.60	0.00	0.00	0.00	1.04	-0.94	0.00	0.00	0.00
	12:12 (45.0°)	1	0.01	-0.70	-1.08	-0.97	-0.80	-0.33	-1.26	-1.93	-1.72	-1.41	-0.51	-1.97	-3.02	-2.69	-2.21
		2	0.54	-0.34	0.00	0.00	0.00	0.95	-0.60	0.00	0.00	0.00	1.48	-0.94	0.00	0.00	0.00
15	Flat < 2:12 (9.46°)	1	NA	NA	-1.04	-0.94	-0.76	NA	NA	-1.86	-1.66	-1.36	NA	NA	-2.91	-2.59	-2.12
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-1.04	-0.51	-1.04	-0.94	-0.76	-1.82	-1.24	-1.86	-1.66	-1.36	-2.85	-2.00	-2.91	-2.59	-2.12
		2	0.15	-0.22	0.00	0.00	0.00	0.26	-0.37	0.00	0.00	0.00	0.41	-0.58	0.00	0.00	0.00
	4: 12 (18.4°)	1	-0.84	-0.69	-1.04	-0.94	-0.76	-1.50	-1.21	-1.86	-1.66	-1.36	-2.34	-1.89	-2.91	-2.59	-2.12
		2	0.29	-0.30	0.00	0.00	0.00	0.52	-0.53	0.00	0.00	0.00	0.81	-0.83	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.68	-0.69	-1.04	-0.94	-0.76	-1.20	-1.21	-1.86	-1.66	-1.36	-1.88	-1.89	-2.91	-2.59	-2.12
		2	0.38	-0.67	0.00	0.00	0.00	NA	-0.58	0.00	0.00	0.00	1.08	-0.91	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.56	-0.69	-1.05	-0.94	-0.76	-0.97	-1.21	-1.86	-1.66	-1.36	-1.51	-1.89	-2.91	-2.59	-2.12
		2	0.42	-0.32	0.00	0.00	0.00	0.76	-0.58	0.00	0.00	0.00	1.19	-0.91	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.05	-0.69	-1.04	-0.94	-0.76	-0.52	-1.21	-1.86	-1.66	-1.36	-0.87	-1.89	-2.91	-2.59	-2.12
		2	0.51	-0.32	0.00	0.00	0.00	0.91	-0.58	0.00	0.00	0.00	1.00	-0.91	0.00	0.00	0.00
	12:12 (45.0°)	1	1.67	-0.69	-1.04	-0.94	-0.76	-0.32	-1.21	-1.86	-1.66	-1.36	-0.49	-1.89	-2.91	-2.59	-2.12
		2	0.51	-0.32	0.00	0.00	0.00	0.91	-0.58	0.00	0.00	0.00	1.42	-0.91	0.00	0.00	0.00

Table 207B.6-2
MWFRS - Part 2: Wind Loads – Roof (kN/m^2)
MWFRS – Roof, $V = 300 - 350$ kph, $h = 15 - 24$ m
Exposure C

V (kph)			300					350				
h (m)	Roof Slope	Load Case	Zone					Zone				
			1	2	3	4	5	1	2	3	4	5
24	Flat < 2:12 (9.46°)	1	NA	NA	-4.62	-4.12	-3.38	NA	NA	-2.38	-2.12	-1.74
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-4.53	-3.08	-4.62	-4.12	-3.38	-2.33	-1.58	-2.38	-2.12	-1.74
		2	0.65	-0.92	0.00	0.00	0.00	0.34	-0.47	0.00	0.00	0.00
	4: 12 (18.4°)	1	-3.73	-3.01	-4.62	-4.12	-3.38	-1.91	-1.55	-2.38	-2.12	-1.74
		2	1.29	-1.32	0.00	0.00	0.00	0.66	-0.68	0.00	0.00	0.00
	5:12 (22.6°)	1	-2.99	-3.01	-4.62	-4.12	-3.38	-1.54	-1.55	-2.38	-2.12	-1.74
		2	1.72	-1.37	0.00	0.00	0.00	0.88	-0.74	0.00	0.00	0.00
	6:12 (26.6°)	1	-2.44	-3.01	-4.62	-4.12	-3.38	-1.23	-1.55	-2.38	-2.12	-1.74
		2	1.89	-1.44	0.00	0.00	0.00	0.98	-0.74	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.39	-3.01	-4.62	-4.12	-3.38	-0.72	-1.55	-2.38	-2.12	-1.74
		2	2.27	-1.44	0.00	0.00	0.00	1.07	-0.68	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.78	-3.01	-4.62	-4.12	-3.38	-0.40	-1.55	-2.38	-2.12	-1.74
		2	2.27	-1.44	0.00	0.00	0.00	1.17	-0.74	0.00	0.00	0.00
21	Flat < 2:12 (9.46°)	1	NA	NA	-4.49	-4.00	-3.29	NA	NA	-2.34	-2.09	-1.71
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-4.41	-2.99	-4.49	-4.00	-3.29	-2.30	-1.56	-2.34	-2.09	-1.71
		2	0.63	-0.90	0.00	0.00	0.00	0.33	-0.47	0.00	0.00	0.00
	4: 12 (18.4°)	1	-3.62	-2.92	-4.49	-4.00	-3.29	-1.89	-1.53	-2.34	-2.09	-1.71
		2	1.25	-1.29	0.00	0.00	0.00	0.65	-0.67	0.00	0.00	0.00
	5:12 (22.6°)	1	-2.91	-2.92	-4.49	-4.00	-3.29	-1.52	-1.53	-2.34	-2.09	-1.71
		2	1.67	-1.40	0.00	0.00	0.00	0.68	-0.73	0.00	0.00	0.00
	6:12 (26.6°)	1	-2.63	-2.92	-4.49	-4.00	-3.29	-1.22	-1.53	-2.34	-2.09	-1.71
		2	1.84	-1.39	0.00	0.00	0.00	0.96	-0.73	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.35	-2.92	-4.49	-4.00	-3.29	-0.71	-1.53	-2.34	-2.09	-1.71
		2	2.20	-1.39	0.00	0.00	0.00	1.15	-0.73	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.76	-2.92	-4.49	-4.00	-3.29	-0.40	-1.53	-2.34	-2.09	-1.71
		2	2.20	-1.39	0.00	0.00	0.00	1.15	-0.73	0.00	0.00	0.00
18	Flat < 2:12 (9.46°)	1	NA	NA	-4.35	-3.88	-3.18	NA	NA	-2.31	-2.06	-1.69
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-4.26	-2.90	-4.35	-3.88	-3.18	-2.27	-1.54	-2.31	-2.06	-1.69
		2	0.61	-0.87	0.00	0.00	0.00	0.33	-0.35	0.00	0.00	0.00
	4: 12 (18.4°)	1	-3.51	-2.83	-4.35	-3.88	-3.18	-1.86	-1.50	-2.31	-2.06	-1.69
		2	1.21	-1.24	0.00	0.00	0.00	0.65	-0.66	0.00	0.00	0.00
	5:12 (22.6°)	1	-2.82	-2.83	-4.35	-3.88	-3.18	-1.49	-1.50	-2.31	-2.06	-1.69
		2	1.62	-1.35	0.00	0.00	0.00	0.24	-0.72	0.00	0.00	0.00
	6:12 (26.6°)	1	-2.26	-2.83	-4.35	-3.88	-3.18	-1.20	-1.50	-2.31	-2.06	-1.69
		2	1.78	-1.35	0.00	0.00	0.00	0.95	-0.72	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.31	-2.83	-4.35	-3.88	-3.18	-0.70	-1.50	-2.31	-2.06	-1.69
		2	2.13	-1.35	0.00	0.00	0.00	1.13	-0.72	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.74	-2.83	-4.35	-3.88	-3.18	-0.39	-1.50	-2.31	-2.06	-1.69
		2	2.13	-1.35	0.00	0.00	0.00	1.09	-0.69	0.00	0.00	0.00
15	Flat < 2:12 (9.46°)	1	NA	NA	-4.18	-3.73	-3.06	NA	NA	-2.27	-2.03	-1.66
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-4.10	-2.79	-4.18	-3.73	-3.06	-2.23	-1.52	-2.27	-2.03	-1.66
		2	0.59	-0.83	0.00	0.00	0.00	0.32	-0.07	0.00	0.00	0.00
	4: 12 (18.4°)	1	-3.37	-2.72	-4.18	-3.73	-3.06	-1.83	-1.48	-2.27	-2.03	-1.66
		2	1.17	-1.20	0.00	0.00	0.00	0.64	-0.65	0.00	0.00	0.00
	5:12 (22.6°)	1	-2.71	-2.72	-4.18	-3.73	-3.06	-1.47	-1.48	-2.27	-2.03	-1.66
		2	1.56	-1.30	0.00	0.00	0.00	0.85	-0.71	0.00	0.00	0.00
	6:12 (26.6°)	1	-2.18	-2.72	-4.18	-3.73	-3.06	-1.18	-1.48	-2.27	-2.03	-1.66
		2	1.72	-1.30	0.00	0.00	0.00	0.93	-0.71	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.26	-2.72	-4.18	-3.73	-3.06	-0.68	-1.48	-2.27	-2.03	-1.66
		2	2.05	-1.30	0.00	0.00	0.00	1.12	-0.71	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.71	-2.72	-4.18	-3.73	-3.06	-0.39	-1.48	-2.27	-2.03	-1.66
		2	2.05	-1.30	0.00	0.00	0.00	19.8	-12.5	0.0	0.0	0.0

Table 207B.6-2
MWFRS - Part 2: Wind Loads – Roof (kN/m²)
MWFRS – Roof, $V = 150 - 250$ kph, $h = 27 - 36$ m
Exposure C

V (kph)			150					200					250				
h (m)	Roof Slope	Load Case	Zone					Zone					Zone				
			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
36	Flat < 2:12 (9.46°)	1	NA	NA	-1.26	-1.11	-0.92	NA	NA	-1.34	-1.20	-0.97	NA	NA	-2.79	-2.48	-2.04
		2	NA	NA	0.00	0.00	0.00	NA	NA	NA	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-1.23	-0.62	-1.26	-1.11	-0.92	-1.31	-0.65	-1.34	-1.20	-0.97	-2.73	-1.93	-2.79	-2.48	-2.04
		2	0.18	-0.25	0.00	0.00	0.00	0.19	-0.27	NA	0.00	0.00	0.39	-0.56	0.00	0.00	0.00
	4: 12 (18.4°)	1	-1.01	-0.82	-1.26	-1.11	-0.92	-1.08	-0.87	-1.34	-1.20	-0.97	-2.25	-1.81	-2.79	-2.48	-2.04
		2	0.35	-0.36	0.00	0.00	0.00	0.37	-0.37	NA	0.00	0.00	0.78	-0.80	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.82	-0.82	-1.26	-1.11	-0.92	-0.86	-0.87	-1.34	-1.20	-0.97	-1.80	-1.81	-2.79	-2.48	-2.04
		2	0.46	-0.38	0.00	0.00	0.00	0.50	-0.41	NA	0.00	0.00	1.04	-0.87	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.65	-0.82	-1.26	-1.11	-0.92	-0.69	-0.87	-1.34	-1.20	-0.97	-1.45	-1.81	-2.79	-2.48	-2.04
		2	-4.19	-0.38	0.00	0.00	0.00	0.55	-0.41	NA	0.00	0.00	1.14	-0.87	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.37	-0.82	-1.26	-1.11	-0.92	-0.40	-0.87	-1.34	-1.20	-0.97	-0.84	-1.81	-2.79	-2.48	-2.04
		2	0.62	-0.38	0.00	0.00	0.00	0.65	-0.41	NA	0.00	0.00	1.37	-0.87	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.21	-0.82	-1.26	-1.11	-0.92	-0.23	-0.87	-1.34	-1.20	-0.97	-0.47	-1.81	-2.79	-2.48	-2.04
		2	0.62	-0.38	0.00	0.00	0.00	0.65	-0.41	NA	0.00	0.00	1.37	-0.87	0.00	0.00	0.00
33	Flat < 2:12 (9.46°)	1	NA	NA	-1.23	-1.10	-0.89	NA	NA	-1.33	-1.18	-0.96	NA	NA	-2.73	-2.44	-2.00
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-1.22	-0.60	-1.23	-1.10	-0.89	-1.28	-0.65	-1.33	-1.18	-0.96	-2.68	-1.90	-2.73	-2.44	-2.00
		2	0.17	-0.25	0.00	0.00	0.00	0.17	-0.26	0.00	0.00	0.00	0.39	-0.55	0.00	0.00	0.00
	4: 12 (18.4°)	1	-1.00	-0.82	-1.23	-1.10	-0.89	-1.06	-0.85	-1.33	-1.18	-0.96	-2.21	-1.78	-2.73	-2.44	-2.00
		2	-0.02	-0.35	0.00	0.00	0.00	0.37	-0.38	0.00	0.00	0.00	0.77	-0.78	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.80	-0.82	-1.23	-1.10	-0.89	-0.85	-0.85	-1.33	-1.18	-0.96	-1.77	-1.78	-2.73	-2.44	-2.00
		2	0.46	-0.38	0.00	0.00	0.00	0.49	-0.41	0.00	0.00	0.00	1.02	-0.85	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.63	-0.82	-1.23	-1.10	-0.89	-0.68	-0.85	-1.33	-1.18	-0.96	-1.42	-1.78	-2.73	-2.44	-2.00
		2	0.51	-0.38	0.00	0.00	0.00	0.54	-0.41	0.00	0.00	0.00	1.12	-0.85	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.36	-0.82	-1.23	-1.10	-0.89	-0.39	-0.85	-1.33	-1.18	-0.96	-0.82	-1.78	-2.73	-2.44	-2.00
		2	0.61	-0.38	0.00	0.00	0.00	0.65	-0.41	0.00	0.00	0.00	1.34	-0.85	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.20	-0.82	-1.23	-1.10	-0.89	-0.22	-0.85	-1.33	-1.18	-0.96	-0.46	-1.78	-2.73	-2.44	-2.00
		2	0.61	-0.38	0.00	0.00	0.00	0.65	-0.41	0.00	0.00	0.00	1.34	-0.85	0.00	0.00	0.00
30	Flat < 2:12 (9.46°)	1	NA	NA	-1.21	-1.08	-0.89	NA	NA	-1.30	-1.16	-0.95	NA	NA	-2.68	-2.39	-1.96
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-1.19	-0.59	-1.21	-1.08	-0.89	-1.27	-0.63	-1.30	-1.16	-0.95	-2.63	-1.86	-2.68	-2.39	-1.96
		2	0.17	-0.24	0.00	0.00	0.00	0.18	-0.26	0.00	0.00	0.00	0.38	-0.53	0.00	0.00	0.00
	4: 12 (18.4°)	1	-0.98	-0.79	-1.21	-1.08	-0.89	-1.05	-0.84	-1.30	-1.16	-0.95	-2.16	-1.74	-2.68	-2.39	-1.96
		2	-1.41	-0.35	0.00	0.00	0.00	0.36	-0.37	0.00	0.00	0.00	0.75	-0.77	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.79	-0.79	-1.21	-1.08	-0.89	-0.84	-0.84	-1.30	-1.16	-0.95	-1.74	-1.74	-2.68	-2.39	-1.96
		2	0.44	-0.38	0.00	0.00	0.00	0.48	-0.40	0.00	0.00	0.00	1.00	-0.84	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.63	-0.79	-1.21	-1.08	-0.89	-0.68	-0.84	-1.30	-1.16	-0.95	-1.39	-1.74	-2.68	-2.39	-1.96
		2	0.50	-0.38	0.00	0.00	0.00	0.54	-0.40	0.00	0.00	0.00	1.10	-0.84	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.36	-0.79	-1.21	-1.08	-0.89	-0.38	-0.84	-1.30	-1.16	-0.95	-0.81	-1.74	-2.68	-2.39	-1.96
		2	0.59	-0.38	0.00	0.00	0.00	0.64	-0.40	0.00	0.00	0.00	1.32	-0.84	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.20	-0.79	-1.21	-1.08	-0.89	-0.22	-0.84	-1.30	-1.16	-0.95	-0.46	-1.74	-2.68	-2.39	-1.96
		2	0.59	-0.38	0.00	0.00	0.00	0.64	-0.40	0.00	0.00	0.00	1.32	-0.84	0.00	0.00	0.00
27	Flat < 2:12 (9.46°)	1	NA	NA	-1.17	-1.05	-0.87	NA	NA	-1.28	-1.14	-0.94	NA	NA	-2.72	-2.42	-1.99
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-1.17	-0.57	-1.17	-1.05	-0.87	-1.25	-0.63	-1.28	-1.14	-0.94	-2.66	-1.88	-2.72	-2.42	-1.99
		2	0.18	-0.24	0.00	0.00	0.00	0.18	-0.25	0.00	0.00	0.00	0.38	-0.54	0.00	0.00	0.00
	4: 12 (18.4°)	1	-2.20	-0.77	-1.17	-1.05	-0.87	-1.03	-0.83	-1.28	-1.14	-0.94	-2.19	-1.77	-2.72	-2.42	-1.99
		2	0.33	-0.34	0.00	0.00	0.00	0.35	-0.37	0.00	0.00	0.00	0.76	-0.78	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.78	-0.77	-1.17	-1.05	-0.87	-0.84	-0.83	-1.28	-1.14	-0.94	-1.76	-1.77	-2.72	-2.42	-1.99
		2	0.44	-0.37	0.00	0.00	0.00	0.47	-0.39	0.00	0.00	0.00	1.01	-0.85	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.63	-0.77	-1.17	-1.05	-0.87	-0.66	-0.83	-1.28	-1.14	-0.94	-1.41	-1.77	-2.72	-2.42	-1.99
		2	0.49	-0.37	0.00	0.00	0.00	-0.68	-0.39	0.00	0.00	0.00	1.12	-0.85	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.35	-0.77	-1.17	-1.05	-0.87	-0.37	-0.83	-1.28	-1.14	-0.94	-0.82	-1.77	-2.72	-2.42	-1.99
		2	NA	-0.37	0.00	0.00	0.00	0.63	-0.39	0.00	0.00	0.00	1.26	-0.85	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.21	-0.77	-1.17	-1.05	-0.87	-0.21	-0.83	-1.28	-1.14	-0.94	-0.46	-1.77	-2.72	-2.42	-1.99
		2	0.57	-0.37	0.00	0.00	0.00	13.1	-8.2	0.0	0.0	0.0	1.33	-0.85	0.00	0.00	0.00

Table 207B.6-2
MWFRS - Part 2: Wind Loads – Roof (kN/m^2)
MWFRS – Roof, $V = 300 - 350$ kph, $h = 27 - 36$ m
Exposure C

V (kph)			300					350				
h (m)	Roof Slope	Load Case	Zone					Zone				
			1	2	3	4	5	1	2	3	4	5
36	Flat < 2:12 (9.46°)	1	NA	NA	-5.03	-4.49	-3.68	NA	NA	-2.38	-2.12	-1.74
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-4.94	-3.36	-5.03	-4.49	-3.68	-2.33	-1.58	-2.38	-2.12	-1.74
		2	0.71	-1.00	0.00	0.00	0.00	0.34	-0.47	0.00	0.00	0.00
	4: 12 (18.4°)	1	-4.06	-3.28	-5.03	-4.49	-3.68	-1.91	-1.55	-2.38	-2.12	-1.74
		2	1.40	-1.44	0.00	0.00	0.00	0.66	-0.68	0.00	0.00	0.00
	5:12 (22.6°)	1	-3.26	-3.28	-5.03	-4.49	-3.68	-1.54	-1.55	-2.38	-2.12	-1.74
		2	1.87	-1.57	0.00	0.00	0.00	0.88	-0.74	0.00	0.00	0.00
	6:12 (26.6°)	1	-2.62	-3.28	-5.03	-4.49	-3.68	-1.23	-1.55	-2.38	-2.12	-1.74
		2	2.06	-1.57	0.00	0.00	0.00	0.98	-0.74	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.51	-3.28	-5.03	-4.49	-3.68	-0.72	-1.55	-2.38	-2.12	-1.74
		2	2.47	-1.57	0.00	0.00	0.00	1.07	-0.68	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.85	-3.28	-5.03	-4.49	-3.68	-0.40	-1.55	-2.38	-2.12	-1.74
		2	2.47	-1.57	0.00	0.00	0.00	1.17	-0.74	0.00	0.00	0.00
33	Flat < 2:12 (9.46°)	1	NA	NA	-4.94	-4.40	-3.61	NA	NA	-2.34	-2.09	-1.71
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-4.85	-3.30	-4.94	-4.40	-3.61	-2.30	-1.56	-2.34	-2.09	-1.71
		2	0.70	-0.98	0.00	0.00	0.00	0.33	-0.47	0.00	0.00	0.00
	4: 12 (18.4°)	1	-3.98	-3.22	-4.94	-4.40	-3.61	-1.89	-1.53	-2.34	-2.09	-1.71
		2	1.38	-1.41	0.00	0.00	0.00	0.65	-0.67	0.00	0.00	0.00
	5:12 (22.6°)	1	-3.20	-3.21	-4.94	-4.40	-3.61	-1.52	-1.53	-2.34	-2.09	-1.71
		2	1.84	-1.54	0.00	0.00	0.00	0.68	-0.73	0.00	0.00	0.00
	6:12 (26.6°)	1	-2.57	-3.22	-4.94	-4.40	-3.61	-1.22	-1.53	-2.34	-2.09	-1.71
		2	2.03	-1.54	0.00	0.00	0.00	0.96	-0.73	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.49	-3.22	-4.94	-4.40	-3.61	-0.71	-1.53	-2.34	-2.09	-1.71
		2	2.42	-1.54	0.00	0.00	0.00	1.15	-0.73	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.84	-3.22	-4.94	-4.40	-3.61	-0.40	-1.53	-2.34	-2.09	-1.71
		2	2.42	-1.54	0.00	0.00	0.00	1.15	-0.73	0.00	0.00	0.00
30	Flat < 2:12 (9.46°)	1	NA	NA	-4.84	-4.32	-3.54	NA	NA	-2.31	-2.06	-1.69
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-4.75	-3.23	-4.84	-4.32	-3.54	-2.27	-1.54	-2.31	-2.06	-1.69
		2	0.69	-0.96	0.00	0.00	0.00	0.33	-0.35	0.00	0.00	0.00
	4: 12 (18.4°)	1	-3.91	-3.15	-4.84	-4.32	-3.54	-1.86	-1.50	-2.31	-2.06	-1.69
		2	1.35	-1.38	0.00	0.00	0.00	0.65	-0.66	0.00	0.00	0.00
	5:12 (22.6°)	1	-3.13	-3.14	-4.84	-4.32	-3.54	-1.49	-1.50	-2.31	-2.06	-1.69
		2	1.80	-1.51	0.00	0.00	0.00	0.24	-0.72	0.00	0.00	0.00
	6:12 (26.6°)	1	-2.52	-3.15	-4.84	-4.32	-3.54	-1.20	-1.50	-2.31	-2.06	-1.69
		2	1.99	-1.50	0.00	0.00	0.00	0.95	-0.72	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.46	-3.15	-4.84	-4.32	-3.54	-0.70	-1.50	-2.31	-2.06	-1.69
		2	2.38	-1.51	0.00	0.00	0.00	1.13	-0.72	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.82	-3.15	-4.84	-4.32	-3.54	-0.39	-1.50	-2.31	-2.06	-1.69
		2	2.38	-1.51	0.00	0.00	0.00	1.09	-0.69	0.00	0.00	0.00
27	Flat < 2:12 (9.46°)	1	NA	NA	-4.74	-4.22	-3.46	NA	NA	-2.27	-2.03	-1.66
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-4.65	-3.16	-4.74	-4.22	-3.46	-2.23	-1.52	-2.27	-2.03	-1.66
		2	0.67	-0.94	0.00	0.00	0.00	0.32	-0.07	0.00	0.00	0.00
	4: 12 (18.4°)	1	-3.82	-3.08	-4.74	-4.22	-3.46	-1.83	-1.48	-2.27	-2.03	-1.66
		2	1.32	-1.35	0.00	0.00	0.00	0.64	-0.65	0.00	0.00	0.00
	5:12 (22.6°)	1	-3.07	-3.08	-4.74	-4.22	-3.46	-1.47	-1.48	-2.27	-2.03	-1.66
		2	1.76	-1.46	0.00	0.00	0.00	0.85	-0.71	0.00	0.00	0.00
	6:12 (26.6°)	1	-2.46	-3.08	-4.74	-4.22	-3.46	-1.18	-1.48	-2.27	-2.03	-1.66
		2	1.94	-1.46	0.00	0.00	0.00	0.93	-0.71	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.42	-3.08	-4.74	-4.22	-3.46	-0.68	-1.48	-2.27	-2.03	-1.66
		2	2.32	-1.47	0.00	0.00	0.00	1.12	-0.71	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.80	-3.08	-4.74	-4.22	-3.46	-0.39	-1.48	-2.27	-2.03	-1.66
		2	2.32	-1.47	0.00	0.00	0.00	19.8	-12.5	0.0	0.0	0.0

Table 207B.6-2
MWFRS - Part 2: Wind Loads – Roof (kN/m²)
MWFRS – Roof, $V = 150 - 250$ kph, $h = 39 - 48$ m
Exposure C

V (kph)			150					200					250				
			Zone					Zone					Zone				
h (m)	Roof Slope	Load Case	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
48	Flat < 2:12 (9.46°)	1	NA	NA	-1.34	-1.20	-0.97	NA	NA	-2.38	-2.12	-1.74	NA	NA	-3.71	-2.57	-2.71
		2	NA	NA	NA	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-1.31	-0.65	-1.34	-1.20	-0.97	-2.33	-1.58	-2.38	-2.12	-1.74	-3.64	-2.56	-3.71	-2.57	-2.71
		2	0.19	-0.27	NA	0.00	0.00	0.34	-0.47	0.00	0.00	0.00	0.53	-0.74	0.00	0.00	0.00
	4: 12 (18.4°)	1	-1.08	-0.87	-1.34	-1.20	-0.97	-1.91	-1.55	-2.38	-2.12	-1.74	-2.99	-2.42	-3.71	-2.57	-2.71
		2	0.37	-0.37	NA	0.00	0.00	0.66	-0.68	0.00	0.00	0.00	1.04	-0.83	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.86	-0.87	-1.34	-1.20	-0.97	-1.54	-1.55	-2.38	-2.12	-1.74	-2.40	-2.42	-3.71	-2.57	-2.71
		2	0.50	-0.41	NA	0.00	0.00	0.88	-0.74	0.00	0.00	0.00	1.38	-1.16	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.69	-0.87	-1.34	-1.20	-0.97	-1.23	-1.55	-2.38	-2.12	-1.74	-1.93	-2.42	-3.71	-2.57	-2.71
		2	0.55	-0.41	NA	0.00	0.00	0.98	-0.74	0.00	0.00	0.00	1.53	-1.16	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.40	-0.87	-1.34	-1.20	-0.97	-0.72	-1.55	-2.38	-2.12	-1.74	-1.12	-2.42	-3.71	-2.57	-2.71
		2	0.65	-0.41	NA	0.00	0.00	1.07	-0.68	0.00	0.00	0.00	1.23	-1.06	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.23	-0.87	-1.34	-1.20	-0.97	-0.40	-1.55	-2.38	-2.12	-1.74	-0.63	-2.42	-3.71	-2.57	-2.71
		2	0.65	-0.41	NA	0.00	0.00	1.17	-0.74	0.00	0.00	0.00	1.82	-1.16	0.00	0.00	0.00
45	Flat < 2:12 (9.46°)	1	NA	NA	-1.33	-1.18	-0.96	NA	NA	-2.34	-2.09	-1.71	NA	NA	-3.66	-1.08	-2.68
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-1.28	-0.65	-1.33	-1.18	-0.96	-2.30	-1.56	-2.34	-2.09	-1.71	-3.59	-2.52	-3.66	-1.08	-2.68
		2	0.17	-0.26	0.00	0.00	0.00	0.33	-0.47	0.00	0.00	0.00	0.52	-0.73	0.00	0.00	0.00
	4: 12 (18.4°)	1	-1.06	-0.85	-1.33	-1.18	-0.96	-1.89	-1.53	-2.34	-2.09	-1.71	-2.96	-2.38	-3.66	-1.08	-2.68
		2	0.37	-0.38	0.00	0.00	0.00	0.65	-0.67	0.00	0.00	0.00	1.02	-0.35	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.85	-0.85	-1.33	-1.18	-0.96	-1.52	-1.53	-2.34	-2.09	-1.71	-2.37	-2.38	-3.66	-1.08	-2.68
		2	0.49	-0.41	0.00	0.00	0.00	0.68	-0.73	0.00	0.00	0.00	1.36	-1.14	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.68	-0.85	-1.33	-1.18	-0.96	-1.22	-1.53	-2.34	-2.09	-1.71	-1.90	-2.38	-3.66	-1.08	-2.68
		2	0.54	-0.41	0.00	0.00	0.00	0.96	-0.73	0.00	0.00	0.00	1.50	-1.14	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.39	-0.85	-1.33	-1.18	-0.96	-0.71	-1.53	-2.34	-2.09	-1.71	-1.10	-2.38	-3.66	-1.08	-2.68
		2	0.65	-0.41	0.00	0.00	0.00	1.15	-0.73	0.00	0.00	0.00	1.26	-1.14	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.22	-0.85	-1.33	-1.18	-0.96	-0.40	-1.53	-2.34	-2.09	-1.71	-0.62	-2.38	-3.66	-1.08	-2.68
		2	0.65	-0.41	0.00	0.00	0.00	1.15	-0.73	0.00	0.00	0.00	1.80	-1.14	0.00	0.00	0.00
42	Flat < 2:12 (9.46°)	1	NA	NA	-1.30	-1.16	-0.95	NA	NA	-2.31	-2.06	-1.69	NA	NA	-3.61	-3.22	-2.64
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-1.27	-0.63	-1.30	-1.16	-0.95	-2.27	-1.54	-2.31	-2.06	-1.69	-3.54	-2.49	-3.61	-3.22	-2.64
		2	0.18	-0.26	0.00	0.00	0.00	0.33	-0.35	0.00	0.00	0.00	0.51	-0.72	0.00	0.00	0.00
	4: 12 (18.4°)	1	-1.05	-0.84	-1.30	-1.16	-0.95	-1.86	-1.50	-2.31	-2.06	-1.69	-2.91	-2.35	-3.61	-3.22	-2.64
		2	0.36	-0.37	0.00	0.00	0.00	0.65	-0.66	0.00	0.00	0.00	1.01	-1.03	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.84	-0.84	-1.30	-1.16	-0.95	-1.49	-1.50	-2.31	-2.06	-1.69	-2.34	-2.35	-3.61	-3.22	-2.64
		2	0.48	-0.40	0.00	0.00	0.00	0.24	-0.72	0.00	0.00	0.00	1.34	-1.12	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.68	-0.84	-1.30	-1.16	-0.95	-1.20	-1.50	-2.31	-2.06	-1.69	-1.88	-2.35	-3.61	-3.22	-2.64
		2	0.54	-0.40	0.00	0.00	0.00	0.95	-0.72	0.00	0.00	0.00	1.48	-1.12	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.38	-0.84	-1.30	-1.16	-0.95	-0.70	-1.50	-2.31	-2.06	-1.69	-1.09	-2.35	-3.61	-3.22	-2.64
		2	0.64	-0.40	0.00	0.00	0.00	1.13	-0.72	0.00	0.00	0.00	1.24	-1.12	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.22	-0.84	-1.30	-1.16	-0.95	-0.39	-1.50	-2.31	-2.06	-1.69	-0.61	-2.35	-3.61	-3.22	-2.64
		2	0.64	-0.40	0.00	0.00	0.00	1.09	-0.69	0.00	0.00	0.00	1.77	-1.12	0.00	0.00	0.00
39	Flat < 2:12 (9.46°)	1	NA	NA	-1.28	-1.14	-0.94	NA	NA	-2.27	-2.03	-1.66	NA	NA	-3.41	-3.04	-2.49
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-1.25	-0.63	-1.28	-1.14	-0.94	-2.23	-1.52	-2.27	-2.03	-1.66	-3.34	-2.35	-3.41	-3.04	-2.49
		2	0.18	-0.25	0.00	0.00	0.00	0.32	-0.07	0.00	0.00	0.00	0.48	-0.68	0.00	0.00	0.00
	4: 12 (18.4°)	1	-1.03	-0.83	-1.28	-1.14	-0.94	-1.83	-1.48	-2.27	-2.03	-1.66	-2.75	-2.22	-3.41	-3.04	-2.49
		2	0.35	-0.37	0.00	0.00	0.00	0.64	-0.65	0.00	0.00	0.00	0.95	-0.97	0.00	0.00	0.00
	5:12 (22.6°)	1	-0.84	-0.83	-1.28	-1.14	-0.94	-1.47	-1.48	-2.27	-2.03	-1.66	-2.20	-2.22	-3.41	-3.04	-2.49
		2	0.47	-0.39	0.00	0.00	0.00	0.85	-0.71	0.00	0.00	0.00	1.27	-1.06	0.00	0.00	0.00
	6:12 (26.6°)	1	-0.66	-0.83	-1.28	-1.14	-0.94	-1.18	-1.48	-2.27	-2.03	-1.66	-1.77	-2.22	-3.41	-3.04	-2.49
		2	-0.68	-0.39	0.00	0.00	0.00	0.93	-0.71	0.00	0.00	0.00	1.40	-1.06	0.00	0.00	0.00
	9:12 (36.9°)	1	-0.37	-0.83	-1.28	-1.14	-0.94	-0.68	-1.48	-2.27	-2.03	-1.66	-1.03	-2.22	-3.41	-3.04	-2.49
		2	0.63	-0.39	0.00	0.00	0.00	1.12	-0.71	0.00	0.00	0.00	1.26	-1.06	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.21	-0.83	-1.28	-1.14	-0.94	-0.39	-1.48	-2.27	-2.03	-1.66	-0.58	-2.22	-3.41	-3.04	-2.49
		2	13.1	-8.2	0.0	0.0	0.0	19.8	-12.5	0.0	0.0	0.0	1.67	-1.06	0.00	0.00	0.00

Table 207B.6-2
MWFRS - Part 2: Wind Loads – Roof (kN/m²)
MWFRS – Roof, $V = 300 - 350$ kph, $h = 39 - 48$ m
Exposure C

V (kph)			300					350				
			Zone					Zone				
h (m)	**Roof Slope**	**Load Case**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
48	Flat < 2:12 (9.46°)	1	NA	NA	-5.35	-4.77	-3.91	NA	NA	-2.38	-2.12	-1.74
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-5.25	-3.56	-5.35	-4.77	-3.91	-2.33	-1.58	-2.38	-2.12	-1.74
		2	0.76	-1.06	0.00	0.00	0.00	0.34	-0.47	0.00	0.00	0.00
	4: 12 (18.4°)	1	-4.31	-3.48	-5.35	-4.77	-3.91	-1.91	-1.55	-2.38	-2.12	-1.74
		2	1.49	-1.53	0.00	0.00	0.00	0.66	-0.68	0.00	0.00	0.00
	5:12 (22.6°)	1	-3.46	-3.43	-5.35	-4.77	-3.91	-1.54	-1.55	-2.38	-2.12	-1.74
		2	1.99	-1.66	0.00	0.00	0.00	0.88	-0.74	0.00	0.00	0.00
	6:12 (26.6°)	1	-2.78	-3.48	-5.35	-4.77	-3.91	-1.23	-1.55	-2.38	-2.12	-1.74
		2	2.20	-1.66	0.00	0.00	0.00	0.98	-0.74	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.61	-3.48	-5.35	-4.77	-3.91	-0.72	-1.55	-2.38	-2.12	-1.74
		2	2.62	-1.66	0.00	0.00	0.00	1.07	-0.68	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.91	-3.48	-5.35	-4.77	-3.91	-0.40	-1.55	-2.38	-2.12	-1.74
		2	2.62	-1.66	0.00	0.00	0.00	1.17	-0.74	0.00	0.00	0.00
45	Flat < 2:12 (9.46°)	1	NA	NA	-5.27	-4.70	-3.86	NA	NA	-2.34	-2.09	-1.71
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-5.18	-3.52	-5.27	-4.70	-3.86	-2.30	-1.56	-2.34	-2.09	-1.71
		2	0.75	-1.05	0.00	0.00	0.00	0.33	-0.47	0.00	0.00	0.00
	4: 12 (18.4°)	1	-4.25	-3.43	-5.27	-4.70	-3.86	-1.89	-1.53	-2.34	-2.09	-1.71
		2	1.47	-1.51	0.00	0.00	0.00	0.65	-0.67	0.00	0.00	0.00
	5:12 (22.6°)	1	-3.41	-3.43	-5.27	-4.70	-3.86	-1.52	-1.53	-2.34	-2.09	-1.71
		2	1.96	-1.64	0.00	0.00	0.00	0.68	-0.73	0.00	0.00	0.00
	6:12 (26.6°)	1	-2.74	-3.43	-5.27	-4.70	-3.86	-1.22	-1.53	-2.34	-2.09	-1.71
		2	2.17	-1.64	0.00	0.00	0.00	0.96	-0.73	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.59	-3.43	-5.27	-4.70	-3.86	-0.71	-1.53	-2.34	-2.09	-1.71
		2	2.59	-1.64	0.00	0.00	0.00	1.15	-0.73	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.90	-3.43	-5.27	-4.70	-3.86	-0.40	-1.53	-2.34	-2.09	-1.71
		2	2.59	-1.64	0.00	0.00	0.00	1.15	-0.73	0.00	0.00	0.00
42	Flat < 2:12 (9.46°)	1	NA	NA	-5.20	-4.63	-3.80	NA	NA	-2.31	-2.06	-1.69
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-5.10	-3.47	-5.20	-4.63	-3.80	-2.27	-1.54	-2.31	-2.06	-1.69
		2	0.74	-1.03	0.00	0.00	0.00	0.33	-0.35	0.00	0.00	0.00
	4: 12 (18.4°)	1	-4.19	-3.38	-5.20	-4.63	-3.80	-1.86	-1.50	-2.31	-2.06	-1.69
		2	1.45	-1.49	0.00	0.00	0.00	0.65	-0.66	0.00	0.00	0.00
	5:12 (22.6°)	1	-3.36	-3.38	-5.20	-4.63	-3.80	-1.49	-1.50	-2.31	-2.06	-1.69
		2	1.93	-1.62	0.00	0.00	0.00	0.24	-0.72	0.00	0.00	0.00
	6:12 (26.6°)	1	-2.70	-3.38	-5.20	-4.63	-3.80	-1.20	-1.50	-2.31	-2.06	-1.69
		2	2.13	-1.62	0.00	0.00	0.00	0.95	-0.72	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.57	-3.38	-5.20	-4.63	-3.80	-0.70	-1.50	-2.31	-2.06	-1.69
		2	2.55	-1.62	0.00	0.00	0.00	1.13	-0.72	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.88	-3.38	-5.20	-4.63	-3.80	-0.39	-1.50	-2.31	-2.06	-1.69
		2	2.55	-1.62	0.00	0.00	0.00	1.09	-0.69	0.00	0.00	0.00
39	Flat < 2:12 (9.46°)	1	NA	NA	-5.12	-4.56	-3.74	NA	NA	-2.27	-2.03	-1.66
		2	NA	NA	0.00	0.00	0.00	NA	NA	0.00	0.00	0.00
	3:12 (14.0°)	1	-5.02	-3.41	-5.12	-4.56	-3.74	-2.23	-1.52	-2.27	-2.03	-1.66
		2	0.72	-1.02	0.00	0.00	0.00	0.32	-0.07	0.00	0.00	0.00
	4: 12 (18.4°)	1	-4.13	-3.33	-5.12	-4.56	-3.74	-1.83	-1.48	-2.27	-2.03	-1.66
		2	1.43	-1.46	0.00	0.00	0.00	0.64	-0.65	0.00	0.00	0.00
	5:12 (22.6°)	1	-3.31	-3.33	-5.12	-4.56	-3.74	-1.47	-1.48	-2.27	-2.03	-1.66
		2	1.90	-1.59	0.00	0.00	0.00	0.85	-0.71	0.00	0.00	0.00
	6:12 (26.6°)	1	-2.66	-3.33	-5.12	-4.56	-3.74	-1.18	-1.48	-2.27	-2.03	-1.66
		2	2.10	-1.59	0.00	0.00	0.00	0.93	-0.71	0.00	0.00	0.00
	9:12 (36.9°)	1	-1.54	-3.33	-5.12	-4.56	-3.74	-0.68	-1.48	-2.27	-2.03	-1.66
		2	2.51	-1.59	0.00	0.00	0.00	1.12	-0.71	0.00	0.00	0.00
	12:12 (45.0°)	1	-0.87	-3.33	-5.12	-4.56	-3.74	-0.39	-1.48	-2.27	-2.03	-1.66
		2	2.51	-1.59	0.00	0.00	0.00	19.8	-12.5	0.0	0.0	0.0

207C.3 Velocity Pressure

207C.3.1 Velocity Pressure Exposure Coefficient

Based on the Exposure Category determined in Section 207A.7.3, a velocity pressure exposure coefficient K_z or K_h, as applicable, shall be determined from Table 207C.3-1.

For a site located in a transition zone between exposure categories that is near to a change in ground surface roughness, intermediate values of K_z or K_h, between those shown in Table 207C.3-1, are permitted, provided that they are determined by a rational analysis method defined in the recognized literature.

Table 207C.2-1
Steps to Determine Wind Loads on MWFRS
Low-Rise Buildings

Step 1:	Determine occupancy category of building or other structure, see Table 103-1
Step 2:	Determine the basic wind speed, V, for the applicable risk category, see Figure 207A.5-1A, B or C
Step 3:	Determine wind load parameters: ➢ Wind directionality factor, K_d, see Section 207A.6 and Table 207A.6-1 ➢ Exposure category B, C or D, see Section 207A.7 ➢ Topographic factor, K_{zt}, see Section 207A.8 and Figure 207A.8-1 ➢ Enclosure classification, see Section 207A.10 ➢ Internal pressure coefficient, (GC_{pi}), see Section 207A.11 and Table 207A.11-1
Step 4:	Determine velocity pressure exposure coefficient, K_z or K_h, see Tables 207C.3-1
Step 5:	Determine velocity pressure, q_z or q_h, see Equation 207C.3-1
Step 6:	Determine external pressure coefficient, (GC_p), using Figure 207C.4-1 for flat and gable roofs.
User Note: *See Commentary Figure C207C.4-1 for guidance on hip roofs.*	
Step 7:	Calculate wind pressure, p, from Equation 207C.4-1

Commentary:

See commentary to Section C207B.3.1.

207C.3.2 Velocity Pressure

Velocity pressure, q_z, evaluated at height z shall be calculated by the following equation:

$$q_z = 0.613 K_z K_{zt} K_d V^2 \text{ (N/m}^2\text{); } V \text{ in m/s} \quad (207C.3\text{-}1)$$

where

K_d = wind directionality factor, see Section 207A.6

K_z = velocity pressure exposure coefficient, see Section 207C.3.1

K_{zt} = topographic factor defined, see Section 207A.8.2

V = basic wind speed, see Section 207A.5.1

q_z = velocity pressure calculated using Equation 207C.3-1 at mean roof height h

The numerical coefficient 0.613 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.

Commentary:

See commentary to Section C207B.3.2.

Loads on Main Wind-Force Resisting Systems:

The pressure coefficients for MWFRS are basically separated into two categories:

1. *Directional Procedure for buildings of all heights (Figure 207B.4-1) as specified in Section 207B for buildings meeting the requirements specified therein.*
2. *Envelope Procedure for low-rise buildings (Figure 207C.4-1) as specified in Section 207C for buildings meeting the requirements specified therein.*

In generating these coefficients, two distinctly different approaches were used. For the pressure coefficients given in Figure 207B.4-1, 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, however, the values of (GC_{pf}) represent "pseudo" loading conditions that, when applied to the building, envelop the desired structural actions (bending moment, shear, thrust) independent of wind direction. 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 or reference corner shown in the eight sketches of Figure 207C.4-1. At each corner, two load patterns are applied, one for each wind direction range. The end zone creates the required structural actions in the end frame or bracing. Note also that for all roof slopes, all eight load cases must be considered individually to determine the critical loading for a given structural assemblage or component thereof. Special attention should be given to roof members, such as trusses, which meet the definition of MWFRS but are not part of the lateral resisting system. When such members span at least from the eave to the ridge or support members spanning at least from eave to ridge, they are not required to be designed for the higher end zone loads under MWFRS. The interior zone loads should be applied. This is due to the enveloped nature of the loads for roof members.

To develop the appropriate "pseudo" values of (GC_{pf}), investigators at the University of Western Ontario (Davenport et al. 1978) used an approach that consisted essentially of permitting the building model to rotate in the wind tunnel through a full 360° while simultaneously monitoring the loading conditions on each of the surfaces (Figure C207C.4-1). 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 (two-hinged frame).*
4. *Bending moment at knees (three-hinged frame).*
5. *Bending moment at ridge (two-hinged frame).*

The next step involved developing sets of "pseudo" pressure coefficients to generate loading conditions that would envelop 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 preceding five categories were used to develop the coefficients. The end result was a set of coefficients that represent fictitious loading conditions but that conservatively envelop 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, that is, single-storey moment-resisting frames in one of the principal directions and bracing in the other principal direction. The approach was later extended to single-storey moment-resisting frames with interior columns (Kavanagh et al. 1983).

Subsequent wind tunnel studies (Isyumov and Case 1995) have shown that the (GC_{pf}) *values of Figure 207C.4-1 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 MWFRS. Two different MWFRS were evaluated. One consisted = of shear walls and roof trusses at different spacing. The other had moment-resisting frames in one direction, positioned at the same spacing 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 207C.4-1 provided satisfactory estimates of the wind forces for both types of structural systems. This work confirms the validity of Figure 207C.4-1, which reflects the combined action of wind pressures on different external surfaces of a building and thus takes advantage of spatial averaging.*

In the original wind tunnel experiments, both B and C exposure terrains were checked. In these early experiments, Exposure B did not include nearby buildings. In general, the force components, bending moments, and so forth 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 Figures 207C.4-1, 207E.4-1, 207E.4-2A, 27E.4-2B, 27E.4-2C, 27E.4-3, 27E.4-4, 27E.4-5A, 27E.4-5B, and 27E.4-6 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 comprehensive wind tunnel studies conducted by Ho at the University of Western Ontario (1992), it was determined that when low buildings ($h < 18$ *m) 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 ASCE 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. Beginning in NSCP 2001 (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.*

Figure 207C.4-1 is most appropriate for low buildings with width greater than twice their height and a mean roof height that does not exceed 10 m. The original database included low buildings with width no greater than five times their eave height, and eave height did not exceed 10m. In the absence of more appropriate data, Figure 207C.4-1 may also be used for buildings with mean roof height that does not exceed the least horizontal dimension and is less than or equal to 18m. Beyond these extended limits, Figure 207B.4-1 should be used.

All the research used to develop and refine the low-rise building method for MWFRS loads was done on gable-roofed buildings. In the absence of research on hip-roofed buildings, the ASCE committee has developed a rational method of applying Figure 207C.4-1 to hip roofs based on its collective experience, intuition, and judgment. This suggested method is presented in Figure C207C.4-2.

Research (Isyumov 1982 and Isyumov and Case 2000) indicated that the low-rise method alone underestimates the amount of torsion caused by wind loads. In ASCE 7-02, Note 5 was added to Figure 207C.4-1 to account for this torsional effect and has been carried forward through subsequent editions. The reduction in loading on only 50 percent of the building results in a torsional load case without an increase in the predicted base shear for the building. The provision will have little or no effect on the design of MWFRS that have well-distributed resistance. However, it will impact the design of systems with centralized resistance, such as a single core in the center of the building. An illustration of the intent of the note on two of the eight load patterns is shown in Figure 207C.4-1. All eight patterns should be modified in this way as a separate set of load conditions in addition to the eight basic patterns.

Internal pressure coefficients (GC_{pi}) *to be used for loads on MWFRS are given in Table 207A.11-1. The internal pressure load can be critical in one-storey moment-*

resisting frames and in the top storey of a building where the MWFRS 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 MWFRS of high-rise buildings.

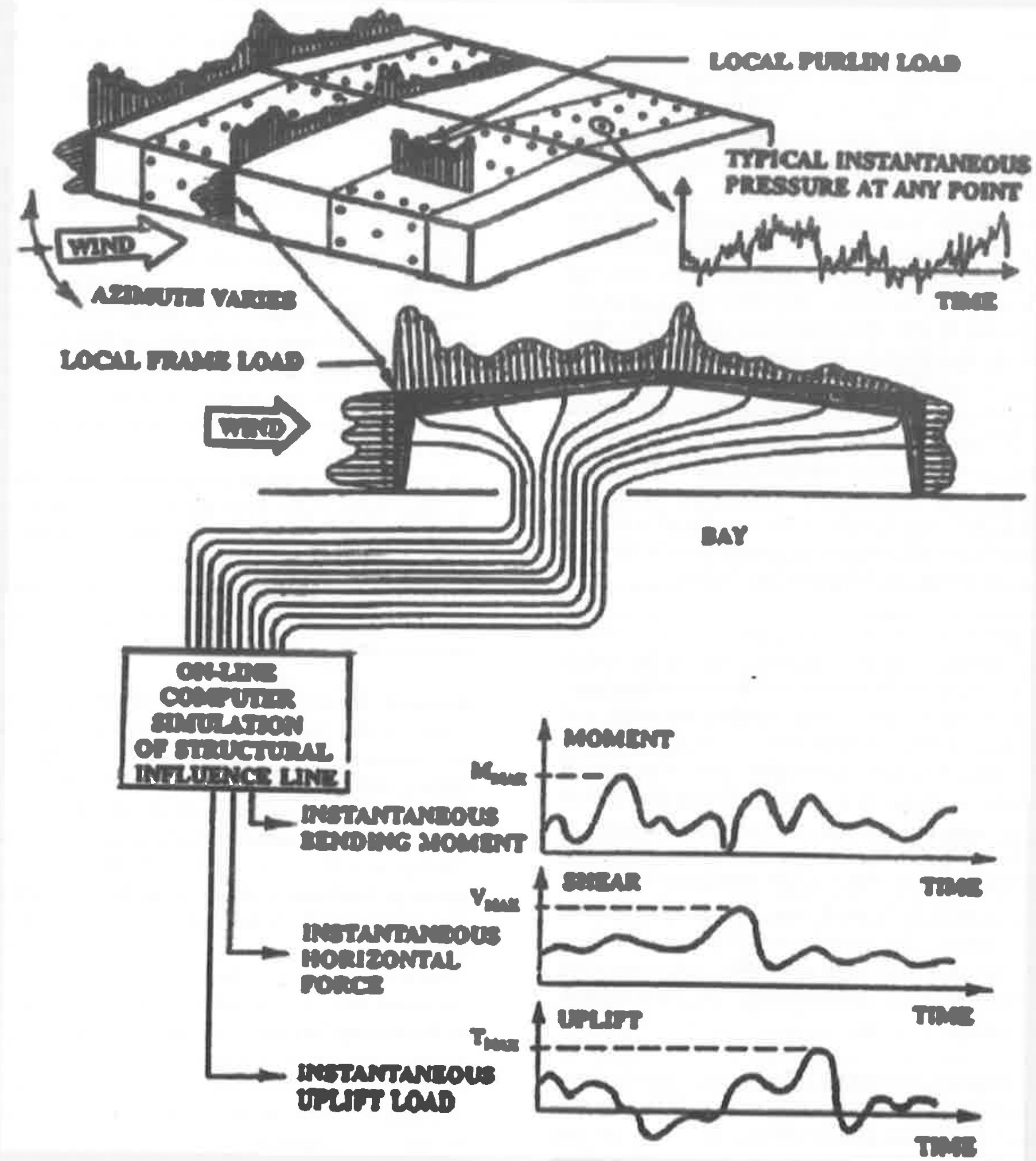


Figure C207C.4-1
Unsteady Wind Loads on Low Buildings for Given Wind Direction (*After Ellingwood 1982*)

207C.4 Wind Loads — Main Wind-Force Resisting System

207C.4.1 Design Wind Pressure for Low-Rise Buildings

Design wind pressures for the MWFRS of low-rise buildings shall be determined by the following equation:

$$p = q_h[(GC_{pf}) - (GC_{pi})] \text{ (N/m}^2\text{)} \qquad (207C.4\text{-}1)$$

where

q_h = velocity pressure evaluated at mean roof height h as defined in Section 207A.3

(GC_{pf}) = external pressure coefficient from Figure 207C.4-1

(GC_{pi}) = internal pressure coefficient from Table 207A.11-1

207C.4.1.1 External Pressure Coefficients (GC_{pf})

The combined gust effect factor and external pressure coefficients for low-rise buildings, (GC_{pf}), are not permitted to be separated.

207C.4.2 Parapets

The design wind pressure for the effect of parapets on MWFRS of low-rise buildings with flat, gable, or hip roofs shall be determined by the following equation:

$$p_p = q_p\,(GC_{pn}) \text{ (N/m}^2\text{)} \qquad (207C.4\text{-}2)$$

where

p_p = combined net pressure on the parapet due to the combination of the net pressures from the front and back parapet surfaces. Plus (and minus) signs signify net pressure acting toward (and away from) the front (exterior) side of the parapet

q_p = velocity pressure evaluated at the top of the
parapet

(GC_{pn}) = combined net pressure coefficient
= +1.5 for windward parapet
= −1.0 for leeward parapet

Commentary:

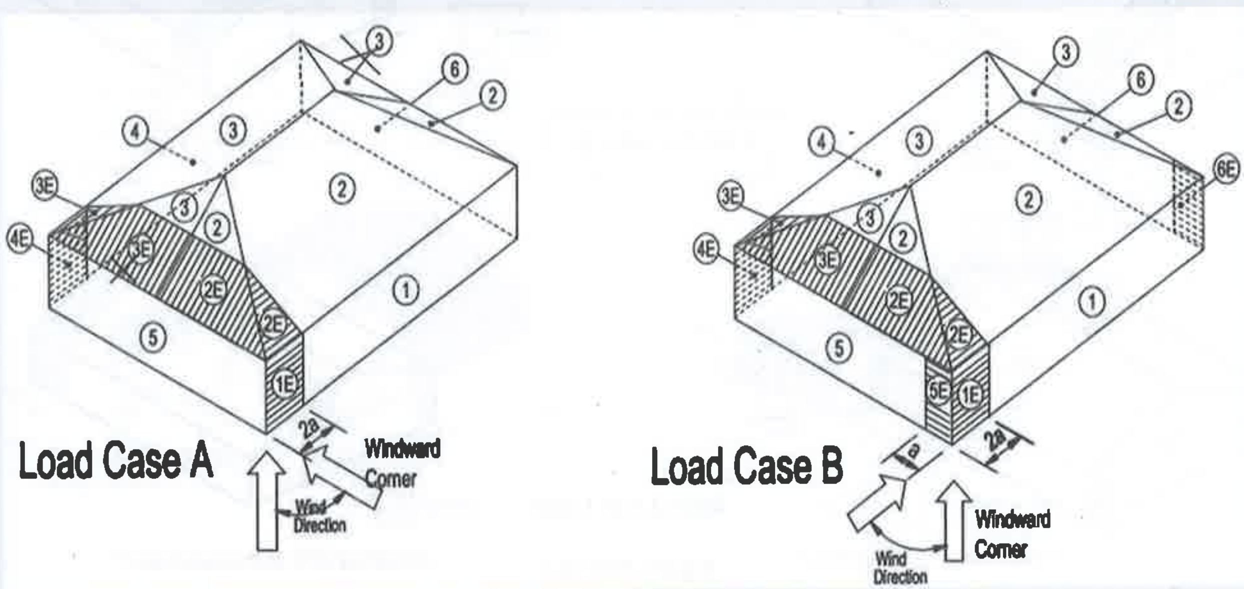
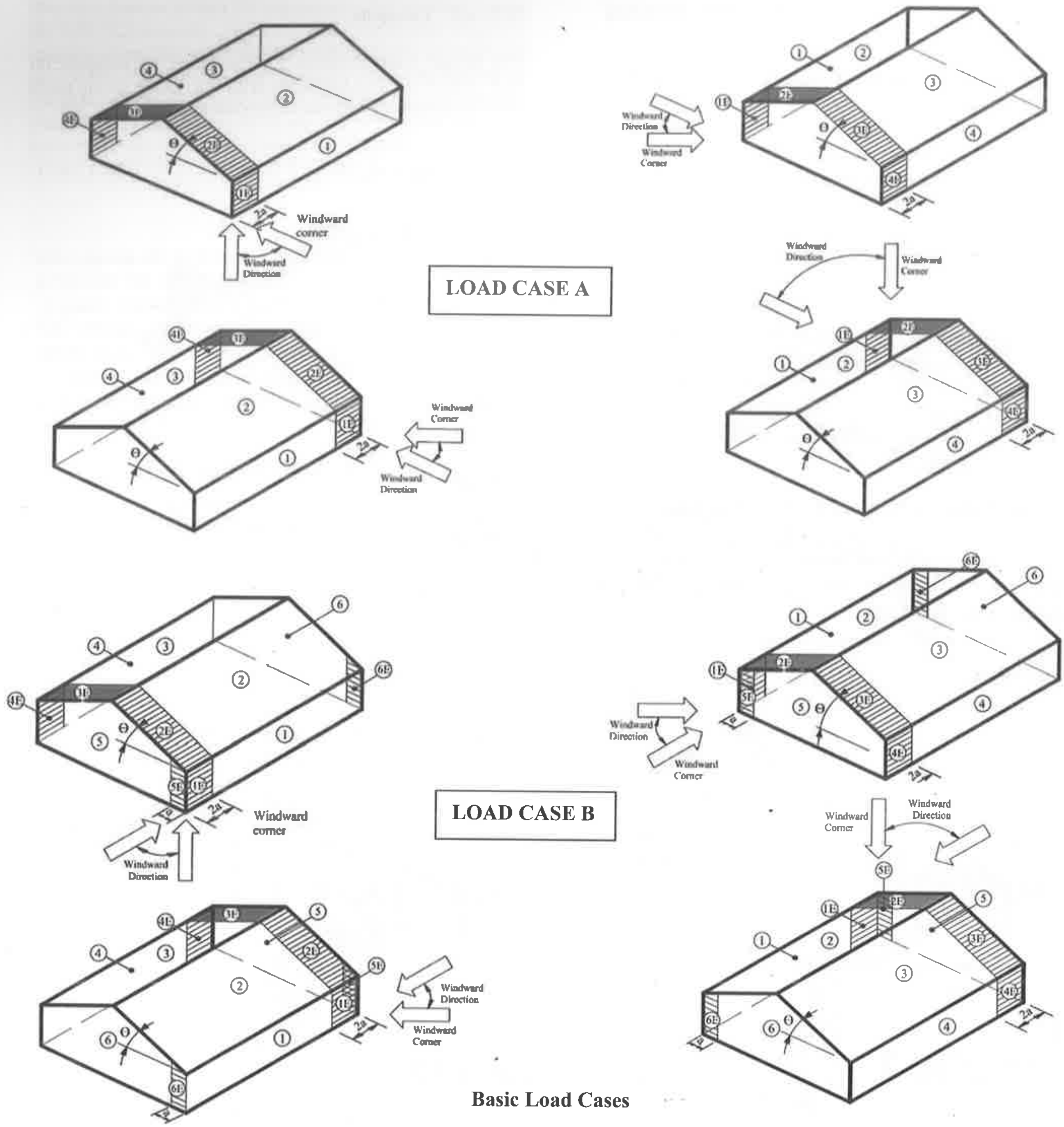


Figure C207C.4-2
Hip Roofed Low-Rise Buildings

Notes:

1. Adapt the loadings shown in Figure 207C.4-1 for hip roofed buildings as shown above. For a given hip roof pitch use the roof coefficients from the Case A table for both Load Case A and Load Case B.
2. The total horizontal shear shall not be less than that determined by neglecting the wind forces on roof surfaces.



Basic Load Cases

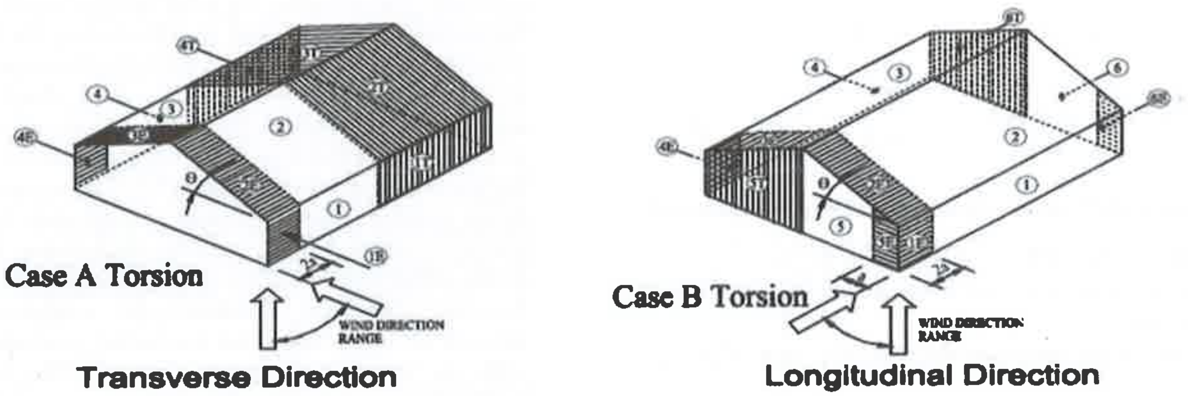
Figure 207C.4-1
Main Wind Force Resisting System – Part 1 External Pressure Coefficients (GC_{pf})
Enclosed, Partially Enclosed Buildings, $h \leq 18$ m Low-rise Walls and Roofs

Roof Angle θ (degrees)	LOAD 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)	LOAD 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. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
2. For values of θ other than those shown, linear interpolation is permitted.
3. The building must be designed for all wind directions using the 8 loading patterns shown. The load patterns are applied to each building corner in turn as the Windward Corner.
4. Combinations of external and internal pressures (see Table 207A.11-1) shall be evaluated as required to obtain the most severe loadings.
5. For the torsional load cases shown below, the pressures in zones designated with a "T" (1T, 2T, 3T, 4T, 5T, 6T) shall be 25% of the full design wind pressures (zones 1, 2, 3, 4, 5, 6).
   *Exception: One storey buildings with **h** less than or equal to 9 m, buildings two storeys or less framed with light frame construction, and buildings two storeys or less designed with flexible diaphragms need to be designed for the torsional load cases.*
   Torsional loading shall apply to all eight basic load patterns using the figures below applied at each Windward Corner.
6. For purposes of designing a building's MWFRS, the total horizontal shear shall not be less than that determined by neglecting the wind forces on the roof.
   Exception: This provision does not apply to buildings using moment frames for the MWFRS.
7. For flat roofs, use $\theta = 0^o$ and locate the zone 2/3 and zone 2E/3E boundary at the mid-width of the building.
8. The pressure coefficient (GC_{pf}), when negative in Zone 2 and 2E, shall be applied in Zone 2/2E for a distance from the edge of the roof equal 0.5 times the horizontal dimension of the building parallel to the direction of MWFRS being designed or 2.5 times the eave height at the windward wall, whichever is less; the remainder of Zone 2/2E extending to the ridge line shall use the pressure coefficient (GC_{pf}) for zone 3/3E.
9. Notation:
   a: 10% of least horizontal dimension or $.4h$, whichever is smaller, but not less than either 4% of least horizontal dimension or 0.9 m
   h: Mean roof height, in meters, except that eave height shall be used for $\theta \leq 10^o$.
   θ: Angle of plane of roof from horizontal, in degrees



Torsional Load Cases

Figure 207C.4-1 (continued)
Main Wind Force Resisting System – Part 1.External Pressure Coefficients (GC_{pf})
Enclosed, Partially Enclosed Buildings, h ≤ 18m Low-rise Walls and Roofs

207C.4.3 Roof Overhangs

The positive external pressure on the bottom surface of windward roof overhangs shall be determined using $C_p = 0.7$ in combination with the top surface pressures determined using Figure 207C.4-1.

207C.4.4 Minimum Design Wind Loads

The wind load to be used in the design of the MWFRS for an enclosed or partially enclosed building shall not be less than 0.77 kN/m² multiplied by the wall area of the building and 0.38 kN/m² multiplied by the roof area of the building projected onto a vertical plane normal to the assumed wind direction.

Table 207C.3-1
Velocity Pressure Exposure Coefficients, K_h and K_z

Height above ground level, z	Exposure		
m	B	C	D
0-4.6	0.70	0.85	1.03
6.1	0.70	0.90	1.08
7.6	0.70	0.94	1.12
9.1	0.70	0.98	1.16
12.2	0.76	1.04	1.22
15.2	0.81	1.09	1.27
18	0.85	1.13	1.31

Notes:

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

   For $4.57\text{ m} \le z \le z_g$

   $$K_z = 2.01(z/z_g)^{2/\alpha}$$

   For $z < 4.57$ m

   $$K_z = 2.01(4.57/z_g)^{2/\alpha}$$

   Note: z shall not be taken less than 9 m in exposure B.

2. α and z_g are tabulated in Table 207A.9-1.
3. Linear interpolation for intermediate values of height z is acceptable.
4. Exposure categories are defined in Section 207A.7.

Commentary

This section specifies a minimum wind load to be applied horizontally on the entire vertical projection of the building as shown in Figure C207B.4-1. This load case is to be applied as a separate load case in addition to the normal load cases specified in other portions of this chapter.

Part 2: Enclosed Simple Diaphragm Low-Rise Buildings

Commentary:

This simplified approach of the Envelope Procedure is for the relatively common low-rise ($h \le 18m$) regular shaped, simple diaphragm building case (see definitions for "simple diaphragm building" and "regular-shaped building") where pressures for the roof and walls can be selected directly from a table. Figure 207C.6-1 provides the design pressures for MWFRS for the specified conditions. Values are provided for enclosed buildings only ($(GC_{pi}) = \pm 0.18$).

Horizontal wall pressures are the net sum of the windward and leeward pressures on vertical projection of the wall. Horizontal roof pressures are the net sum of the windward and leeward pressures on vertical projection of the roof. Vertical roof pressures are the net sum of the external and internal pressures on the horizontal projection of the roof.

Note that for the MWFRS in a diaphragm building, the internal pressure cancels for loads on the walls and for the horizontal component of loads on the roof. This is true because when wind forces are transferred by horizontal diaphragms (e.g., floors and roofs) to the vertical elements of the MWFRS (e.g., shear walls, X-bracing, or moment frames), the collection of wind forces from windward and leeward sides of the building occurs in the horizontal diaphragms. Once transferred into the horizontal diaphragms by the vertically spanning wall systems, the wind forces become a net horizontal wind force that is delivered to the lateral force resisting elements of the MWFRS. There should be no structural separations in the diaphragms. Additionally, there should be no girts or other horizontal members that transmit significant wind loads directly to vertical frame members of the MWFRS in the direction under consideration. The equal and opposite internal pressures on the walls cancel each other in the horizontal diaphragm. This simplified approach of the Envelope Procedure combines the windward and leeward pressures into a net horizontal wind pressure, with the internal pressures canceled. The user is cautioned to consider the precise application of windward and leeward wall loads to members of the roof diaphragm where openings may exist and where particular members, such as drag struts, are designed. The design of the roof members of the MWFRS for vertical loads is influenced by internal pressures. The maximum uplift, which is controlled by Load Case B, is produced by a positive internal pressure. At a roof slope *of approximately 28° and above the windward roof pressure becomes positive and a negative internal pressure used in Load Case 2 in the table may produce a controlling case. From 25° to 45°, both positive and negative internal pressure cases (Load Cases 1 and 2, respectively) must be checked for the roof.*

For the designer to use this method for the design of the MWFRS, the building must conform to all of the requirements listed in Section 207A.8.2; otherwise the Directional Procedure, Part 1 of the Envelope Procedure, or the Wind Tunnel Procedure must be used. This method is based on Part 1 of the Envelope Procedure, as shown in Figure 207C.4-1, for a specific group of buildings (simple diaphragm buildings). However, the torsional loading from Figure 207C.4-1 is deemed to be too complicated for a simplified method. The last requirement in Section 207C.6.2 prevents the use of this method for buildings with lateral systems that are sensitive to torsional wind loading.

Note 5 of Figure 207C.4-1 identifies several building types that are known to be insensitive to torsion and may therefore be designed using the provisions of Section 207C.6. Additionally, buildings whose lateral resistance in each principal direction is provided by two shear walls, braced frames, or moment frames that are spaced apart a distance not less than 75 percent of the width of the building measured normal to the orthogonal wind direction, and other building types and element arrangements described in Section 207B.6.1 or 207B.6.2 are also insensitive to torsion. This property could be demonstrated by designing the building using Part 1 of Section 207C, Figure 207C.4-1, and showing that the torsion load cases defined in Note 5 do not govern the design of any of the lateral resisting elements. Alternatively, it can be demonstrated within the context of Part 2 of Section 207C by defining torsion load cases based on the loads in Figure 207C.6-1 and reducing the pressures on one-half of the building by 75 percent, as described in Figure 207C.4-1, Note 5. If none of the lateral elements are governed by these torsion cases, then the building can be designed using Part 2 of Section 207C; otherwise the building must be designed using Part 1 of Section 207B or Part 1 of Section 207C.

Values are tabulated for Exposure B at $\boldsymbol{h}$ *= 9.0 m, and* $\boldsymbol{K_{zt}}$ *= 1.0. Multiplying factors are provided for other exposures and heights. The following values have been used in preparation of the figures:*

Exposure B

$(GC_{pi}) = \pm 0.18$ *(enclosed building)*

$h = 9.0\ m$

$K_d = 0.85$

$K_z = 0.70$

$K_{zt} = 1.0$

Pressure coefficients are from Figure 207C.4-1.

Wall elements resisting two or more simultaneous wind-induced structural actions (e.g., bending, uplift, or shear) should be designed for the interaction of the wind loads as part of the MWFRS. The horizontal loads in Figure 207C.6-1 are the sum of the windward and leeward pressures and are therefore not applicable as individual wall pressures for the interaction load cases. Design wind pressures, $\boldsymbol{p_s}$ *for zones A and C, should be multiplied by +0.85 for use on windward walls and by –0.70 for use on leeward walls (the plus sign signifies pressures acting toward the wall surface). For side walls,* $\boldsymbol{p_s}$ *for zone C multiplied by –0.65 should be used. These wall elements must also be checked for the various separately acting (not simultaneous) component and cladding load cases.*

Main wind-force resisting roof members spanning at least from the eave to the ridge or supporting members spanning at least from eave to ridge are not required to be designed for the higher end zone loads. The interior zone loads should be applied. This is due to the enveloped nature of the loads for roof members.

207C.5 General Requirements

The steps required for the determination of MWFRS wind loads on enclosed simple diaphragm buildings are shown in Table 207C.5-1.

> *User Note:*
>
> *Part 2 of Section 207C is a simplified method to determine the wind pressure on the MWFRS of enclosed simple diaphragm low-rise buildings having a flat, gable or hip roof. The wind pressures are obtained directly from a table and applied on horizontal and vertical projected surfaces of the building. This method is a simplification of the Envelope Procedure contained in Part 1 of Section 207C.*

207C.5.1 Wind Load Parameters Specified in Section 207A

The following wind load parameters are specified in Section 207A:

- Basic Wind Speed $\boldsymbol{V}$ (Section 207A.5)
- Exposure category (Section 207A.7)

- Topographic factor K_{zt} (Section 207A.8)
- Enclosure classification (Section 207A.10)

Table 207C.5-1
Steps to Determine Wind Loads on MWFRS Simple Diaphragm Low-Rise Buildings

Step 1:	Determine occupancy category of building or other structure, see Table 103-1
Step 2:	Determine the basic wind speed, V, for the applicable risk category, see Figure 207A.5-1A, B or C
Step 3:	Determine wind load parameters: ➢ Exposure category B, C or D, see Section 207A.7 ➢ Topographic factor, K_{zt}, see Section 207A.8 and Figure 207A.8-1
Step 4:	Enter figure to determine wind pressures for h = 9 m, p_{S30}, see Figure 207C.6-1
Step 5:	Enter figure to determine adjustment for building height and exposure, λ, see Figure 207C.6-1
Step 6:	Determine adjusted wind pressures, p_s, see Equation 207C.6-1

207C.6 Wind Loads - Main Wind-Force Resisting System

207C.6.1 Scope

A building whose design wind loads are determined in accordance with this section shall meet all the conditions of Section 207C.6.2. If a building does not meet all of the conditions of Section 207C.6.2, then its MWFRS wind loads shall be determined by Part 1 of this chapter, by the Directional Procedure of Section 207B, or by the Wind Tunnel Procedure of Section 207F.

207C.6.2 Conditions

For the design of MWFRS the building shall comply with all of the following conditions:

1. The building is a simple diaphragm building as defined in Section 207A.2.
2. The building is a low-rise building as defined in Section 207A.2.
3. The building is enclosed as defined in Section 207A.2 and conforms to the wind-borne debris provisions of Section 207A.10.3.
4. The building is a regular-shaped building or structure as defined in Section 207A.2.
5. The building is not classified as a flexible building as defined in Section 207A.2.
6. The building does not have response characteristics making it subject to across wind loading, vortex shedding, instability due to galloping or flutter; and it does not have a site location for which channeling effects or buffeting in the wake of upwind obstructions warrant special consideration.
7. The building has an approximately symmetrical cross-section in each direction with either a flat roof or a gable or hip roof with $\theta \leq 45°$.
8. The building is exempted from torsional load cases as indicated in Note 5 of Figure 207C.4-1, or the torsional load cases defined in Note 5 do not control the design of any of the MWFRS of the building.

207C.6.3 Design Wind Loads

Simplified design wind pressures, p_s, for the MWFRS of low-rise simple diaphragm buildings represent the net pressures (sum of internal and external) to be applied to the horizontal and vertical projections of building surfaces as shown in Figure 207C.6-1. For the horizontal pressures (Zones A, B, C, D), p_s is the combination of the windward and leeward net pressures. p_s shall be determined by the following equation:

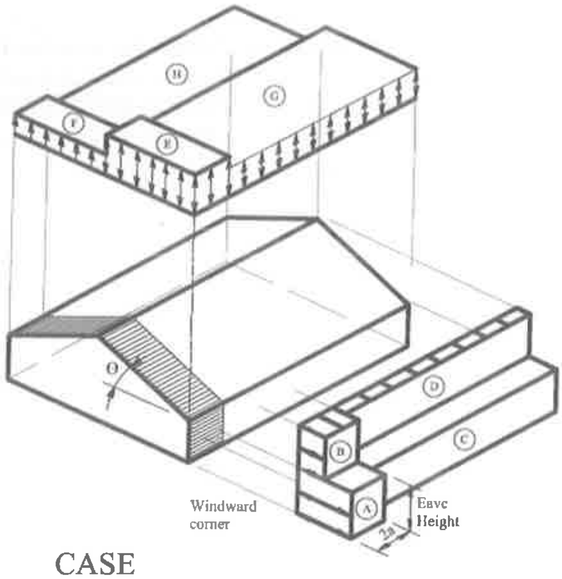
$$p_s = \lambda K_{zt} p_{S30} \qquad (207C.6\text{-}1)$$

where

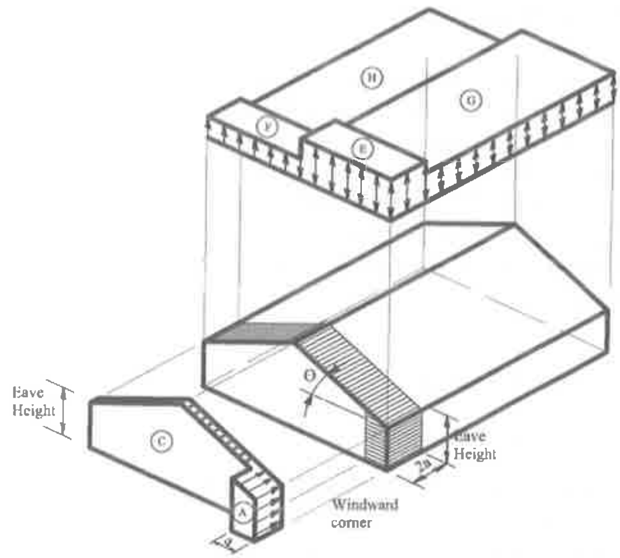
λ	adjustment factor for building height and exposure from Figure 207C.6-1
K_{zt}	topographic factor as defined in Section 207A.8 evaluated at mean roof height, h
p_{S30}	simplified design wind pressure for Exposure B, at h = 9 m from Figure 207C.6-1

207C.6.4 Minimum Design Wind Loads

The load effects of the design wind pressures from Section 207C.6.3 shall not be less than a minimum load defined by assuming the pressures, p_s, for zones A and C equal to +766 Pa, Zones B and D equal to +383 Pa, while assuming p_s for Zones E, F, G, and H are equal to 0.0 Pa.



CASE A



CASE B

Notes:

1. Pressures shown are applied to the horizontal and vertical projections, for exposure B, at h = 9 m. Adjust to other exposures and height with adjustment factor λ.
2. The load patterns show shall bé applied to each corner of the building in turn as the reference corner. (See Figure 207C.4-1)
3. For Case B use $\theta = 0^o$.
4. Load cases 1 and 2 must be checked for $25^o < \theta \leq 45^o$. Load case 2 at 25^o is provided only for interpolation between 25^o and 30^o.
5. Plus and minus signs signify pressures acting toward and away from the projected surfaces, respectively.
6. For roof slopes other than those shown, linear interpolation is permitted.
7. The total horizontal load shall not be less than that determined by assuming $p_s = 0$ in zones B and D.
8. Where zone E or G falls on a roof overhang on the windward side of the building, use E_{OH} and G_{OH} for the pressure on the horizontal projection of the overhang. Overhangs on the leeward and side edges shall have the basic zone pressure applied.
9. Notation:

   α: 10% of least horizontal dimension or $0.4h$, whichever is smaller, but not less than either 4% of least horizontal dimension or 0.9 m
   h: Mean roof height, in meters, except that eave height shall be used for roof angles < 10^0.
   θ: Angle of plane of roof from horizontal, in degrees.

Figure 207C.6-1
Main Wind Force Resisting System – Method 2.Design Wind Pressure
Enclosed Buildings $h \leq 18\,m$ Walls and Roofs

Basic Wind Speed (kph)	Roof Angle (degrees)	Load Case	Zones									
			Horizontal Pressures				Vertical Pressures				Overhangs	
			A	B	C	D	E	F	G	H	EOH	GOH
150	0 to 5°	1	0.66	-0.34	0.44	-0.2	-0.79	-0.45	-0.55	-0.35	-1.11	-0.87
	10°	1	0.74	-0.31	0.49	-0.18	-0.79	-0.48	-0.55	-0.37	-1.11	-0.87
	15°	1	0.83	-0.27	0.55	-0.16	-0.79	-0.52	-0.55	-0.39	-1.11	-0.87
	20°	1	0.91	-0.24	0.61	-0.13	-0.79	-0.55	-0.55	-0.42	-1.11	-0.87
	25°	1	0.83	0.13	0.6	0.14	-0.37	-0.5	-0.27	-0.41	-0.68	-0.58
		2	0	0	0	0	-0.14	-0.27	-0.04	-0.18	0	0
	30 to 45°	1	0.74	0.51	0.59	0.41	0.06	-0.45	0.02	-0.39	-0.26	-0.3
		2	0.74	0.51	0.59	0.41	0.29	-0.22	0.25	-0.16	-0.26	-0.3
200	0 to 5°	1	1.17	-0.61	0.78	-0.36	-1.41	-0.8	-0.98	-0.62	-1.97	-1.54
	10°	1	1.32	-0.55	0.88	-0.32	-1.41	-0.86	-0.98	-0.67	-1.97	-1.54
	15°	1	1.48	-0.48	0.98	-0.28	-1.41	-0.92	-0.98	-0.7	-1.97	-1.54
	20°	1	1.62	-0.43	1.08	-0.23	-1.41	-0.98	-0.98	-0.74	-1.97	-1.54
	25°	1	1.48	0.23	1.07	0.25	-0.65	-0.89	-0.47	-0.72	-1.22	-1.03
		2	0	0	0	0	-0.25	-0.48	-0.07	-0.32	0	0
	30 to 45°	1	1.32	0.9	1.05	0.72	0.1	-0.8	0.03	-0.68	-0.46	-0.53
		2	1.32	0.9	1.05	0.72	0.51	-0.39	0.44	-0.28	-0.46	-0.53
250	0 to 5°	1	1.83	-0.95	1.22	-0.57	-2.2	-1.25	-1.53	-0.97	-3.08	-2.41
	10°	1	2.06	-0.86	1.37	-0.49	-2.2	-1.34	-1.53	-1.04	-3.08	-2.41
	15°	1	2.31	-0.76	1.53	-0.44	-2.2	-1.44	-1.53	-1.09	-3.08	-2.41
	20°	1	2.53	-0.67	1.69	-0.37	-2.2	-1.53	-1.53	-1.16	-3.08	-2.41
	25°	1	2.31	0.37	1.67	0.39	-1.02	-1.39	-0.74	-1.13	-1.9	-1.62
		2	0	0	0	0	-0.39	-0.76	-0.11	-0.49	0	0
	30 to 45°	1	2.06	1.41	1.64	1.13	0.16	-1.25	0.05	-1.07	-0.72	-0.83
		2	2.06	1.41	1.64	1.13	0.79	-0.62	0.68	-0.44	-0.72	-0.83

Figure 207C.6-1
Main Wind Force Resisting System – Method 2 Design Wind Pressure
Enclosed Buildings h ≤ 18 m Walls and Roofs, Simplified Design Wind Pressure, $p_{S9.0}$ (Pa)
(Exposure B at h = 9.0 m with I = 1.0)

Basic Wind Speed (kph)	Roof Angle (degrees)	Load Case	Zones									
			Horizontal Pressures				Vertical Pressures				Overhangs	
			A	B	C	D	E	F	G	H	EOH	GOH
300	0 to 5°	1	2.63	-1.37	1.75	-0.81	-3.17	-1.8	-2.2	-1.39	-4.44	-3.47
	10°	1	2.97	-1.24	1.98	-0.71	-3.17	-1.93	-2.2	-1.49	-4.44	-3.47
	15°	1	3.32	-1.09	2.2	-0.63	-3.17	-2.08	-2.2	-1.57	-4.44	-3.47
	20°	1	3.65	-0.96	2.43	-0.53	-3.17	-2.2	-2.2	-1.67	-4.44	-3.47
	25°	1	3.32	0.53	2.41	0.56	-1.47	-2	-1.06	-1.62	-2.74	-2.33
		2	0	0	0	0	-0.56	-1.09	-0.15	-0.71	0	0
	30 to 45°	1	2.97	2.03	2.36	1.62	0.23	-1.8	0.08	-1.55	-1.04	-1.19
		2	2.97	2.03	2.36	1.62	1.14	-0.89	0.99	-0.63	-1.04	-1.19
350	0 to 5°	1	3.59	-1.86	2.38	-1.11	-4.32	-2.45	-3	-1.9	-6.04	-4.73
	10°	1	4.04	-1.69	2.69	-0.97	-4.32	-2.62	-3	-2.04	-6.04	-4.73
	15°	1	4.52	-1.48	3	-0.86	-4.32	-2.83	-3	-2.14	-6.04	-4.73
	20°	1	4.97	-1.31	3.31	-0.72	-4.32	-3	-3	-2.28	-6.04	-4.73
	25°	1	4.52	0.72	3.28	0.76	-2	-2.73	-1.45	-2.21	-3.73	-3.18
		2	0	0	0	0	-0.76	-1.48	-0.21	-0.97	0	0
	30 to 45°	1	4.04	2.76	3.21	2.21	0.31	-2.45	0.11	-2.1	-1.41	-1.62
		2	4.04	2.76	3.21	2.21	1.55	-1.21	1.35	-0.86	-1.41	-1.62

Adjustment Factor for Building Height and Exposure, λ

Mean Roof Height (m)	Exposure		
	B	C	D
0-5	1.0	1.21	1.47
6	1.0	1.29	1.55
8	1.0	1.35	1.61
9	1.0	1.40	1.66
11	1.05	1.45	1.70
12	1.09	1.49	1.74
14	1.12	1.53	1.78
15	1.16	1.56	1.81
17	1.19	1.59	1.84
18	1.22	1.62	1.87

Figure 207C.6-1 (continued)
Main Wind Force Resisting System – Method 2 Design Wind Pressure
Enclosed Buildings h ≤ 18 m Walls and Roofs, Simplified Design Wind Pressure, $p_{S9.0}$ (Pa)
(Exposure B at h = 9.0 m with I = 1.0

207D Wind Loads on Other Structures and Building Appurtenances - MWFRS

207D.1 Scope

207D.1.1 Structure Types

This section applies to the determination of wind loads on building appurtenances (such as rooftop structures and rooftop equipment) and other structures of all heights (such as solid freestanding walls and freestanding solid signs, chimneys, tanks, open signs, lattice frameworks, and trussed towers) using the Directional Procedure.

The steps required for the determination of wind loads on building appurtenances and other structures are shown in Table 207D.1-1.

> *User Note:*
>
> *Use Section 207D to determine wind pressures on the MWFRS of solid freestanding walls, freestanding solid signs, chimneys, tanks, open signs, lattice frameworks and trussed towers. Wind loads on rooftop structures and equipment may be determined from the provisions of this chapter. The wind pressures are calculated using specific equations based upon the Directional Procedure.*

207D.1.2 Conditions

A structure whose design wind loads are determined in accordance with this section shall comply with all of the following conditions:

1. The structure is a regular-shaped structure as defined in Section 207A.2.

2. The structure does not have response characteristics making it subject to across-wind loading, vortex shedding, or instability due to galloping or flutter; or it does not have a site location for which channeling effects or buffeting in the wake of upwind obstructions warrant special consideration.

207D.1.3 Limitations

The provisions of this chapter take into consideration the load magnification effect caused by gusts in resonance with along-wind vibrations of flexible structures. Structures not meeting the requirements of Section 207D.1.2, or having unusual shapes or response characteristics, shall be designed using recognized literature documenting such wind load effects or shall use the Wind Tunnel Procedure specified in Section 207F.

207D.1.4 Shielding

There shall be no reductions in velocity pressure due to apparent shielding afforded by buildings and other structures or terrain features.

207D.2 General Requirements

207D.2.1 Wind Load Parameters Specified in Section 207A

The following wind load parameters shall be determined in accordance with Section 207A:

- Basic Wind Speed $\boldsymbol{V}$ (Section 207A.5)
- Wind directionality Factor $\boldsymbol{K_d}$ (Section 207A.6)
- Exposure category (Section 207A.7)
- Topographic factor $\boldsymbol{K_{zt}}$ (Section 207A.8)
- Enclosure classification (Section 207A.10)

207D.3 Velocity Pressure

207D.3.1 Velocity Pressure Exposure Coefficient

Based on the exposure category determined in Section 207A.7.3, a velocity pressure exposure coefficient $\boldsymbol{K_z}$ or $\boldsymbol{K_h}$, as applicable, shall be determined from Table 207D.3-1.

For a site located in a transition zone between exposure categories that is near to a change in ground surface roughness, intermediate values of $\boldsymbol{K_z}$ or $\boldsymbol{K_h}$, between those shown in Table 207D.3-1, are permitted, provided that they are determined by a rational analysis method defined in the recognized literature.

Commentary:

See commentary, Section C207B.3.1.

207D.3.2 Velocity Pressure

Velocity pressure, q_z, evaluated at height z shall be calculated by the following equation:

$$q_z = 0.613K_zK_{zt}K_dV^2 \text{ (N/m}^2\text{); } V \text{ in m/s} \quad (207D.3\text{-}1)$$

where

K_d	=	wind directionality factor, see Section 207A.6
K_z	=	velocity pressure exposure coefficient, see Section 207D.3.1
K_{zt}	=	topographic factor defined, see Section 207A.8.2
V	=	basic wind speed, see Section 207A.5
q_h	=	velocity pressure calculated using Equation 207D.3-1 at height h

The numerical coefficient 0.613 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.

Table 207D.1-1
Steps to Determine Wind Loads on MWFRS Rooftop Equipment and Other Structures

Step 1:	Determine occupancy category of building or other structure, see Table 103-1
Step 2:	Determine the basic wind speed, V, for the applicable risk category, see Figure 207A.5-1A, B or C
Step 3:	Determine wind load parameters: ➢ Wind directionality factor, K_d, see Section 207A.6 and Table 207A.6-1 ➢ Exposure category B, C or D, see Section 207A.7 ➢ Topographic factor, K_{zt}, see Section 207A.8 and Figure 207A.8-1 ➢ Gust Effect Factor, G, see Section 207A.9
Step 4:	Determine velocity pressure exposure coefficient, K_z or K_h, see Table 207D.2-1
Step 5:	Determine velocity pressure q_z or q_h, see Equation 207D.3-1
Step 6:	Determine force coefficient, C_f: ➢ Solid freestanding signs or solid freestanding walls, Figure 207D.4-1 ➢ Chimneys, tanks, rooftop equipment Figure 207D.5-1 ➢ Open signs, lattice frameworks Figure 207D.5-2 ➢ Trussed towers Figure 207D.4-3
Step 7:	Calculate wind force, F: ➢ Equation 207D.4-1 for signs and walls ➢ Equation 207D.6-1 and Equation 207D.6-2 for rooftop structures and equipment ➢ Equation 207D.5-1 for other structures

Commentary:

See commentary, Section C207B.3.2.

Figure 207D.4-1. The force coefficients for solid freestanding walls and signs in Figure 207D.4-1 date back to ANSI A58.1-1972. It was shown by Letchford (2001) that these data originated from wind tunnel studies performed by Flachsbart in the early 1930s in smooth uniform flow. The current values in Figure 207D.4-1 are based on the results of boundary layer wind tunnel studies (Letchford 1985, 2001, Holmes 1986, Letchford and Holmes 1994, Ginger et al. 1998a and 1998b, and Letchford and Robertson 1999).

A surface curve fit to Letchford's (2001) and Holmes's (1986) area averaged mean net pressure coefficient data (equivalent to mean force coefficients in this case) is given by the following equation

$$C_f = \left\{ \begin{array}{c} 1.563 + 0.0042\ln(x) - 0.06148y \\ +0.009011[\ln(x)]^2 - 0.2603y^2 \\ -0.08393y[\ln(x)] \end{array} \right\} \Big/ 0.8$$

where $x = B/s$ and $y = s/h$

The 0.85 term in the denominator modifies the wind tunnel-derived force coefficients into a format where the gust effect factor as defined in Section 207A.9 can be used.

Force coefficients for Cases A and B were generated from the preceding equation, then rounded off to the nearest 0.05. That equation is only valid within the range of B/s and s/h ratios given in the figure for Case A and B.

Of all the pertinent studies, only Letchford (2001) specifically addressed eccentricity (i.e., Case B). Letchford reported that his data provided a reasonable match to Cook's (1990) recommendation for using an eccentricity of 0.25 times the average width of the sign. However, the data were too limited in scope to justify changing the existing eccentricity value of 0.2 times the average width of the sign, which is also used in the latest Australian / New Zealand Standard (Standards Australia 2002).

Case C was added to account for the higher pressures observed in both wind tunnel (Letchford 1985, 2001, Holmes 1986, Letchford and Holmes 1994, Ginger et al. 1998a and 1998b, and Letchford and Robertson 1999) and full-scale studies (Robertson et al. 1997) near the windward edge of a freestanding wall or sign for oblique wind directions. Linear regression equations were fit to the local mean net pressure coefficient data (for wind direction 45°) from the referenced wind tunnel studies to generate force coefficients for square regions starting at the windward edge. Pressures near this edge increase significantly as the length of the structure increases. No data were available on the spatial distribution of pressures for structures with low aspect ratios ($B/s <$ 2).

The sample illustration for Case C at the top of Figure 207D.4-1 is for a sign with an aspect ratio $B/s = 4$. For signs of differing B/s ratios, the number of regions is equal to the number of force coefficient entries located below each B/s column heading.

For oblique wind directions (Case C), increased force coefficients have been observed on aboveground signs compared to the same aspect ratio walls on ground (Letchford 1985, 2001 and Ginger et al. 1998a). The ratio of force coefficients between above-ground and on-ground signs (i.e., $s/h = 0.8$ and 1.0, respectively) is 1.25, which is the same ratio used in the Australian / New Zealand Standard (Standards Australia 2002). Note 5 of Figure 207D.4-1 provides for linear interpolation between these two cases.

For walls and signs on the ground ($s/h = 1$), the mean vertical center of pressure ranged from $0.5h$ to $0.6h$ (Holmes 1986, Letchford 1989, Letchford and Holmes 1994, Robertson et al. 1995, 1996, and Ginger et al. 1998a) with $0.55h$ being the average value. For above-ground walls and signs, the geometric center best represents the expected vertical center of pressure.

The reduction in C_f due to porosity (Note 2) follows a recommendation (Letchford 2001). Both wind tunnel and full-scale data have shown that return corners significantly reduce the net pressures in the region near the windward edge of the wall or sign (Letchford and Robertson 1999).

207D.4 Design Wind Loads - Solid Freestanding Walls and Solid Signs

207D.4.1 Solid Freestanding Walls and Solid Freestanding Signs

The design wind force for solid freestanding walls and solid freestanding signs shall be determined by the following formula:

$$F = q_h G C_f A_s \text{ (N)} \quad (207D.4\text{-}1)$$

where

q_h = velocity pressure evaluated at height h (defined in Figure 207D.4-1) as determined in accordance with Section 207D.3.2
G = gust-effect factor from Section 207A.9
C_f = net force coefficient from Figure 207D.4-1
A_s = the gross area of the solid freestanding wall or freestanding solid sign, m^2

207D.4.2 Solid Attached Signs

The design wind pressure on a solid sign attached to the wall of a building, where the plane of the sign is parallel to and in contact with the plane of the wall, and the sign does not extend beyond the side or top edges of the wall, shall be determined using procedures for wind pressures on walls in accordance with Section 207E, and setting the internal pressure coefficient (GC_{pi}) equal to 0.

This procedure shall also be applicable to solid signs attached to but not in direct contact with the wall, provided the gap between the sign and wall is no more than 0.9 m and the edge of the sign is at least 0.9 m in from free edges of the wall, i.e., side and top edges and bottom edges of elevated walls.

Commentary:

Signs attached to walls and subject to the geometric limitations of Section 207D.4.2 should experience wind pressures approximately equal to the external pressures on the wall to which they are attached. The dimension requirements for signs supported by frameworks, where there is a small gap between the sign and the wall, are based on the collective judgment of the committee.

Figures 207D.5-1, 207D.5-2 and 207D.5-3. With the exception of Figure 207D.5-3, the pressure and force coefficient values in these tables are unchanged from ANSI A58.1-1972. The coefficients specified in these tables are based on wind-tunnel tests conducted under conditions of uniform flow and low turbulence, and their validity in turbulent boundary-layer flows has yet to be completely established. Additional pressure coefficients for conditions not specified herein may be found in two references (SIA 1956 and ASCE 1961).

With regard to Figure 207D.5-3, the force coefficients are a refinement of the coefficients specified in ANSI A58.1-1982 and in ASCE 7-93. The force coefficients specified are offered as a simplified procedure that may be used for trussed towers and are consistent with force coefficients given in ANSI/EIA/TIA–222–E-1991, Structural Standards for Steel Antenna Towers and Antenna Supporting Structures, and force coefficients recommended by Working Group No. 4 (Recommendations for Guyed Masts), International Association for Shell and Spatial Structures (1981).

It is not the intent of this code to exclude the use of other recognized literature for the design of special structures, such as transmission and telecommunications towers. Recommendations for wind loads on tower guys are not provided as in previous editions of the code. Recognized literature should be referenced for the design of these special structures as is noted in Section 207D.1.3. For the design of flagpoles, see ANSI/NAAMM FP1001-97, 4th Ed., Guide Specifications for Design of Metal Flagpoles.

207D.5 Design Wind Loads—Other Structures

The design wind force for other structures (chimneys, tanks, rooftop equipment for $h > 60°$, and similar structures, open signs, lattice frameworks, and trussed towers) shall be determined by the following equation:

$$F = q_z G C_f A_f \text{ (N)} \quad (207D.5\text{-}1)$$

where

q_z = velocity pressure evaluated at height z as defined in Section 207D.3, of the centroid of area A_f
G = gust-effect factor from Section 207A.9
C_f = force coefficients from Figures 207D.5-1 through 207D.5-3
A_s = projected area normal to the wind except where C_f is specified for the actual surface area, m^2

207D.5.1 Rooftop Structures and Equipment for Buildings with $h \leq 18$ m

The lateral force F_h on rooftop structures and equipment located on buildings with a mean roof height $h \leq 18$ m shall be determined from Equation 207D.5-2.

$$F_h = q_h(GC_r)A_f \text{ (N)} \qquad (207D.5\text{-}2)$$

where

(GC_r) = 1.9 for rooftop structures and equipment with A_f less than $(0.1Bh)$. (GCr) shall be permitted to be reduced linearly from 1.9 to 1.0 as the value of A_f is increased from $(0.1Bh)$ to (Bh)

q_h = velocity pressure evaluated at mean roof height of the building

A_f = vertical projected area of the rooftop structure or equipment on a plane normal to the direction of wind, m^2

The vertical uplift force, F_v, on rooftop structures and equipment shall be determined from Equation 207D.5-3.

$$F_v = q_h(GC_r)A_r \text{ (N)} \qquad (207D.5\text{-}3)$$

Where

(GC_r) = 1.5 for rooftop structures and equipment with A_r less than $(0.1BL)$. (GC_r) shall be permitted to be reduced linearly from 1.5 to 1.0 as the value of A_r is increased from $(0.1BL)$ to (BL)

q_h = velocity pressure evaluated at mean roof height of the building

A_f = horizontal projected area of rooftop structure or equipment, m^2

Commentary:

This code requires the use of Figure 207D.5-1 for the determination of the wind force on small structures and equipment located on a rooftop. Because of the small size of the structures in comparison to the building, it is expected that the wind force will be higher than predicted by Equation 207D.6-1 due to higher correlation of pressures across the structure surface, higher turbulence on the building roof, and accelerated wind speed on the roof.

A limited amount of research is available to provide better guidance for the increased force (Hosoya et al. 2001 and Kopp and Traczuk 2008). Based on this research, the force of Equation 207D.6-1 should be increased for units with areas that are relatively small with respect to that of the buildings they are on. Because GC_r is expected to approach 1.0 as A_f or A_r approaches that of the building (Bh or BL), a linear interpolation is included as a way to avoid a step function in load if the designer wants to treat other sizes. The research in Hosoya et al (2001) only treated one value of A_f $(0.04Bh)$. The research in Kopp and Traczuk (2008) treated values of $A_f = 0.02Bh$ and $0.03Bh$, and values of $A_r = 0.0067BL$.

In both cases the research also showed high uplifts on the top of rooftop. Hence uplift load should also be considered by the designer and is addressed in Section 207D.6.

207D.6 Parapets

Wind loads on parapets are specified in Section 207B.4.5 for buildings of all heights designed using the Directional Procedure and in Section 207C.4.2 for low-rise buildings designed using the Envelope Procedure.

Commentary:

Prior to the 2002 edition of the standard, no provisions for the design of parapets had been included due to the lack of direct research. In the 2002 edition of this standard, a rational method was added based on the committee's collective experience, intuition, and judgment. In the 2005 edition, the parapet provisions were updated as a result of research performed at the University of Western Ontario (Mans et al. 2000, 2001) and at Concordia University (Stathopoulos et al. 2002a, 2002b).

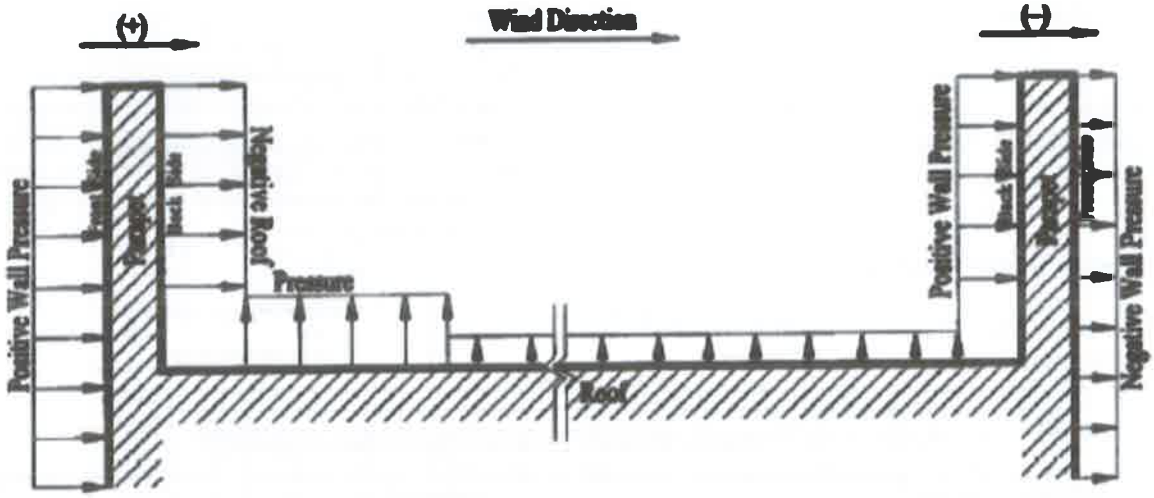
Wind pressures on a parapet are a combination of wall and roof pressures, depending on the location of the parapet and the direction of the wind (Figure C207D.7-1). A windward parapet will experience the positive wall pressure on its front surface (exterior side of the building) and the negative roof edge zone pressure on its back surface (roof side). This behavior is based on the concept that the zone of suction caused by the wind stream separation at the roof eave moves up to the top of the parapet when one is present. Thus the same suction that acts on the roof edge will also act on the back of the parapet.

The leeward parapet will experience a positive wall pressure on its back surface (roof side) and a negative wall pressure on its front surface (exterior side of the building). There should be no reduction in the positive wall pressure to the leeward parapet due to shielding by the windward parapet because, typically, they are too far apart to experience this effect. Because all parapets would be designed for all wind directions, each parapet would in *turn be the windward and leeward parapet and, therefore, must be designed for both sets of pressures.*

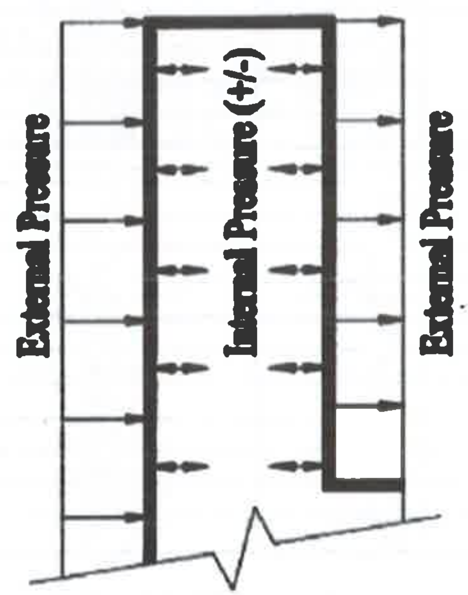
For the design of the MWFRS, the pressures used describe the contribution of the parapet to the overall wind loads on that system. For simplicity, the front and back pressures on the parapet have been combined into one coefficient for MWFRS design. The designer should not typically need the separate front and back pressures for MWFRS design. The internal pressures inside the parapet cancel out in the determination of the combined coefficient. The summation of these external and internal, front and back pressure coefficients is a new term GC_{pn}, *the Combined Net Pressure Coefficient for a parapet.*

For the design of the components and cladding, a similar approach was used. However, it is not possible to simplify the coefficients due to the increased complexity of the components and cladding pressure coefficients. In addition, the front and back pressures are not combined because the designer may be designing separate elements on each face of the parapet. The internal pressure is required to determine the net pressures on the windward and leeward surfaces of the parapet. The provisions guide the designer to the correct GC_p *and velocity pressure to use for each surface, as illustrated in Figure C207D.7-1. Interior walls that protrude through the roof, such as party walls and fire walls, should be designed as windward parapets for both MWFRS and components and cladding.*

The internal pressure that may be present inside a parapet is highly dependent on the porosity of the parapet envelope. In other words, it depends on the likelihood of the wall surface materials to leak air pressure into the internal cavities of the parapet. For solid parapets, such as concrete or masonry, the internal pressure is zero because there is no internal cavity. Certain wall materials may be impervious to air leakage, and as such have little or no internal pressure or suction, so using the value of GC_{pi} *for an enclosed building may be appropriate. However, certain materials and systems used to construct parapets containing cavities are more porous, thus justifying the use of the* GC_{pi} *values for partially enclosed buildings, or higher. Another factor in the internal pressure determination is whether the parapet cavity connects to the internal space of the building, allowing the building's internal pressure to propagate into the parapet. Selection of the appropriate internal pressure coefficient is left to the judgment of the design professional.*



Methodology used to Develop External Parapet Pressures
(Main Wind Force Resisting Systems and Components and Cladding)



External and Internal Parapet Pressures
(Components and Cladding Only)

Figure C207D.7-1
Design Wind Pressures on Parapets

207D.7 Roof Overhangs

Wind loads on roof overhangs are specified in Section 207B.4.4 for buildings of all heights designed using the Directional Procedure and in Section 207C.4.3 for low-rise buildings designed using the Envelope Procedure.

Commentary:

This section specifies a minimum wind load to be applied horizontally on the entire vertical projection of the building or other structure, as shown in Figure C207B.4-1. This load case is to be applied as a separate load case in addition to the normal load cases specified in other portions of this chapter.

207D.8 Minimum Design Wind Loading

The design wind force for other structures shall be not less than 0.77 kN/m^2 multiplied by the area A_f.

Table 207D.3-1 Velocity Pressure Exposure Coefficients, K_h and K_z

Height above ground level, **z** (meters)	Exposure		
	B	**C**	**D**
0 - 4.5	0.572	0.846	1.027
6.0	0.621	0.899	1.080
7.5	0.662	0.942	1.123
9.0	0.697	0.979	1.159
12.0	0.757	1.040	1.218
15.0	0.807	1.090	1.267
18.0	0.850	1.133	1.307
21.0	0.888	1.170	1.343
24.0	0.923	1.204	1.375
27.0	0.955	1.234	1.403
30.0	0.984	1.261	1.429
36.0	1.036	1.311	1.475
42.0	1.083	1.354	1.515
48.0	1.125	1.393	1.551
54.0	1.164	1.428	1.583
60.0	1.199	1.460	1.612
75.0	1.278	1.530	1.676
90.0	1.347	1.590	1.730
105.0	1.407	1.642	1.777
120.0	1.462	1.689	1.819
135.0	1.512	1.731	1.856
150.0	1.558	1.770	1.891

Notes:

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

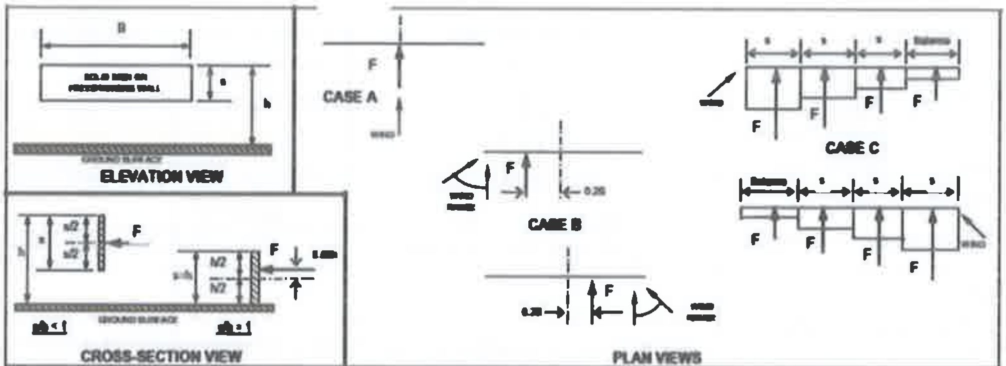
   For 4.5 m$\leq z \leq z_g$

   $$K_z = 2.01\left(z/z_g\right)^{2/\alpha}$$

   For z <4.5 m

   $$K_z = 2.01\left(4.57/z_g\right)^{2/\alpha}$$

2. The constants α and z_g are tabulated in Table 207A.9-1.
3. Linear interpolation for intermediate values of height z is permitted.
4. Exposure categories are defined in Section 207A.7.



C_f, CASE A & CASE B

Clearance Ratio, s/h	Aspect Ratio, B/s ≤ 0.05	0.1	0.2	0.5	1	2	4	5	10	20	30	≥ 45
1	1.80	1.70	1.65	1.55	1.45	1.40	1.35	1.35	1.30	1.30	1.30	1.30
0.9	1.85	1.75	1.70	1.60	1.55	1.50	1.45	1.45	1.40	1.40	1.40	1.40
0.7	1.90	1.85	1.75	1.70	1.65	1.60	1.60	1.55	1.55	1.55	1.55	1.55
0.5	1.95	1.85	1.80	1.75	1.75	1.70	1.70	1.70	1.70	1.70	1.70	1.75
0.3	1.95	1.90	1.85	1.80	1.80	1.80	1.80	1.80	1.80	1.85	1.85	1.85
0.2	1.95	1.90	1.85	1.80	1.80	1.80	1.80	1.80	1.85	1.90	1.90	1.95
≤ 0.16	1.95	1.90	1.85	1.85	1.80	1.80	1.85	1.85	1.85	1.90	1.90	1.95

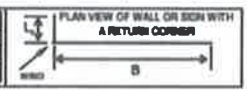
C_f, CASE C

Region (horizontal distance from windward edge)	Aspect Ratio, B/s 2	3	4	5	6	7	8	9	10
0 to s	2.25	2.60	2.90	3.10*	3.30*	3.40*	3.55*	3.65*	3.75*
s to 2s	1.50	1.70	1.90	2.00	2.15	2.25	2.30	2.35	2.45
2s to 3s		1.15	1.30	1.45	1.55	1.65	1.70	1.75	1.85
3s to 10s			1.10	1.05	1.05	1.05	1.05	1.00	0.95

Region (horizontal distance from windward edge)	Aspect Ratio, B/s 13	≥ 45
0 to s	4.00*	4.30*
s to 2s	2.60	2.55
2s to 3s	2.00	1.95
3s to 4s	1.60	1.85
4s to 5s	1.35	1.85
5s to 10s	0.90	1.10
>10s	0.55	0.55

*Values shall be multiplied by the following reduction factor when a return corner is present:

L_r/s	Reduction Factor
0.3	0.90
1.0	0.75
≥2	0.60



Notes:

1. The term "signs" in notes below also applies to "freestanding walls".

2. Signs with openings comprising less than 30% of the gross area are classified as solid signs. Force coefficients for solid signs with openings shall be permitted to be multiplied by the reduction factor $(\mathbf{1}-(\mathbf{1}-\boldsymbol{\varepsilon})^{1.5})$.

3. To allow for both normal and oblique wind directions, the following cases shall be considered:
   For $s/h < 1$:
   CASE A: resultant force acts normal to the face of the sign through the geometric center.
   CASE B: resultant force acts normal to the face of the sign at a distance from the geometric center toward the windward edge equal to 0.2 times the average width of the sign.
   For $B/s \geq 2$, CASE C must also be considered:
   CASE C: resultant forces act normal to the face of the sign through the geometric centers of each region.

   For $s/h = 1$:
   The same cases as above except that the vertical locations of the resultant forces occur at a distance above the geometric center equal to 0.05 times the average height of the sign.

4. For CASE C where $s/h > 0.8$, force coefficients shall be multiplied by the reduction factor $(\mathbf{1.8} - s/h)$.

5. Linear interpolation is permitted for values of s/h, B/s and L_r/s other than shown.

6. Notation:
   B: horizontal dimension of sign, m;
   h: height of the sign, m
   s : vertical dimension of the sign, m;
   ε: ratio of solid area to gross area;
   L_r: horizontal dimension of return corner, m

Figure 207D.4-1
Design Wind Loads Force Coefficients (C_f) Other Structures
All Heights of Solid Freestanding Walls & Solid Freestanding Signs

Cross-Section	Type of Surface	h/D		
		1	7	25
Square (wind normal to face)	All	1.3	1.4	2.0
Square (wind along diagonal)	All	1.0	1.1	1.5
Hexagonal or Octagonal	All	1.0	1.2	1.4
Round $(D\sqrt{q_z} > 2.5)$ $(D\sqrt{q_z} > 5.3, D \text{ in m}, q_z \text{ in N/m}^2)$	Moderately Smooth	0.5	0.6	0.7
	Rough (D'/D = 0.02)	0.7	0.8	0.9
	Very Rough (D'/D = 0.08)	0.8	1.0	1.2
Round $(D\sqrt{q_z} \leq 2.5)$ $(D\sqrt{q_z} \leq 5.3, D \text{ in m}, q_z \text{ in N/m}^2)$	All	0.7	0.8	1.2

Notes:

1. The design wind force shall be calculated based on the area of the structure projected on a plane normal to the wind direction. The force shall be assumed to act parallel to the wind direction.
2. Linear interpolation is permitted for h/D values other than shown.
3. Notation:

   D: diameter of circular cross-section and least horizontal dimension of square, hexagonal or octagonal cross-sections at elevation under consideration, in meters;

   D': depth of protruding elements such as ribs and spoilers, m; and

   h: height of structure, m; and

   q_z: velocity pressure evaluated at height z above ground, N/m²
4. For rooftop equipment on buildings with a mean roof height of $h \leq 18$ m, use Section 207D.5.1.

Figure 207D.5-1
Other Structures Force Coefficients, C_f
Chimneys, Tanks, Rooftop Equipment, & Similar Structures

$\in$	Flat-Sided Members	Rounded Members	
		$D\sqrt{q_z} \leq 5.3$	$D\sqrt{q_z} > 5.3$
< 0.1	2.0	1.2	0.8
0.1 to 0.29	1.8	1.3	0.9
0.3 to 0.7	1.6	1.5	1.1

Notes:

1. Signs with openings comprising 30% or more of the gross area are classified as open signs.
2. The calculation of the design wind forces shall be based on the area of all exposed members and elements projected on a plane normal to the wind direction. Forces shall be assumed to act parallel to the wind direction.
3. The area A_f consistent with these force coefficients is the solid area projected normal to the wind direction.
4. Notation:

   ϵ: ratio of solid area to gross area;

   D: diameter of a typical round member, m;

   q_z: velocity pressure evaluated at height z above ground, N/m²

Figure 207D.5-2
Other Structures Force Coefficients, C_f All Heights of Open Signs & Lattice Frameworks

Tower Cross Section	C_f
Square	$4.0\epsilon^2 - 5.9\epsilon + 4.0$
Triangle	$3.4\epsilon^2 - 4.7\epsilon + 3.4$

Notes:

1. For all wind directions considered, the area A_f consistent with the specified force coefficients shall be the solid area of a tower face projected on the plane of that face for the tower segment under consideration.
2. The specified force coefficients are for towers with structural angles or similar flat sided members.
3. For towers containing rounded members, it is acceptable to multiply the specified force coefficients by the following factor when determining wind forces on such members:

   $0.51\epsilon^2 + 0.57$, but not > 1.0
4. Wind forces shall be applied in the directions resulting in maximum member forces and reactions. For towers with square cross-sections, wind forces shall be multiplied by the following factor when the wind is directed along a tower diagonal:

   $1 + 0.75\epsilon$, but not > 1.2
5. Wind forces on tower appurtenances such as ladders, conduits, lights, elevators, etc., shall be calculated using appropriate force coefficients for these elements.
6. Notation:

   ϵ: ratio of solid area to gross area of one tower face for the segment under consideration.

Figure 207D.5-2
Other Structures Force Coefficients, C_f Trussed Towers of All Heights

207E Wind Loads – Components and Cladding (C&C)

Commentary:

In developing the set of pressure coefficients applicable for the design of components and cladding (C&C) as given in Figures 207E.4-1, 207E.4-2A, 207E.4-2B, 207E.4-2C, 207E.4-3, 207E.4-4, 207E.4-5A, 207E.4-5B, and 207E.4-6, an envelope approach was followed but using different methods than for the MWFRS of Figure 207C.4-1. Because of the small effective area that may be involved in the design of a particular component (consider, e.g., 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 Figure C207C.4-1. 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°. 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 Figures 207E.4-1, 207E.4-2A, 207E.4-2B, 207E.4-2C, 207E.4-3, 207E.4-4, 207E.4-5A, 207E.4-5B, and 207E.4-6, 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 207C.4-1, the wind tunnel experiments checked both Exposure B and C terrains. Basically (GC_p) values associated with Exposure B terrain would be higher than those for Exposure C terrain because of reduced velocity pressure in Exposure B terrain. The (GC_p) values given in Figures 207E.4-1, 207E.4-2A, 207E.4-2B, 207E.4-2C, 207E.4-3, 207E.4-4, 207E.4-5A, 207E.4-5B, and 207E.4-6 are associated with Exposure C terrain as obtained in the wind tunnel. However, they may also be used for any exposure when the correct velocity pressure representing the appropriate exposure is used as discussed below.

The wind tunnel studies conducted by ESDU (1990) determined that when low-rise buildings (h < 18 m) 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. Hence, the code permits the use of the applicable exposure category when using these coefficients.

The pressure coefficients given in Figure 207E.6-1 for buildings with mean height greater than 18 m were developed following a similar approach, but the influence of exposure was not enveloped (Stathopoulos and Dumitrescu-Brulotte 1989). Therefore, exposure categories B, C, or D may be used with the values of (GC_p) in Figure 207E.6-1 as appropriate.

207E.1 Scope

207E.1.1 Building Types

This chapter applies to the determination of wind pressures on components and cladding (C&C) on buildings.

1. Part 1 is applicable to an enclosed or partially enclosed:

   - Low-rise building (see definition in Section 207A.2)
   - Building with $h \leq 18\ m$

   The building has a flat roof, gable roof, multispan gable roof, hip roof, monoslope roof, stepped roof, or sawtooth roof and the wind pressures are calculated from a wind pressure equation.

2. Part 2 is a simplified approach and is applicable to an enclosed:

   - Low-rise building (see definition in Section 207A.2)
   - Building with $h \leq 18\ m$

   The building has a flat roof, gable roof, or hip roof and the wind pressures are determined directly from a table.

3. Part 3 is applicable to an enclosed or partially enclosed:

   - Building with $h > 18\ m$

   The building has a flat roof, pitched roof, gable roof, hip roof, mansard roof, arched roof, or domed roof and the wind pressures are calculated from a wind pressure equation.

4. Part 4 is a simplified approach and is applicable to an enclosed:

   - Building with $h \leq 48\ m$

   The building has a flat roof, gable roof, hip roof, monoslope roof, or mansard roof and the wind pressures are determined directly from a table.

5. Part 5 is applicable to an open building of all heights having a pitched free roof, monoslope free roof, or trough free roof.

6. Part 6 is applicable to building appurtenances such as roof overhangs and parapets and rooftop equipment.

207E.1.2 Conditions

A building whose design wind loads are determined in accordance with this chapter shall comply with all of the following conditions:

1. The building is a regular-shaped building as defined in Section 207A.2.

2. The building does not have response characteristics making it subject to across wind loading, vortex shedding, or instability due to galloping or flutter; or it does not have a site location for which channeling effects or buffeting in the wake of upwind obstructions warrant special consideration.

207E1.3 Limitations

The provisions of this chapter take into consideration the load magnification effect caused by gusts in resonance with along-wind vibrations of flexible buildings. The loads on buildings not meeting the requirements of Section 207E.1.2, or having unusual shapes or response characteristics, shall be determined using recognized literature documenting such wind load effects or shall use the wind tunnel procedure specified in Section 207F.

207E.1.4 Shielding

There shall be no reductions in velocity pressure due to apparent shielding afforded by buildings and other structures or terrain features.

207E.1.5 Air-Permeable Cladding

Design wind loads determined from Section 207E shall be used for air-permeable cladding unless approved test data or recognized literature demonstrates lower loads for the type of air-permeable cladding being considered.

Commentary:

Air-permeable roof or wall claddings allow partial air pressure equalization between their exterior and interior surfaces. Examples include siding, pressure-equalized rain screen walls, shingles, tiles, concrete roof pavers, and aggregate roof surfacing.

The peak pressure acting across an air-permeable cladding material is dependent on the characteristics of other components or layers of a building envelope assembly. At any given instant the total net pressure across a building envelope assembly will be equal to the sum of the partial pressures across the individual layers as shown in Figure C207E.1-1. However, the proportion of the total net pressure borne by each layer will vary from instant to instant due to fluctuations in the external and internal pressures and will depend on the porosity and stiffness of each layer, as well as the volumes of the air spaces between the layers. As a result, although there is load sharing among the various layers, the sum of the peak pressures across the individual layers will typically exceed the peak pressure across the entire system. In the absence of detailed information on the division of loads, a simple, conservative approach is to assign the entire differential pressure to each layer designed to carry load.

To maximize pressure equalization (reduction) across any cladding system (irrespective of the permeability of the cladding itself), the layer or layers behind the cladding should be:

- *relatively stiff in comparison to the cladding material and*

- *relatively air-impermeable in comparison to the cladding material.*

Furthermore, the air space between the cladding and the next adjacent building envelope surface behind the cladding (e.g., the exterior sheathing) should be as small as practicable and compartmentalized to avoid communication or venting between different pressure zones of a building's surfaces.

The design wind pressures derived from Section 207E represent the pressure differential between the exterior and interior surfaces of the exterior envelope (wall or roof system). Because of partial air-pressure equalization provided by air-permeable claddings, the components and cladding pressures derived from Section 207E can overestimate the load on air-permeable cladding elements. The designer may elect either to use the loads derived from Section 207E or to use loads derived by an approved alternative method. If the designer desires to determine the *pressure differential across a specific cladding element in combination with other elements comprising a specific building envelope assembly, appropriate full-scale pressure measurements should be made on the applicable building envelope assembly, or reference should be made to recognized literature (Cheung and Melbourne 1986, Haig 1990, Baskaran 1992, Southern Building Code Congress International 1994, Peterka et al. 1997, ASTM 2006, 2007, and Kala et al. 2008) for documentation pertaining to wind loads. Such alternative methods may vary according to a given cladding product or class of cladding products or assemblies because each has unique features that affect pressure equalization.*

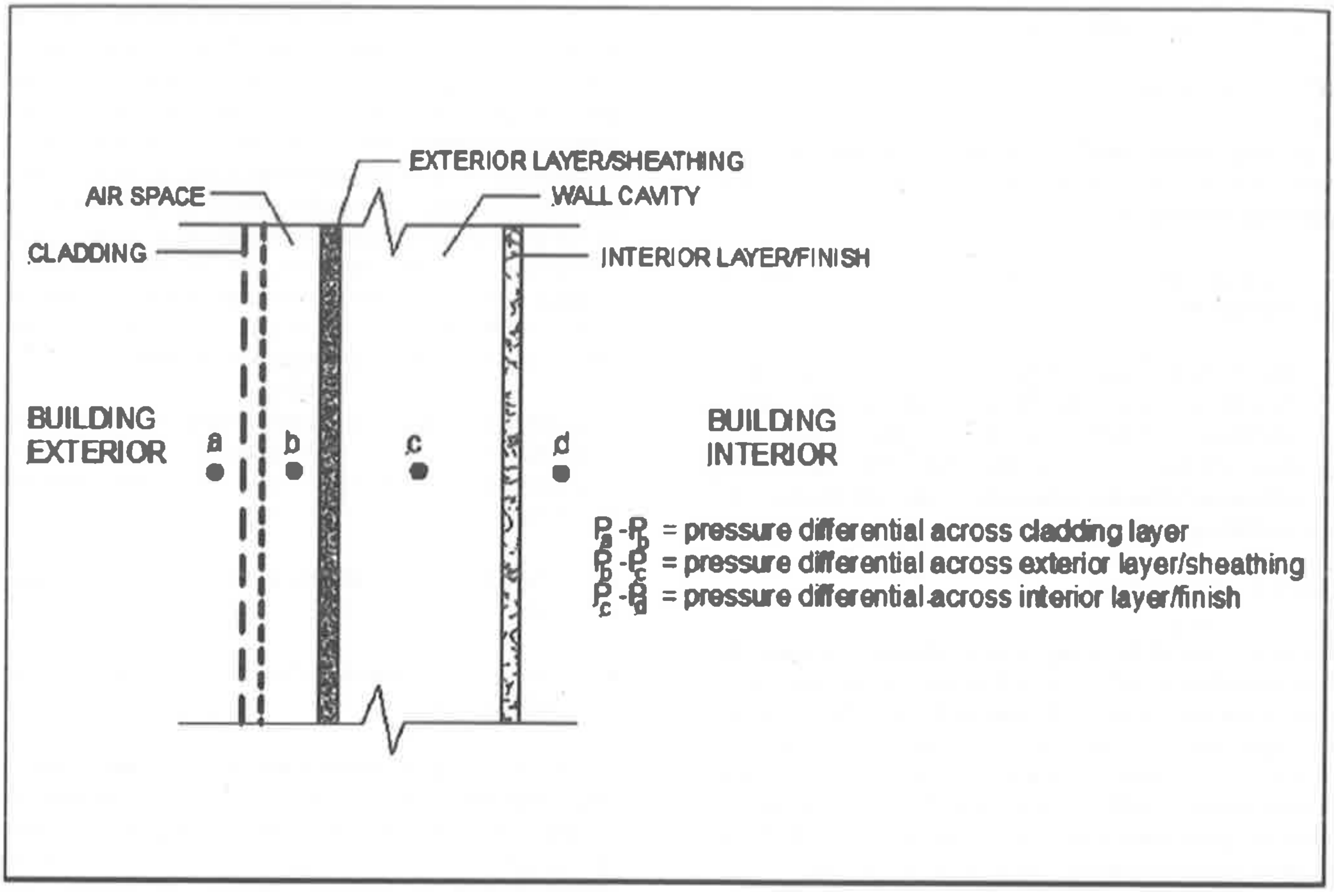


Figure C207E.1-1
Distribution of Net Components and Cladding Pressure Acting on a Building Surface (Building Envelope) Comprised of Three Components (Layers)

207E.2 General Requirements

207E.2.1 Wind Load Parameters Specified in Section 207A

The following wind load parameters are specified in Section 207A:

- Basic Wind Speed $\boldsymbol{V}$ (Section 207A.5)
- Wind directionality factor K_d (Section 207A.6)
- Exposure category (Section 207A.7)
- Topographic factor K_{zt} (Section 207A.8)
- Gust Effect Factor (Section 207A.9)
- Enclosure classification (Section 207A.10)

- Internal pressure coefficient (GC_{pi}) (Section 207A.11).

207E.2.2 Minimum Design Wind Pressures

The design wind pressure for components and cladding of buildings shall not be less than a net pressure of 0.77 kN/m^2 acting in either direction normal to the surface.

207E.2.3 Tributary Areas Greater than 65 m^2

Component and cladding elements with tributary areas greater than 65 m^2 shall be permitted to be designed using the provisions for MWFRS.

207E.2.4 External Pressure Coefficients

Combined gust effect factor and external pressure coefficients for components and cladding, (GC_p), are given in the figures associated with this chapter. The pressure coefficient values and gust effect factor shall not be separated.

207E.3 Velocity Pressure

207E.3.1 Velocity Pressure Exposure Coefficient

Based on the exposure category determined in Section 207A.7.3, a velocity pressure exposure coefficient K_z or K_h, as applicable, shall be determined from Table 207E.3-1. For a site located in a transition zone between exposure categories, that is, near to a change in ground surface roughness, intermediate values of K_z or K_h, between those shown in Table 207E.3-1, are permitted, provided that they are determined by a rational analysis method defined in the recognized literature.

Commentary:

See commentary, Section C207B.3.1.

207E.3.2 Velocity Pressure

Velocity pressure, q_z, evaluated at height z shall be calculated by the following equation:

$$q_z = 0.613 K_z K_{zt} K_d V^2 \quad (\text{N/m}^2); V \text{ in m/s} \qquad (207\text{E}.3\text{-}1)$$

where

K_d = wind directionality factor, see Section 207A.6
K_z = velocity pressure exposure coefficient, see Section 207E.3.1
K_{zt} = topographic factor defined, see Section 207A.8
V = basic wind speed, see Section 207A.5
q_h = velocity pressure calculated using Equation 207E.3-1 at height h

The numerical coefficient 0.613 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.

Commentary:

See commentary, Section C207B.3.2.

Figures 207E.4-1, 207E.4-2A, 207E.4-2B, and 207E.4-2C. *The pressure coefficient values provided in these figures are to be used for buildings with a mean roof height of 18 m or less. The values were obtained from wind-tunnel tests conducted at the University of Western Ontario (Davenport et al. 1977, 1978), at the James Cook University of North Queensland (Best and Holmes 1978), and at Concordia University (Stathopoulos 1981, Stathopoulos and Zhu 1988, Stathopoulos and Luchian 1990, 1992, and Stathopoulos and Saathoff 1991). These coefficients were refined to reflect results of full-scale tests conducted by the National Bureau of Standards (Marshall 1977) and the Building Research Station, England (Eaton and Mayne 1975). Pressure coefficients for hemispherical domes on the ground or on cylindrical structures were based on wind-tunnel tests (Taylor 1991). 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 Figure C207A.5-1) to adjust for the reduced pressure coefficient values associated with a 3-s 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. Research (Stathopoulos and Zhu 1988, 1990) indicated that the pressure coefficients provided generally apply to facades with architectural features, such as balconies, ribs, and various facade textures. In ASCE 7-02, the roof slope range and values of (GC_p) were updated based on subsequent studies (Stathopoulos et al. 1999, 2000, 2001).*

***Figures 207E.4-4, 207E.4-5A, and 207E.4-5B**. 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 (Stathopoulos and Mohammadian 1986, Surry and Stathopoulos 1988, and Stathopoulos and Saathoff 1991).*

***Figure 207E.4-6**. 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 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°, values of (GC_p) for regular gable roofs (Figure 207E.4-2A) are to be used. The coefficients included in Figure 207E.4-6 are based on wind tunnel studies reported by Saathoff and Stathopoulos (1992).*

***Figure 207E.4-7**. This figure for cladding pressures on dome roofs is based on Taylor (1991). Negative pressures are to be applied to the entire surface, because they apply along the full arc that is perpendicular to the wind direction and that passes through the top of the dome. Users are cautioned that only three shapes were available to define values in this figure ($h_D/D = 0.5$, $f/D = 0.5$; $h_D/D = 0.0$, $f/D = 0.5$; and $h_D/D = 0.0$, $f/D = 0.33$).*

***Figure 207E.6-1**. The pressure coefficients shown in this figure reflect the results obtained from comprehensive wind tunnel studies carried out (Stathopoulos and Dumitrescu-Brulotte 1989). 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 Figure 207E.6-1 were established by wind tunnel tests on isolated "box-like" buildings (Akins and Cermak 1975 and Peterka and Cermak 1975). 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 (Templin and Cermak 1978). These variations are due to building geometry, low attached buildings, nonrectangular 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 "boxlike" in shape.

Table 207E.3-1
Velocity Pressure Exposure Coefficients, K_h and K_z

Height above ground level, z	Exposure		
(m)	B	C	D
0 - 4.5	0.70	0.85	1.03
6.0	0.70	0.90	1.08
7.5	0.70	0.94	1.12
9.0	0.70	0.98	1.16
12.0	0.76	1.04	1.22
15.0	0.81	1.09	1.27
18.0	0.85	1.13	1.31
21.0	0.89	1.17	1.34
24.0	0.93	1.21	1.38
27.0	0.96	1.24	1.40
30.0	0.99	1.26	1.43
36.0	1.04	1.31	1.48
42.0	1.09	1.36	1.52
48.0	1.13	1.39	1.55
54.0	1.17	1.43	1.58
60.0	1.20	1.46	1.61
75.0	1.28	1.53	1.68
90.0	1.35	1.59	1.73
105.0	1.41	1.64	1.78
120.0	1.47	1.69	1.82
135.0	1.52	1.73	1.86
150.0	1.56	1.77	1.89

Notes:

1. The velocity pressure exposure coefficient $\boldsymbol{K_z}$ may be determined from the following formula:

For 4.57 m $\leq \boldsymbol{z} \leq \boldsymbol{z_g}$ For $\boldsymbol{z} < 4.57$ m

$$K_z = 2.01(z/z_g)^{2/\alpha} \qquad K_z = 2.01(4.57/z_g)^{2/\alpha}$$

2. $\boldsymbol{\alpha}$ and $\boldsymbol{z_g}$ are tabulated in Table 207A.9-1.
3. Linear interpolation for intermediate values of height $\boldsymbol{z}$ is acceptable.
4. Exposure categories are defined in Section 207A.7.

Part 1: Low-Rise Buildings

Commentary:

The component and cladding tables in Figure 207E.5-1 are a tabulation of the pressures on an enclosed, regular, 9-m high building with a roof as described. The pressures can be modified to a different exposure and height with the same adjustment factors as the MWFRS pressures. For the designer to use this method for the design of the components and cladding, the building must conform to all five requirements in Section 207E.6; otherwise one of the other procedures specified in Section 207E.1.1 must be used.

207E.4 Building Types

The provisions of Section 207E.4 are applicable to an enclosed and partially enclosed:

- Low-rise building (see definition in Section 207A.2)
- Building with $h \leq 18$ m

The building has a flat roof, gable roof, multispan gable roof, hip roof, monoslope roof, stepped roof, or sawtooth roof. The steps required for the determination of wind loads on components and cladding for these building types are shown in Table 207E.4-1.

207E.4.1 Conditions

For the determination of the design wind pressures on the components and claddings using the provisions of Section 207E.4.2 the conditions indicated on the selected figure(s) shall be applicable to the building under consideration.

207E.4.2 Design Wind Pressures

Design wind pressures on component and cladding elements of low-rise buildings and buildings with $h \leq 18$ m shall be determined from the following equation:

$$p = q_h[(GC_p) - (GC_{pi})] \text{ (N/m}^2\text{)} \qquad \text{207E.4-1}$$

where

q_z = velocity pressure evaluated at mean roof height h as defined in Section 207E.3

(GC_p) = external pressure coefficients given in:

- Figure 207E.4-1 (walls)
- Figures. 207E.4-2A to 207E.4-2C (flat roofs, gable roofs, and hip roofs)
- Figure 207E.4-3 (stepped roofs)
- Figure 207E.4-4 (multispan gable roofs)
- Figures 207E.4-5A and 207E.4-5B (monoslope roofs)
- Figure 207E.4-6 (sawtooth roofs)
- Figure 207E.4-7 (domed roofs)
- Figure 207B.4-3, footnote 4 (arched roofs)

(GC_{pi}) = internal pressure coefficient given in Table 207A.11-1

User Note:

Use Part 1 of Section 207E to determine wind pressures on C&C of enclosed and partially enclosed low-rise buildings having roof shapes as specified in the applicable figures. The provisions in Part 1 are based on the Envelope Procedure with wind pressures calculated using the specified equation as applicable to each building surface. For buildings for which these provisions are applicable this method generally yields the lowest wind pressures of all analytical methods contained in this code.

Table 207E.4-1
Steps to Determine C&C Wind Loads
Enclosed and Partially Enclosed
Low-rise Buildings

Step 1:	Determine risk category of building or other structure, see Table 103-1
Step 2:	Determine the basic wind speed, $\boldsymbol{V}$, for the applicable risk category, see Figure 207A.5-1A, B or C
Step 3:	Determine wind load parameters: ➢ Wind directionality factor, $\boldsymbol{K_d}$, see Section 207A.6 and Table 207A.6-1 ➢ Exposure category B, C or D, see Section 207A.7 ➢ Topographic factor, $\boldsymbol{K_{zt}}$, see Section 207A.8 and Figure 207A.8-1 ➢ Enclosure classification, see Section 207A.10 ➢ Internal pressure coefficient, $(\boldsymbol{GC_{pi}})$, see Section 207A.11 and Table 207A.11-1
Step 4:	Determine velocity pressure exposure coefficient $\boldsymbol{K_z}$ or $\boldsymbol{K_h}$, see Table 207E.3-1
Step 5:	Determine velocity pressure, $\boldsymbol{q_h}$, see Equation 207E.3-1
Step 6:	Determine external pressure coefficient, $(\boldsymbol{GC_p})$ ➢ Walls, see Figure 207E.4-1 ➢ Flat roofs, gable roofs, hip roofs, see Figure 207E.4-2 ➢ Stepped roofs, see Figure 207E.4-3 ➢ Multispan gable roofs, see Figure 207E.4-4 ➢ Monoslope roofs, see Figure 207E.4-5 ➢ Sawtooth roofs, see Figure 207E.4-6 ➢ Domed roofs, see Figure 207E.4-7 ➢ Arched roofs, see Figure 207B.4-3 footnote 4
Step 7:	Calculate wind pressure, $\boldsymbol{p}$, Equation 207E.4-1

Part 2: Low-Rise Buildings (Simplified)

207E.5 Building Types

The provisions of Section 207E.5 are applicable to an enclosed:

- Low-rise building (see definition in Section 207A.2)
- Building with $\boldsymbol{h} \leq 18$ m

The building has a flat roof, gable roof, or hip roof. The steps required for the determination of wind loads on components and cladding for these building types are shown in Table 207E.5-1.

207E.5.1 Conditions

For the design of components and cladding the building shall comply with all the following conditions:

1. The mean roof height $\boldsymbol{h}$ must be less than or equal to 18 m (i.e. $\boldsymbol{h} \leq 18$ m).
2. The building is enclosed as defined in Section 207A.2 and conforms to the wind-borne debris provisions of Section 207A.10.3.
3. The building is a regular-shaped building or structure as defined in Section 207A.2.
4. The building does not have response characteristics making it subject to across wind loading, vortex shedding, or instability due to galloping or flutter; and it does not have a site location for which channeling effects or buffeting in the wake of upwind obstructions warrant special consideration.
5. The building has either a flat roof, a gable roof with $\boldsymbol{\theta \leq 45^o}$, or a hip roof with $\boldsymbol{\theta \leq 27^o}$.

207E.5.2 Design Wind Pressures

Net design wind pressures, $\boldsymbol{p_{net}}$, for component and cladding of buildings designed using the procedure specified herein represent the net pressures (sum of internal and external) that shall be applied normal to each building surface as shown in Figure 207E.5-1. $\boldsymbol{p_{net}}$ shall be determined by the following equation:

$$p_{net} = \lambda K_{zt} p_{net9} \qquad (207E.5\text{-}1)$$

where

λ = adjustment factor for building height and exposure from Figure 207E.5-1

K_{zt} = topographic factor as defined in Section 207A.8 evaluated at 0.33 mean roof height, $\boldsymbol{0.33h}$

p_{net30} = net design wind pressure for Exposure B, at $\boldsymbol{h}$ = 9 m, from Figure 207E.5-1

User Note:

Part 2 of Section 207E is a simplified method to determine wind pressures on C&C of enclosed low-rise buildings having flat, gable or hip roof shapes. The provisions of Part 2 are based on the Envelope Procedure of Part 1 with wind pressures determined from a table and adjusted as appropriate.

Table 207E.5-1
Steps to Determine C&C
Wind Loads Enclosed Low-rise Buildings
(Simplified Method)

Step 1:	Determine risk category, see Table 103-1
Step 2:	Determine the basic wind speed, $\boldsymbol{V}$, for the applicable risk category, see Figure 207A.5-1A, B or C
Step 3:	Determine wind load parameters: ➢ Exposure category B, C or D, see Section 207A.7 ➢ Topographic factor, $\boldsymbol{K_{zt}}$, see Section 207A.8 and Figure 207A.8-1
Step 4:	Enter figure to determine wind pressures at $\boldsymbol{h}$ = 9 m., $\boldsymbol{p_{net9}}$, see Figure 207E.5-1
Step 5:	Enter figure to determine adjustment for building height and exposure, $\boldsymbol{\lambda}$, see Figure 207E.5-1
Step 6:	Determine adjusted wind pressures, $\boldsymbol{p_{net}}$, see Equation 207E.5-1.

Part 3: Buildings with $h > 18$ m

Commentary:

In Equation 207E.6-1 a velocity pressure term, qi, appears that is defined as the "velocity pressure for internal pressure determination." The positive internal pressure is dictated by the positive exterior pressure on the windward face at the point where there is an opening. The positive exterior pressure at the opening is governed by the value of q at the level of the opening, not q_h. For positive internal pressure evaluation, q_i may conservatively be evaluated at height h ($q_i = q_h$). For low buildings this does not make much difference, but for the example of a 91.5-m-tall building in Exposure B with the highest opening at 18 m, the difference between $q_{9.15}$ and q_{18} represents a 59 percent increase in internal pressure. This is unrealistic and represents an unnecessary degree of conservatism. Accordingly, $q_i = q_z$ for positive internal pressure evaluation in partially enclosed buildings where height z is defined as the level of the highest opening in the building that could affect the positive internal pressure. For buildings sited in wind-borne debris regions, glazing that is not impact resistant or protected with an impact protective system, q_i should be treated as an opening.

207E.6 Building Types

The provisions of Section 207E.6 are applicable to an enclosed or partially enclosed building with a mean roof height $h > 18$ m with a flat roof, pitched roof, gable roof, hip roof, mansard roof, arched roof, or domed roof. The steps required for the determination of wind loads on components and cladding for these building types are shown in Table 207E.6-1.

207E.6.1 Conditions

For the determination of the design wind pressures on the component and cladding using the provisions of Section 207E.6.2, the conditions indicated on the selected figure(s) shall be applicable to the building under consideration.

207E.6.2 Design Wind Pressures

Design wind pressures on component and cladding for all buildings with $h > 18$ m shall be determined from the following equation:

$$p = q(GC_p) - (GC_{pi}) \text{ (N/m}^2\text{)} \qquad 207E.6\text{-}1$$

where

q = q_z for windward walls calculated at height z above the ground

q = q_h for leeward walls, side walls, and roofs evaluated at height h

q_i = q_h for windward walls, side walls, leeward walls, and roofs of enclosed buildings and for negative internal pressure evaluation in partially enclosed buildings

q_i = q_z for positive internal pressure evaluation in partially enclosed buildings where height z is defined as the level of the highest opening in the building that could affect the positive internal pressure. For positive internal pressure evaluation, q_i may conservatively be evaluated at height $h(qi = qh)$

(GC_p) = External pressure coefficients given in:
- Figure 207E.6-1 for walls and flat roofs
- Figure 207B.4-3, footnote 4, for arched roofs
- Figure 207E.4-7 for domed roofs
- Note 6 of Figure 207E.6-1

(GC_{pi}) = Internal pressure coefficient given in Table 207A.11-1

q and q_i shall be evaluated using exposure defined in Section 207A.11-1

Exception:

In buildings with a mean roof height h greater than 18 m and less than 27.4 m, (GC_p) values from Figures 207E.4-1 through 207E.4-6 shall be permitted to be used if the height to width ratio is one or less.

User Note:

Section Part 3 of Section 207E for determining wind pressures for C&C of enclosed and partially enclosed buildings with h > 18 m having roof shapes as specified in the applicable figures. These provisions are based on the Directional Procedure with wind pressures calculated from the specified equation applicable to each building surface.

Table 207E.6-1
Steps to Determine C&C Wind Loads
Enclosed and Partially Enclosed
Building with $h > 18$ m

Step 1:	Determine risk category, see Table 103-1
Step 2:	Determine the basic wind speed, V, for the applicable risk category, see Figure 207A.5-1A, B or C
Step 3:	Determine wind load parameters: ➢ Wind directionality factor, K_d, see Section 207A.6 and Table 207A.6-1 ➢ Exposure category B, C or D, see Section 207A.7 ➢ Topographic factor, K_{zt}, see Section 207A.8 and Figure 207A.8-1 ➢ Enclosure classification, see Section 207A.10 ➢ Internal pressure coefficient, (GC_{pi}), see Section 207A.11 and Table 207A.11-1
Step 4:	Determine velocity pressure exposure coefficient K_z or K_h, see Table 207E.3-1
Step 5:	Determine velocity pressure, q_h, see Table 207E.3-1
Step 6:	Determine external pressure coefficient, (GC_p) ➢ Walls and flat roofs, $(\theta < 10^o)$, see Figure 207E.6-1 ➢ Gable and hip roofs, see Figure 207E.4-2 per Note 6 of Figure 207E.6-1 ➢ Arched roofs, see Figure 207B.4-3, footnote 4 ➢ Domed roofs, see Figure 207E.4-7
Step 7:	Calculate wind pressure, p, Equation 207E.6-1

Part 4: Buildings with $h \leq 48$ m (Simplified)

Commentary:

This section has been added to ASCE 7-10 to cover the common practical case of enclosed buildings up to height h = 49 m. Table 207E.7-2 includes wall and roof pressures for flat roofs (θ < 10°), gable roofs, hip roofs, monoslope roofs, and mansard roofs. Pressures are derived from Figure 207E.6-1 (flat roofs), Figure 207E.4-2A, B, and C (gable and hip roofs), and Figure 207E.4-5A and B (monoslope roofs) of Part 3. Pressures were selected for each zone that encompasses the largest pressure coefficients for the comparable zones from the different roof shapes. Thus, for some cases, the pressures tabulated are conservative in order to maintain simplicity. The (GC_p) values from these figures were combined with an internal pressure coefficient (+ or – 0.18) to obtain a net coefficient from which pressures were calculated. The tabulated pressures are applicable to the entire zone shown in the various figures.

Pressures are shown for an effective wind area of 0.93 m^2. A reduction factor is also shown to obtain pressures for larger effective wind areas. The reduction factors are based on the graph of external pressure coefficients shown in the figures in Part 3 and are based on the most conservative reduction for each zone from the various figures.

207E.7 Building Types

The provisions of Section 207E.7 are applicable to an enclosed building having a mean roof height $h \leq 49$ m with a flat roof, gable roof, hip roof, monoslope roof, or mansard roof. The steps required for the determination of wind loads on components and cladding for these building types are shown in Table 207E.7-1.

207E.7.1 Wind Loads—Components and Cladding

207E.7.1.1 Wall and Roof Surfaces

Design wind pressures on the designated zones of walls and roofs surfaces shall be determined from Table 207E.7-2 based on the applicable basic wind speed V, mean roof height h, and roof slope θ. Tabulated pressures shall be multiplied by the exposure adjustment factor (EAF) shown in the table if exposure is different than Exposure C. Pressures in Table 207E.7-2 are based on an effective wind area of 0.93 m^2. Reductions in wind pressure for larger effective wind areas may be taken based on the reduction multipliers (RF) shown in the table. Pressures are to be applied over the entire zone shown in the figures. Final design wind pressure shall be determined from the following equation:

$$p = p_{table}(EAF)(RF)K_{zt} \qquad (207E.7\text{-}1)$$

where

RF = effective area reduction factor from Table 207E.7-2
EAF = Exposure adjustment factor from Table 207E.7-2
K_{zt} = topographic factor as defined in Section 207A.8

207E.7.1.2 Parapets

Design wind pressures on parapet surfaces shall be based on wind pressures for the applicable edge and corner zones in which the parapet is located, as shown in Table 207E.7-2, modified based on the following two load cases:

- Load Case A shall consist of applying the applicable positive wall pressure from the table to the front surface of the parapet while applying the applicable negative edge or corner zone roof pressure from the table to the back surface.

- Load Case B shall consist of applying the applicable positive wall pressure from the table to the back of the parapet surface and applying the applicable negative wall pressure from the table to the front surface.

User Note:

Part 4 of Section 207E is a simplified method for determining wind pressures for C&C of enclosed and partially enclosed buildings with $h \leq 49$ m. having roof shapes as specified in the applicable figures. These provisions are based on the Directional Procedure from Part 3 with wind pressures selected directly from a table and adjusted as applicable.

Table 207E.7-1
Steps to Determine C&C Wind Loads
Enclosed Building with $h > 48.8\ m$

Step 1:	Determine risk category, see Table 103-1
Step 2:	Determine the basic wind speed, V, for the applicable risk category, see Figure 207A.5-1A, B or C
Step 3:	Determine wind load parameters: ➢ Exposure category B, C or D, see Section 207A.7
Step 4:	Enter Table 207E.7-2 to determine pressure on walls and roof, p, using Equation 207E.7-1. Roof types are: ➢ Flat roof $(\theta < 10°)$ ➢ Gable roof ➢ Hip roof ➢ Monoslope roof ➢ Mansard roof
Step 5:	Determine topographic factors, K_{zt}, and apply factor to pressures determined from tables (if applicable), see Section 207A.8

Pressures in Table 207E.7-2 are based on an effective wind area of 0.93 m^2. Reduction in wind pressure for larger effective wind area may be taken based on the reduction factor shown in the table. Pressures are to be applied to the parapet in accordance with Figure 207E.7-1. The height h to be used with Figure 207E.7-1 to determine the pressures shall be the height to the top of the parapet. Determine final pressure from Equation 207E.7-1.

Commentary:

Parapet component and cladding wind pressures can be obtained from the tables as shown in the parapet figures *from the table. The pressures obtained are slightly conservative based on the net pressure coefficients for parapets compared to roof zones from Part 3. Two load cases must be considered based on pressures applied to both windward and leeward parapet surfaces as shown in Figure 207E.7-1.*

207E.7.1.3 Roof Overhangs

Design wind pressures on roof overhangs shall be based on wind pressures shown for the applicable zones in Table 207E.7-2 modified as described herein. For Zones 1 and 2, a multiplier of 1.0 shall be used on pressures shown in Table 207E.7-2. For Zone 3, a multiplier of 1.15 shall be used on pressures shown in Table 207E.7-2.

Pressures in Table 207E.7-2 are based on an effective wind area of 0.93 m^2. Reductions in wind pressure for larger effective wind areas may be taken based on the reduction multiplier shown in Table 207E.7-2. Pressures on roof overhangs include the pressure from the top and bottom surface of overhang. Pressures on the underside of the overhangs are equal to the adjacent wall pressures. Refer to the overhang drawing shown in Figure 207E.7-2. Determine final pressure from Equation 207E.7-1.

Commentary:

Component and cladding pressures for roof overhangs can be obtained from the tables as shown in Figure 207E.7-2. These pressures are slightly conservative and are based on the external pressure coefficients contained in Figure 207E.4-2A to 207E.4-2C from Part 3.

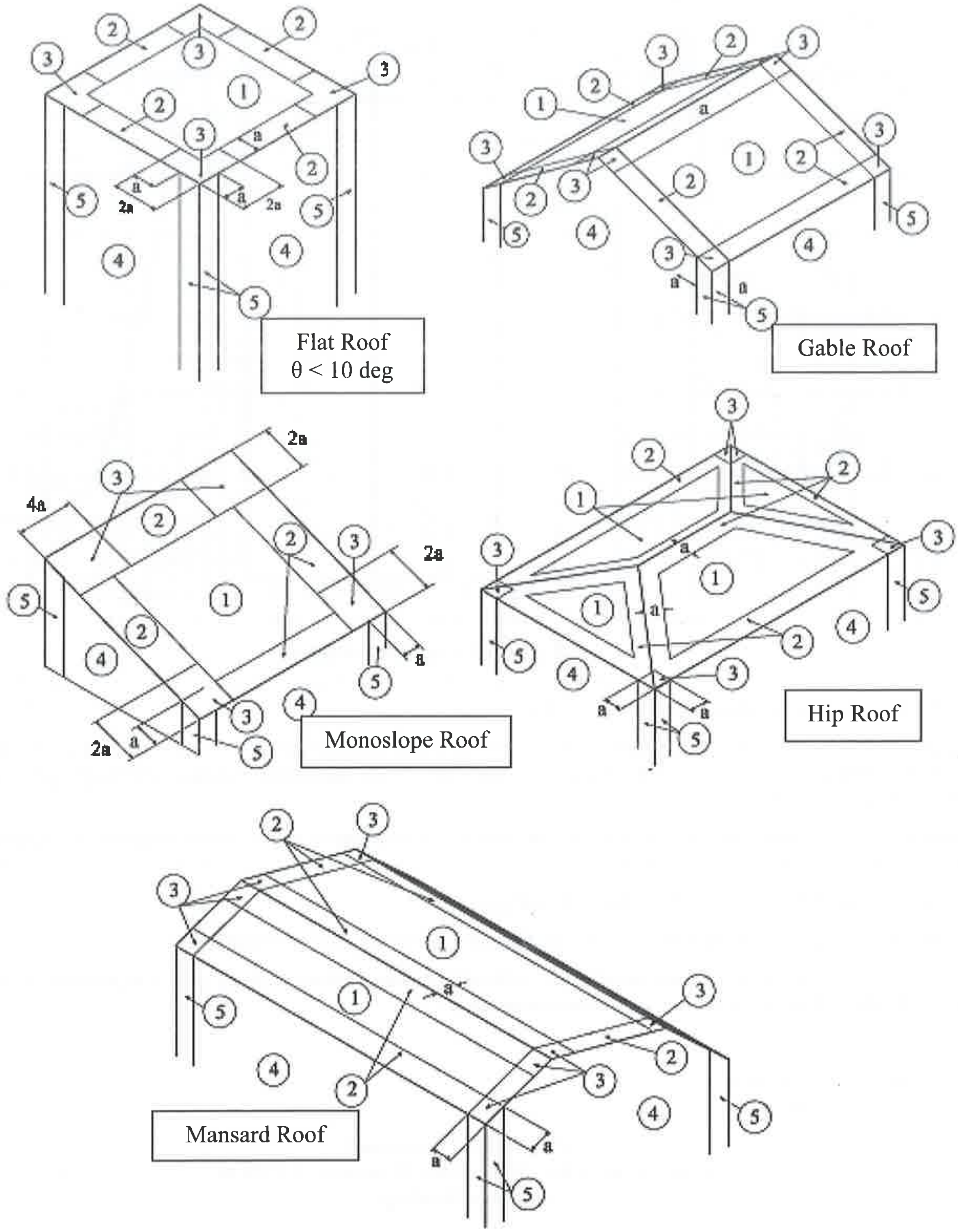
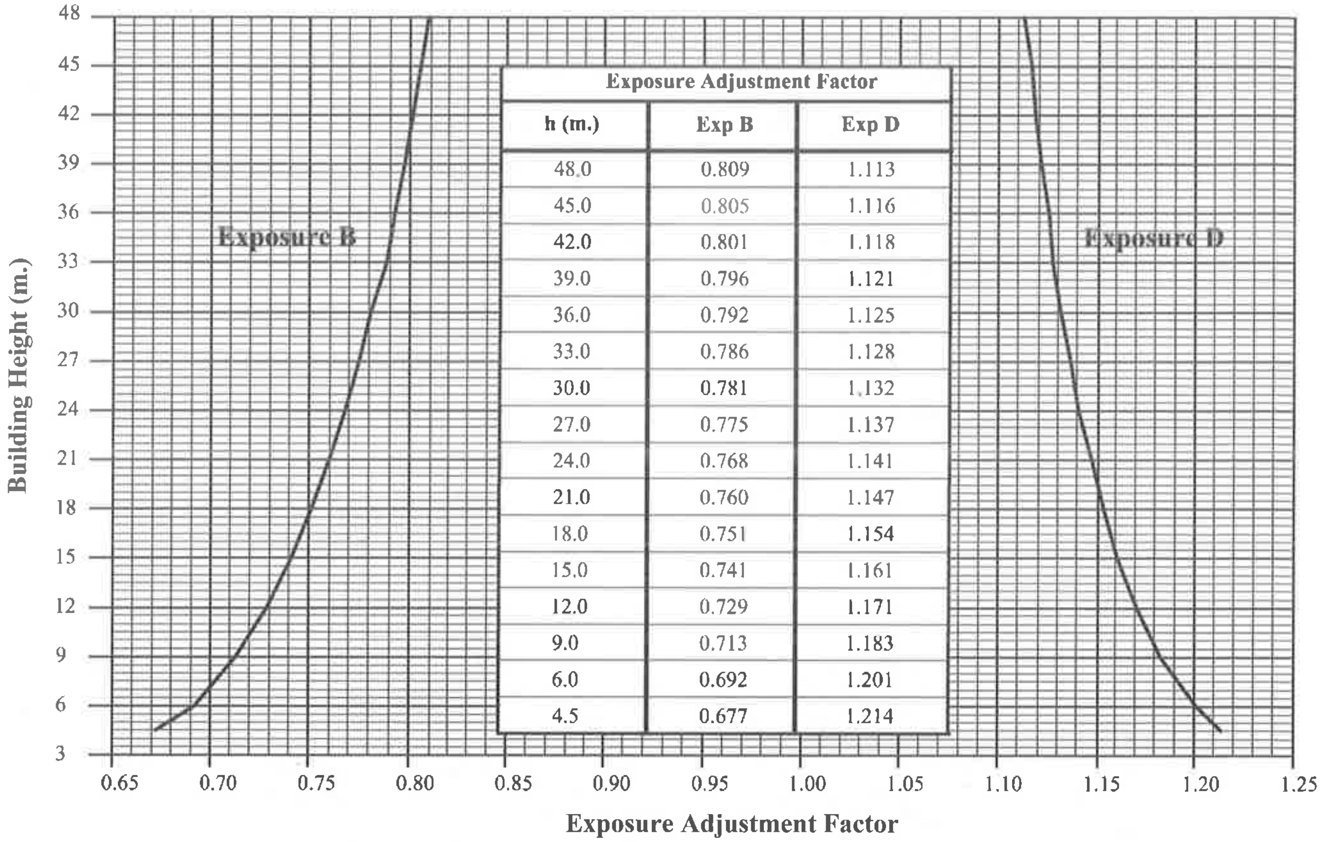


Figure 207E.7-2
C & C Zones C&C Wall and Roof Pressures, $h \leq 48$ m
Enclosed Buildings

Roof and Wall Pressures-Components and Cladding
Exposure Adjustment Factor



Exposure Adjustment Factor		
h (m.)	Exp B	Exp D
48.0	0.809	1.113
45.0	0.805	1.116
42.0	0.801	1.118
39.0	0.796	1.121
36.0	0.792	1.125
33.0	0.786	1.128
30.0	0.781	1.132
27.0	0.775	1.137
24.0	0.768	1.141
21.0	0.760	1.147
18.0	0.751	1.154
15.0	0.741	1.161
12.0	0.729	1.171
9.0	0.713	1.183
6.0	0.692	1.201
4.5	0.677	1.214

Notes to Component and Cladding Wind Pressure Table:

1. For each roof form, Exposure C, V and h determine roof and wall cladding pressures for the applicable zone from tables above. For other exposures B or D, multiply pressures from table by the appropriate exposure adjustment factor determined from figure above.
2. Interpolation between h values is permitted. For pressures at other V values than shown in the table, multiply table value for any given V' in the table as shown above:

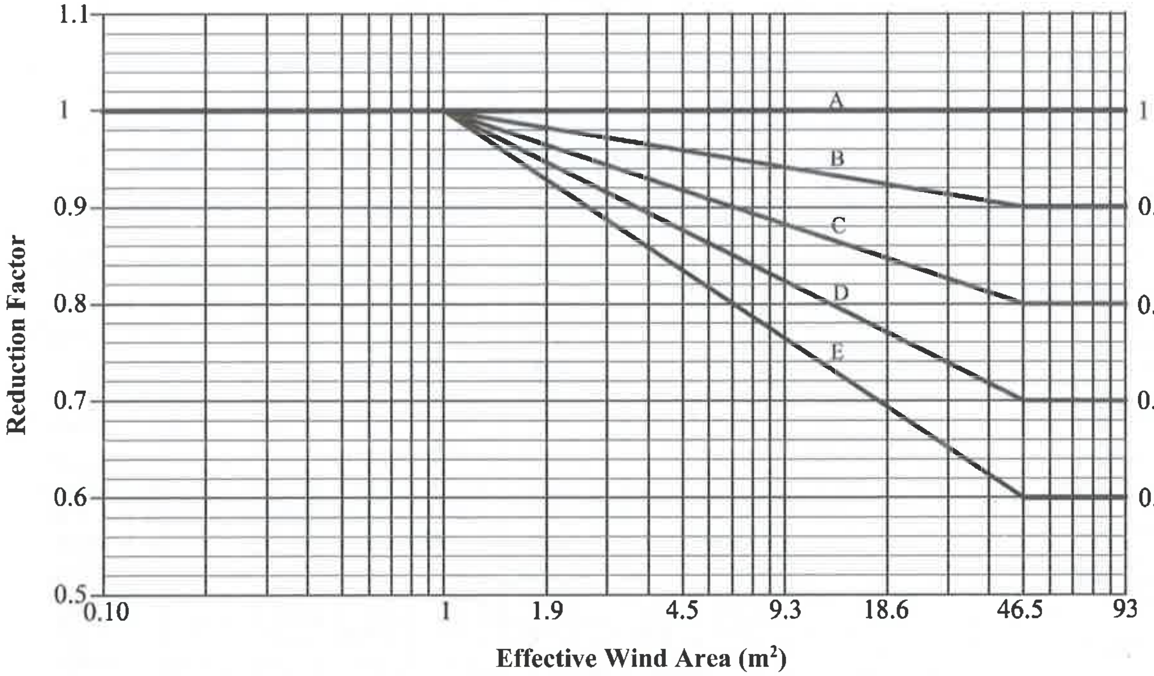
   Pressure at desired V = pressure from table at $V' \times [V_{desired}/V']^2$
3. Where two load cases are shown, both positive and negative pressures shall be considered.
4. Pressures are shown for an effective wind area = 0.93 m^2. For larger effective wind areas, the pressure shown may be reduced by the reduction coefficient applicable to each zone.

Notation:

h	mean roof height (m)
V	Basic wind speed (kph)

Table 207E.7-2 (continued)
C & C Zones C&C Wall and Roof Pressures, $h \leq 48$ m
Enclosed Buildings

Reduction Factors
Effective Wind Area



Reduction Factors
Effective Wind Area

Roof Form	Sign Pressure	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Flat	Minus	D	D	D	C	E
Flat	Plus	NA	NA	NA	D	D
Gable, Mansard	Minus	B	C	C	C	E
Gable, Mansard	Plus	B	B	B	D	D
Hip	Minus	B	C	C	C	E
Hip	Plus	B	B	B	D	D
Monoslope	Minus	A	B	D	C	E
Monoslope	Plus	C	C	C	D	D
Overhangs	All	A	A	B	NA	NA

Table 207E.7-2 (continued)
C & C Effective Wind Area C&C Wall and Roof Pressures, $h \leq 48$ m
Enclosed Buildings

Table 207E.7-2
Components and Cladding – Part 4
C&C, V = 150 -200 kph, h = 4.5 - 15 m
Exposure C

V (kph)			**150**					**200**				
h (m)	**Roof Form**	**Load Case**	**Zone**					**Zone**				
			1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
15	Flat Roof	1	-1.5579	-2.4453	-3.3328	-1.0649	-1.9523	-2.7696	-4.3473	-5.9249	-1.8932	-3.4708
		2	NA	NA	NA	1.0649	1.0649	NA	NA	NA	1.8932	1.8932
	Gable Roof Mansard Roof	1	-1.1635	-1.9523	-2.9384	-1.2621	-1.9523	-2.0685	-3.4708	-5.2238	-2.2438	-3.4708
		2	0.6705	0.6705	0.6705	1.1635	1.0649	1.1920	1.1920	1.1920	2.0685	1.8932
	Hip Roof	1	-1.0649	-1.8537	-2.7412	-1.2621	-1.9523	-1.8932	-3.2955	-4.8732	-2.2438	-3.4708
		2	0.6705	0.6705	0.6705	1.1635	1.0649	1.1920	1.1920	1.1920	2.0685	1.8932
	Monoslope Roof	1	-1.3607	-1.7551	-3.0370	-1.2621	-1.9523	-2.4191	-3.1202	-5.3990	-2.2438	-3.4708
		2	0.5719	0.5719	0.5719	1.1635	1.0649	1.0167	1.0167	1.0167	2.0685	1.8932
12	Flat Roof	1	-1.4865	-2.3332	-3.1799	-1.0161	-1.8628	-2.6426	-4.1479	-5.6531	-1.8063	-3.3116
		2	NA	NA	NA	1.0161	1.0161	NA	NA	NA	1.8063	1.8063
	Gable Roof Mansard Roof	1	-1.1101	-1.8628	-2.8036	-1.2042	-1.8628	-1.9736	-3.3116	-4.9841	-2.1408	-3.3116
		2	0.6397	0.6397	0.6397	1.1101	1.0161	1.1373	1.1373	1.1373	1.9736	1.8063
	Hip Roof	1	-1.0161	-1.7687	-2.6154	-1.2042	-1.8628	-1.8063	-3.1444	-4.6496	-2.1408	-3.3116
		2	0.6397	0.6397	0.6397	1.1101	1.0161	1.1373	1.1373	1.1373	1.9736	1.8063
	Monoslope Roof	1	-1.2983	-1.6746	-2.8977	-1.2042	-1.8628	-2.3081	-2.9771	-5.1514	-2.1408	-3.3116
		2	0.5457	0.5457	0.5457	1.1101	1.0161	0.9701	0.9701	0.9701	1.9736	1.8063
9	Flat Roof	1	-1.4007	-2.1986	-2.9964	-0.9574	-1.7553	-2.4901	-3.9086	-5.3270	-1.7021	-3.1206
		2	NA	NA	NA	0.9574	0.9574	NA	NA	NA	1.7021	1.7021
	Gable Roof Mansard Roof	1	-1.0461	-1.7553	-2.6418	-1.1347	-1.7553	-1.8597	-3.1206	-4.6966	-2.0173	-3.1206
		2	0.6028	0.6028	0.6028	1.0461	0.9574	1.0717	1.0717	1.0717	1.8597	1.7021
	Hip Roof	1	-0.9574	-1.6667	-2.4645	-1.1347	-1.7553	-1.7021	-2.9629	-4.3814	-2.0173	-3.1206
		2	0.6028	0.6028	0.6028	1.0461	0.9574	1.0717	1.0717	1.0717	1.8597	1.7021
	Monoslope Roof	1	-1.2234	-1.5780	-2.7305	-1.1347	-1.7553	-2.1749	-2.8053	-4.8542	-2.0173	-3.1206
		2	0.5142	0.5142	0.5142	1.0461	0.9574	0.9141	0.9141	0.9141	1.8597	1.7021
7.5	Flat Roof	1	-1.3435	-2.1088	-2.8741	-0.9184	-1.6837	-2.3885	-3.7490	-5.1096	-1.6326	-2.9932
		2	NA	NA	NA	0.9184	0.9184	NA	NA	NA	1.6326	1.6326
	Gable Roof Mansard Roof	1	-1.0034	-1.6837	-2.5340	-1.0884	-1.6837	-1.7838	-2.9932	-4.5049	-1.9350	-2.9932
		2	0.5782	0.5782	0.5782	1.0034	0.9184	1.0280	1.0280	1.0280	1.7838	1.6326
	Hip Roof	1	-0.9184	-1.5986	-2.3639	-1.0884	-1.6837	-1.6326	-2.8420	-4.2025	-1.9350	-2.9932
		2	0.5782	0.5782	0.5782	1.0034	0.9184	1.0280	1.0280	1.0280	1.7838	1.6326
	Monoslope Roof	1	-1.1735	-1.5136	-2.6190	-1.0884	-1.6837	-2.0862	-2.6908	-4.6561	-1.9350	-2.9932
		2	0.4932	0.4932	0.4932	1.0034	0.9184	0.8768	0.8768	0.8768	1.7838	1.6326
6	Flat Roof	1	-1.2864	-2.0191	-2.7518	-0.8793	-1.6120	-2.2869	-3.5895	-4.8921	-1.5632	-2.8658
		2	NA	NA	NA	0.8793	0.8793	NA	NA	NA	1.5632	1.5632
	Gable Roof Mansard Roof	1	-0.9607	-1.6120	-2.4262	-1.0421	-1.6120	-1.7079	-2.8658	-4.3132	-1.8526	-2.8658
		2	0.5536	0.5536	0.5536	0.9607	0.8793	0.9842	0.9842	0.9842	1.7079	1.5632
	Hip Roof	1	-0.8793	-1.5306	-2.2633	-1.0421	-1.6120	-1.5632	-2.7211	-4.0237	-1.8526	-2.8658
		2	0.5536	0.5536	0.5536	0.9607	0.8793	0.9842	0.9842	0.9842	1.7079	1.5632
	Monoslope Roof	1	-1.1235	-1.4492	-2.5076	-1.0421	-1.6120	-1.9974	-2.5763	-4.4579	-1.8526	-2.8658
		2	0.4722	0.4722	0.4722	0.9607	0.8793	0.8395	0.8395	0.8395	1.7079	1.5632
4.5	Flat Roof	1	-1.2149	-1.9069	-2.5990	-0.8304	-1.5225	-2.1598	-3.3901	-4.6204	-1.4763	-2.7066
		2	NA	NA	NA	0.8304	0.8304	NA	NA	NA	1.4763	1.4763
	Gable Roof Mansard Roof	1	-0.9073	-1.5225	-2.2914	-0.9842	-1.5225	-1.6130	-2.7066	-4.0736	-1.7497	-2.7066
		2	0.5229	0.5229	0.5229	0.9073	0.8304	0.9295	0.9295	0.9295	1.6130	1.4763
	Hip Roof	1	-0.8304	-1.4456	-2.1376	-0.9842	-1.5225	-1.4763	-2.5699	-3.8002	-1.7497	-2.7066
		2	0.5229	0.5229	0.5229	0.9073	0.8304	0.9295	0.9295	0.9295	1.6130	1.4763
	Monoslope Roof	1	-1.0611	-1.3687	-2.3683	-0.9842	-1.5225	-1.8864	-2.4332	-4.2103	-1.7497	-2.7066
		2	0.4460	0.4460	0.4460	0.9073	0.8304	0.7928	0.7928	0.7928	1.6130	1.4763

Table 207E.7-2
Components and Cladding – Part 4
C&C, V = 250 -300 kph, h = 4.5 - 15 m
Exposure C

***V* (kph)**			**250**					**300**				
***h* (m)**	**Roof Form**	**Load Case**	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**
15	Flat Roof	1	-4.3276	-6.7926	-9.2577	-2.9581	-5.4232	-6.2317	-9.7814	-13.3311	-4.2596	-7.8093
		2	NA	NA	NA	2.9581	2.9581	NA	NA	NA	4.2596	4.2596
	Gable Roof Mansard Roof	1	-3.2320	-5.4232	-8.1621	-3.5059	-5.4232	-4.6541	-7.8093	-11.7534	-5.0485	-7.8093
		2	1.8625	1.8625	1.8625	3.2320	2.9581	2.6820	2.6820	2.6820	4.6541	4.2596
	Hip Roof	1	-2.9581	-5.1493	-7.6143	-3.5059	-5.4232	-4.2596	-7.4149	-10.9646	-5.0485	-7.8093
		2	1.8625	1.8625	1.8625	3.2320	2.9581	2.6820	2.6820	2.6820	4.6541	4.2596
	Monoslope Roof	1	-3.7798	-4.8754	-8.4360	-3.5059	-5.4232	-5.4429	-7.0205	-12.1479	-5.0485	-7.8093
		2	1.5886	1.5886	1.5886	3.2320	2.9581	2.2876	2.2876	2.2876	4.6541	4.2596
12	Flat Roof	1	-4.1291	-6.4810	-8.8330	-2.8224	-5.1744	-5.9458	-9.3327	-12.7196	-4.0642	-7.4511
		2	NA	NA	NA	2.8224	2.8224	NA	NA	NA	4.0642	4.0642
	Gable Roof Mansard Roof	1	-3.0837	-5.1744	-7.7877	-3.3451	-5.1744	-4.4406	-7.4511	-11.2143	-4.8169	-7.4511
		2	1.7771	1.7771	1.7771	3.0837	2.8224	2.5590	2.5590	2.5590	4.4406	4.0642
	Hip Roof	1	-2.8224	-4.9131	-7.2650	-3.3451	-5.1744	-4.0642	-7.0748	-10.4617	-4.8169	-7.4511
		2	1.7771	1.7771	1.7771	3.0837	2.8224	2.5590	2.5590	2.5590	4.4406	4.0642
	Monoslope Roof	1	-3.6064	-4.6517	-8.0490	-3.3451	-5.1744	-5.1932	-6.6985	-11.5906	-4.8169	-7.4511
		2	1.5157	1.5157	1.5157	3.0837	2.8224	2.1826	2.1826	2.1826	4.4406	4.0642
9	Flat Roof	1	-3.8908	-6.1071	-8.3234	-2.6596	-4.8759	-5.6028	-8.7943	-11.9858	-3.8298	-7.0212
		2	NA	NA	NA	2.6596	2.6596	NA	NA	NA	3.8298	3.8298
	Gable Roof Mansard Roof	1	-2.9058	-4.8759	-7.3384	-3.1521	-4.8759	-4.1844	-7.0212	-10.5673	-4.5390	-7.0212
		2	1.6745	1.6745	1.6745	2.9058	2.6596	2.4113	2.4113	2.4113	4.1844	3.8298
	Hip Roof	1	-2.6596	-4.6296	-6.8459	-3.1521	-4.8759	-3.8298	-6.6666	-9.8581	-4.5390	-7.0212
		2	1.6745	1.6745	1.6745	2.9058	2.6596	2.4113	2.4113	2.4113	4.1844	3.8298
	Monoslope Roof	1	-3.3983	-4.3834	-7.5847	-3.1521	-4.8759	-4.8936	-6.3120	-10.9219	-4.5390	-7.0212
		2	1.4283	1.4283	1.4283	2.9058	2.6596	2.0567	2.0567	2.0567	4.1844	3.8298
7.5	Flat Roof	1	-3.7320	-5.8579	-7.9837	-2.5510	-4.6768	-5.3741	-8.4353	-11.4965	-3.6735	-6.7347
		2	NA	NA	NA	2.5510	2.5510	NA	NA	NA	3.6735	3.6735
	Gable Roof Mansard Roof	1	-2.7872	-4.6768	-7.0389	-3.0234	-4.6768	-4.0136	-6.7347	-10.1360	-4.3537	-6.7347
		2	1.6062	1.6062	1.6062	2.7872	2.5510	2.3129	2.3129	2.3129	4.0136	3.6735
	Hip Roof	1	-2.5510	-4.4406	-6.5665	-3.0234	-4.6768	-3.6735	-6.3945	-9.4557	-4.3537	-6.7347
		2	1.6062	1.6062	1.6062	2.7872	2.5510	2.3129	2.3129	2.3129	4.0136	3.6735
	Monoslope Roof	1	-3.2596	-4.2044	-7.2751	-3.0234	-4.6768	-4.6939	-6.0544	-10.4761	-4.3537	-6.7347
		2	1.3700	1.3700	1.3700	2.7872	2.5510	1.9728	1.9728	1.9728	4.0136	3.6735
6	Flat Roof	1	-3.5732	-5.6086	-7.6440	-2.4425	-4.4778	-5.1454	-8.0764	-11.0073	-3.5171	-6.4481
		2	NA	NA	NA	2.4425	2.4425	NA	NA	NA	3.5171	3.5171
	Gable Roof Mansard Roof	1	-2.6686	-4.4778	-6.7394	-2.8948	-4.4778	-3.8428	-6.4481	-9.7047	-4.1685	-6.4481
		2	1.5378	1.5378	1.5378	2.6686	2.4425	2.2145	2.2145	2.2145	3.8428	3.5171
	Hip Roof	1	-2.4425	-4.2517	-6.2871	-2.8948	-4.4778	-3.5171	-6.1224	-9.0534	-4.1685	-6.4481
		2	1.5378	1.5378	1.5378	2.6686	2.4425	2.2145	2.2145	2.2145	3.8428	3.5171
	Monoslope Roof	1	-3.1209	-4.0255	-6.9655	-2.8948	-4.4778	-4.4941	-5.7968	-10.0303	-4.1685	-6.4481
		2	1.3117	1.3117	1.3117	2.6686	2.4425	1.8888	1.8888	1.8888	3.8428	3.5171
4.5	Flat Roof	1	-3.3747	-5.2970	-7.2193	-2.3068	-4.2291	-4.8596	-7.6277	-10.3958	-3.3217	-6.0899
		2	NA	NA	NA	2.3068	2.3068	NA	NA	NA	3.3217	3.3217
	Gable Roof Mansard Roof	1	-2.5204	-4.2291	-6.3650	-2.7339	-4.2291	-3.6293	-6.0899	-9.1655	-3.9369	-6.0899
		2	1.4524	1.4524	1.4524	2.5204	2.3068	2.0915	2.0915	2.0915	3.6293	3.3217
	Hip Roof	1	-2.3068	-4.0155	-5.9378	-2.7339	-4.2291	-3.3217	-5.7823	-8.5504	-3.9369	-6.0899
		2	1.4524	1.4524	1.4524	2.5204	2.3068	2.0915	2.0915	2.0915	3.6293	3.3217
	Monoslope Roof	1	-2.9475	-3.8019	-6.5785	-2.7339	-4.2291	-4.2444	-5.4747	-9.4731	-3.9369	-6.0899
		2	1.2388	1.2388	1.2388	2.5204	2.3068	1.7839	1.7839	1.7839	3.6293	3.3217

Table 207E.7-2
Components and Cladding – Part 4
C&C, V = 350 kph, h = 4.5 - 15 m
Exposure C

V (kph)			**350**				
h (m)	**Roof Form**	**Load Case**	**Zone**				
			1	**2**	**3**	**4**	**5**
15	Flat Roof	1	-8.4820	-13.3136	-18.1451	-5.7978	-10.6294
		2	NA	NA	NA	5.7978	5.7978
	Gable Roof Mansard Roof	1	-6.3347	-10.6294	-15.9978	-6.8715	-10.6294
		2	3.6505	3.6505	3.6505	6.3347	5.7978
	Hip Roof	1	-5.7978	-10.0925	-14.9241	-6.8715	-10.6294
		2	3.6505	3.6505	3.6505	6.3347	5.7978
	Monoslope Roof	1	-7.4084	-9.5557	-16.5346	-6.8715	-10.6294
		2	3.1137	3.1137	3.1137	6.3347	5.7978
12	Flat Roof	1	-8.0929	-12.7029	-17.3128	-5.5319	-10.1418
		2	NA	NA	NA	5.5319	5.5319
	Gable Roof Mansard Roof	1	-6.0441	-10.1418	-15.2639	-6.5563	-10.1418
		2	3.4830	3.4830	3.4830	6.0441	5.5319
	Hip Roof	1	-5.5319	-9.6296	-14.2395	-6.5563	-10.1418
		2	3.4830	3.4830	3.4830	6.0441	5.5319
	Monoslope Roof	1	-7.0685	-9.1174	-15.7761	-6.5563	-10.1418
		2	2.9708	2.9708	2.9708	6.0441	5.5319
9	Flat Roof	1	-7.6260	-11.9700	-16.3139	-5.2127	-9.5567
		2	NA	NA	NA	5.2127	5.2127
	Gable Roof Mansard Roof	1	-5.6954	-9.5567	-14.3833	-6.1781	-9.5567
		2	3.2821	3.2821	3.2821	5.6954	5.2127
	Hip Roof	1	-5.2127	-9.0740	-13.4180	-6.1781	-9.5567
		2	3.2821	3.2821	3.2821	5.6954	5.2127
	Monoslope Roof	1	-6.6607	-8.5914	-14.8660	-6.1781	-9.5567
		2	2.7994	2.7994	2.7994	5.6954	5.2127
7.5	Flat Roof	1	-7.3148	-11.4814	-15.6481	-5.0000	-9.1666
		2	NA	NA	NA	5.0000	5.0000
	Gable Roof Mansard Roof	1	-5.4629	-9.1666	-13.7962	-5.9259	-9.1666
		2	3.1481	3.1481	3.1481	5.4629	5.0000
	Hip Roof	1	-5.0000	-8.7037	-12.8703	-5.9259	-9.1666
		2	3.1481	3.1481	3.1481	5.4629	5.0000
	Monoslope Roof	1	-6.3889	-8.2407	-14.2592	-5.9259	-9.1666
		2	2.6852	2.6852	2.6852	5.4629	5.0000
6	Flat Roof	1	-7.0035	-10.9929	-14.9822	-4.7872	-8.7766
		2	NA	NA	NA	4.7872	4.7872
	Gable Roof Mansard Roof	1	-5.2305	-8.7766	-13.2092	-5.6737	-8.7766
		2	3.0142	3.0142	3.0142	5.2305	4.7872
	Hip Roof	1	-4.7872	-8.3333	-12.3226	-5.6737	-8.7766
		2	3.0142	3.0142	3.0142	5.2305	4.7872
	Monoslope Roof	1	-6.1170	-7.8900	-13.6524	-5.6737	-8.7766
		2	2.5709	2.5709	2.5709	5.2305	4.7872
4.5	Flat Roof	1	-6.6144	-10.3821	-14.1498	-4.5213	-8.2890
		2	NA	NA	NA	4.5213	4.5213
	Gable Roof Mansard Roof	1	-4.9399	-8.2890	-12.4753	-5.3585	-8.2890
		2	2.8467	2.8467	2.8467	4.9399	4.5213
	Hip Roof	1	-4.5213	-7.8703	-11.6380	-5.3585	-8.2890
		2	2.8467	2.8467	2.8467	4.9399	4.5213
	Monoslope Roof	1	-5.7772	-7.4517	-12.8939	-5.3585	-8.2890
		2	2.4281	2.4281	2.4281	4.9399	4.5213

Table 207E.7-2
Components and Cladding – Part 4
C&C, V = 150 -200 kph, h = 18 - 33 m
Exposure C

V (kph)			150					200				
h (m)	Roof Form	Load Case	Zone					Zone				
			1	2	3	4	5	1	2	3	4	5
33	Flat Roof	1	-1.8438	-2.8940	-3.9443	-1.2603	-2.3106	-3.2778	-5.1450	-7.0121	-2.2405	-4.1077
		2	NA	NA	NA	1.2603	1.2603	NA	NA	NA	2.2405	2.2405
	Gable Roof Mansard Roof	1	-1.3770	-2.3106	-3.4775	-1.4937	-2.3106	-2.4480	-4.1077	-6.1822	-2.6555	-4.1077
		2	0.7935	0.7935	0.7935	1.3770	1.2603	1.4107	1.4107	1.4107	2.4480	2.2405
	Hip Roof	1	-1.2603	-2.1939	-3.2441	-1.4937	-2.3106	-2.2405	-3.9002	-5.7673	-2.6555	-4.1077
		2	0.7935	0.7935	0.7935	1.3770	1.2603	1.4107	1.4107	1.4107	2.4480	2.2405
	Monoslope Roof	1	-1.6104	-2.0772	-3.5942	-1.4937	-2.3106	-2.8629	-3.6927	-6.3897	-2.6555	-4.1077
		2	0.6768	0.6768	0.6768	1.3770	1.2603	1.2033	1.2033	1.2033	2.4480	2.2405
30	Flat Roof	1	-1.8009	-2.8267	-3.8526	-1.2310	-2.2568	-3.2016	-5.0253	-6.8490	-2.1884	-4.0121
		2	NA	NA	NA	1.2310	1.2310	NA	NA	NA	2.1884	2.1884
	Gable Roof Mansard Roof	1	-1.3450	-2.2568	-3.3966	-1.4590	-2.2568	-2.3911	-4.0121	-6.0385	-2.5937	-4.0121
		2	0.7751	0.7751	0.7751	1.3450	1.2310	1.3779	1.3779	1.3779	2.3911	2.1884
	Hip Roof	1	-1.2310	-2.1428	-3.1687	-1.4590	-2.2568	-2.1884	-3.8095	-5.6332	-2.5937	-4.0121
		2	0.7751	0.7751	0.7751	1.3450	1.2310	1.3779	1.3779	1.3779	2.3911	2.1884
	Monoslope Roof	1	-1.5729	-2.0289	-3.5106	-1.4590	-2.2568	-2.7963	-3.6069	-6.2411	-2.5937	-4.0121
		2	0.6611	0.6611	0.6611	1.3450	1.2310	1.1753	1.1753	1.1753	2.3911	2.1884
27	Flat Roof	1	-1.7723	-2.7819	-3.7914	-1.2115	-2.2210	-3.1508	-4.9455	-6.7403	-2.1537	-3.9485
		2	NA	NA	NA	1.2115	1.2115	NA	NA	NA	2.1537	2.1537
	Gable Roof Mansard Roof	1	-1.3236	-2.2210	-3.3427	-1.4358	-2.2210	-2.3531	-3.9485	-5.9426	-2.5525	-3.9485
		2	0.7628	0.7628	0.7628	1.3236	1.2115	1.3560	1.3560	1.3560	2.3531	2.1537
	Hip Roof	1	-1.2115	-2.1088	-3.1184	-1.4358	-2.2210	-2.1537	-3.7490	-5.5438	-2.5525	-3.9485
		2	0.7628	0.7628	0.7628	1.3236	1.2115	1.3560	1.3560	1.3560	2.3531	2.1537
	Monoslope Roof	1	-1.5480	-1.9967	-3.4549	-1.4358	-2.2210	-2.7520	-3.5496	-6.1420	-2.5525	-3.9485
		2	0.6506	0.6506	0.6506	1.3236	1.2115	1.1566	1.1566	1.1566	2.3531	2.1537
24	Flat Roof	1	-1.7294	-2.7146	-3.6997	-1.1821	-2.1673	-3.0746	-4.8259	-6.5772	-2.1016	-3.8529
		2	NA	NA	NA	1.1821	1.1821	NA	NA	NA	2.1016	2.1016
	Gable Roof Mansard Roof	1	-1.2916	-2.1673	-3.2619	-1.4011	-2.1673	-2.2962	-3.8529	-5.7988	-2.4908	-3.8529
		2	0.7443	0.7443	0.7443	1.2916	1.1821	1.3232	1.3232	1.3232	2.2962	2.1016
	Hip Roof	1	-1.1821	-2.0578	-3.0429	-1.4011	-2.1673	-2.1016	-3.6583	-5.4097	-2.4908	-3.8529
		2	0.7443	0.7443	0.7443	1.2916	1.1821	1.3232	1.3232	1.3232	2.2962	2.1016
	Monoslope Roof	1	-1.5105	-1.9484	-3.3713	-1.4011	-2.1673	-2.6854	-3.4637	-5.9934	-2.4908	-3.8529
		2	0.6349	0.6349	0.6349	1.2916	1.1821	1.1286	1.1286	1.1286	2.2962	2.1016
21	Flat Roof	1	-1.6723	-2.6248	-3.5774	-1.1431	-2.0956	-2.9729	-4.6664	-6.3598	-2.0321	-3.7256
		2	NA	NA	NA	1.1431	1.1431	NA	NA	NA	2.0321	2.0321
	Gable Roof Mansard Roof	1	-1.2489	-2.0956	-3.1540	-1.3547	-2.0956	-2.2203	-3.7256	-5.6072	-2.4084	-3.7256
		2	0.7197	0.7197	0.7197	1.2489	1.1431	1.2795	1.2795	1.2795	2.2203	2.0321
	Hip Roof	1	-1.1431	-1.9898	-2.9423	-1.3547	-2.0956	-2.0321	-3.5374	-5.2308	-2.4084	-3.7256
		2	0.7197	0.7197	0.7197	1.2489	1.1431	1.2795	1.2795	1.2795	2.2203	2.0321
	Monoslope Roof	1	-1.4606	-1.8839	-3.2599	-1.3547	-2.0956	-2.5966	-3.3492	-5.7953	-2.4084	-3.7256
		2	0.6139	0.6139	0.6139	1.2489	1.1431	1.0913	1.0913	1.0913	2.2203	2.0321
18	Flat Roof	1	-1.6151	-2.5351	-3.4551	-1.1040	-2.0240	-2.8713	-4.5068	-6.1424	-1.9626	-3.5982
		2	NA	NA	NA	1.1040	1.1040	NA	NA	NA	1.9626	1.9626
	Gable Roof Mansard Roof	1	-1.2062	-2.0240	-3.0462	-1.3084	-2.0240	-2.1444	-3.5982	-5.4155	-2.3261	-3.5982
		2	0.6951	0.6951	0.6951	1.2062	1.1040	1.2357	1.2357	1.2357	2.1444	1.9626
	Hip Roof	1	-1.1040	-1.9218	-2.8417	-1.3084	-2.0240	-1.9626	-3.4165	-5.0520	-2.3261	-3.5982
		2	0.6951	0.6951	0.6951	1.2062	1.1040	1.2357	1.2357	1.2357	2.1444	1.9626
	Monoslope Roof	1	-1.4107	-1.8195	-3.1484	-1.3084	-2.0240	-2.5078	-3.2347	-5.5972	-2.3261	-3.5982
		2	0.5929	0.5929	0.5929	1.2062	1.1040	1.0540	1.0540	1.0540	2.1444	1.9626

Table 207E.7-2
Components and Cladding – Part 4
C&C, V = 250 -300 kph, h = 18 - 33 m
Exposure C

V (kph)			**250**					**300**				
			Zone					**Zone**				
***h* (m)**	**Roof Form**	**Load Case**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
33	Flat Roof	1	-5.1216	-8.0390	-10.9564	-3.5009	-6.4182	-7.3751	-11.5761	-15.7772	-5.0412	-9.2422
		2	NA	NA	NA	3.5009	3.5009	NA	NA	NA	5.0412	5.0412
	Gable Roof Mansard Roof	1	-3.8250	-6.4182	-9.6598	-4.1492	-6.4182	-5.5080	-9.2422	-13.9100	-5.9748	-9.2422
		2	2.2042	2.2042	2.2042	3.8250	3.5009	3.1741	3.1741	3.1741	5.5080	5.0412
	Hip Roof	1	-3.5009	-6.0941	-9.0114	-4.1492	-6.4182	-5.0412	-8.7755	-12.9765	-5.9748	-9.2422
		2	2.2042	2.2042	2.2042	3.8250	3.5009	3.1741	3.1741	3.1741	5.5080	5.0412
	Monoslope Roof	1	-4.4733	-5.7699	-9.9839	-4.1492	-6.4182	-6.4416	-8.3087	-14.3768	-5.9748	-9.2422
		2	1.8801	1.8801	1.8801	3.8250	3.5009	2.7073	2.7073	2.7073	5.5080	5.0412
30	Flat Roof	1	-5.0025	-7.8520	-10.7016	-3.4194	-6.2690	-7.2036	-11.3069	-15.4103	-4.9240	-9.0273
		2	NA	NA	NA	3.4194	3.4194	NA	NA	NA	4.9240	4.9240
	Gable Roof Mansard Roof	1	-3.7360	-6.2690	-9.4351	-4.0527	-6.2690	-5.3799	-9.0273	-13.5866	-5.8358	-9.0273
		2	2.1530	2.1530	2.1530	3.7360	3.4194	3.1003	3.1003	3.1003	5.3799	4.9240
	Hip Roof	1	-3.4194	-5.9524	-8.8019	-4.0527	-6.2690	-4.9240	-8.5714	-12.6747	-5.8358	-9.0273
		2	2.1530	2.1530	2.1530	3.7360	3.4194	3.1003	3.1003	3.1003	5.3799	4.9240
	Monoslope Roof	1	-4.3693	-5.6357	-9.7517	-4.0527	-6.2690	-6.2918	-8.1155	-14.0425	-5.8358	-9.0273
		2	1.8364	1.8364	1.8364	3.7360	3.4194	2.6444	2.6444	2.6444	5.3799	4.9240
27	Flat Roof	1	-4.9231	-7.7274	-10.5317	-3.3652	-6.1695	-7.0893	-11.1275	-15.1656	-4.8458	-8.8840
		2	NA	NA	NA	3.3652	3.3652	NA	NA	NA	4.8458	4.8458
	Gable Roof Mansard Roof	1	-3.6767	-6.1695	-9.2853	-3.9883	-6.1695	-5.2945	-8.8840	-13.3709	-5.7432	-8.8840
		2	2.1188	2.1188	2.1188	3.6767	3.3652	3.0511	3.0511	3.0511	5.2945	4.8458
	Hip Roof	1	-3.3652	-5.8579	-8.6622	-3.9883	-6.1695	-4.8458	-8.4353	-12.4735	-5.7432	-8.8840
		2	2.1188	2.1188	2.1188	3.6767	3.3652	3.0511	3.0511	3.0511	5.2945	4.8458
	Monoslope Roof	1	-4.2999	-5.5463	-9.5969	-3.9883	-6.1695	-6.1919	-7.9866	-13.8196	-5.7432	-8.8840
		2	1.8072	1.8072	1.8072	3.6767	3.3652	2.6024	2.6024	2.6024	5.2945	4.8458
24	Flat Roof	1	-4.8040	-7.5404	-10.2769	-3.2837	-6.0202	-6.9178	-10.8582	-14.7987	-4.7286	-8.6691
		2	NA	NA	NA	3.2837	3.2837	NA	NA	NA	4.7286	4.7286
	Gable Roof Mansard Roof	1	-3.5878	-6.0202	-9.0607	-3.8918	-6.0202	-5.1664	-8.6691	-13.0474	-5.6043	-8.6691
		2	2.0675	2.0675	2.0675	3.5878	3.2837	2.9773	2.9773	2.9773	5.1664	4.7286
	Hip Roof	1	-3.2837	-5.7161	-8.4526	-3.8918	-6.0202	-4.7286	-8.2313	-12.1717	-5.6043	-8.6691
		2	2.0675	2.0675	2.0675	3.5878	3.2837	2.9773	2.9773	2.9773	5.1664	4.7286
	Monoslope Roof	1	-4.1959	-5.4121	-9.3647	-3.8918	-6.0202	-6.0421	-7.7934	-13.4852	-5.6043	-8.6691
		2	1.7635	1.7635	1.7635	3.5878	3.2837	2.5394	2.5394	2.5394	5.1664	4.7286
21	Flat Roof	1	-4.6452	-7.2912	-9.9372	-3.1752	-5.8212	-6.6891	-10.4993	-14.3095	-4.5723	-8.3825
		2	NA	NA	NA	3.1752	3.1752	NA	NA	NA	4.5723	4.5723
	Gable Roof Mansard Roof	1	-3.4692	-5.8212	-8.7612	-3.7632	-5.8212	-4.9956	-8.3825	-12.6161	-5.4190	-8.3825
		2	1.9992	1.9992	1.9992	3.4692	3.1752	2.8788	2.8788	2.8788	4.9956	4.5723
	Hip Roof	1	-3.1752	-5.5272	-8.1732	-3.7632	-5.8212	-4.5723	-7.9591	-11.7694	-5.4190	-8.3825
		2	1.9992	1.9992	1.9992	3.4692	3.1752	2.8788	2.8788	2.8788	4.9956	4.5723
	Monoslope Roof	1	-4.0572	-5.2332	-9.0552	-3.7632	-5.8212	-5.8423	-7.5358	-13.0394	-5.4190	-8.3825
		2	1.7052	1.7052	1.7052	3.4692	3.1752	2.4555	2.4555	2.4555	4.9956	4.5723
18	Flat Roof	1	-4.4864	-7.0419	-9.5974	-3.0666	-5.6222	-6.4604	-10.1403	-13.8203	-4.4160	-8.0959
		2	NA	NA	NA	3.0666	3.0666	NA	NA	NA	4.4160	4.4160
	Gable Roof Mansard Roof	1	-3.3506	-5.6222	-8.4616	-3.6345	-5.6222	-4.8248	-8.0959	-12.1848	-5.2337	-8.0959
		2	1.9308	1.9308	1.9308	3.3506	3.0666	2.7804	2.7804	2.7804	4.8248	4.4160
	Hip Roof	1	-3.0666	-5.3382	-7.8937	-3.6345	-5.6222	-4.4160	-7.6870	-11.3670	-5.2337	-8.0959
		2	1.9308	1.9308	1.9308	3.3506	3.0666	2.7804	2.7804	2.7804	4.8248	4.4160
	Monoslope Roof	1	-3.9185	-5.0543	-8.7456	-3.6345	-5.6222	-5.6426	-7.2782	-12.5937	-5.2337	-8.0959
		2	1.6469	1.6469	1.6469	3.3506	3.0666	2.3715	2.3715	2.3715	4.8248	4.4160

Table 207E.7-2
Components and Cladding – Part 4
C&C, V = 350 kph, h = 18 - 33 m
Exposure C

V (kph)			350				
h (m)	Roof Form	Load Case	Zone				
			1	2	3	4	5
33	Flat Roof	1	-10.0384	-15.7564	-21.4745	-6.8617	-12.5797
		2	NA	NA	NA	6.8617	6.8617
	Gable Roof Mansard Roof	1	-7.4970	-12.5797	-18.9331	-8.1323	-12.5797
		2	4.3203	4.3203	4.3203	7.4970	6.8617
	Hip Roof	1	-6.8617	-11.9444	-17.6624	-8.1323	-12.5797
		2	4.3203	4.3203	4.3203	7.4970	6.8617
	Monoslope Roof	1	-8.7677	-11.3090	-19.5685	-8.1323	-12.5797
		2	3.6850	3.6850	3.6850	7.4970	6.8617
30	Flat Roof	1	-9.8049	-15.3900	-20.9751	-6.7021	-12.2872
		2	NA	NA	NA	6.7021	6.7021
	Gable Roof Mansard Roof	1	-7.3227	-12.2872	-18.4928	-7.9432	-12.2872
		2	4.2198	4.2198	4.2198	7.3227	6.7021
	Hip Roof	1	-6.7021	-11.6666	-17.2517	-7.9432	-12.2872
		2	4.2198	4.2198	4.2198	7.3227	6.7021
	Monoslope Roof	1	-8.5638	-11.0460	-19.1134	-7.9432	-12.2872
		2	3.5993	3.5993	3.5993	7.3227	6.7021
27	Flat Roof	1	-9.6493	-15.1457	-20.6421	-6.5957	-12.0921
		2	NA	NA	NA	6.5957	6.5957
	Gable Roof Mansard Roof	1	-7.2064	-12.0921	-18.1993	-7.8171	-12.0921
		2	4.1529	4.1529	4.1529	7.2064	6.5957
	Hip Roof	1	-6.5957	-11.4814	-16.9778	-7.8171	-12.0921
		2	4.1529	4.1529	4.1529	7.2064	6.5957
	Monoslope Roof	1	-8.4279	-10.8707	-18.8100	-7.8171	-12.0921
		2	3.5421	3.5421	3.5421	7.2064	6.5957
24	Flat Roof	1	-9.4158	-14.7793	-20.1427	-6.4361	-11.7996
		2	NA	NA	NA	6.4361	6.4361
	Gable Roof Mansard Roof	1	-7.0321	-11.7996	-17.7590	-7.6280	-11.7996
		2	4.0524	4.0524	4.0524	7.0321	6.4361
	Hip Roof	1	-6.4361	-11.2036	-16.5671	-7.6280	-11.7996
		2	4.0524	4.0524	4.0524	7.0321	6.4361
	Monoslope Roof	1	-8.2240	-10.6077	-18.3549	-7.6280	-11.7996
		2	3.4564	3.4564	3.4564	7.0321	6.4361
21	Flat Roof	1	-9.1046	-14.2907	-19.4768	-6.2234	-11.4095
		2	NA	NA	NA	6.2234	6.2234
	Gable Roof Mansard Roof	1	-6.7996	-11.4095	-17.1719	-7.3758	-11.4095
		2	3.9184	3.9184	3.9184	6.7996	6.2234
	Hip Roof	1	-6.2234	-10.8333	-16.0194	-7.3758	-11.4095
		2	3.9184	3.9184	3.9184	6.7996	6.2234
	Monoslope Roof	1	-7.9521	-10.2570	-17.7481	-7.3758	-11.4095
		2	3.3422	3.3422	3.3422	6.7996	6.2234
18	Flat Roof	1	-8.7933	-13.8021	-18.8110	-6.0106	-11.0194
		2	NA	NA	NA	6.0106	6.0106
	Gable Roof Mansard Roof	1	-6.5671	-11.0194	-16.5848	-7.1237	-11.0194
		2	3.7845	3.7845	3.7845	6.5671	6.0106
	Hip Roof	1	-6.0106	-10.4629	-15.4717	-7.1237	-11.0194
		2	3.7845	3.7845	3.7845	6.5671	6.0106
	Monoslope Roof	1	-7.6802	-9.9064	-17.1414	-7.1237	-11.0194
		2	3.2279	3.2279	3.2279	6.5671	6.0106

Table 207E.7-2
Components and Cladding – Part 4
C&C, V = 150 -200 kph, h = 36 - 48 m
Exposure C

***V* (kph)**			**150**					**200**				
***h* (m)**	**Roof Form**	**Load Case**	**Zone**					**Zone**				
			1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
48	Flat Roof	1	-1.9867	-3.1184	-4.2501	-1.3580	-2.4897	-3.5319	-5.5438	-7.5556	-2.4142	-4.4261
		2	NA	NA	NA	1.3580	1.3580	NA	NA	NA	2.4142	2.4142
	Gable Roof Mansard Roof	1	-1.4837	-2.4897	-3.7471	-1.6095	-2.4897	-2.6378	-4.4261	-6.6615	-2.8613	-4.4261
		2	0.8550	0.8550	0.8550	1.4837	1.3580	1.5201	1.5201	1.5201	2.6378	2.4142
	Hip Roof	1	-1.3580	-2.3639	-3.4956	-1.6095	-2.4897	-2.4142	-4.2025	-6.2144	-2.8613	-4.4261
		2	0.8550	0.8550	0.8550	1.4837	1.3580	1.5201	1.5201	1.5201	2.6378	2.4142
	Monoslope Roof	1	-1.7352	-2.2382	-3.8728	-1.6095	-2.4897	-3.0848	-3.9790	-6.8850	-2.8613	-4.4261
		2	0.7293	0.7293	0.7293	1.4837	1.3580	1.2965	1.2965	1.2965	2.6378	2.4142
45	Flat Roof	1	-1.9724	-3.0959	-4.2195	-1.3482	-2.4718	-3.5065	-5.5039	-7.5013	-2.3969	-4.3942
		2	NA	NA	NA	1.3482	1.3482	NA	NA	NA	2.3969	2.3969
	Gable Roof Mansard Roof	1	-1.4731	-2.4718	-3.7201	-1.5979	-2.4718	-2.6188	-4.3942	-6.6136	-2.8407	-4.3942
		2	0.8489	0.8489	0.8489	1.4731	1.3482	1.5091	1.5091	1.5091	2.6188	2.3969
	Hip Roof	1	-1.3482	-2.3469	-3.4705	-1.5979	-2.4718	-2.3969	-4.1723	-6.1697	-2.8407	-4.3942
		2	0.8489	0.8489	0.8489	1.4731	1.3482	1.5091	1.5091	1.5091	2.6188	2.3969
	Monoslope Roof	1	-1.7227	-2.2221	-3.8450	-1.5979	-2.4718	-3.0627	-3.9504	-6.8355	-2.8407	-4.3942
		2	0.7241	0.7241	0.7241	1.4731	1.3482	1.2872	1.2872	1.2872	2.6188	2.3969
42	Flat Roof	1	-1.9438	-3.0511	-4.1583	-1.3287	-2.4359	-3.4557	-5.4241	-7.3926	-2.3621	-4.3306
		2	NA	NA	NA	1.3287	1.3287	NA	NA	NA	2.3621	2.3621
	Gable Roof Mansard Roof	1	-1.4517	-2.4359	-3.6662	-1.5747	-2.4359	-2.5808	-4.3306	-6.5177	-2.7996	-4.3306
		2	0.8366	0.8366	0.8366	1.4517	1.3287	1.4873	1.4873	1.4873	2.5808	2.3621
	Hip Roof	1	-1.3287	-2.3129	-3.4202	-1.5747	-2.4359	-2.3621	-4.1118	-6.0803	-2.7996	-4.3306
		2	0.8366	0.8366	0.8366	1.4517	1.3287	1.4873	1.4873	1.4873	2.5808	2.3621
	Monoslope Roof	1	-1.6978	-2.1899	-3.7892	-1.5747	-2.4359	-3.0183	-3.8931	-6.7364	-2.7996	-4.3306
		2	0.7136	0.7136	0.7136	1.4517	1.3287	1.2685	1.2685	1.2685	2.5808	2.3621
39	Flat Roof	1	-1.9152	-3.0062	-4.0972	-1.3092	-2.4001	-3.4049	-5.3444	-7.2839	-2.3274	-4.2669
		2	NA	NA	NA	1.3092	1.3092	NA	NA	NA	2.3274	2.3274
	Gable Roof Mansard Roof	1	-1.4304	-2.4001	-3.6123	-1.5516	-2.4001	-2.5429	-4.2669	-6.4219	-2.7584	-4.2669
		2	0.8243	0.8243	0.8243	1.4304	1.3092	1.4654	1.4654	1.4654	2.5429	2.3274
	Hip Roof	1	-1.3092	-2.2789	-3.3699	-1.5516	-2.4001	-2.3274	-4.0514	-5.9909	-2.7584	-4.2669
		2	0.8243	0.8243	0.8243	1.4304	1.3092	1.4654	1.4654	1.4654	2.5429	2.3274
	Monoslope Roof	1	-1.6728	-2.1577	-3.7335	-1.5516	-2.4001	-2.9739	-3.8359	-6.6374	-2.7584	-4.2669
		2	0.7031	0.7031	0.7031	1.4304	1.3092	1.2499	1.2499	1.2499	2.5429	2.3274
36	Flat Roof	1	-1.8724	-2.9389	-4.0054	-1.2798	-2.3464	-3.3287	-5.2247	-7.1208	-2.2753	-4.1713
		2	NA	NA	NA	1.2798	1.2798	NA	NA	NA	2.2753	2.2753
	Gable Roof Mansard Roof	1	-1.3984	-2.3464	-3.5314	-1.5169	-2.3464	-2.4860	-4.1713	-6.2781	-2.6966	-4.1713
		2	0.8058	0.8058	0.8058	1.3984	1.2798	1.4326	1.4326	1.4326	2.4860	2.2753
	Hip Roof	1	-1.2798	-2.2279	-3.2944	-1.5169	-2.3464	-2.2753	-3.9607	-5.8567	-2.6966	-4.1713
		2	0.8058	0.8058	0.8058	1.3984	1.2798	1.4326	1.4326	1.4326	2.4860	2.2753
	Monoslope Roof	1	-1.6354	-2.1094	-3.6499	-1.5169	-2.3464	-2.9073	-3.7500	-6.4888	-2.6966	-4.1713
		2	0.6873	0.6873	0.6873	1.3984	1.2798	1.2219	1.2219	1.2219	2.4860	2.2753

Table 207E.7-2
Components and Cladding – Part 4
C&C, V = 250 -300 kph, h = 36 - 48 m
Exposure C

V (kph)			250					300				
h (m)	Roof Form	Load Case	Zone					Zone				
			1	2	3	4	5	1	2	3	4	5
48	Flat Roof	1	-5.5186	-8.6622	-11.8057	-3.7722	-6.9158	-7.9468	-12.4735	-17.0002	-5.4320	-9.9587
		2	NA	NA	NA	3.7722	3.7722	NA	NA	NA	5.4320	5.4320
	Gable Roof Mansard Roof	1	-4.1215	-6.9158	-10.4086	-4.4708	-6.9158	-5.9350	-9.9587	-14.9883	-6.4379	-9.9587
		2	2.3751	2.3751	2.3751	4.1215	3.7722	3.4202	3.4202	3.4202	5.9350	5.4320
	Hip Roof	1	-3.7722	-6.5665	-9.7100	-4.4708	-6.9158	-5.4320	-9.4557	-13.9824	-6.4379	-9.9587
		2	2.3751	2.3751	2.3751	4.1215	3.7722	3.4202	3.4202	3.4202	5.9350	5.4320
	Monoslope Roof	1	-4.8201	-6.2172	-10.7579	-4.4708	-6.9158	-6.9409	-8.9528	-15.4913	-6.4379	-9.9587
		2	2.0258	2.0258	2.0258	4.1215	3.7722	2.9172	2.9172	2.9172	5.9350	5.4320
45	Flat Roof	1	-5.4789	-8.5998	-11.7208	-3.7451	-6.8660	-7.8897	-12.3838	-16.8779	-5.3929	-9.8871
		2	NA	NA	NA	3.7451	3.7451	NA	NA	NA	5.3929	5.3929
	Gable Roof Mansard Roof	1	-4.0919	-6.8660	-10.3337	-4.4386	-6.8660	-5.8923	-9.8871	-14.8805	-6.3916	-9.8871
		2	2.3580	2.3580	2.3580	4.0919	3.7451	3.3956	3.3956	3.3956	5.8923	5.3929
	Hip Roof	1	-3.7451	-6.5192	-9.6402	-4.4386	-6.8660	-5.3929	-9.3877	-13.8818	-6.3916	-9.8871
		2	2.3580	2.3580	2.3580	4.0919	3.7451	3.3956	3.3956	3.3956	5.8923	5.3929
	Monoslope Roof	1	-4.7854	-6.1725	-10.6805	-4.4386	-6.8660	-6.8910	-8.8884	-15.3799	-6.3916	-9.8871
		2	2.0113	2.0113	2.0113	4.0919	3.7451	2.8962	2.8962	2.8962	5.8923	5.3929
42	Flat Roof	1	-5.3995	-8.4752	-11.5509	-3.6908	-6.7665	-7.7753	-12.2043	-16.6333	-5.3148	-9.7438
		2	NA	NA	NA	3.6908	3.6908	NA	NA	NA	5.3148	5.3148
	Gable Roof Mansard Roof	1	-4.0326	-6.7665	-10.1839	-4.3743	-6.7665	-5.8069	-9.7438	-14.6649	-6.2990	-9.7438
		2	2.3238	2.3238	2.3238	4.0326	3.6908	3.3463	3.3463	3.3463	5.8069	5.3148
	Hip Roof	1	-3.6908	-6.4248	-9.5004	-4.3743	-6.7665	-5.3148	-9.2517	-13.6806	-6.2990	-9.7438
		2	2.3238	2.3238	2.3238	4.0326	3.6908	3.3463	3.3463	3.3463	5.8069	5.3148
	Monoslope Roof	1	-4.7160	-6.0830	-10.5257	-4.3743	-6.7665	-6.7911	-8.7595	-15.1570	-6.2990	-9.7438
		2	1.9821	1.9821	1.9821	4.0326	3.6908	2.8542	2.8542	2.8542	5.8069	5.3148
39	Flat Roof	1	-5.3201	-8.3506	-11.3810	-3.6365	-6.6670	-7.6610	-12.0248	-16.3887	-5.2366	-9.6005
		2	NA	NA	NA	3.6365	3.6365	NA	NA	NA	5.2366	5.2366
	Gable Roof Mansard Roof	1	-3.9733	-6.6670	-10.0342	-4.3100	-6.6670	-5.7215	-9.6005	-14.4492	-6.2064	-9.6005
		2	2.2897	2.2897	2.2897	3.9733	3.6365	3.2971	3.2971	3.2971	5.7215	5.2366
	Hip Roof	1	-3.6365	-6.3303	-9.3607	-4.3100	-6.6670	-5.2366	-9.1156	-13.4794	-6.2064	-9.6005
		2	2.2897	2.2897	2.2897	3.9733	3.6365	3.2971	3.2971	3.2971	5.7215	5.2366
	Monoslope Roof	1	-4.6467	-5.9936	-10.3709	-4.3100	-6.6670	-6.6912	-8.6307	-14.9341	-6.2064	-9.6005
		2	1.9530	1.9530	1.9530	3.9733	3.6365	2.8123	2.8123	2.8123	5.7215	5.2366
36	Flat Roof	1	-5.2010	-8.1636	-11.1262	-3.5551	-6.5177	-7.4895	-11.7556	-16.0218	-5.1194	-9.3855
		2	NA	NA	NA	3.5551	3.5551	NA	NA	NA	5.1194	5.1194
	Gable Roof Mansard Roof	1	-3.8843	-6.5177	-9.8095	-4.2135	-6.5177	-5.5934	-9.3855	-14.1257	-6.0674	-9.3855
		2	2.2384	2.2384	2.2384	3.8843	3.5551	3.2233	3.2233	3.2233	5.5934	5.1194
	Hip Roof	1	-3.5551	-6.1886	-9.1512	-4.2135	-6.5177	-5.1194	-8.9115	-13.1777	-6.0674	-9.3855
		2	2.2384	2.2384	2.2384	3.8843	3.5551	3.2233	3.2233	3.2233	5.5934	5.1194
	Monoslope Roof	1	-4.5427	-5.8594	-10.1387	-4.2135	-6.5177	-6.5414	-8.4375	-14.5997	-6.0674	-9.3855
		2	1.9092	1.9092	1.9092	3.8843	3.5551	2.7493	2.7493	2.7493	5.5934	5.1194

Table 207E.7-2
Components and Cladding – Part 4
C&C, V = 350 kph, h = 36 - 48 m
Exposure C

***V* (kph)**			**350**				
			Zone				
***h* (m)**	**Roof Form**	**Load Case**	**1**	**2**	**3**	**4**	**5**
48	Flat Roof	1	-10.8165	-16.9778	-23.1392	-7.3936	-13.5549
		2	NA	NA	NA	7.3936	7.3936
	Gable Roof Mansard Roof	1	-8.0782	-13.5549	-20.4008	-8.7628	-13.5549
		2	4.6552	4.6552	4.6552	8.0782	7.3936
	Hip Roof	1	-7.3936	-12.8703	-19.0316	-8.7628	-13.5549
		2	4.6552	4.6552	4.6552	8.0782	7.3936
	Monoslope Roof	1	-9.4474	-12.1857	-21.0854	-8.7628	-13.5549
		2	3.9706	3.9706	3.9706	8.0782	7.3936
45	Flat Roof	1	-10.7387	-16.8557	-22.9727	-7.3404	-13.4574
		2	NA	NA	NA	7.3404	7.3404
	Gable Roof Mansard Roof	1	-8.0201	-13.4574	-20.2540	-8.6997	-13.4574
		2	4.6217	4.6217	4.6217	8.0201	7.3404
	Hip Roof	1	-7.3404	-12.7777	-18.8947	-8.6997	-13.4574
		2	4.6217	4.6217	4.6217	8.0201	7.3404
	Monoslope Roof	1	-9.3794	-12.0980	-20.9337	-8.6997	-13.4574
		2	3.9421	3.9421	3.9421	8.0201	7.3404
42	Flat Roof	1	-10.5831	-16.6114	-22.6398	-7.2340	-13.2623
		2	NA	NA	NA	7.2340	7.2340
	Gable Roof Mansard Roof	1	-7.9038	-13.2623	-19.9605	-8.5736	-13.2623
		2	4.5547	4.5547	4.5547	7.9038	7.2340
	Hip Roof	1	-7.2340	-12.5925	-18.6209	-8.5736	-13.2623
		2	4.5547	4.5547	4.5547	7.9038	7.2340
	Monoslope Roof	1	-9.2435	-11.9227	-20.6303	-8.5736	-13.2623
		2	3.8849	3.8849	3.8849	7.9038	7.2340
39	Flat Roof	1	-10.4274	-16.3671	-22.3068	-7.1276	-13.0673
		2	NA	NA	NA	7.1276	7.1276
	Gable Roof Mansard Roof	1	-7.7876	-13.0673	-19.6670	-8.4476	-13.0673
		2	4.4878	4.4878	4.4878	7.7876	7.1276
	Hip Roof	1	-7.1276	-12.4073	-18.3470	-8.4476	-13.0673
		2	4.4878	4.4878	4.4878	7.7876	7.1276
	Monoslope Roof	1	-9.1075	-11.7474	-20.3269	-8.4476	-13.0673
		2	3.8278	3.8278	3.8278	7.7876	7.1276
36	Flat Roof	1	-10.1940	-16.0007	-21.8074	-6.9680	-12.7748
		2	NA	NA	NA	6.9680	6.9680
	Gable Roof Mansard Roof	1	-7.6132	-12.7748	-19.2267	-8.2584	-12.7748
		2	4.3873	4.3873	4.3873	7.6132	6.9680
	Hip Roof	1	-6.9680	-12.1296	-17.9363	-8.2584	-12.7748
		2	4.3873	4.3873	4.3873	7.6132	6.9680
	Monoslope Roof	1	-8.9036	-11.4844	-19.8718	-8.2584	-12.7748
		2	3.7421	3.7421	3.7421	7.6132	6.9680

Part 5: Open Buildings

Commentary:

In determining loads on component and cladding elements for open building roofs using Figures 207E.8-1, 207E.8-2 and 207E.8-3, it is important for the designer to note that the net pressure coefficient C_N is based on contributions from the top and bottom surfaces of the roof. This implies that the element receives load from both surfaces. Such would not be the case if the surface below the roof were separated structurally from the top roof surface. In this case, the pressure coefficient should be separated for the effect of top and bottom pressures, or conservatively, each surface could be designed using the C_N value from Figures 207E.8-1, 207E.8-2 and 207E.8-3.

207E.8 Building Types

The provisions of Section 207E.8 are applicable to an open building of all heights having a pitched free roof, monosloped free roof, or troughed free roof. The steps required for the determination of wind loads on components and cladding for these building types is shown in Table 207E.8-1.

207E.8.1 Conditions

For the determination of the design wind pressures on components and claddings using the provisions of Section 207E.8.2, the conditions indicated on the selected figure(s) shall be applicable to the building under consideration.

207E.8.2 Design Wind Pressures

The net design wind pressure for component and cladding elements of open buildings of all heights with monoslope, pitched, and troughed roofs shall be determined by the following equation:

$$p = q_h G C_N \qquad (207E.8\text{-}1)$$

where

q_h = velocity pressure evaluated at mean roof height h using the exposure as defined in Section 207A.7.3 that results in the highest wind loads for any wind direction at the site

G = gust-effect factor from Section 207A.9

C_N = net pressure coefficient given in:

- Figure 207E.8-1 for monosloped roof
- Figure 207E.8-2 for pitched roof
- Figure 207E.8-3 for troughed roof

Net pressure coefficients C_N include contributions from top and bottom surfaces. All load cases shown for each roof angle shall be investigated. Plus and minus signs signify pressure acting toward and away from the top surface of the roof, respectively.

> *User Note:*
>
> *Use Part 5 of Section 207E for determining wind pressures for C&C of open buildings having pitched, monoslope or troughed roofs. These provisions are based on the Directional Procedure with wind pressures calculated from the specified equation applicable to each roof surface.*

Table 207E.8-1
Steps to Determine C&C Wind Loads
Open Buildings

Step 1:	Determine risk category, see Table 103-1
Step 2:	Determine the basic wind speed, V, for the applicable risk category, see Figure 207A.5-1A, B or C
Step 3:	Determine wind load parameters: ➢ Wind directionality factor K_{zt}, see Section 207A.6 and Table 207A.6-1 ➢ Exposure category B, C or D, see Section 207A.7 ➢ Topographic factor K_{zt}, see Section 207A.8 and Figure 207A.8-1 ➢ Gust effect factor, G, see Section 207A.9
Step 4:	Determine velocity pressure exposure coefficient, K_z or K_h, see Table 207E.3-1
Step 5:	Determine velocity pressure, q_h, see Equation 207E.3-1
Step 6:	Determine net pressure coefficients, C_N ➢ Monosloped roof, see Figure 207E.8-1 ➢ Pitched roof, see Figure 207E.8-2 ➢ Troughed roof, see Figure 207E.8-3
Step 7:	Calculate wind pressure, p, see Equation 207E.8-1

Part 6: Building Appurtenances and Rooftop Structures and Equipment

207E.9 Parapets

The design wind pressure for component and cladding elements of parapets for all building types and heights, except enclosed buildings with $\boldsymbol{h} \leq 48$ m for which the provisions of Part 4 are used, shall be determined from the following equation:

$$p = q_p[(GC_p) - (GC_{pi})] \quad (207E.9\text{-}1)$$

where

q_p = velocity pressure evaluated at the top of the parapet

(GC_p) = external pressure coefficient given in

- Figure 207E.4-1 for walls with $\boldsymbol{h} > 18$ m
- Figures 207E.4-2A to 207E.4-2C for flat roofs, gable roofs, and hip roofs
- Figure 207E.4-3 for stepped roofs
- Figure 207E.4-4 for multispan gable roofs
- Figure 207E.4-5A and 207E.4-5B for monoslope roofs
- Figure 207E.4-6 for sawtooth roofs
- Figure 207E.4-7 for domed roofs of all heights
- Figure 207E.6-1 for walls and flat roofs with $\boldsymbol{h} > 18$ m
- Figure 207B.4-3 for footnote 4 for arched roofs

(GC_{pi}) = internal pressure coefficient from Table 207A.11-1, based on the porosity of the parapet envelope

Two load cases, see Figure 207E.9-1, shall be considered:

- Load Case A: Windward Parapet shall consist of applying the applicable positive wall pressure from Figure 207E.4-1 ($\boldsymbol{h} \leq 18$ m) or Figure 207E.6-1 ($\boldsymbol{h} > 18$ m) to the windward surface of the parapet while applying the applicable negative edge or corner zone roof pressure from Figures 207E.4-2 (A, B or C), 207E.4-3, 207E.4-4, 207E.4-5 (A or B), 207E.4-6, 207E.4-7, Figure 207B.4-3 footnote 4, or Figure 207E.6-1 ($\boldsymbol{h} > 18$ m) as applicable to the leeward surface of the parapet.
- Load Case B: Leeward Parapet shall consist of applying the applicable positive wall pressure from Figure 207E.4-1 ($\boldsymbol{h} \leq 18$ m) or Figure 207E.6-1 ($\boldsymbol{h} > 18$ m) to the windward surface of the parapet, and applying the applicable negative wall pressure from Figure 207E.4-1 ($\boldsymbol{h} \leq 18$ m) or Figure 207E.6-1 ($\boldsymbol{h} > 18$ m) as applicable to the leeward surface. Edge and corner zones shall be arranged as shown in the applicable figures. (GC_p) shall be determined for appropriate roof angle and effective wind area from the applicable figures.

If internal pressure is present, both load cases should be evaluated under positive and negative internal pressure.

The steps required for the determination of wind loads on component and cladding of parapets are shown in Table 207E.9-1.

> *User Note:*
>
> *Use Part 6 of Section 207E for determining wind pressures for C&C on roof overhangs and parapets of buildings. These provisions are based on the Directional Procedure with wind pressures calculated from the specified equation applicable to each roof overhang or parapet surface.*

Table 207E.9-1
Steps to Determine C&C Wind Loads
Parapets

Step 1:	Determine risk category, see Table 103-1
Step 2:	Determine the basic wind speed, V, for the applicable risk category, see Figure 207A.5-1A, B or C
Step 3:	Determine wind load parameters: ➢ Wind directionality factor K_{zt}, see Section 207A.6 and Table 207A.6-1 ➢ Exposure category B, C or D, see Section 207A.7 ➢ Topographic factor K_{zt}, see Section 207A.8 and Figure 207A.8-1 ➢ Enclosure classification, see Section 207A.10 ➢ Internal pressure coefficient, (GC_{pi}), see Section 207A.11 and Table 207A.11-1
Step 4:	Determine velocity pressure exposure coefficient, K_h, at the top of the parapet see Table 207E.3-1
Step 5:	Determine velocity pressure, q_p, at the top of the parapet, see Equation 207E.3-1
Step 6:	Determine external pressure coefficient for wall and roof surfaces adjacent to parapet, (GC_p) ➢ Walls with $h \leq 18$ m, see Figure 207E.4-1 ➢ Flat, gable and hip roofs, see Figures 207E.4-2A to 207E.4.2C ➢ Stepped roofs, see Figure 207E.4-3 ➢ Multispan gable roofs, see Figure 207E.4-4 ➢ Monoslope roofs, Figures 207E.4-5A and 207E.4-5B ➢ Sawtooth roofs, see Figure 207E.4-6 ➢ Domed roofs of all heights, see Figure 207E.4-7 ➢ Walls and flat roofs with $h > 18$ m, see Figure 207E.6-1 ➢ Arched roofs, see footnote 4 of Figure 207B.4-3
Step 7:	Calculate wind pressure, p, see Equation 207E.9-1 on windward and leeward face of parapet, considering two load cases (Case A and Case B) as shown in Figure 207E.9-1

207E.10 Roof Overhangs

The design wind pressure for roof overhangs of enclosed and partially enclosed buildings of all heights, except enclosed buildings with $h \leq 48$ m for which the provisions of Part 4 are used, shall be determined from the following equation:

$$p = q_h[(GC_p) - (GC_{pi})] \text{ (N/m}^2\text{)} \qquad (207E.10\text{-}1)$$

where

q_h = velocity pressure from Section 207E.3.2 evaluated at mean roof height h using exposure defined in Section 207A.7.3

(GC_p) = external pressure coefficients for overhangs given in Figures 207E.4-2A to 207E.4-2C (flat roofs, gable roofs, and hip roofs), including contributions from top and bottom surfaces of overhang. The external pressure coefficient for the covering on the underside of the roof overhang is the same as the external pressure coefficient on the adjacent wall surface, adjusted for effective wind area, determined from Figure 207E.4-1 or Figure 207E.6-1 as applicable

(GC_{pi}) internal pressure coefficient given in Table 207A.11-1

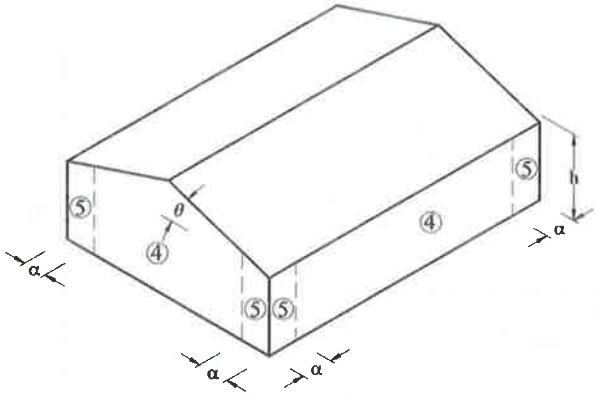
The steps required for the determination of wind loads on components and cladding of roof overhangs are shown in Table 207E.10-1.

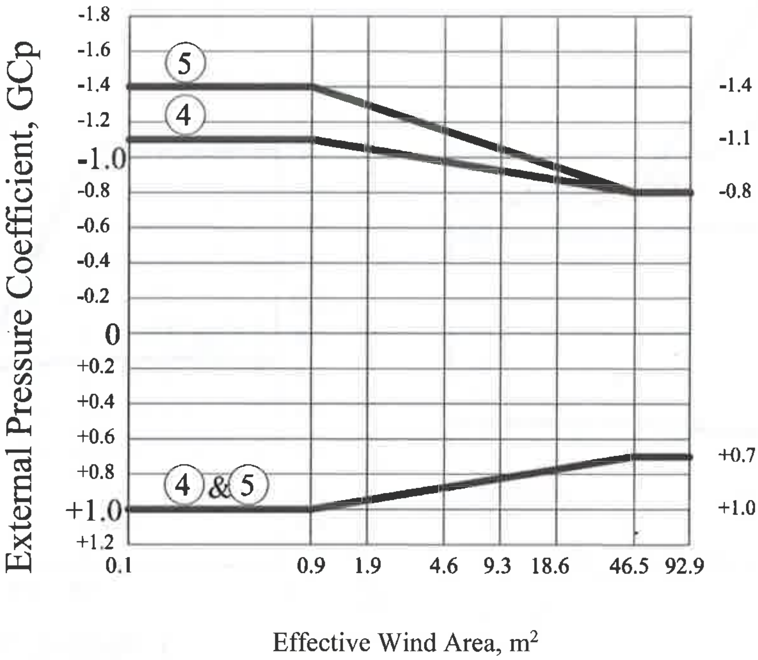
Table 207E.10-1
Steps to Determine C&C Wind Loads
Roof Overhangs

Step 1:	Determine risk category, see Table 103-1
Step 2:	Determine the basic wind speed, $\boldsymbol{V}$, for the applicable risk category, see Figure 207A.5-1A, B or C
Step 3:	Determine wind load parameters: ➢ Wind directionality factor $\boldsymbol{K_{zt}}$, see Section 207A.6 and Table 207A.6-1 ➢ Exposure category B, C or D, see Section 207A.7 ➢ Topographic factor $\boldsymbol{K_{zt}}$, see Section 207A.8 and Figure 207A.8-1 ➢ Enclosure classification, see Section 207A.10 ➢ Internal pressure coefficient, (GC_{pi}), see Section 207A.11 and Table 207A.11-1
Step 4:	Determine velocity pressure exposure coefficient, $\boldsymbol{K_h}$, see Table 207E.3-1
Step 5:	Determine velocity pressure, $\boldsymbol{q_h}$, at mean roof height $\boldsymbol{h}$ using Equation 207E.3-1
Step 6:	Determine external pressure coefficient, $(\boldsymbol{GC_p})$, using Figures 207E.4-2A through C for flat, gabled and hip roofs
Step 7:	Calculate wind pressure, $\boldsymbol{p}$, using Equation 207E.10-1, refer to Figure 207E.10-1

207E.11 Rooftop Structures and Equipment for Buildings with $\boldsymbol{h \leq}$ 18 m

The components and cladding pressure on each wall of the rooftop structure shall be equal to the lateral force determined in accordance with Section 207D.5.1 divided by the respective wall surface are of the rooftop structure and shall be considered to act inward and outward. The components and cladding pressure on the roof shall be equal to the vertical uplift force determined in accordance with Section 207D.5.1 divided by the horizontal projected area of the roof of the rooftop structure and shall be considered to act in the upward direction.



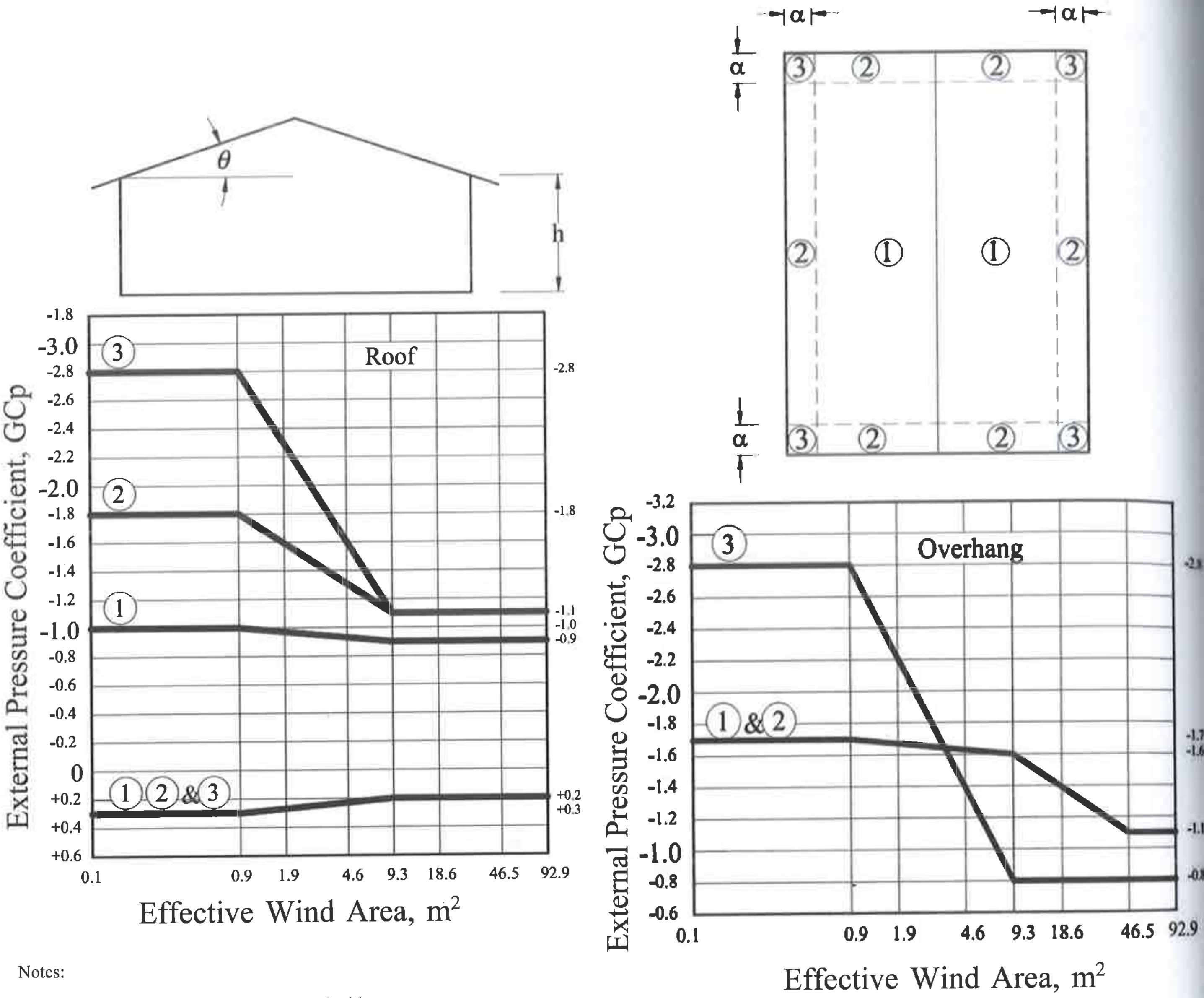


Notes:

1. Vertical scale denotes GC_p to be used with q_h.
2. Horizontal scale denotes effective wind area, m².
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. Values of GC_p for walls shall be reduced by 10% when $\theta \leq 10°$.
6. Notation:

a = 10% of least horizontal dimension or $0.4h$, whichever is smaller, but not less than either 4% of least horizontal dimension or 0.9 m.
h = mean roof height, m, except that eave height shall be used for $\theta \leq 10°$.
θ = angle of plane of roof from horizontal, °

Figure 207E.4-1
External Pressure Coefficients, GC_p Walls, $h \leq 18$ m Enclosed
Partially Enclosed Buildings

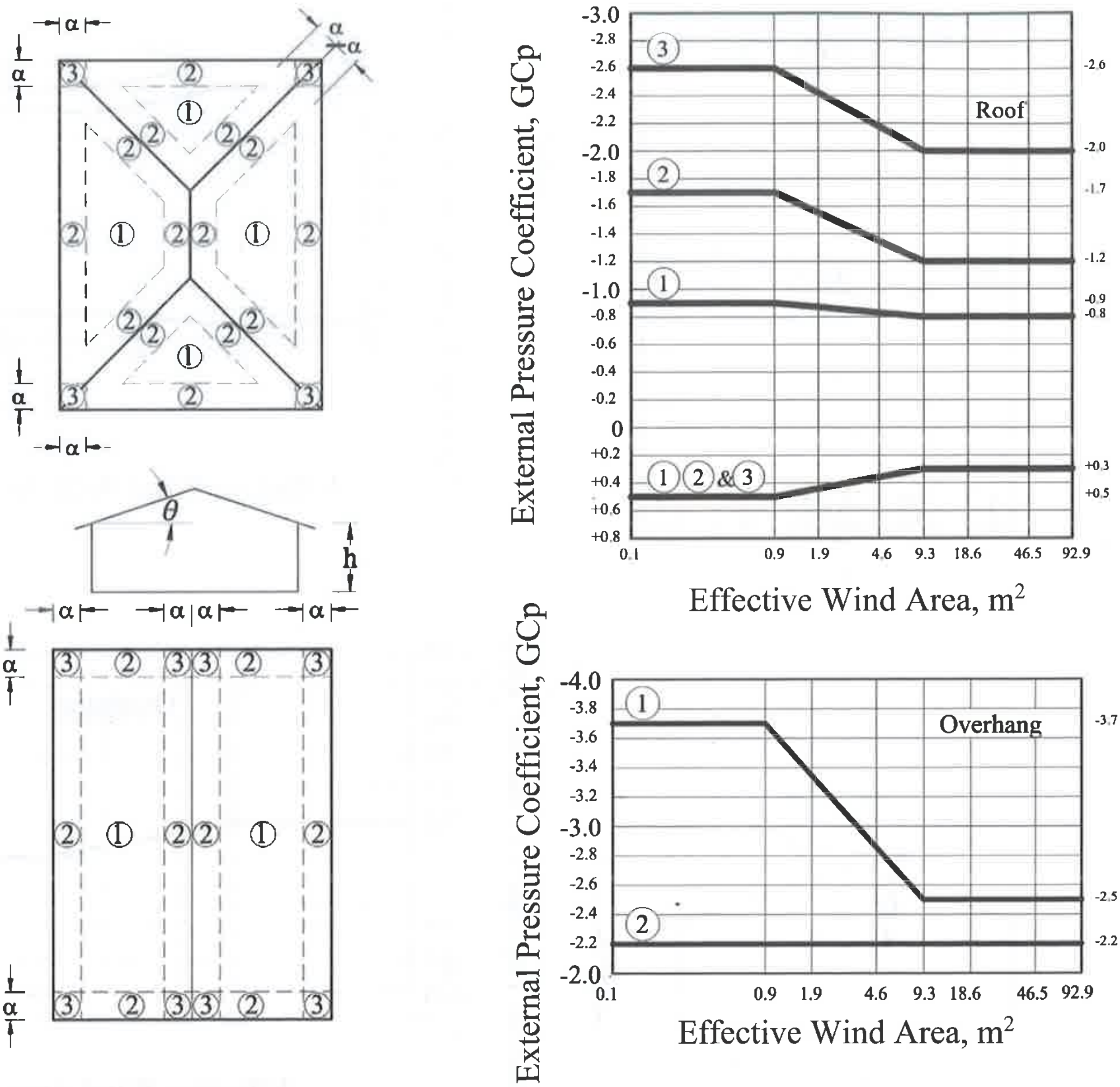


Notes:

1. Vertical scale denotes GC_p to be used with q_h.
2. Horizontal scale denotes effective wind area, m².
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. If a parapet equal to or higher than 0.9 m is provided around the perimeter of the roof with $\theta \leq 7°$, the negative values of GC_p in Zone 3 shall be equal to those for Zone 2 and positive values of GC_p in Zones 2 and 3 shall be set equal to those for wall Zones 4 and 5 respectively in Figure 207E.4-1.
6. Values of GC_p for roof overhangs include pressure contributions from both upper and lower surfaces.
7. Notation:

   a = 10% of least horizontal dimension or $\mathbf{0.4}\boldsymbol{h}$, whichever is smaller, but not less than either 4% of least horizontal dimension or 0.9 m.
   $\boldsymbol{h}$ = eave height shall be used for $\boldsymbol{\theta} \leq \mathbf{10}°$.
   $\boldsymbol{\theta}$ = angle of plane of roof from horizontal, °

Figure 207E.4-2A
External Pressure Coefficients, GC_p Gable Roofs $\theta \leq 7^o$, $h \leq 18$ m
Enclosed, Partially Enclosed Buildings

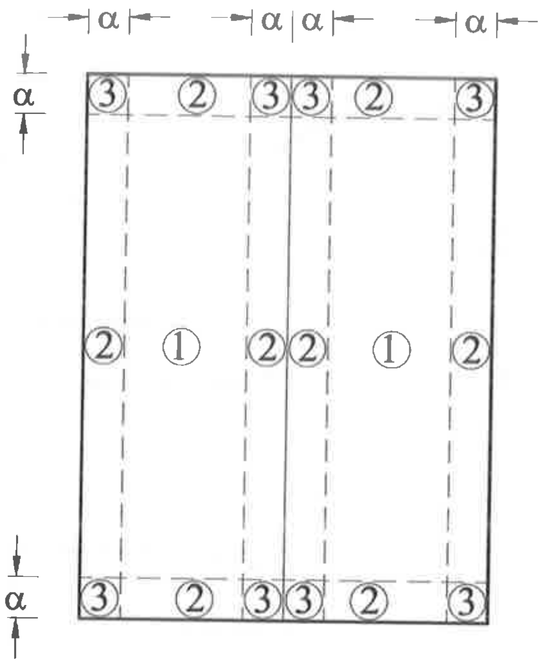


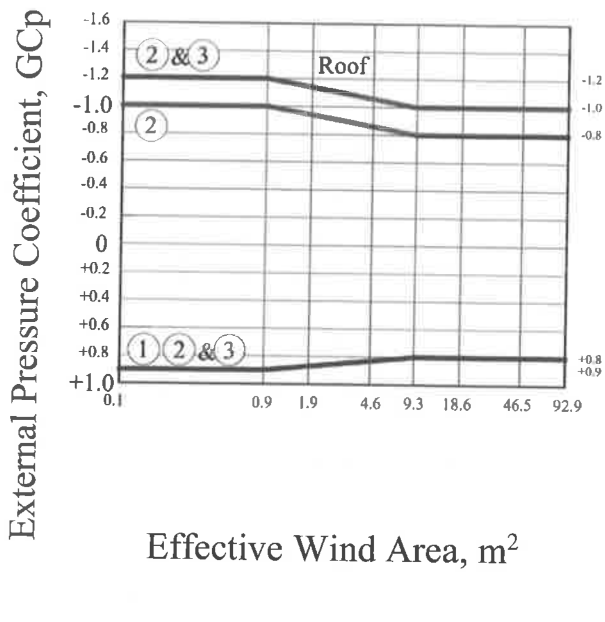
Notes:

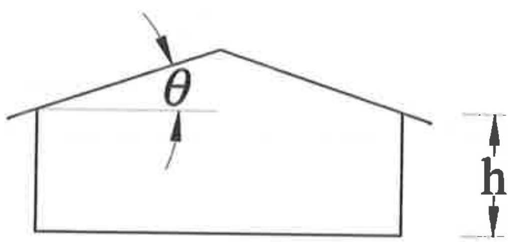
1. Vertical scale denotes GC_p to be used with q_h.
2. Horizontal scale denotes effective wind area, m².
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. Values of GC_p for roof overhangs include pressure contributions from both upper and lower surfaces.
6. For hip roofs with $7 < \theta \leq 27^o$, edge/ridge strips and pressure coefficients for ridges of gabled roofs shall apply on each hip.
7. For hip roofs with $\theta \leq 25^o$, Zone 3 shall be treated as Zone 2.
8. Notation:

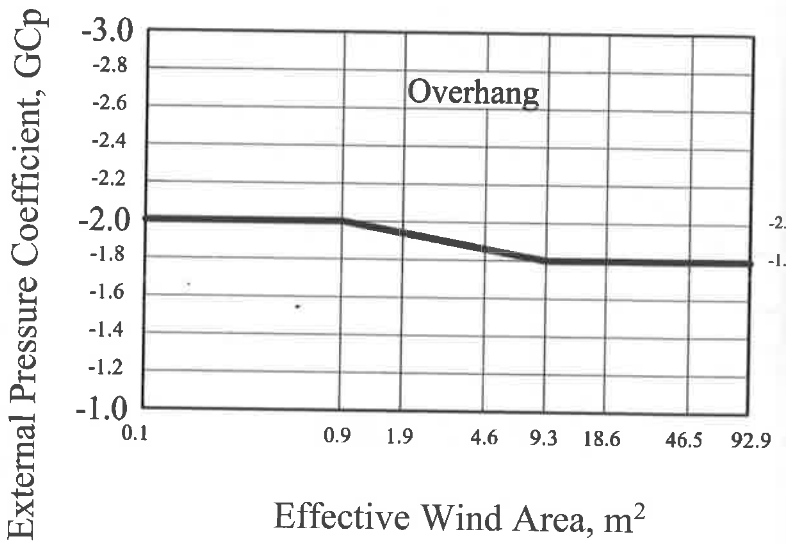
A	=	10% of least horizontal dimension or $0.4h$, whichever is smaller, but not less than either 4% of least horizontal dimension 0.9 m.
h	=	mean roof height, m, except that eave height shall be used for $\theta \leq 10°$.
θ	=	angle of plane of roof from horizontal, °

Figure 207E.4-2B
External Pressure Coefficients, GC_p Gable/Hip Roofs $7^o < \theta \leq 27^o$, $h \leq 18$ m
Enclosed, Partially Enclosed Buildings









Notes:

1. Vertical scale denotes GC_p to be used with q_h.
2. Horizontal scale denotes effective wind area, m²
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. Values of GC_p for roof overhangs include pressure contributions from both upper and lower surfaces.
6. Notation:

   a = 10% of least horizontal dimension or $0.4h$, whichever is smaller, but not less than either 4% of least horizontal dimension 0.9 m.

   h = mean roof height, m

   θ = angle of plane of roof from horizontal, °

Figure 207E.4-2C
External Pressure Coefficients, GC_p Gable Roofs $27^o < \theta \leq 45^o$, $h \leq 18$ m
Enclosed, Partially Enclosed Buildings

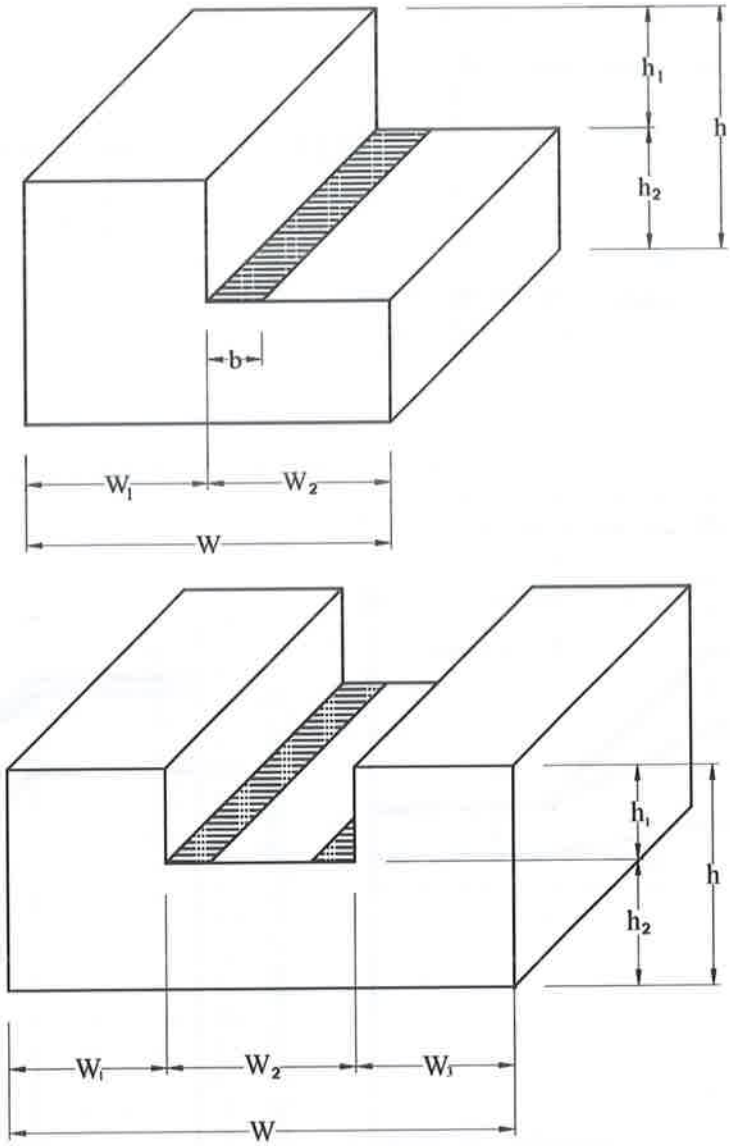
$h_1 \geq 3\ m$

$b = 1.5h_1$

$b < 30\ m$

$\frac{h_1}{h} = 0.30 \text{ to } 0.70$

$\frac{W_1}{W} = 0.25 \text{ to } 0.75$



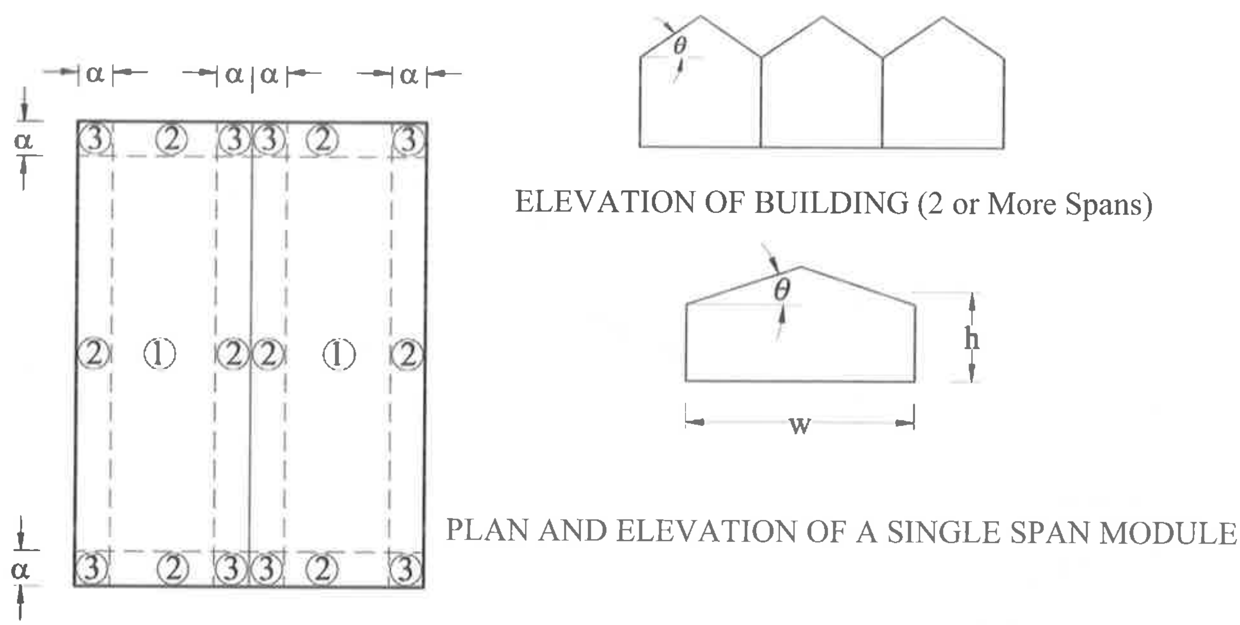
Notes:

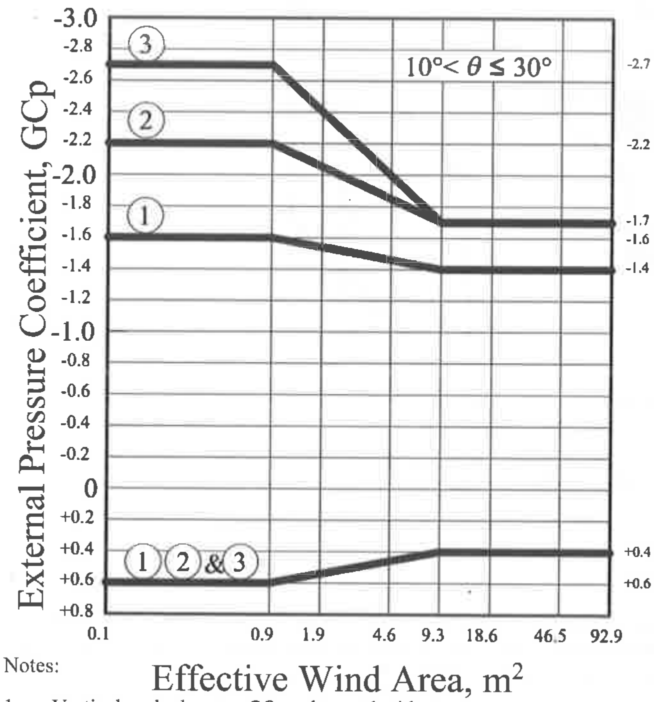
1. On the lower level of flat, stepped roofs shown in Figure 207E.4-3, the zone designations and pressure coefficients shown in Figure 207E.4-2A shall apply, except that at the roof-upper wall intersection(s), Zone 3 shall be treated as Zone 2 and Zone 2 shall be treated as Zone 1. Positive values of GC_p equal to those for walls in Figure 207E.4-1 shall apply on the cross-hatched areas shown in Figure 207E.4-3.

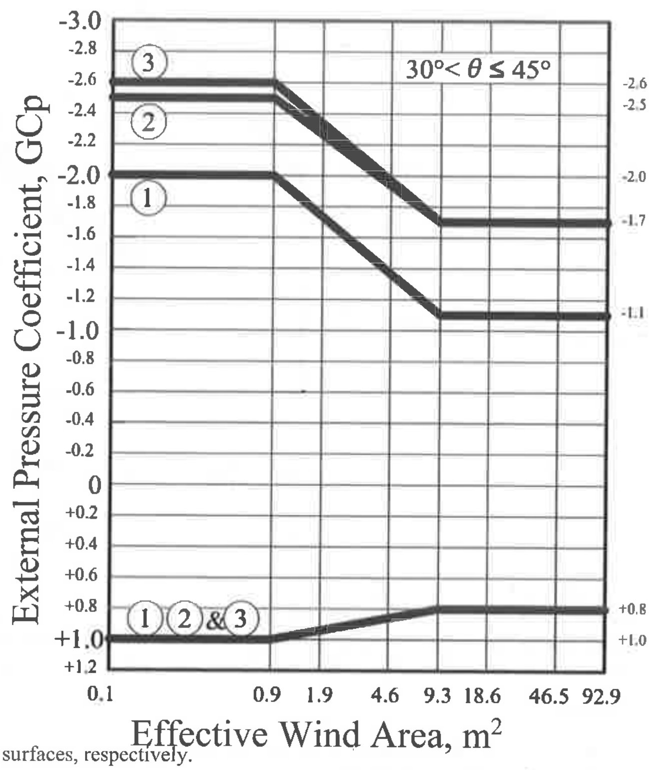
2. Notation:

$\boldsymbol{b}$	=	$\mathbf{1.5}\boldsymbol{h_1}$ in Figure 207E.4-3, but not greater than 30 m.
$\boldsymbol{h}$	=	mean roof height, m
$\boldsymbol{h_i}$	=	$\boldsymbol{h_1}$ or $\boldsymbol{h_2}$ in Figure 207E.4-3; $\boldsymbol{h} = \boldsymbol{h_1} + \boldsymbol{h_2}$; $\boldsymbol{h_1} \geq 3.1$ m; $\boldsymbol{h_i}/\boldsymbol{h} = \mathbf{0.3}$ to $\mathbf{0.7}$.
$\boldsymbol{W}$	=	Building width in Figure 207E.4-3.
$\boldsymbol{W_i}$	=	$\boldsymbol{W_1}$ or $\boldsymbol{W_2}$ or $\boldsymbol{W_3}$ in Figure 207E.4-3. $\boldsymbol{W} = \boldsymbol{W_1} + \boldsymbol{W_2}$ ***or*** $\boldsymbol{W_1} + \boldsymbol{W_2} + \boldsymbol{W_3}$; $\boldsymbol{W_i}/\boldsymbol{W} = \mathbf{0.25}$ to $\mathbf{0.75}$.
$\boldsymbol{\theta}$	=	Angle of plane of roof from horizontal, °

Figure 207E.4-3
External Pressure Coefficients, GC_p Stepped Roofs, $h \leq 18$ m
Enclosed, Partially Enclosed Buildings





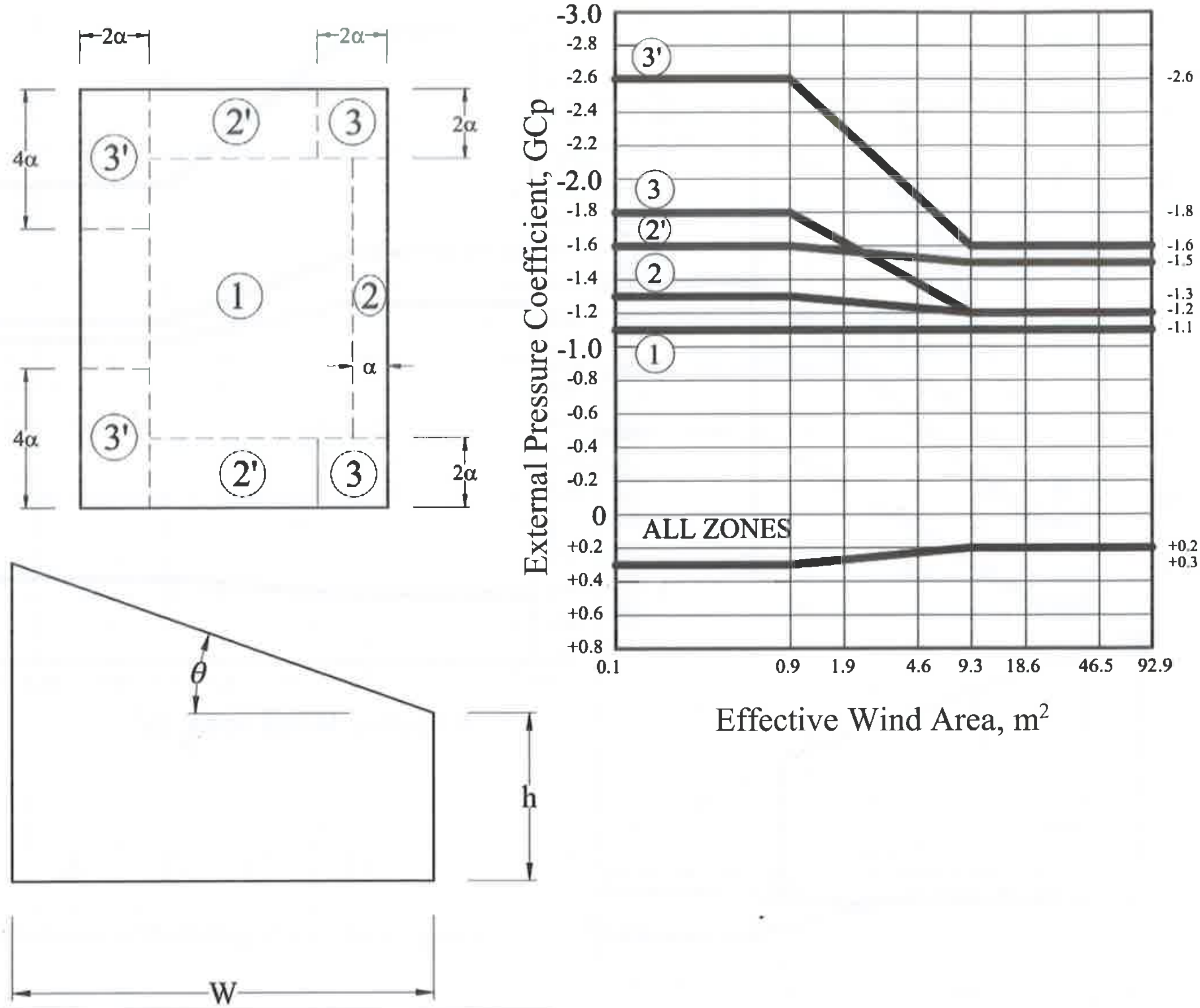


Notes:

1. Vertical scale denotes GC_p to be used with q_h.
2. Horizontal scale denotes effective wind area A, m²
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. For $\theta \leq 10^o$, values of GC_p from Figure 207E.4-2A shall be used.
6. Notation:

a	=	10% of least horizontal dimension or $0.4h$, whichever is smaller, but not less than either 4% of least horizontal dimension or 0.9 m.
h	=	mean roof height, m, except that the eave height shall be used for $\theta \leq 10^o$
W	=	building module width, m
θ	=	angle of plane of roof from horizontal, °

Figure 207E.4-4
External Pressure Coefficients, GC_p Multispan Gable Roofs, $h \leq 18$ m
Enclosed, Partially Enclosed Buildings

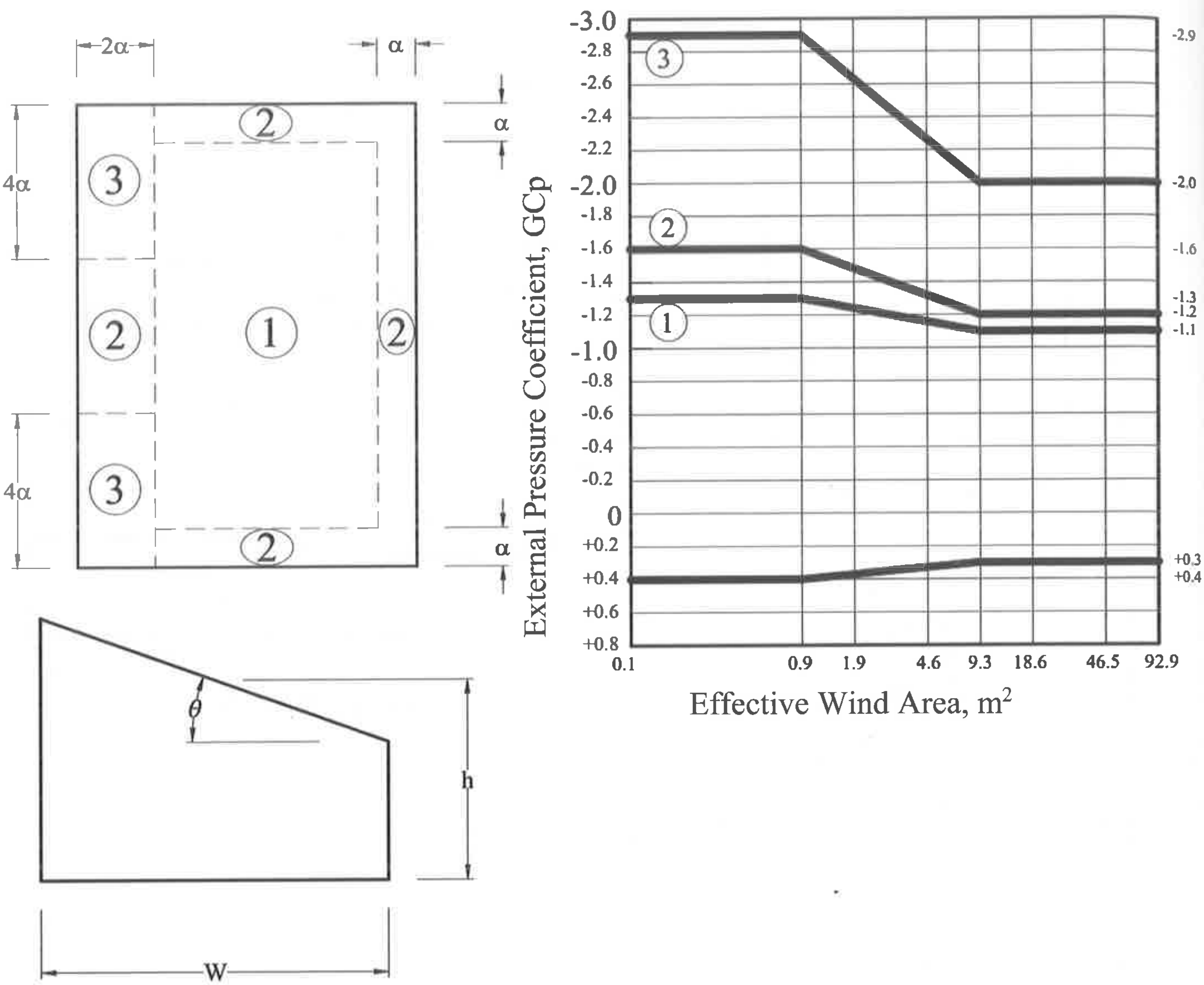


Notes:

1. Vertical scale denotes GC_p to be used with q_h.
2. Horizontal scale denotes effective wind area A, m²
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. For $\theta \leq 3^o$, values of GC_p from Figure 207E.4-2A shall be used.
6. Notation:

a	=	10% of least horizontal dimension or $0.4h$, whichever is smaller, but not less than either 4% of least horizontal dimension or 0.9 m.
h	=	eave height shall be used for $\theta \leq 10^o$
W	=	building width, m
θ	=	angle of plane of roof from horizontal, °

Figure 207E.4-5A
External Pressure Coefficients, GC_p Monoslope Roofs, $3^o < \theta \leq 10^o, h \leq 18$ m
Enclosed, Partially Enclosed Buildings

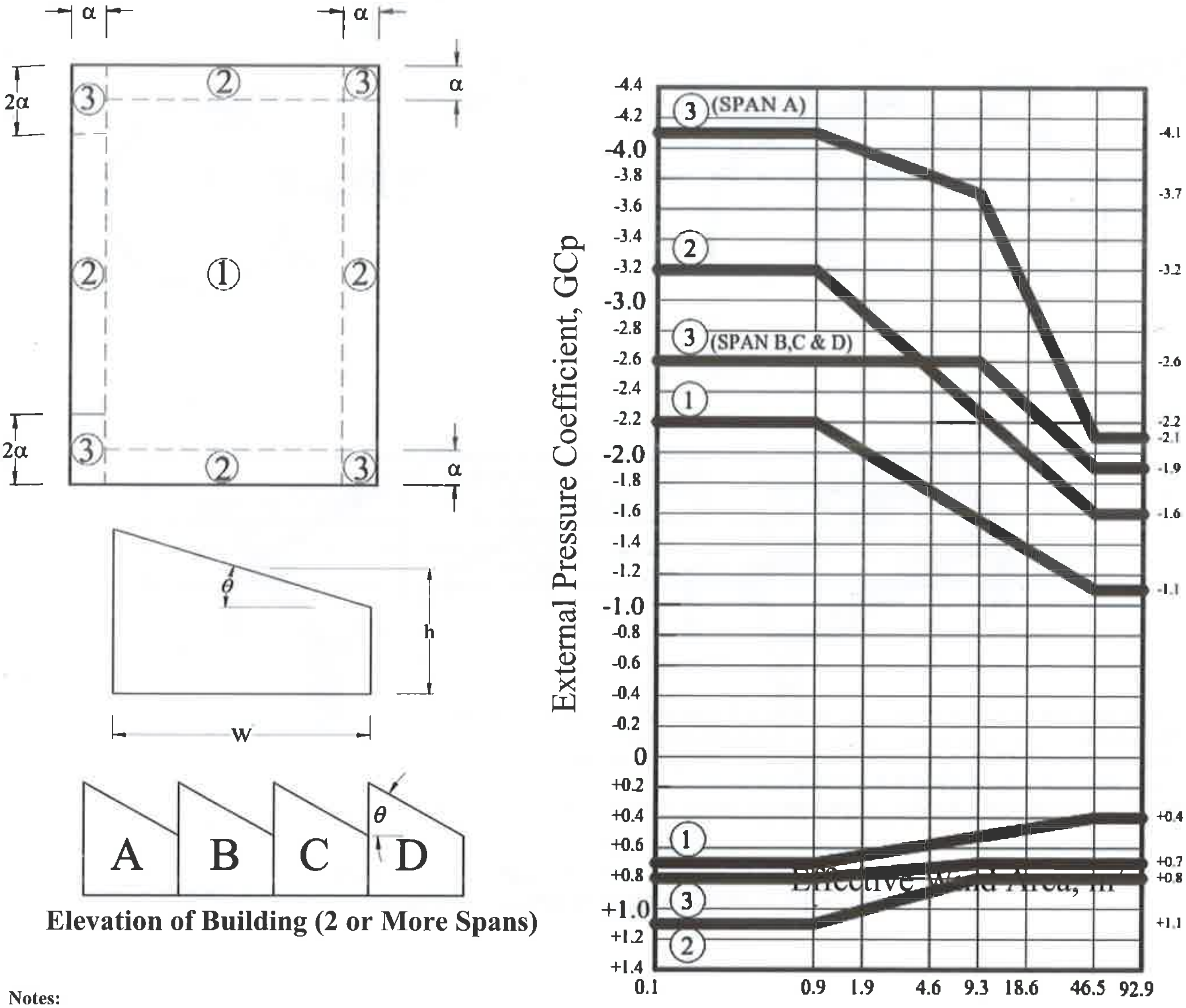


Notes:

1. Vertical scale denotes GC_p to be used with q_h.
2. Horizontal scale denotes effective wind area A, m^2
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. Notation:

a	=	10% of least horizontal dimension or $0.4h$, whichever is smaller, but not less than either 4% of least horizontal dimension 0.9 m
h	=	mean roof height, m
W	=	building width, m
θ	=	angle of plane of roof from horizontal, °

Figure 207E.4-5B
External Pressure Coefficients, GC_p Monoslope Roofs, $10^o < \theta \leq 30^o$, $h \leq 18$ m
Enclosed, Partially Enclosed Buildings

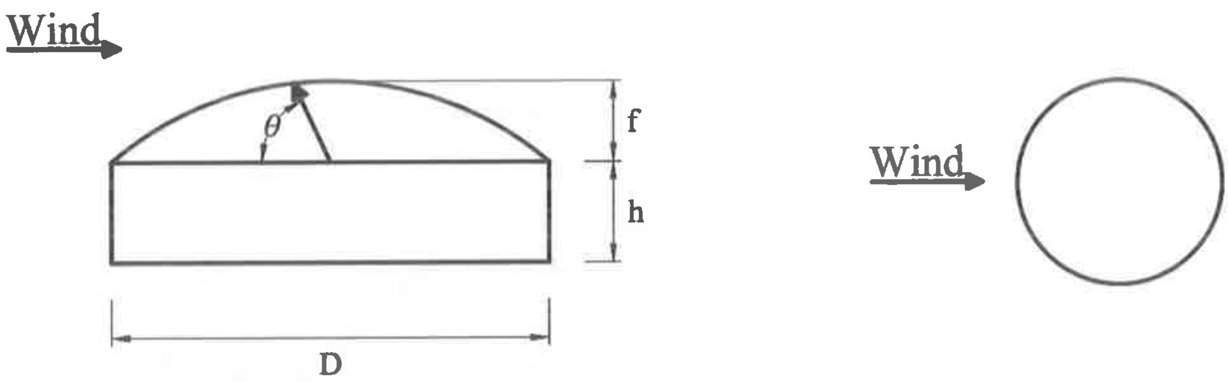


Notes:

1. Vertical scale denotes GC_p to be used with q_h.
2. Horizontal scale denotes effective wind area A, m²
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Each component shall be designed for maximum positive and negative pressures.
5. For $\theta \leq 10^o$, values of GC_p from Figure 207E.4-2A shall be used.
6. Notation:

a	=	10% of least horizontal dimension or $0.4h$, whichever is smaller, but not less than either 4% of least horizontal dimension or 0.9 m.
h	=	mean roof height, m, except that the eave height shall be used for $\theta \leq 10^o$
W	=	building module width, m
θ	=	angle of plane of roof from horizontal, °

Figure 207E.4-6
External Pressure Coefficients, GC_p Sawtooth Roofs, $h \leq 18$ m
Enclosed, Partially Enclosed Buildings

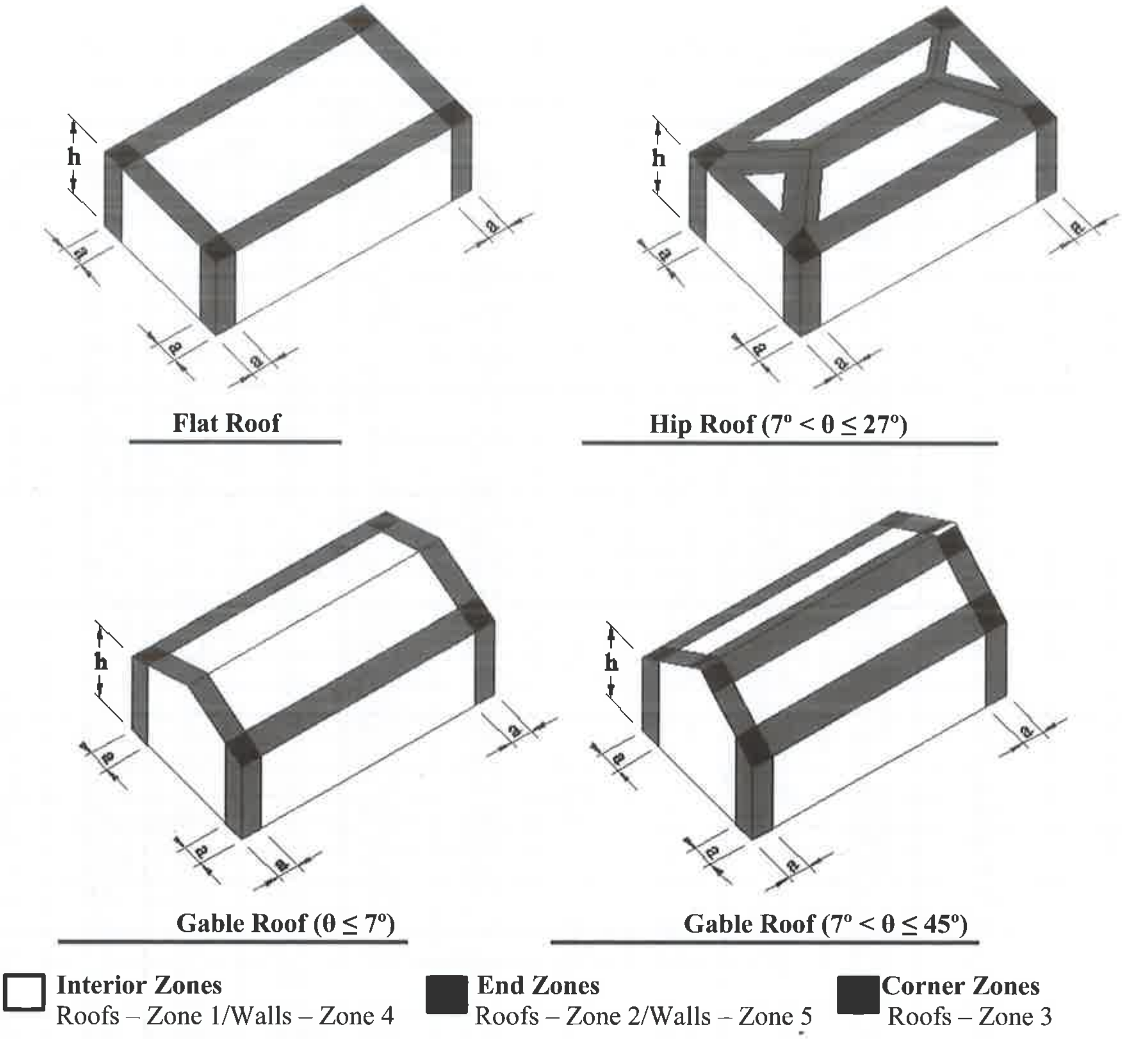


External Pressure Coefficient for Domes with a Circular Base			
θ, degrees	Negative Pressures	Positive Pressures	Positive Pressures
	0 – 90	0 – 60	61 – 90
GC_p	-0.90	+0.90	+0.50

Notes:

1. Values denote GC_p to be used with $q_{(h_D+f)}$, where $h_D + f$ is the height at the top of the dome.
2. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
3. Each component shall be designed for maximum positive and negative pressures.
4. Values apply to $0 \leq h_D/D \leq 0.5, 0.2 \leq f/D \leq 0.5$.
5. $\theta = 0^o$ on dome springline, $\theta = 90^o$ at dome center top point. f is measured from spring line to top.

Figure 207E.4-7
External Pressure Coefficients, GC_p Doomed Roofs, All Heights
Enclosed, Partially Enclosed Buildings and Structures



Notes:

1. Pressures shown are applied normal to the surface, for exposure B, at $h = 9$ m. Adjust to other conditions using Equation 207E.5-1.
2. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
3. For hip roofs with $\theta \leq 25^o$, Zone 3 shall be treated as Zone 2.
4. For effective wind areas between those given, value may be interpolated, otherwise use the value associated with the lower effective wind area.
5. Notation:
   - **a** = 10% of least horizontal dimension or $0.4h$, whichever is smaller, but not less than either 4% of least horizontal dimension or 0.9 m.
   - h = mean roof height, m, except that the eave height shall be used for $\theta < 10^o$
   - θ = angle of plane of roof from horizontal, °

Figure 207E.5-1
Design Wind Pressures Walls and Roofs, $h \leq 18$ m
Enclosed Buildings

Net Design Wind Pressure, p_{net} (kPa) (Exposure B at $h = 10$ m with $I = 1.0$ and $K_d = 1.0$)

	Zone	Effective wind area (sq. m.)	Basic Wind Speed V (kph)									
			150		200		250		300		350	
Roof 0 to 7 degrees	1	1.0	0.30	-0.75	0.54	-1.33	0.84	-2.08	1.22	-2.99	1.65	-4.07
	1	2.0	0.28	-0.73	0.51	-1.29	0.79	-2.02	1.14	-2.91	1.55	-3.96
	1	4.5	0.26	-0.70	0.46	-1.25	0.72	-1.95	1.04	-2.81	1.41	-3.83
	1	9.5	0.24	-0.68	0.43	-1.22	0.67	-1.90	0.96	-2.74	1.31	-3.72
	2	1.0	0.30	-1.25	0.54	-2.23	0.84	-3.48	1.22	-5.02	1.65	-6.83
	2	2.0	0.28	-1.12	0.51	-1.99	0.79	-3.11	1.14	-4.48	1.55	-6.10
	2	4.5	0.26	-0.94	0.46	-1.68	0.72	-2.62	1.04	-3.77	1.41	-5.14
	2	9.5	0.24	-0.81	0.43	-1.44	0.67	-2.25	0.96	-3.24	1.31	-4.41
	3	1.0	0.30	-1.89	0.54	-3.36	0.84	-5.25	1.22	-7.56	1.65	-10.29
	3	2.0	0.28	-1.56	0.51	-2.78	0.79	-4.34	1.14	-6.26	1.55	-8.52
	3	4.5	0.26	-1.14	0.46	-2.02	0.72	-3.16	1.04	-4.55	1.41	-6.19
	3	9.5	0.24	-0.81	0.43	-1.44	0.67	-2.25	0.96	-3.24	1.31	-4.41
Roof > 7 to 27 degrees	1	1.0	0.43	-0.68	0.77	-1.22	1.20	-1.90	1.72	-2.74	2.34	-3.72
	1	2.0	0.39	-0.66	0.70	-1.18	1.09	-1.85	1.57	-2.66	2.14	-3.62
	1	4.5	0.34	-0.64	0.61	-1.14	0.95	-1.78	1.37	-2.56	1.86	-3.48
	1	9.5	0.31	-0.62	0.55	-1.10	0.85	-1.72	1.23	-2.48	1.67	-3.38
	2	1.0	0.43	-1.19	0.77	-2.12	1.20	-3.32	1.72	-4.77	2.34	-6.50
	2	2.0	0.39	-1.10	0.70	-1.95	1.09	-3.04	1.57	-4.38	2.14	-5.96
	2	4.5	0.34	-0.97	0.61	-1.72	0.95	-2.69	1.37	-3.88	1.86	-5.27
	2	9.5	0.31	-0.88	0.55	-1.56	0.85	-2.44	1.23	-3.51	1.67	-4.77
	3	1.0	0.43	-1.76	0.77	-3.14	1.20	-4.90	1.72	-7.05	2.34	-9.60
	3	2.0	0.39	-1.65	0.70	-2.93	1.09	-4.57	1.57	-6.59	2.14	-8.96
	3	4.5	0.34	-1.49	0.61	-2.66	0.95	-4.15	1.37	-5.98	1.86	-8.14
	3	9.5	0.31	-1.38	0.55	-2.45	0.85	-3.83	1.23	-5.52	1.67	-7.52
Roof > 27 to 45 degrees	1	1.0	0.68	-0.75	1.22	-1.33	1.90	-2.08	2.74	-3.00	3.72	-4.09
	1	2.0	0.66	-0.71	1.18	-1.27	1.85	-1.98	2.66	-2.85	3.62	-3.88
	1	4.5	0.64	-0.66	1.14	-1.17	1.78	-1.83	2.56	-2.63	3.48	-3.59
	1	9.5	0.62	-0.62	1.10	-1.10	1.72	-1.72	2.48	-2.48	3.38	-3.38
	2	1.0	0.68	-0.88	1.22	-1.56	1.90	-2.44	2.74	-3.51	3.72	-4.77
	2	2.0	0.66	-0.84	1.18	-1.49	1.85	-2.32	2.66	-3.34	3.62	-4.55
	2	4.5	0.64	-0.79	1.14	-1.40	1.78	-2.18	2.56	-3.14	3.48	-4.27
	2	9.5	0.62	-0.75	1.10	-1.33	1.72	-2.08	2.48	-3.00	3.38	-4.09
	3	1.0	0.68	-0.88	1.22	-1.56	1.90	-2.44	2.74	-3.51	3.72	-4.77
	3	2.0	0.66	-0.84	1.18	-1.49	1.85	-2.32	2.66	-3.34	3.62	-4.55
	3	4.5	0.64	-0.79	1.14	-1.40	1.78	-2.18	2.56	-3.14	3.48	-4.27
	3	9.5	0.62	-0.75	1.10	-1.33	1.72	-2.08	2.48	-3.00	3.38	-4.09
Wall	4	1.0	0.75	-0.81	1.33	-1.44	2.08	-2.25	2.99	-3.24	4.07	-4.41
	4	2.0	0.72	-0.78	1.27	-1.38	1.99	-2.16	2.86	-3.12	3.90	-4.24
	4	4.5	0.67	-0.73	1.19	-1.30	1.86	-2.03	2.68	-2.93	3.65	-3.98
	4	9.5	0.64	-0.70	1.13	-1.24	1.77	-1.94	2.55	-2.80	3.46	-3.81
	4	46.5	0.56	-0.62	0.99	-1.10	1.55	-1.72	2.23	-2.48	3.03	-3.38
	5	1.0	0.75	-1.00	1.33	-1.78	2.08	-2.78	2.99	-4.00	4.07	-5.45
	5	2.0	0.72	-0.94	1.27	-1.67	1.99	-2.60	2.86	-3.75	3.90	-5.10
	5	4.5	0.67	-0.85	1.19	-1.50	1.86	-2.35	2.68	-3.38	3.65	-4.60
	5	9.5	0.64	-0.78	1.13	-1.38	1.77	-2.15	2.55	-3.10	3.46	-4.22
	5	46.5	0.56	-0.62	0.99	-1.10	1.55	-1.72	2.23	-2.48	3.03	-3.38

Note: For effective areas between those given above the load may be interpolated, otherwise use the load associated with the lower effective area. The final value, including all permitted reductions, used in the design shall not be less than that required by Section 207E.2.2.

Figure 207E.5-1 (continued)
Design Wind Pressures on Walls and Roofs of Enclosed Buildings with $h \leq 18$ m
Components and Cladding

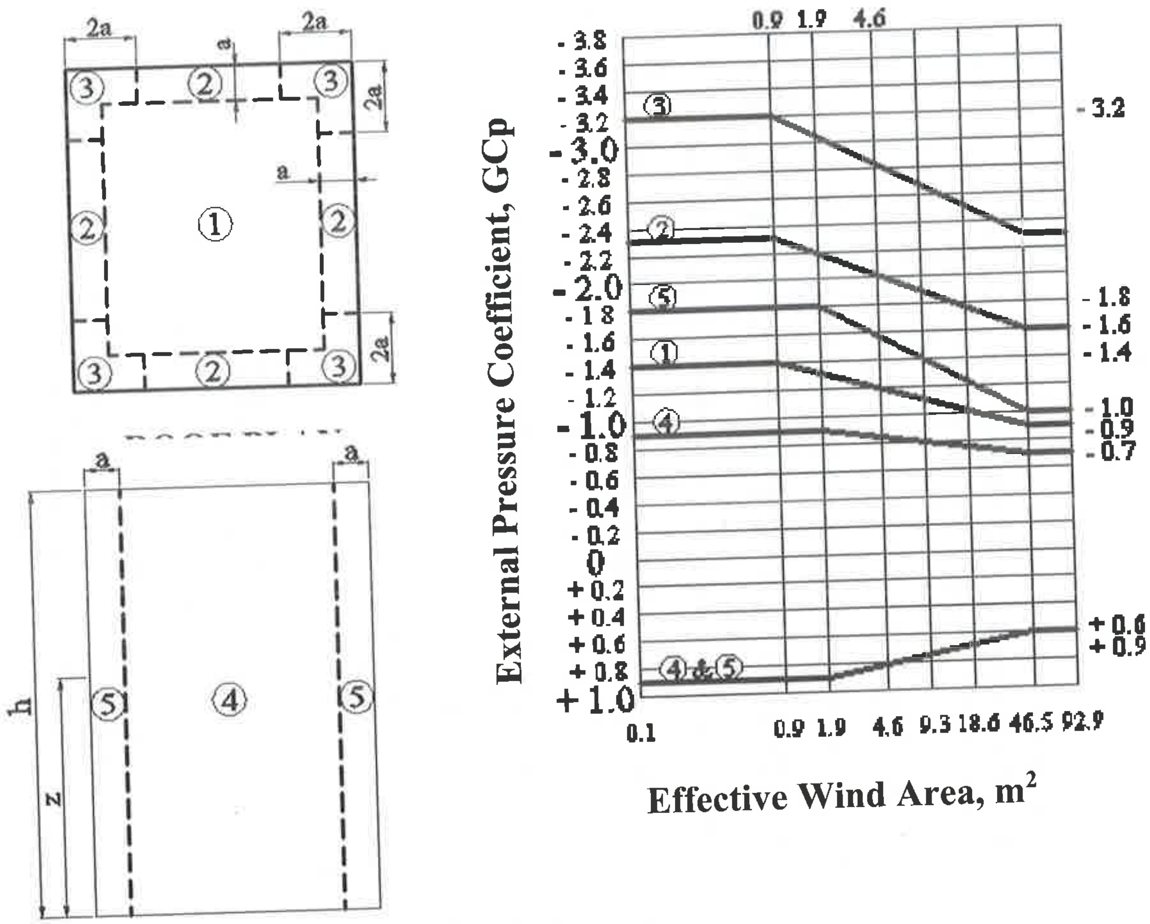
Roof Overhang Net Design Wind Pressure, p_{net} (kPa)
(Exposure B at $h = 10$ m with $I = 1.0$ and $K_d = 1.0$)

	Zone	Effective wind area (sq.m)	Basic Wind Speed V (kph)				
			150	200	250	300	350
Roof 0 to 7 degrees	2	0.9	-1.19	-2.12	-3.31	-4.76	-6.48
	2	1.9	-1.17	-2.08	-3.25	-4.69	-10.27
	2	4.6	-1.14	-2.03	-3.17	-4.57	-6.38
	2	9.3	-1.13	-2.00	-3.13	-4.51	-8.21
	3	0.9	-1.89	-3.35	-5.24	-7.55	-6.22
	3	1.9	-1.51	-2.68	-4.19	-6.03	-5.45
	3	4.6	-1.00	-1.78	-2.78	-4.00	-6.14
	3	9.3	-1.25	-2.23	-3.48	-5.02	-6.83
Roof > 7 to 27 degrees	2	0.9	-1.51	-2.68	-4.19	-6.03	-8.21
	2	1.9	-1.51	-2.68	-4.19	-6.03	-13.38
	2	4.6	-1.51	-2.68	-4.19	-6.03	-8.21
	2	9.3	-1.51	-2.68	-4.19	-6.03	-12.17
	3	0.9	-2.46	-4.37	-6.82	-9.83	-8.21
	3	1.9	-2.24	-3.97	-6.21	-8.94	-10.45
	3	4.6	-1.92	-3.41	-5.33	-7.67	-8.21
	3	9.3	-1.70	-3.02	-4.71	-6.79	-9.24
Roof > 27 to 45 degrees	2	0.9	-1.38	-2.45	-3.83	-5.52	-7.52
	2	1.9	-1.35	-2.40	-3.75	-5.40	-7.52
	2	4.6	-1.29	-2.29	-3.57	-5.14	-7.34
	2	9.3	-1.25	-2.23	-3.48	-5.02	-7.34
	3	0.9	-1.38	-2.45	-3.83	-5.52	-7.00
	3	1.9	-1.35	-2.40	-3.75	-5.40	-7.00
	3	4.6	-1.29	-2.29	-3.57	-5.14	-6.83
	3	9.3	-1.25	-2.23	-3.48	-5.02	-6.83

Adjustment Factor
for Building Height and Exposure, λ

Mean roof height (m)	Exposure		
	B	C	D
4.5	1.00	1.21	1.47
6.0	1.00	1.29	1.55
7.5	1.00	1.35	1.61
9.0	1.00	1.40	1.66
10.5	1.05	1.45	1.70
12.0	1.09	1.49	1.74
13.5	1.12	1.53	1.78
15.0	1.16	1.56	1.81
16.5	1.19	1.59	1.84
18.0	1.22	1.62	1.87

Figure 207E.5-1 (continued)
Design Wind Pressures on Walls and Roofs of Enclosed Buildings with $h \leq 18$ m
Components and Cladding



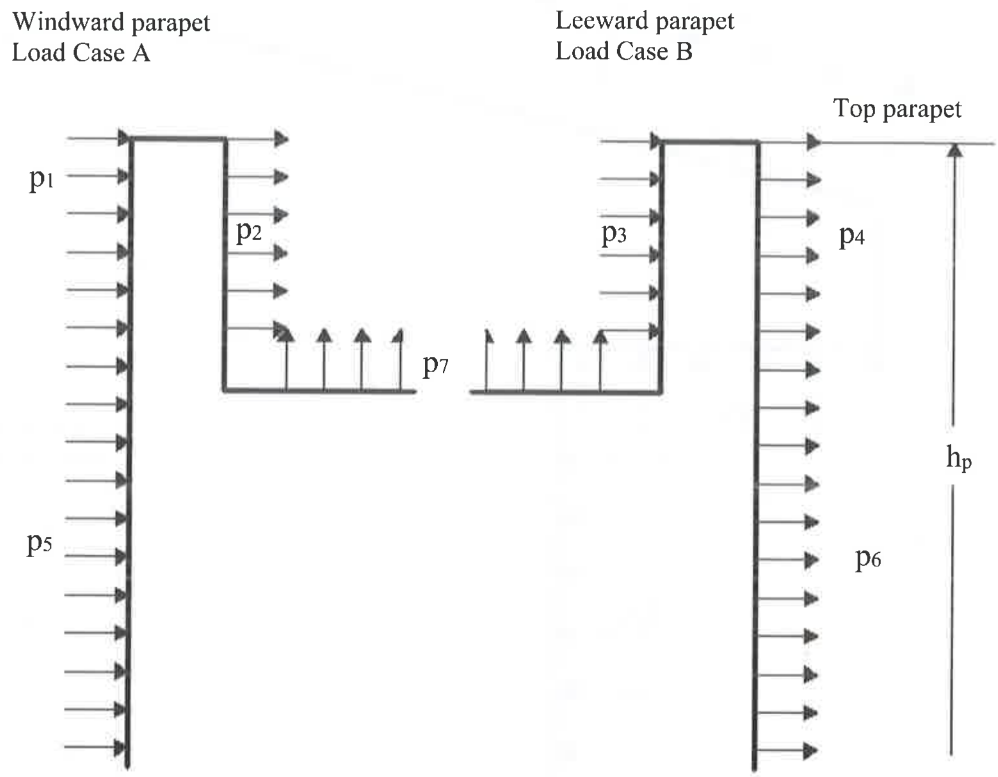
WALL ELEVATION

Notes:

1. Vertical scale denotes GC_p to be used with appropriate q_z or q_h.
2. Horizontal scale denotes effective wind area, m2
3. Plus and minus signs signify pressures acting toward and away from the surfaces, respectively.
4. Use q_z with positive values of GC_p and q_h with negative values of GC_p.
5. Each component shall be designed for maximum positive and negative pressures.
6. Coefficients are for roofs with angle $\theta \leq 10°$. For other roof angles and geometry, use GC_p values from Figure 207E.4-2A, B and C and attendant q_h based on exposure defined in Section 207A.7.
7. If a parapet equal to or higher than 0.9 m is provided around the perimeter of the roof with $\theta \leq 10°$, Zone 3 shall be treated as Zone 2.
8. Notation:

a	=	10% of least horizontal dimension, but not less than 0.9 m.
h	=	mean roof height, m, except that eave height shall be used for $\theta \leq 10°$.
z		height above ground, m
θ	=	angle of plane of roof from horizontal, °

Figure 207E.6-1
External Pressure Coefficients, GC_p Walls and Roofs, $h > 18$ m
Enclosed, Partially Enclosed Buildings



Windward Parapet

Load Case A

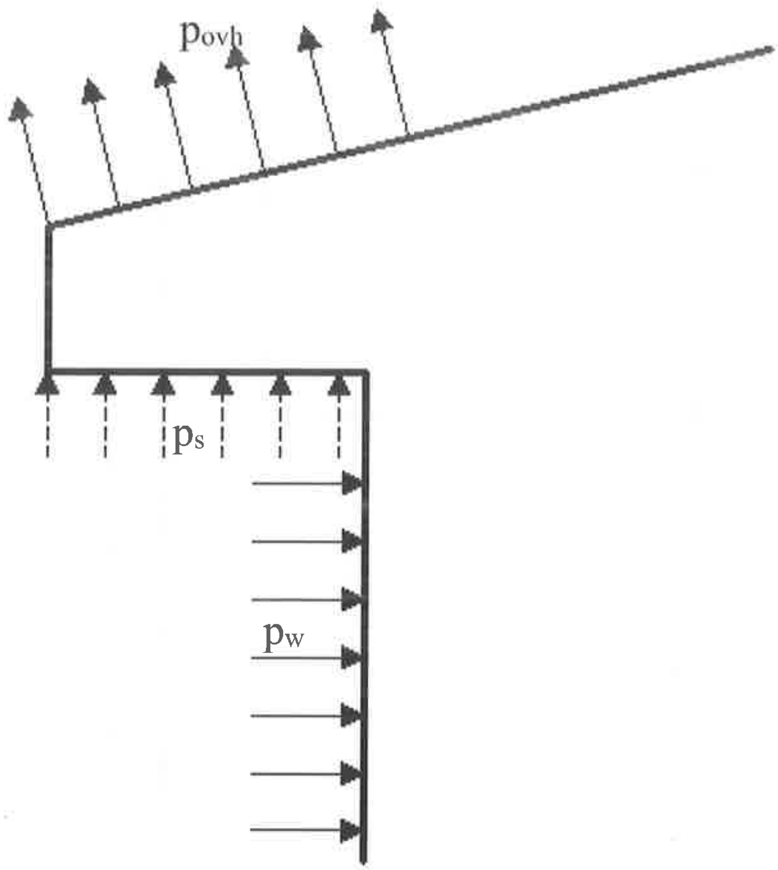
1. Windward parapet pressure (p_1) is determined using the positive wall pressure (p_5) zones 4 or 5 from Table 207E.7-2.
2. Leeward parapet pressure (p_2) is determined using the negative roof pressure (p_7) zones 2 or 3 from Table 207E.7-2.

Leeward Parapet

Load Case B

1. Windward parapet pressure (p_3) is determined using the positive wall pressure (p_5) zones 4 or 5 from Table 207E.7-2.
2. Leeward parapet pressure (p_4) is determined using the negative wall pressure (p_6) zones 4 or 5 from Table 207E.7-2.

Figure 207E.7-1
Parapet Wind Loads Application of Parapet Wind Loads, $h \leq 48.8$ m
Enclosed Simple Diaphragm Buildings



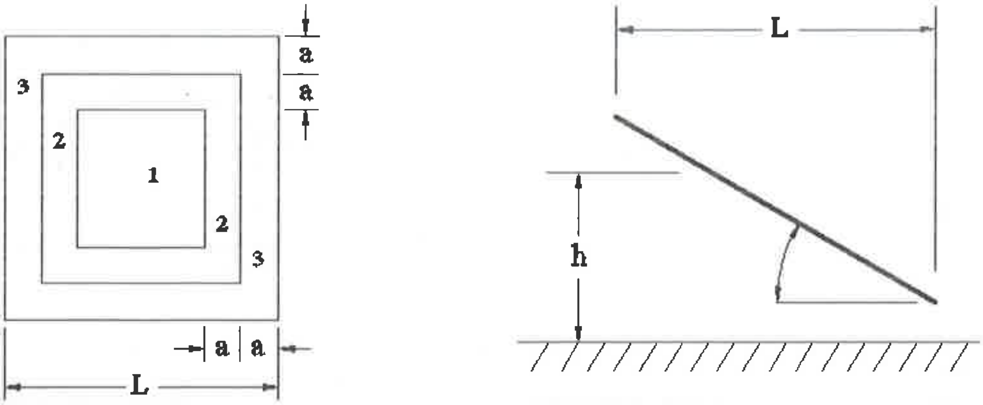
p_{ovh} = 1.0 x roof pressure p from tables for edge Zones 1, 2

p_{ovh} = 1.15 x roof pressure p from tables for corner Zone 3

Notes:

1. p_{ovh} = roof pressure at overhang for edge or corner zone as applicable from figures in roof pressure table.
2. p_{ovh} from figures includes load from both top and bottom surface of overhang.
3. Pressure p_s at soffit of overhang can be assumed same as wall pressure, p_w.

Figure 207E.7-2
Roof Overhang Wind Loads Application of Overhang Wind Loads, $h \leq 48$ m
Enclosed Simple Diaphragm Buildings



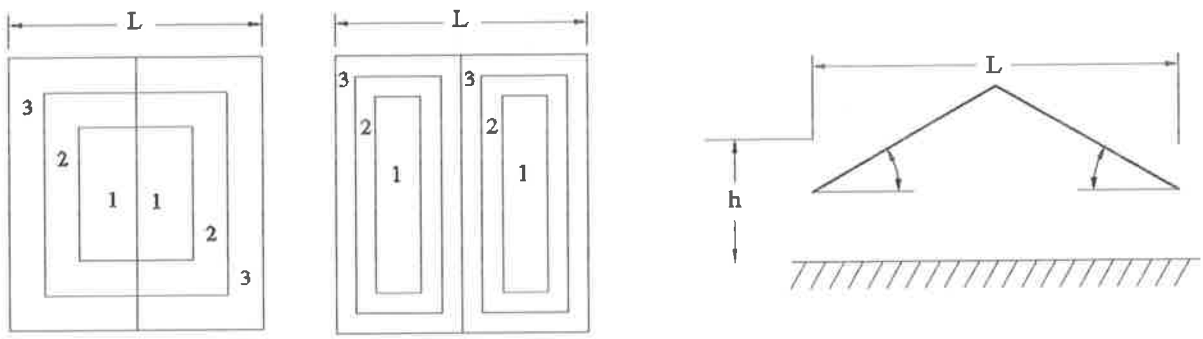
Roof Angle θ	Effective Wind Area	C_N											
		Clear Wind Flow						Obstructed Wind Flow					
		Zone 3		Zone 2		Zone 1		Zone 3		Zone 2		Zone 1	
0^o	$\leq a^2$	2.4	-3.3	1.8	-1.7	1.2	-1.1	1	-3.6	0.8	-1.8	0.5	-1.2
	$> a^2$, $\leq 4.0a^2$	1.8	-1.7	1.8	-1.7	1.2	-1.1	0.8	-1.8	0.8	-1.8	0.5	-1.2
	$> 4.0a^2$	1.2	-1.1	1.2	-1.1	1.2	-1.1	0.5	-1.2	0.5	-1.2	0.5	-1.2
7.5^o	$\leq a^2$	3.2	-4.2	2.4	-2.1	1.6	-1.4	1.6	-5.1	1.2	-2.6	0.8	-1.7
	$> a^2$, $\leq 4.0a^2$	2.4	-2.1	2.4	-2.1	1.6	-1.4	1.2	-2.6	1.2	-2.6	0.8	-1.7
	$> 4.0a^2$	1.6	-1.4	1.6	-1.4	1.6	-1.4	0.8	-1.7	0.8	-1.7	0.8	-1.7
15^o	$\leq a^2$	3.6	-3.8	2.7	-2.9	1.8	-1.9	2.4	-4.2	1.8	-3.2	1.2	-2.1
	$> a^2$, $\leq 4.0a^2$	2.7	-2.9	2.7	-2.9	1.8	-1.9	1.8	-3.2	1.8	-3.2	1.2	-2.1
	$> 4.0a^2$	1.8	-1.9	1.8	-1.9	1.8	-1.9	1.2	-2.1	1.2	-2.1	1.2	-2.1
30^o	$\leq a^2$	5.2	-5	3.9	-3.8	2.6	2.5	3.2	-4.6	2.4	-3.5	1.6	-2.3
	$> a^2$, $\leq 4.0a^2$	3.9	-3.8	3.9	-3.8	2.6	2.5	2.4	-3.5	2.4	-3.5	1.6	-2.3
	$> 4.0a^2$	2.6	-2.5	2.6	-2.5	2.6	2.5	1.6	-2.3	1.6	-2.3	1.6	-2.3
45^o	$\leq a^2$	5.2	-4.6	3.9	-3.5	2.6	2.3	4.2	-3.8	3.2	-2.9	2.1	-1.9
	$> a^2$, $\leq 4.0a^2$	3.9	-3.5	3.9	-3.5	2.6	2.3	3.2	-2.9	3.2	-2.9	2.1	-1.9
	$> 4.0a^2$	2.6	-2.3	2.6	-2.3	2.6	2.3	2.1	-1.9	2.1	-1.9	2.1	-1.9

Notes:

1. C_N denotes net pressures (contributions from top and bottom surfaces).
2. Clear wind flow denotes relatively unobstructed wind flow with blockage less than or equal to 50%. Obstructed wind flow denotes objects below roof inhibiting wind flow (>50% blockage).
3. For values of θ other than those shown, linear interpolation is permitted.
4. Plus and minus signs signify pressures acting towards and away from the top roof surface, respectively.
5. Components and cladding elements shall be designed for positive and negative pressure coefficients shown.
6. Notation:

a = 10% of least horizontal dimension or $0.4h$, whichever is smaller but not less than 4% of least horizontal dimension or 0.9 m.
h = mean roof height, m
L = Horizontal dimension of building, measured in along wind direction, m
θ = angle of plane of roof from horizontal, °

Figure 207E.8-1
Net Pressure Coefficient, C_N Monoslope Free Roofs, $\theta \leq 45^o$, $0.25 \leq h/L \leq 1.0$
Open Buildings



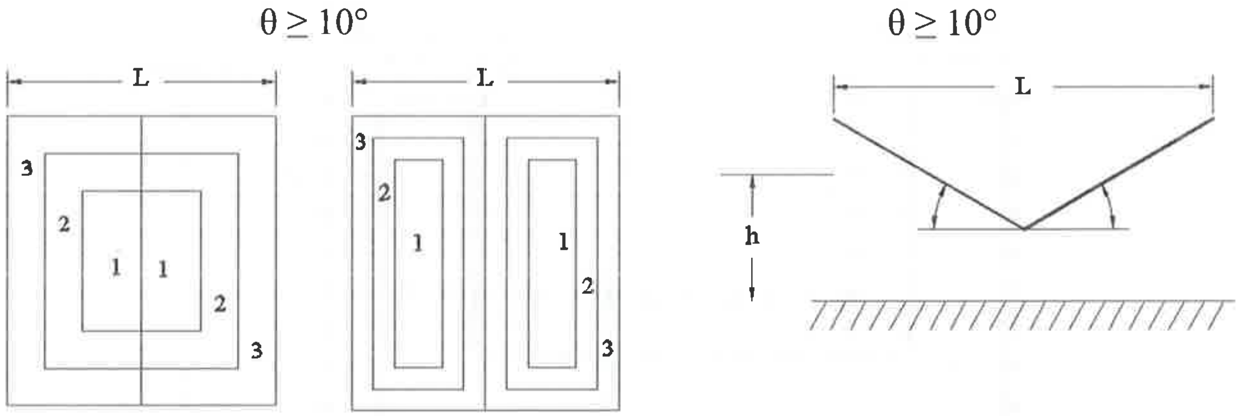
Roof Angle θ	Effective Wind Area	C_N											
		Clear Wind Flow						Obstructed Wind Flow					
		Zone 3		Zone 2		Zone 1		Zone 3		Zone 2		Zone 1	
0^o	$\leq a^2$	2.4	-3.3	1.8	-1.7	1.2	-1.1	1	-3.6	0.8	-1.8	0.5	-1.2
	$> a^2$, $\leq 4.0a^2$	1.8	-1.7	1.8	-1.7	1.2	-1.1	0.8	-1.8	0.8	-1.8	0.5	-1.2
	$> 4.0a^2$	1.2	-1.1	1.2	-1.1	1.2	-1.1	0.5	-1.2	0.5	-1.2	0.5	-1.2
7.5^o	$\leq a^2$	2.2	-3.6	1.7	-1.8	1.1	-1.2	1	-5.1	0.8	-2.6	0.5	-1.7
	$> a^2$, $\leq 4.0a^2$	1.7	-1.8	1.7	-1.8	1.1	-1.2	0.8	-2.6	0.8	-2.6	0.5	-1.7
	$> 4.0a^2$	1.1	-1.2	1.2	-1.2	1.1	-1.2	0.5	-1.7	0.5	-1.7	0.5	-1.7
15^o	$\leq a^2$	2.2	-2.2	1.7	-1.7	1.1	-1.1	1	-3.2	0.8	-2.4	0.5	-1.6
	$> a^2$, $\leq 4.0a^2$	1.7	-1.7	1.7	-1.7	1.1	-1.1	0.8	-2.4	0.8	-2.4	0.5	-1.6
	$> 4.0a^2$	1.1	-1.1	1.1	-1.1	1.1	-1.1	0.5	-1.6	0.5	-1.6	0.5	-1.6
30^o	$\leq a^2$	2.6	-1.8	2	-1.4	1.3	-0.9	1	-2.4	0.8	-1.8	0.5	-1.2
	$> a^2$, $\leq 4.0a^2$	2	-1.4	2	-1.4	1.3	-0.9	0.8	-1.8	0.8	-1.8	0.5	-1.2
	$> 4.0a^2$	1.3	-0.9	1.3	-0.9	1.3	-0.9	0.5	-1.2	0.5	-1.2	0.5	-1.2
45^o	$\leq a^2$	2.2	-1.6	1.7	-1.2	1.1	-0.8	1	-2.4	0.8	-1.8	0.5	-1.2
	$> a^2$, $\leq 4.0a^2$	1.7	-1.2	1.7	-1.2	1.1	-0.8	0.8	-1.8	0.8	-1.8	0.5	-1.2
	$> 4.0a^2$	1.1	-0.8	1.1	-0.8	1.1	-0.8	0.5	-1.2	0.5	-1.2	0.5	-1.2

Notes:

1. C_N denotes net pressures (contributions from top and bottom surfaces).
2. Clear wind flow denotes relatively unobstructed wind flow with blockage less than or equal to 50%. Obstructed wind flow denotes objects below roof inhibiting wind flow (>50% blockage).
3. For values of θ other than those shown, linear interpolation is permitted.
4. Plus and minus signs signify pressures acting towards and away from the top roof surface, respectively.
5. Components and cladding elements shall be designed for positive and negative pressure coefficients shown.
6. Notation:

a = 10% of least horizontal dimension or $0.4h$, whichever is smaller but not less than 4% of least horizontal dimension or 0.9 m. Dimension "a" is as shown in Figure 207E.8-1.
h = mean roof height, m
L Horizontal dimension of building, measured in along wind direction, m
θ = angle of plane of roof from horizontal, °

Figure 207E.8-2
Net Pressure Coefficient, C_N Pitched Free Roofs, $\theta \leq 45^o$, $0.25 \leq h/L \leq 1.0$
Open Buildings



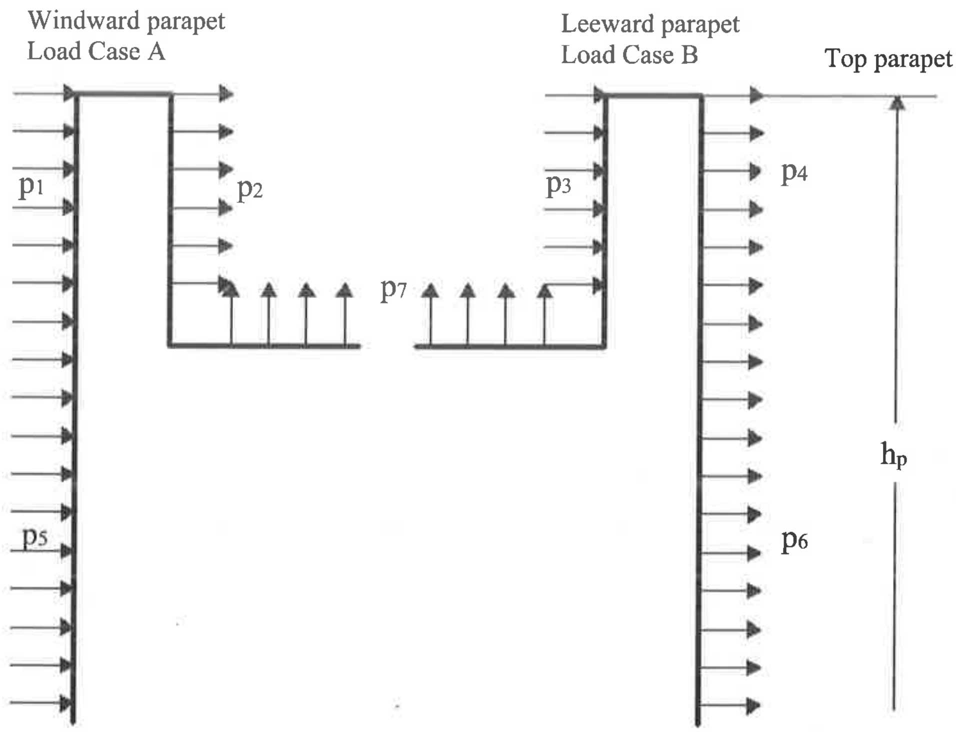
Roof Angle θ	Effective Wind Area	C_N											
		Clear Wind Flow						Obstructed Wind Flow					
		Zone 3		Zone 2		Zone 1		Zone 3		Zone 2		Zone 1	
0^o	$\leq a^2$	2.4	-3.3	1.8	-1.7	1.2	-1.1	1	-3.6	0.8	-1.8	0.5	-1.2
	$> a^2$, $\leq 4.0a^2$	1.8	-1.7	1.8	-1.7	1.2	-1.1	0.8	-1.8	0.8	-1.8	0.5	-1.2
	$> 4.0a^2$	1.2	-1.1	1.2	-1.1	1.2	-1.1	0.5	-1.2	0.5	-1.2	0.5	-1.2
7.5^o	$\leq a^2$	2.4	-3.3	1.8	-1.7	1.2	-1.1	1	-4.8	0.8	-2.4	0.5	-1.6
	$> a^2$, $\leq 4.0a^2$	1.8	-1.1	1.8	-1.7	1.2	-1.1	0.8	-2.4	0.8	-2.4	0.5	-1.6
	$> 4.0a^2$	1.2	-1.1	1.2	-1.1	1.2	-1.1	0.5	-1.6	0.5	-1.6	0.5	-1.6
15^o	$\leq a^2$	2.2	-2.2	1.7	-1.7	1.1	-1.1	1	-2.4	0.8	-1.8	0.5	-1.2
	$> a^2$, $\leq 4.0a^2$	1.7	-1.7	1.7	-1.7	1.1	-1.1	0.8	-1.8	0.8	-1.8	0.5	-1.2
	$> 4.0a^2$	1.1	-1.1	1.1	-1.1	1.1	-1.1	0.5	-1.2	0.5	-1.2	0.5	-1.2
30^o	$\leq a^2$	1.8	-2.6	1.4	-2	0.9	-1.3	1	-2.8	0.8	-2.1	0.5	-1.4
	$> a^2$, $\leq 4.0a^2$	1.4	-2	1.4	-2	0.9	-1.3	0.8	-2.1	0.8	-2.1	0.5	-1.4
	$> 4.0a^2$	0.9	-1.3	0.9	-1.3	0.9	-1.3	0.5	-1.4	0.5	-1.4	0.5	-1.4
45^o	$\leq a^2$	1.6	-2.2	1.2	-1.7	0.8	-1.1	1	-2.4	0.8	-1.8	0.5	-1.2
	$> a^2$, $\leq 4.0a^2$	1.2	-1.7	1.2	-1.7	0.8	-1.1	0.8	-1.8	0.8	-1.8	0.5	-1.2
	$> 4.0a^2$	0.8	-1.1	0.8	-1.1	0.8	-1.1	0.5	-1.2	0.5	-1.2	0.5	-1.2

Notes:

1. C_N denotes net pressures (contributions from top and bottom surfaces).
2. Clear wind flow denotes relatively unobstructed wind flow with blockage less than or equal to 50%. Obstructed wind flow denotes objects below roof inhibiting wind flow (>50% blockage).
3. For values of θ other than those shown, linear interpolation is permitted.
4. Plus and minus signs signify pressures acting towards and away from the top roof surface, respectively.
5. Components and cladding elements shall be designed for positive and negative pressure coefficients shown.
6. Notation:

a = 10% of least horizontal dimension or $0.4h$, whichever is smaller but not less than 4% of least horizontal dimension or 0.9 m. Dimension "**a**" is as shown in Figure 207E.8-1.
h = mean roof height, m
L = Horizontal dimension of building, measured in along wind direction, m
θ = angle of plane of roof from horizontal, °

Figure 207E.8-3
Net Pressure Coefficient, C_N Troughed Free Roofs, $\theta \leq 45^o$, $0.25 \leq h/L \leq 1.0$
Open Buildings



Windward Parapet

Load Case A

1. Windward parapet pressure (p_1) is determined using the positive wall pressure (p_5) zones 4 or 5 from the applicable figure.
2. Leeward parapet pressure (p_2) is determined using the negative roof pressure (p_7) zones 2 or 3 from the applicable figure.

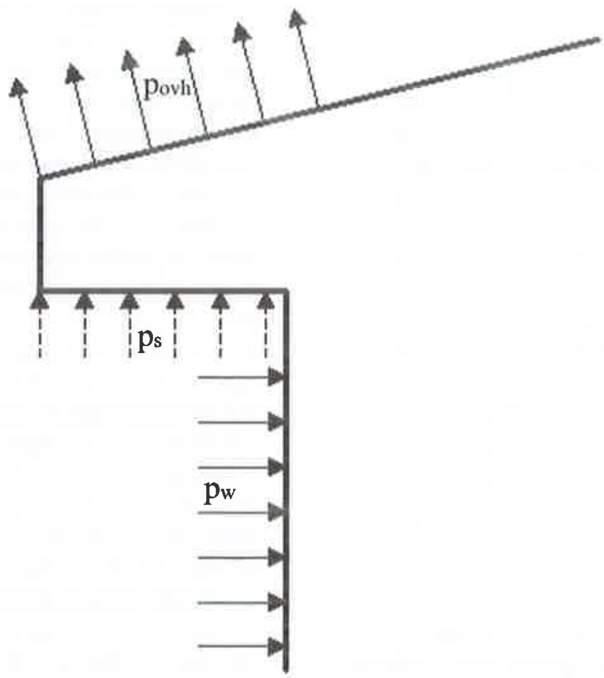
Leeward Parapet

Load Case B

1. Windward parapet pressure (p_3) is determined using the positive wall pressure (p_5) zones 4 or 5 from the applicable figure.
2. Leeward parapet pressure (p_4) is determined using the negative wall pressure (p_6) zones 4 or 5 from the applicable figure.

> *User Note:*
>
> *See Note 5 in Figure 207E.4-2A and Note 7 in Figure 207E.6-1 for reductions in component and cladding roof pressures when parapets 0.9 m or higher are present.*

Figure 207E.9-1
Parapet Wind Loads C&C – Part 6, All Building Heights All Building Types



Notes:

1. Net roof pressure p_{ovh} on roof overhangs is determined from interior, edge or corner zones as applicable from figures.
2. Net pressure p_{ovh} from figures includes pressure contribution from top and bottom surfaces of roof overhang.
3. Positive pressure at roof overhang soffit p_s is the same as adjacent wall pressure p_w.

Figure 207E.10-1
Wind Loading – Roof Overhangs, C&C, All Building Heights All Building Types

207F Wind Tunnel Procedure

Wind tunnel testing is specified when a structure contains any of the characteristics defined in Sections 207B.1.3, 207C.1.3, 207D.1.3, or 207E.1.3 or when the designer wishes to more accurately determine the wind loads. For some building shapes wind tunnel testing can reduce the conservatism due to enveloping of wind loads inherent in the Directional Procedure, Envelope Procedure, or Analytical Procedure for Components and Cladding. Also, wind tunnel testing accounts for shielding or channeling and can more accurately determine wind loads for a complex building shape than the Directional Procedure, Envelope Procedure, or Analytical Procedure for Components and Cladding. It is the intent of the code that any building or other structure be allowed to use the wind tunnel testing method to determine wind loads. Requirements for proper testing are given in Section 207F.2.

It is common practice to resort to wind tunnel tests when design data are required for the following wind-induced loads:

1. *Curtain wall pressures resulting from irregular geometry.*

2. *Across-wind and/or torsional loads.*

3. *Periodic loads caused by vortex shedding.*

4. *Loads resulting from instabilities, such as flutter or galloping.*

Boundary-layer wind tunnels capable of developing flows that meet the conditions stipulated in Section 207F.2 typically have test-section dimensions in the following ranges: width of 2 to 4 m, height of 2 to 3 m, and length of 15 to 30 m. Maximum wind speeds are ordinarily in the range of 10 to 45 m/s. The wind tunnel may be either an open-circuit or closed circuit type.

Three basic types of wind-tunnel test models are commonly used. These are designated as follows: (1) rigid Pressure Model (PM), (2) rigid high-frequency base balance model (H-FBBM), and (3) Aero-elastic Model (AM). One or more of the models may be employed to obtain design loads for a particular building or structure. The PM provides local peak pressures for design of elements, such as cladding and mean pressures, for the determination of overall mean loads. The H-FBBM measures overall fluctuating loads (aerodynamic admittance) for the determination of dynamic responses. When motion of a building or structure influences the wind loading, the AM is employed for direct measurement of overall loads, deflections, and accelerations. Each of these models, together with a model of the surroundings (proximity model), can provide information other than wind loads, such as snow loads on complex roofs, wind data to evaluate environmental impact on pedestrians, and concentrations of air-pollutant emissions for environmental impact determinations. Several references provide detailed information and guidance for the determination of wind loads and other types of design data by wind tunnel tests (Cermak 1977, Reinhold 1982, ASCE 1999, and Boggs and Peterka 1989).

Wind tunnel tests frequently measure wind loads that are significantly lower than required by Sections 207A, 207B, 207C, 207D, and 207E due to the shape of the building, the likelihood that the highest wind speeds occur at directions where the building's shape or pressure coefficients are less than their maximum values, specific buildings included in a detailed proximity model that may provide shielding in excess of that implied by exposure categories, and necessary conservatism in enveloping load coefficients in Sections 207C and 207E. In some cases, adjacent structures may shield the structure sufficiently that removal of one or two structures could significantly increase wind loads. Additional wind tunnel testing without specific nearby buildings (or with additional buildings if they might cause increased loads through channeling or buffeting) is an effective method for determining the influence of adjacent buildings.

For this reason, the code limits the reduction that can be accepted from wind tunnel tests to 80 percent of the result obtained from Part 1 of Section 207B or Part 1 of Section 207C, or Section 207E, if the wind tunnel proximity model included any specific influential buildings or other objects that, in the judgment of an experienced wind engineer, are likely to have substantially influenced the results beyond those characteristic of the general surroundings. If there are any such buildings or objects, supplemental testing can be performed to quantify their effect on the original results and possibly justify a limit lower than 80 percent, by removing them from the detailed proximity model and replacing them with characteristic ground roughness consistent with the adjacent roughness. A specific influential building or object is one within the detailed proximity model that protrudes well above its surroundings, or is unusually close to the subject building, or may otherwise cause substantial sheltering effect or magnification of the wind loads. When these supplemental test results are included with the original results, the acceptable results are then considered to be the higher of both conditions.

However, the absolute minimum reduction permitted is 65 percent of the baseline result for components and cladding, and 50 percent for the main wind force resisting system. A higher reduction is permitted for MWFRS, because *components and cladding loads are more subject to changes due to local channeling effects when surroundings change and can easily be dramatically increased when a new adjacent building is constructed. It is also recognized that cladding failures are much more common than failures of the MWFRS. In addition, for the case of MWFRS it is easily demonstrated that the overall drag coefficient for certain common building shapes, such as circular cylinders especially with rounded or domed tops, is one-half or less of the drag coefficient for the rectangular prisms that form the basis of Section 207B, 207C, and 207E.*

For components and cladding, the 80-percent limit is defined by the interior zones 1 and 4 in Figures 207E.4-1, 207E.4-2A, 207E.4-2B, 207E.4-2C, 207E.4-3, 207E.4-4, 207E.4-5A, 207E.4-5B, 207E.4-6, 207E.4-7, and 207E.5-1. This limitation recognizes that pressures in the edge zones are the ones most likely to be reduced by the specific geometry of real buildings compared to the rectangular prismatic buildings assumed in Section 207E. Therefore, pressures in edge and corner zones are permitted to be as low as 80 percent of the interior pressures from Section 207E without the supplemental tests. The 80 percent limit based on zone 1 is directly applicable to all roof areas, and the 80 percent limit based on zone 4 is directly applicable to all wall areas.

The limitation on MWFRS loads is more complex because the load effects (e.g., member stresses or forces, deflections) at any point are the combined effect of a vector of applied loads instead of a simple scalar value. In general the ratio of forces or moments or torques (force eccentricity) at various floors throughout the building using a wind tunnel study will not be the same as those ratios determined from Sections 207B and 207C, and therefore comparison between the two methods is not well defined. Requiring each load effect from a wind tunnel test to be no less than 80 percent of the same effect resulting from Sections 207B and 207C is impractical and unnecessarily complex and detailed, given the approximate nature of the 80 percent value. Instead, the intent of the limitation is effectively implemented by applying it only to a simple index that characterizes the overall loading. For flexible (tall) buildings, the most descriptive index of overall loading is the base overturning moment. For other buildings, the overturning moment can be a poor characterization of the overall loading, and the base shear is recommended instead.

207F.1 Scope

The Wind Tunnel Procedure shall be used where required by Sections 207B.1.3, 207C.1.3, and 207D.1.3. The Wind Tunnel Procedure shall be permitted for any building or structure in lieu of the design procedures specified in Section 207B (MWFRS for buildings of all heights and simple diaphragm buildings with $h \leq 49$ m, Section 207C (MWFRS of low-rise buildings and simple diaphragm low-rise buildings), Section 207D (MWFRS for all other structures), and Section 207E (components and cladding for all building types and other structures).

> *User Note:*
>
> *Section 207F may always be used for determining wind pressures for the MWFRS and/or for C&C of any building or structure. This method is considered to produce the most accurate wind pressures of any method specified in this Code.*

207F.2 Test Conditions

Wind tunnel tests, or similar tests employing fluids other than air, used for the determination of design wind loads for any building or other structure, shall be conducted in accordance with this section. Tests for the determination of mean and fluctuating forces and pressures shall meet all of the following conditions:

1. The natural atmospheric boundary layer has been modeled to account for the variation of wind speed with height.
2. The relevant macro-(integral) length and micro-length scales of the longitudinal component of atmospheric turbulence are modeled to approximately the same scale as that used to model the building or structure.
3. The modeled building or other structure and surrounding structures and topography are geometrically similar to their full-scale counterparts, except that, for low-rise buildings meeting the requirements of Section 207C.1.2, tests shall be permitted for the modeled building in a single exposure site as defined in Section 207A.7.3.
4. The projected area of the modeled building or other structure and surroundings is less than 8 percent of the test section cross-sectional area unless correction is made for blockage.
5. The longitudinal pressure gradient in the wind tunnel test section is accounted for.

6. Reynolds number effects on pressures and forces are minimized.

7. Response characteristics of the wind tunnel instrumentation are consistent with the required measurements.

207F.3 Dynamic Response

Tests for the purpose of determining the dynamic response of a building or other structure shall be in accordance with Section 207F.2. The structural model and associated analysis shall account for mass distribution, stiffness, and damping.

207F.4 Load Effects

207F.4.1 Mean Recurrence Intervals of Load Effects

The load effect required for Strength Design shall be determined for the same mean recurrence interval as for the Analytical Method, by using a rational analysis method, defined in the recognized literature, for combining the directional wind tunnel data with the directional meteorological data or probabilistic models based thereon. The load effect required for Allowable Stress Design shall be equal to the load effect required for Strength Design divided by 1.6. For buildings that are sensitive to possible variations in the values of the dynamic parameters, sensitivity studies shall be required to provide a rational basis for design recommendations.

Commentary:

Examples of analysis methods for combining directional wind tunnel data with the directional meteorological data or probabilistic models based thereon are described in Lepage and Irwin (1985), Rigato et al. (2001), Isyumov et al. (2003), Irwin et al. (2005), Simiu and Filliben (2005), and Simiu and Miyata (2006).

207F.4.2 Limitations on Wind Speeds

The wind speeds and probabilistic estimates based thereon shall be subject to the limitations described in Section 207A.5.3.

Commentary:

Section 207F.4.2 specifies that the statistical methods used to analyze historical wind speed and direction data for wind tunnel studies shall be subject to the same limitations specified in Section 207F.4.2 that apply to the Analytical Method.

Database-Assisted Design. *Wind-tunnel aerodynamics databases that contain records of pressures measured synchronously at large numbers of locations on the exterior surface of building models have been developed by wind researchers, e.g., Simiu et al. (2003) and Main and Fritz (2006). Such databases include data that permit a designer to determine, without specific wind tunnel tests, wind-induced forces and moments in Main Wind Force Resisting Systems and Components and Cladding of selected shapes and sizes of buildings. A public domain set of such databases, recorded in tests conducted at the University of Western Ontario (Ho et al. 2005 and St. Pierre et al. 2005) for buildings with gable roofs is available on the National Institute of Standards and Technology (NIST) website: www.nist.gov/wind. Interpolation software for buildings with similar shape and with dimensions close to and intermediate between those included in the set of databases is also available on that site. Because the database results are for generic surroundings as permitted in item 3 of Section 207F.2, interpolation or extrapolation from these databases should be used only if condition 2 of Section 207B.1.2 is true. Extrapolations from available building shapes and sizes are not permitted, and interpolations in some instances may not be advisable. For these reasons, the guidance of an engineer experienced in wind loads on buildings and familiar with the usage of these databases is recommended. All databases must have been obtained using testing methodology that meets the requirements for wind tunnel testing specified in Section 207F.*

207F.4.3 Limitations on Loads

Loads for the main wind force resisting system determined by wind tunnel testing shall be limited such that the overall principal loads in the x and y directions are not less than 80 percent of those that would be obtained from Part 1 of Section 207B or Part 1 of Section 207C. The overall principal load shall be based on the overturning moment for flexible buildings and the base shear for other buildings.

Pressures for components and cladding determined by wind tunnel testing shall be limited to not less than 80 percent of those calculated for Zone 4 for walls and Zone 1 for roofs using the procedure of Section 207E. These Zones refer to those shown in Figures 207E.4-1, 207E.4-2A, 207E.4-2B, 207E.4-2C, 207E.4-3, 207E.4-4, 207E.4-5A, 207E.4-5B, 207E.4-6, 207E.4-7, and 207E.6-1.

The limiting values of 80 percent may be reduced to 50 percent for the main wind force resisting system and 65 percent for components and cladding if either of the following conditions applies:

1. There were no specific influential buildings or objects within the detailed proximity model.

2. Loads and pressures from supplemental tests for all significant wind directions in which specific influential buildings or objects are replaced by the roughness representative of the adjacent roughness condition, but not rougher than exposure B, are included in the test results.

207F.5 Wind-Borne Debris

Glazing in buildings in wind-borne debris regions shall be protected in accordance with Section 207A.10.3.

SECTION 208
EARTHQUAKE LOADS

208.1 General

208.1.1 Purpose

The purpose of the succeeding earthquake provisions is primarily to design seismic-resistant structures to safeguard against major structural damage that may lead to loss of life and property. These provisions are not intended to assure zero-damage to structures nor maintain their functionality after a severe earthquake.

208.1.2 Minimum Seismic Design

Structures and portions thereof shall, as a minimum, be designed and constructed to resist the effects of seismic ground motions as provided in this section.

208.1.3 Seismic and Wind Design

When the code-prescribed wind design produces greater effects, the wind design shall govern, but detailing requirements and limitations prescribed in this section and referenced sections shall be made to govern.

208.2 Definitions

See Section 202.

208.3 Symbols and Notations

A_B = ground floor area of structure to include area covered by all overhangs and projections, m^2

A_c = the combined effective area of the shear walls in the first storey of the structure, m^2

A_e = the minimum cross-sectional area in any horizontal plane in the first storey of a shear wall, m^2

A_x = the torsional amplification factor at Level x

a_p = numerical coefficient specified in Section 208.7 and set forth in Table 208-13

C_a = seismic coefficient, as set forth in Table 208-7

C_t = numerical coefficient given in Section 208.5.2.2

C_v = seismic coefficient, as set forth in Table 208-8

D = dead load

D_e = the length of a shear wall in the first storey in the direction parallel to the applied forces, m

E, E_h, E_m, E_v = earthquake loads set forth in Section 208.6

F_x = design seismic force applied to Level i, n or x, respectively

F_p = design seismic force on a part of the structure

F_{px} = design seismic force on a diaphragm

F_t = that portion of the base shear, V, considered concentrated at the top of the structure in addition to F_n

f_i = lateral force at Level i for use in Equation 208-14

g = acceleration due to gravity = 9.815 m/sec^2

h_i, h_n, h_x = height above the base to Level i, n or x, respectively, m

I = importance factor given in Table 208-1

I_p = importance factor for nonstructural component as given in Table 208-1

L = live load

Level i = level of the structure referred to by the subscript i

"i = 1" designates the first level above the base

Level n = that level that is uppermost in the main portion of the structure

Level x = that level that is under design consideration

"x = 1" designates the first level above the base

M = maximum moment magnitude

N_a = near-source factor used in the determination of C_a in Seismic Zone 4 related to both the proximity of the building or structure to known faults with magnitudes as set forth in Tables 208-4 and 208-5

N_v = near-source factor used in the determination of C_v in Seismic Zone 4 related to both the proximity of the building or structure to known faults with magnitudes as set forth in Tables 208-4 and 208-6

PI = plasticity index of soil determined in accordance with approved national standards

R = numerical coefficient representative of the inherent over-strength and global ductility capacity of lateral-force-resisting systems, as set forth in Table 208-11 or 208-12

r = a ratio used in determining ρ□□the redundancy/reliability factor. See Section 208.5.

$S_A, S_B, S_C, S_D, S_E, S_F$ = soil profile types as set forth in Table 208-2

T = elastic fundamental period of vibration of the structure in the direction under consideration, sec

V = base shear given by Equations. 208-8, 208-9, 208-10, 208-11 or 208-15

V_x = the design storey shear in Storey x

W = the total seismic dead load defined in Section 208.5.2.1

w_i, w_x = that portion of W located at or assigned to Level i or x, respectively

W_p = the weight of an element or component

w_{px} = the weight of the diaphragm and the element tributary thereto at Level x, including applicable portions of other loads defined in Section 208.6.1

Z = seismic zone factor as given in Table 208-3

Δ_M = Maximum Inelastic Response Displacement, which is the total drift or total storey drift that occurs when the structure is subjected to the Design Basis Ground Motion, including estimated elastic and inelastic contributions to the total deformation defined in Section 208.6.4.2, mm

Δ_S = Design Level Response Displacement, which is the total drift or total storey drift that occurs when the structure is subjected to the design seismic forces, mm

δ_i = horizontal displacement at Level i relative to the base due to applied lateral forces, f_i, for use in Equation 208-14, mm

ρ = Redundancy/Reliability Factor given by Equation 208-20

Ω_o = Seismic Force Amplification Factor, which is required to account for structural over-strength and set forth in Table 208-11

208.4 Basis for Design

208.4.1 General

The procedures and the limitations for the design of structures shall be determined considering seismic zoning, site characteristics, occupancy, configuration, structural system and height in accordance with this section. Structures shall be designed with adequate strength to withstand the lateral displacements induced by the Design Basis Ground Motion, considering the inelastic response of the structure and the inherent redundancy, over-strength and ductility of the lateral force-resisting system.

The minimum design strength shall be based on the Design Seismic Forces determined in accordance with the static lateral force procedure of Section 208.5, except as modified by Section 208.5.3.5.4.

Where strength design is used, the load combinations of Section 203.3 shall apply. Where Allowable Stress Design is used, the load combinations of Section 203.4 shall apply.

Allowable Stress Design may be used to evaluate sliding or overturning at the soil-structure interface regardless of the design approach used in the design of the structure, provided load combinations of Section 203.4 are utilized.

208.4.2 Occupancy Categories

For purposes of earthquake-resistant design, each structure shall be placed in one of the occupancy categories listed in Table 103-1. Table 208-1 assigns importance factors, I and I_p, and structural observation requirements for each category.

Table 208-1 - Seismic Importance Factors

Occupancy Category [1]	Seismic Importance Factor, I	Seismic Importance [2] Factor, I_p
I. Essential Facilities [3]	1.50	1.50
II. Hazardous Facilities	1.25	1.50
III. Special Occupancy Structures	1.00	1.00
IV. Standard Occupancy Structures	1.00	1.00
V. Miscellaneous structures	1.00	1.00

[1] *See Table 103-1 for occupancy category listing*

[2] *The limitation of I_p for panel connections in Section 208.7.2.3 shall be **1.0** for the entire connector*

[3] *Structural observation requirements are given in Section 107.9*

[4] *For anchorage of machinery and equipment required for life-safety systems, the value of I_p shall be taken as **1.5***

208.4.3 Site Geology and Soil Characteristics

Each site shall be assigned a soil profile type based on properly substantiated geotechnical data using the site categorization procedure set forth in Section 208.4.3.1.1 and Table 208-2.

Exception:

When the soil properties are not known in sufficient detail to determine the soil profile type, Type S_D shall be used. Soil Profile Type S_E or S_F need not be assumed unless the building official determines that Type S_E or S_F may be present at the site or in the event that Type S_E or S_F is established by geotechnical data.

208.4.3.1 Soil Profile Type

Soil Profile Types S_A, S_B, S_C, S_D and S_E are defined in Table 208-2 and Soil Profile Type S_F is defined as soils requiring site-specific evaluation as follows:

1. Soils vulnerable to potential failure or collapse under seismic loading, such as liquefiable soils, quick and highly sensitive clays, and collapsible weakly cemented soils.

2. Peats and/or highly organic clays, where the thickness of peat or highly organic clay exceeds 3.0 m.

3. Very high plasticity clays with a plasticity index, $PI > 75$, where the depth of clay exceeds 7.5 m.

4. Very thick soft/medium stiff clays, where the depth of clay exceeds 35 m.

5. The criteria set forth in the definition for Soil Profile Type S_F requiring site-specific evaluation shall be considered. If the site corresponds to these criteria, the site shall be classified as Soil Profile Type S_F and a site-specific evaluation shall be conducted.

208.4.3.1.1 Site Categorization Procedure

208.4.3.1.1.1 Scope

This section describes the procedure for determining Soil Profile Types S_A through S_F as defined in Table 208-2.

Table 208-2 - Soil Profile Types

Soil Profile Type	Soil Profile Name / Generic Description	Average Soil Properties for Top 30 m of Soil Profile		
		Shear Wave Velocity, V_S (m/s)	SPT, N (blows/ 300 mm)	Undrained Shear Strength, S_U (kPa)
S_A	Hard Rock	> 1500		
S_B	Rock	760 to 1500		
S_C	Very Dense Soil and Soft Rock	360 to 760	> 50	> 100
S_D	Stiff Soil Profile	180 to 360	15 to 50	50 to 100
S_E[1]	Soft Soil Profile	< 180	< 15	< 50
S_F	Soil Requiring Site-specific Evaluation. See Section 208.4.3.1			

[1] *Soil Profile Type* S_E *also includes any soil profile with more than 3.0 m of soft clay defined as a soil with plasticity index,* $PI > 20$, $w_{mc} \geq 40\%$ *and* $s_u < 24\ kPa$. *The Plasticity Index,* PI, *and the moisture content,* w_{mc}, *shall be determined in accordance with approved national standards.*

208.4.3.1.1.2 Definitions

Soil profile types are defined as follows:

S_A Hard rock with measured shear wave velocity, $v_s > 1500\ m/s$

S_B Rock with $760\ m/s < v_s \leq 1500\ m/s$

S_C Very dense soil and soft rock with $360\ m/s < v_s < 760\ m/s$ or with either $N > 50$ or $s_u \geq 100\ kPa$

S_D Stiff soil with $180\ m/s \leq vs \leq 360\ m/s$ or with $15 \leq N \leq 50$ or $50\ kPa \leq s_u \leq 100\ kPa$

S_E A soil profile with $v_s < 180\ m/s$ or any profile with more than 3 m of soft clay defined as soil with $PI > 20$, $w_{mc} \geq 40$ percent and $s_u < 25\ kPa$

S_F Soils requiring site-specific evaluation, refer to Section 208.4.3.1

208.4.3.1.1.2.1 $\bar{v}_s$, Average Shear Wave Velocity

$\bar{v}_s$ shall be determined in accordance with the following equation:

$$\bar{v}_s = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{v_{si}}} \quad (208\text{-}1)$$

where

d_i = thickness of Layer i , m
v_{si} = shear wave velocity in Layer i , m/s

208.4.3.1.1.2.2 $\bar{N}$, Average Field Standard Penetration Resistance and $\bar{N}_{ch}$, Average Standard Penetration Resistance for Cohesionless Soil Layers

$\bar{N}$ and $\bar{N}_{ch}$ shall be determined in accordance with the following equation:

$$\bar{N} = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{N_i}} \quad (208\text{-}2)$$

$$\bar{N}_{ch} = \frac{d_s}{\sum_{i=1}^{n} \frac{d_i}{N_i}} \quad (208\text{-}3)$$

where

d_i = thickness of Layer i in mm
d_s = the total thickness of cohesionless soil layers in the top 30 m
N_i = the standard penetration resistance of soil layer in accordance with approved nationally recognized standards

208.4.3.1.1.2.3 $\bar{s}_u$, Average Undrained Shear Strength

$\bar{s}_u$ shall be determined in accordance with the following equation:

$$\bar{s}_u = \frac{d_c}{\sum_{i=1}^{n} \frac{d_i}{s_{ui}}} \quad (208\text{-}4)$$

where

d_c = the total thickness $(100 - d_s)$ of cohesive soil layers in the top 30 m
s_{ui} = the undrained shear strength in accordance with approved nationally recognized standards, not to exceed 250 kPa

208.4.3.1.1.2.4 Rock Profiles, S_A and S_B

The shear wave velocity for rock, Soil Profile Type S_B, shall be either measured on site or estimated by a geotechnical engineer, engineering geologist or seismologist for competent rock with moderate fracturing and weathering. Softer and more highly fractured and weathered rock shall either be measured on site for shear wave velocity or classified as Soil Profile Type S_C.

The hard rock, Soil Profile Type S_A, category shall be supported by shear wave velocity measurement either on site or on profiles of the same rock type in the same formation with an equal or greater degree of weathering and fracturing. Where hard rock conditions are known to be continuous to a depth of 30 m, surficial shear wave velocity measurements may be extrapolated to assess $\bar{v}_s$. The rock categories, Soil Profile Types S_A and S_B, shall not be used if there is more than 3 meters of soil between the rock surface and the bottom of the spread footing or mat foundation.

The definitions presented herein shall apply to the upper 30 m of the site profile. Profiles containing distinctly different soil layers shall be subdivided into those layers designated by a number from 1 to n at the bottom, where there are a total of n distinct layers in the upper 30 m. The symbol i then refer to any one of the layers between 1 and n.

208.4.3.1.1.2.5 Soft Clay Profile, S_E

The existence of a total thickness of soft clay greater than 3 m shall be investigated where a soft clay layer is defined by $s_u < 24\ kPa$, $w_{mc} \geq 40$ percent and $PI > 20$. If these criteria are met, the site shall be classified as Soil Profile Type S_E.

208.4.3.1.1.2.6 Soil Profiles S_C, S_D and S_E

Sites with Soil Profile Types S_C, S_D and S_E shall be classified by using one of the following three methods with $\bar{v}_s$, $\bar{N}$ and $\bar{s}_u$ computed in all cases as specified in Section 208.4.3.1.1.2.

1. $\bar{v}_s$ for the top 30 meters ($\bar{v}_s$ method).
2. $\bar{N}$ for the top 30 meters ($\bar{N}$ method).
3. $\bar{N}_{CH}$ for cohesionless soil layers ($PI < 20$) in the top 30 m and average $\bar{s}_u$ for cohesive soil layers ($PI > 20$) in the top 30 m ($\bar{s}_u$ method).

208.4.4 Site Seismic Hazard Characteristics

Seismic hazard characteristics for the site shall be established based on the seismic zone and proximity of the site to active seismic sources, site soil profile characteristics and the structure's importance factor.

208.4.4.1 Seismic Zone

The Philippine archipelago is divided into two seismic zones only. Zone 2 covers the provinces of Palawan (except Busuanga) , Sulu and Tawi-Tawi while the rest of the country is under Zone 4 as shown in Figure 208-1. Each structure shall be assigned a seismic zone factor Z, in accordance with Table 208-3.

Table 208-3 Seismic Zone Factor Z

ZONE	2	4
Z	0.20	0.40

208.4.4.2 Seismic Source Types

Table 208-4 defines the types of seismic sources. The location and type of seismic sources to be used for design shall be established based on approved geological data; see Figure 208-2A. Type A sources shall be determined from Figure 208-2B, 2C, 2D, 2E or the most recent mapping of active faults by the Philippine Institute of Volcanology and Seismology (PHIVOLCS).

Table 208-4 - Seismic Source Types [1]

Seismic Source Type	Seismic Source Description	Seismic Source Definition
		Maximum Moment Magnitude, M
A	Faults that are capable of producing large magnitude events and that have a high rate of seismic activity.	$7.0 \leq M \leq 8.4$
B	All faults other than Types A and C.	$6.5 \leq M < 7.0$
C	Faults that are not capable of producing large magnitude earthquakes and that have a relatively low rate of seismic activity.	$M < 6.5$

[1]Subduction sources shall be evaluated on a site-specific basis.

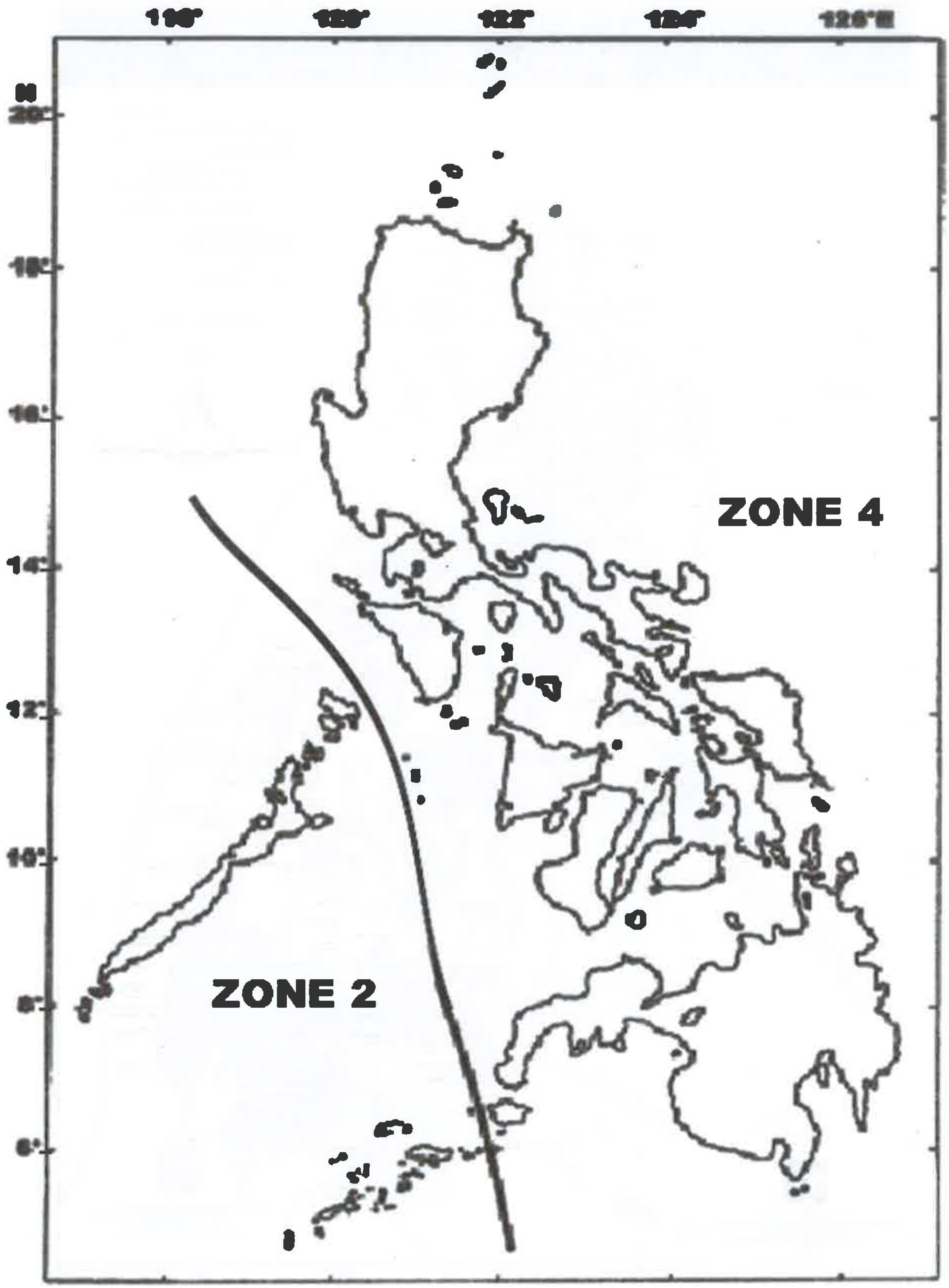


Figure 208-1 Referenced Seismic Map of the Philippines
National Structural Code of the Philippines Volume I, 7th Edition, 2015

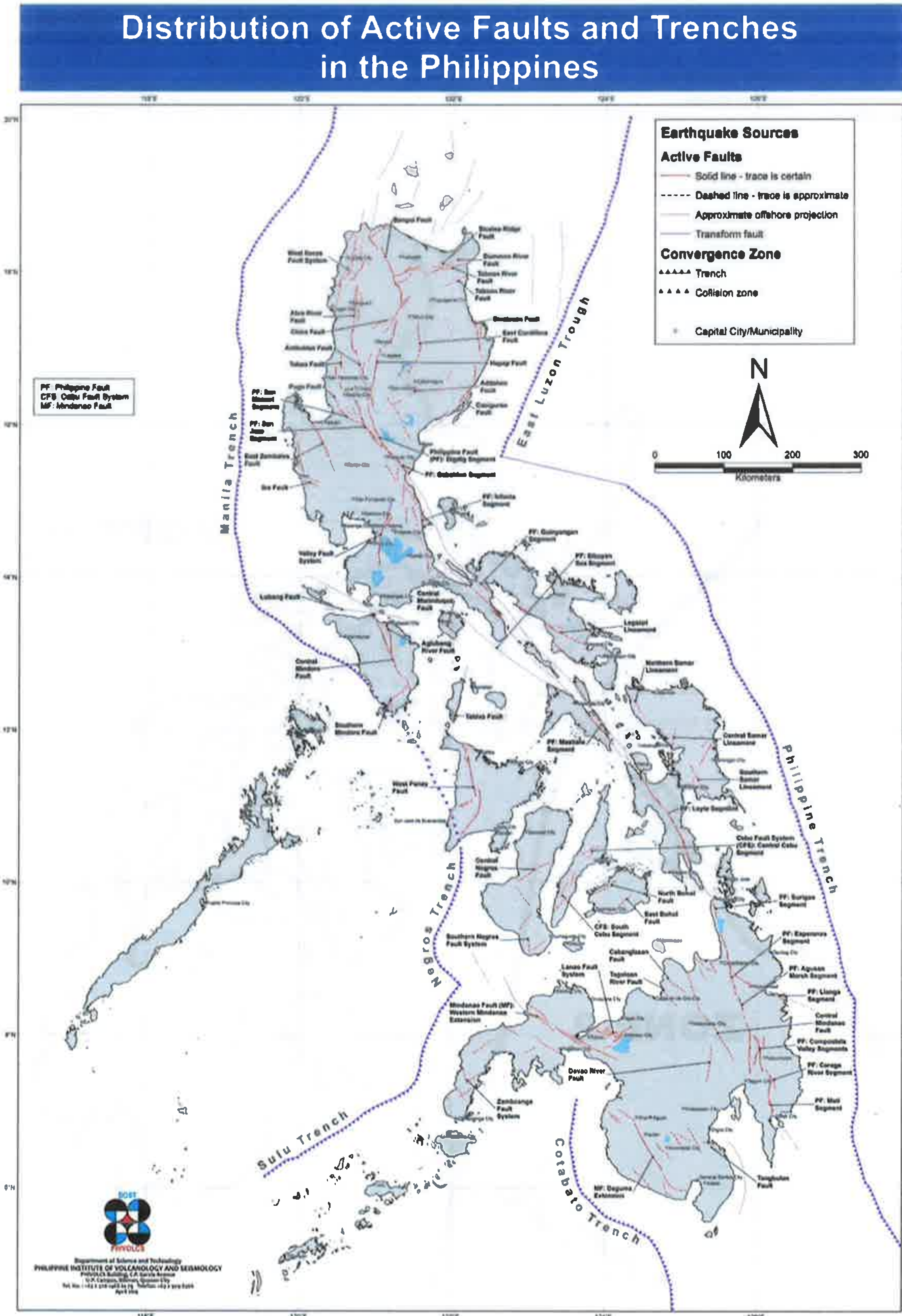


Figure 208-2A Distribution of Active Faults and Trenches in the Philippines

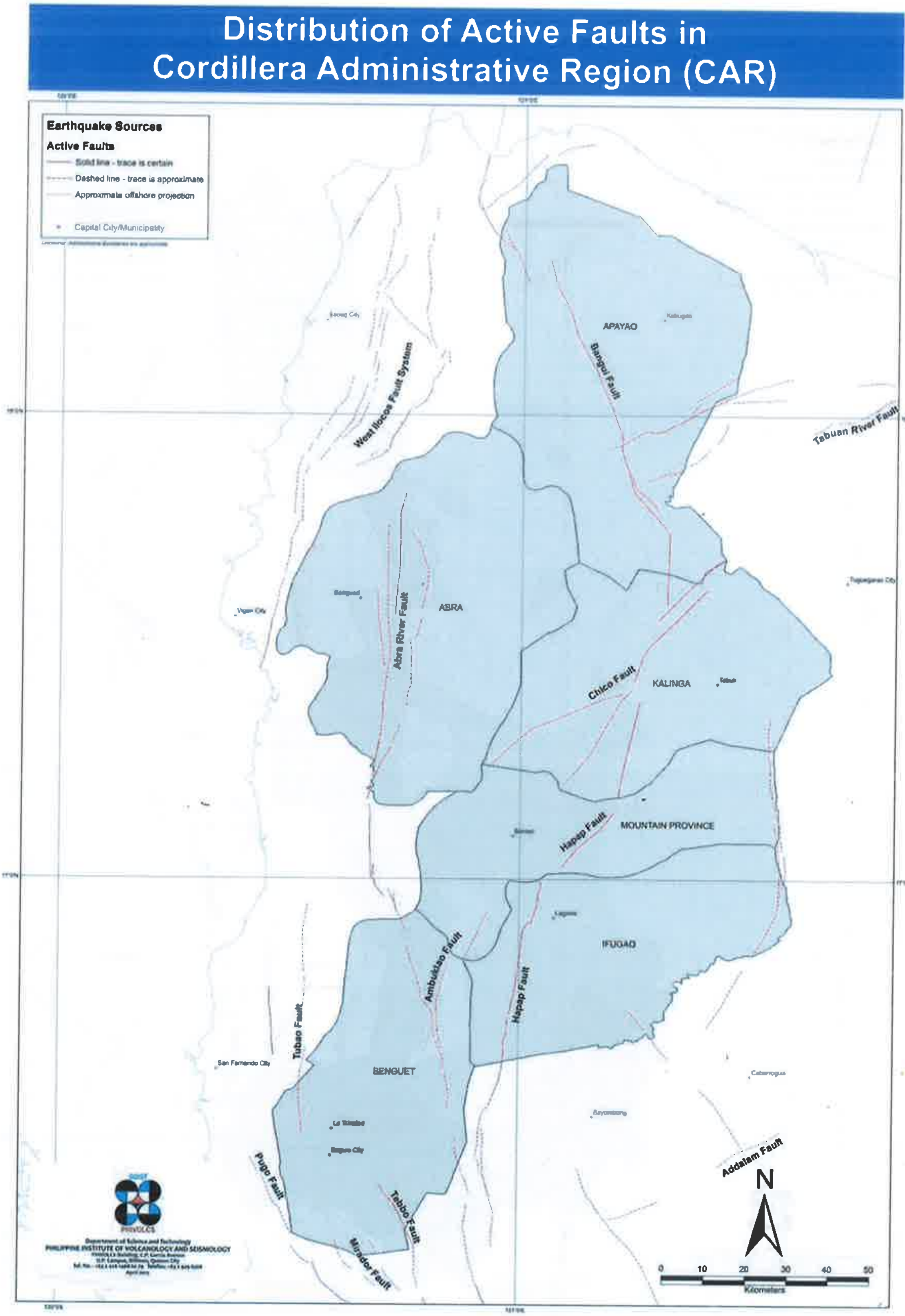


Figure 208-2B Distribution of Active Faults in Cordillera Administrative Region (CAR)

National Structural Code of the Philippines Volume I, 7th Edition, 2015

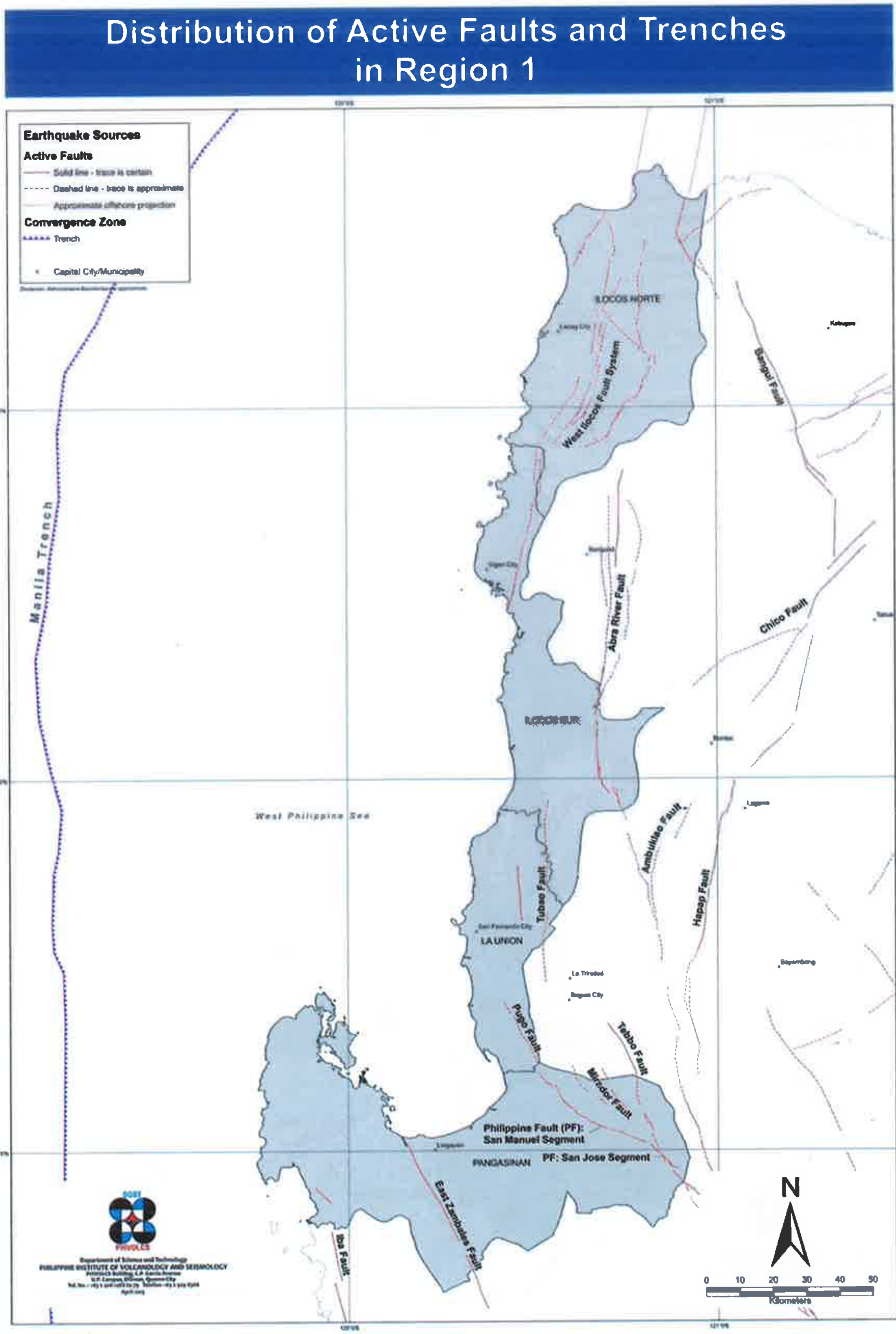


Figure 208-2C Distribution of Active Faults and Trenches in Region 1

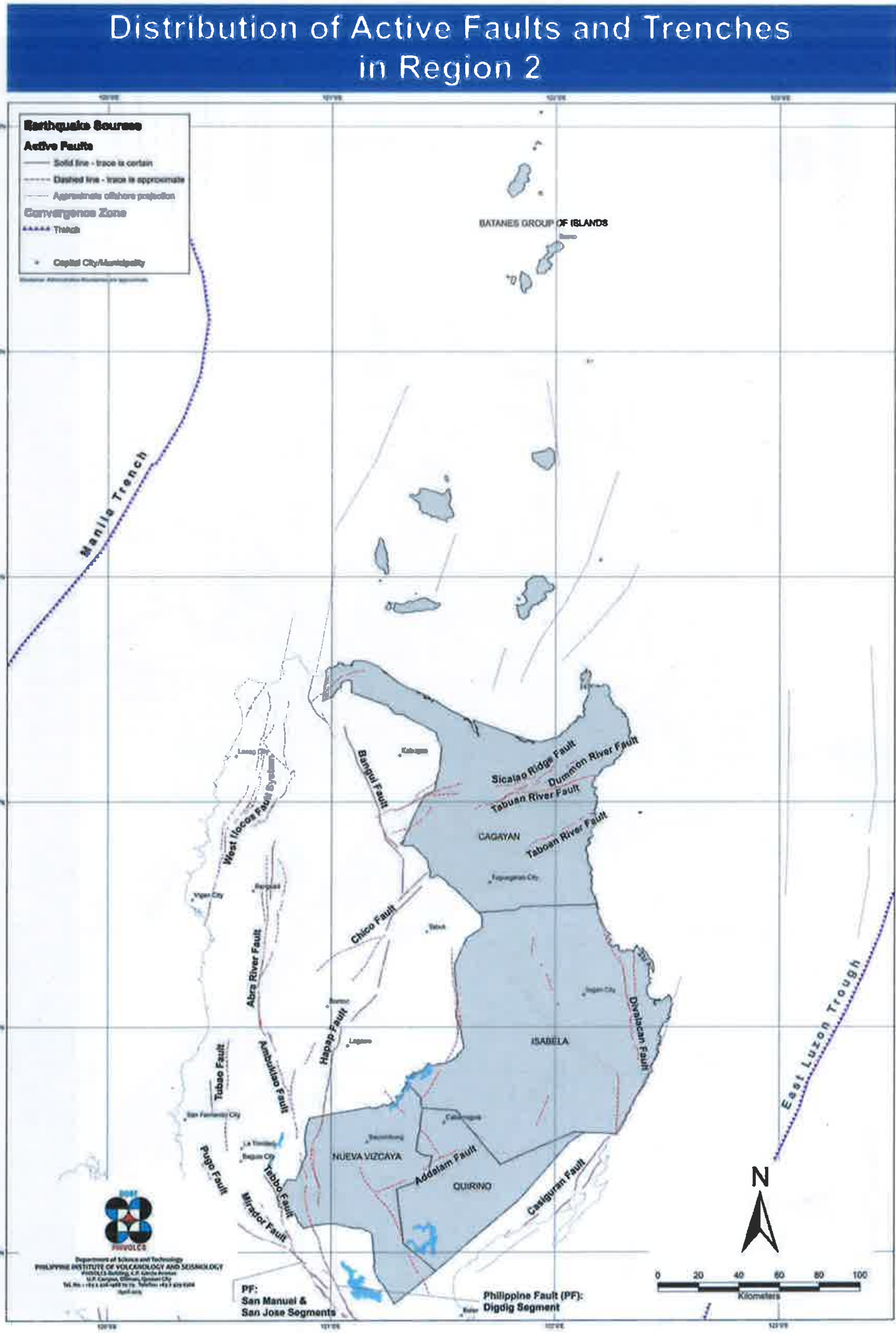


Figure 208-2D Distribution of Active Faults and Trenches in Region 2
National Structural Code of the Philippines Volume I, 7th Edition, 2015

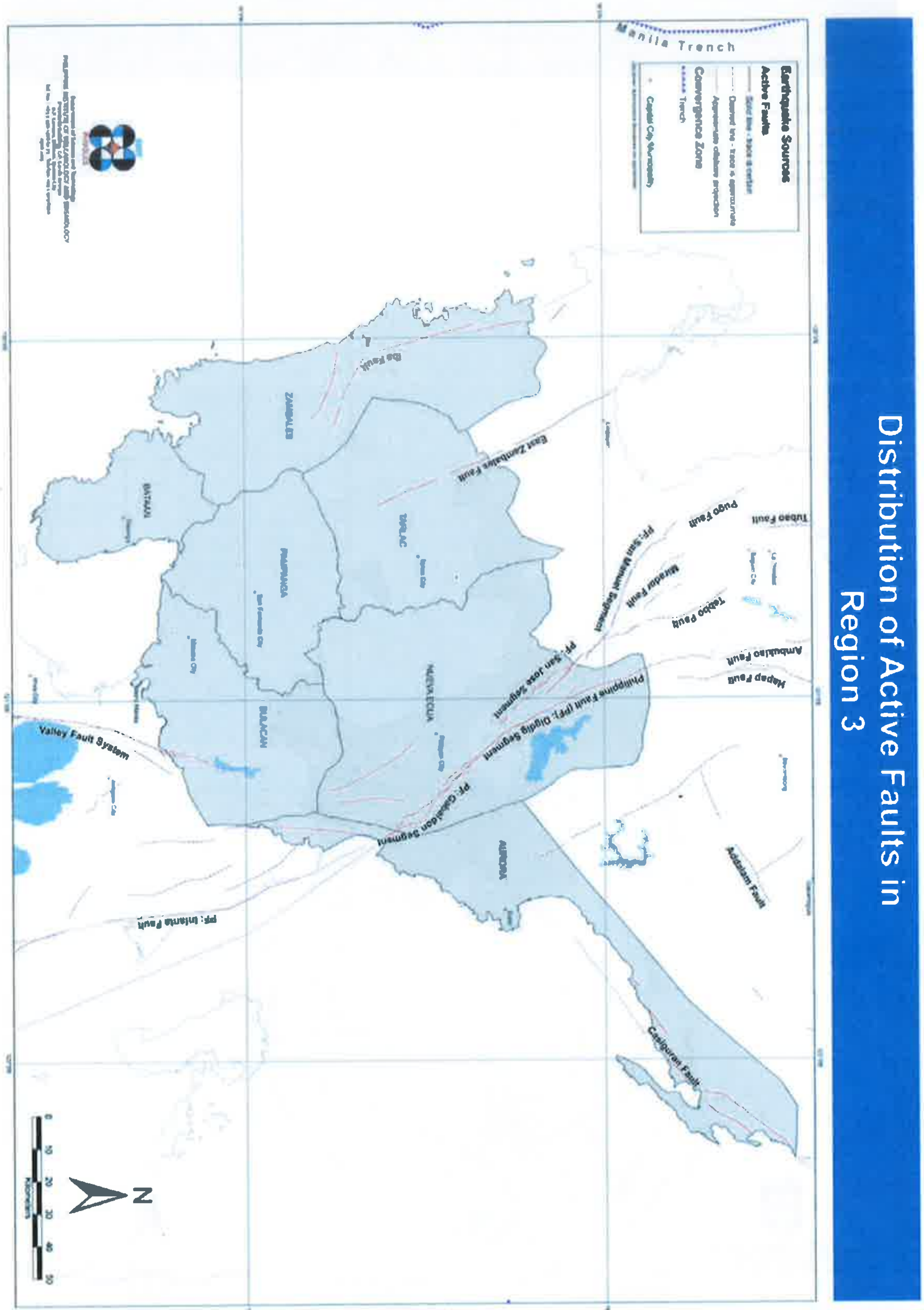


Figure 208-2E Distribution of Active Faults in Region 3

Distribution of Active Faults and Trenches in Region 4A

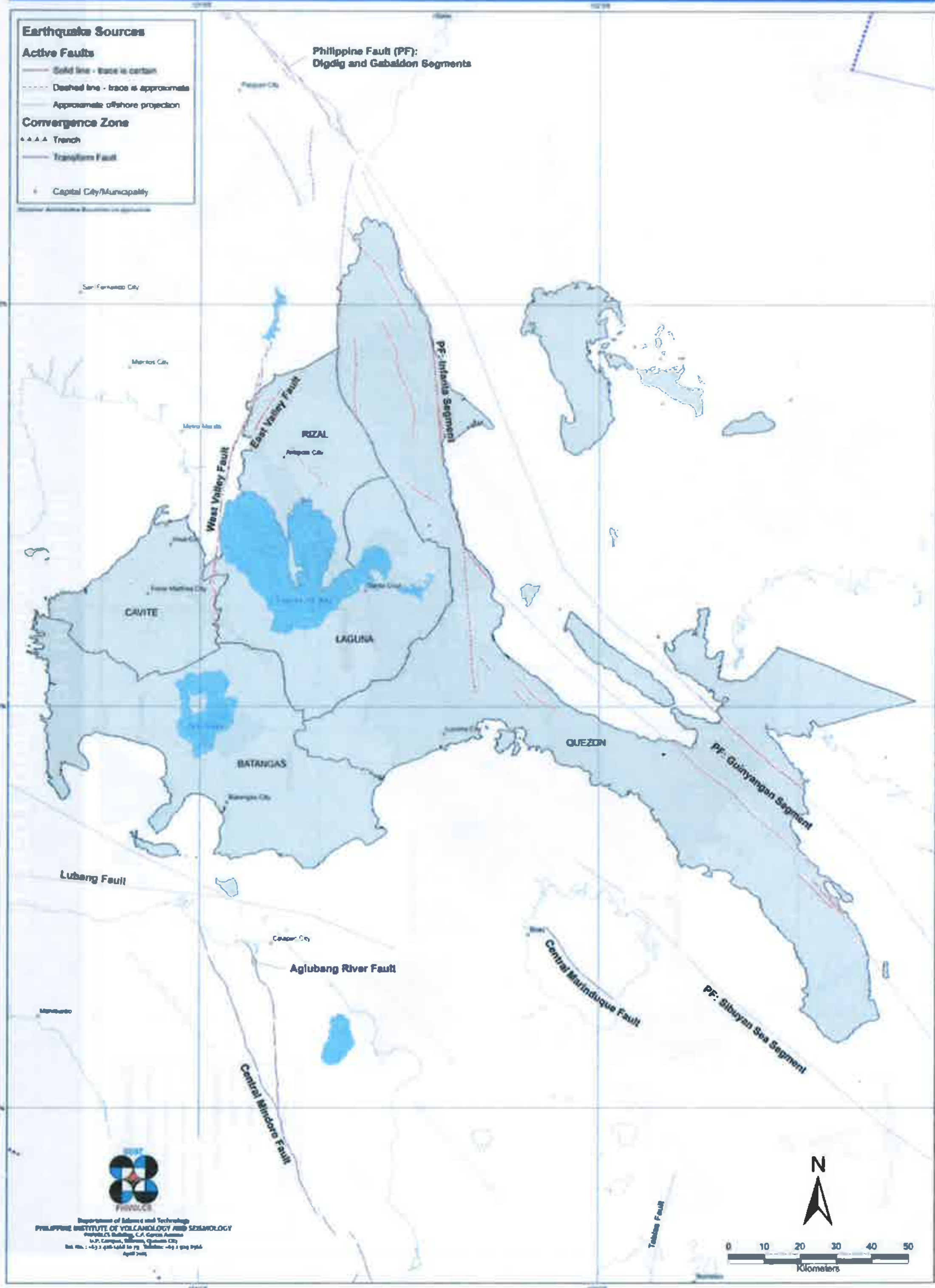


Figure 208-2F Distribution of Active Faults and Trenches in Region 4A

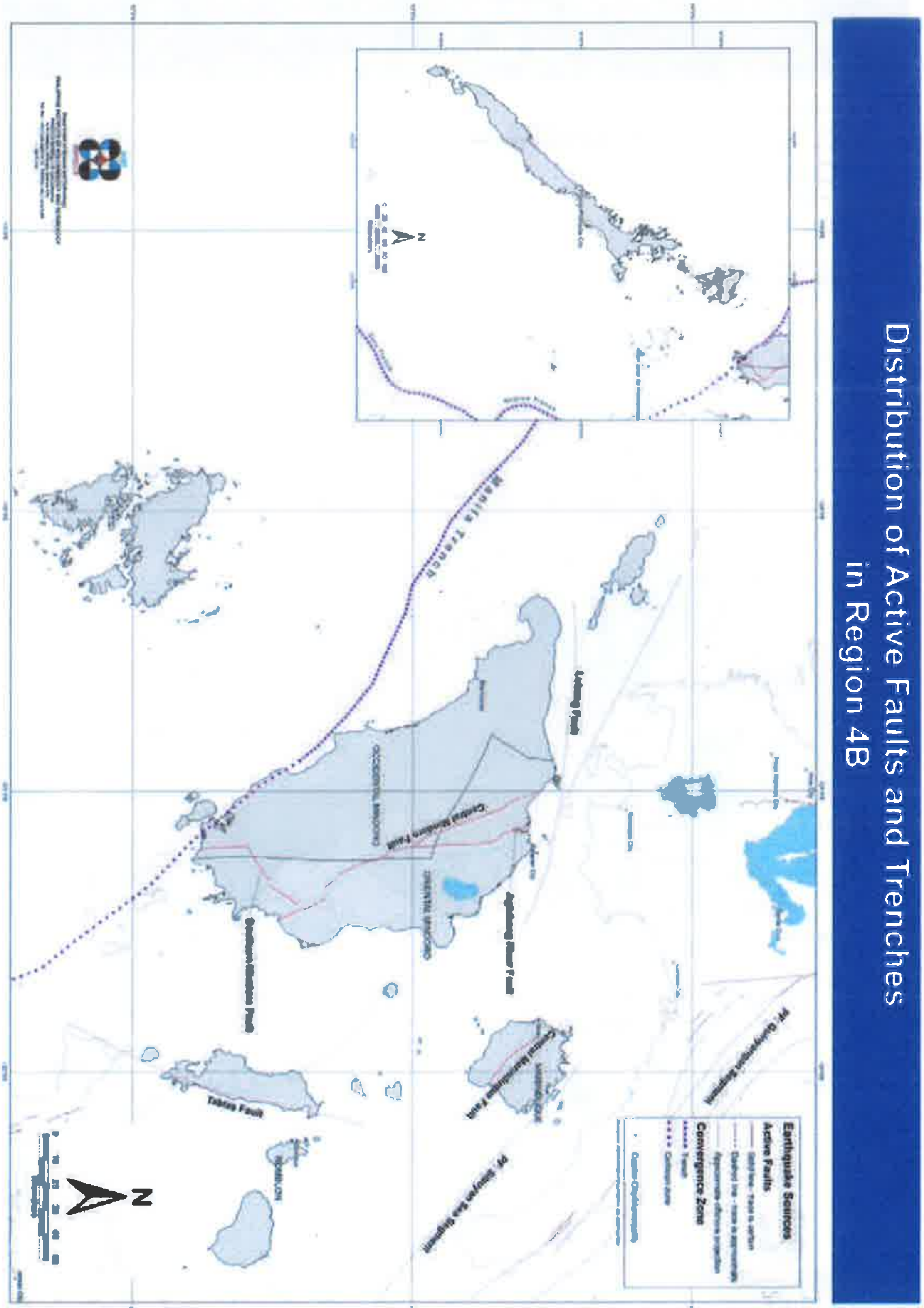


Figure 208-2F Distribution of Active Faults and Trenches in Region 4B

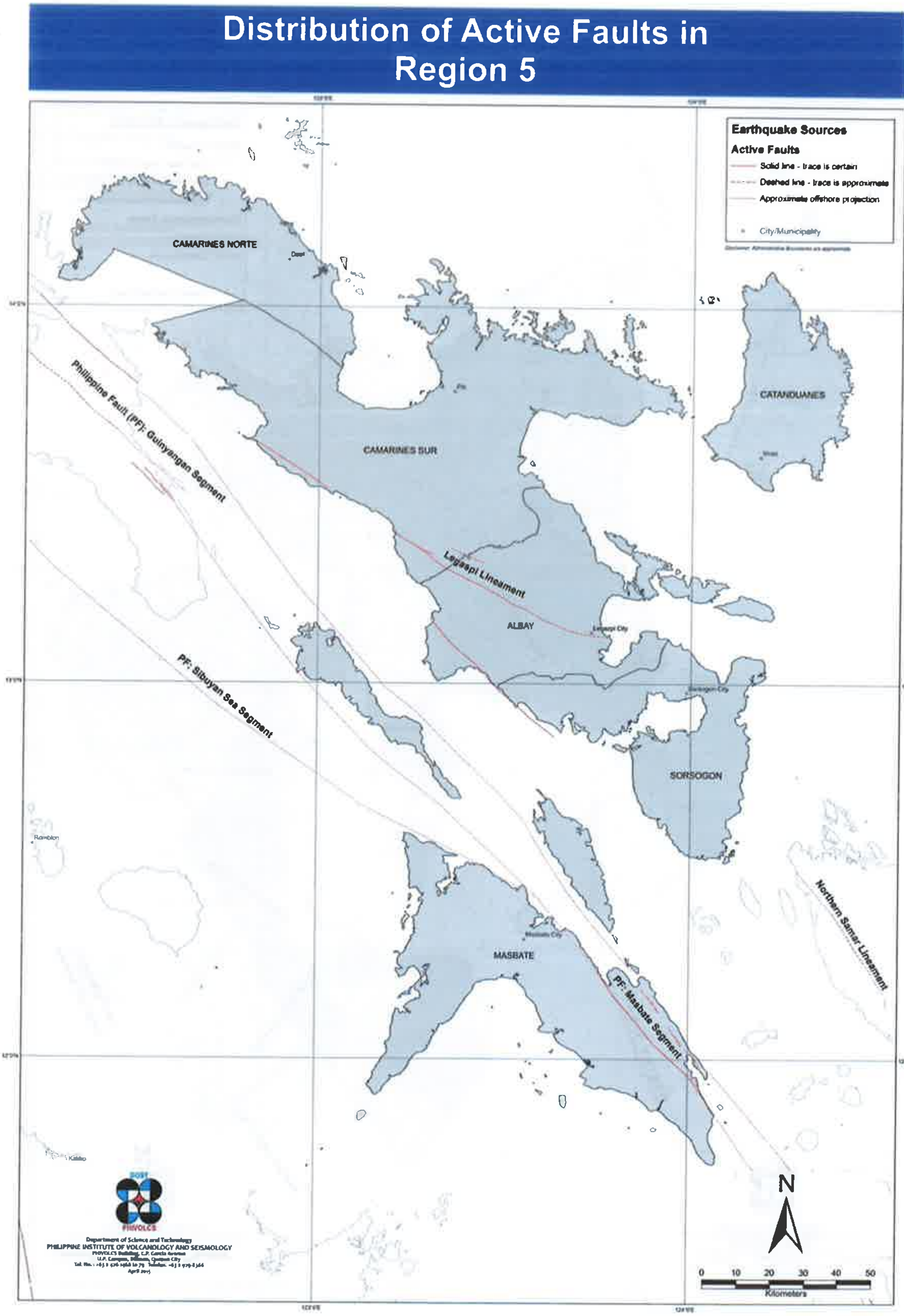


Figure 208-2E Distribution of Active Faults in Region 5

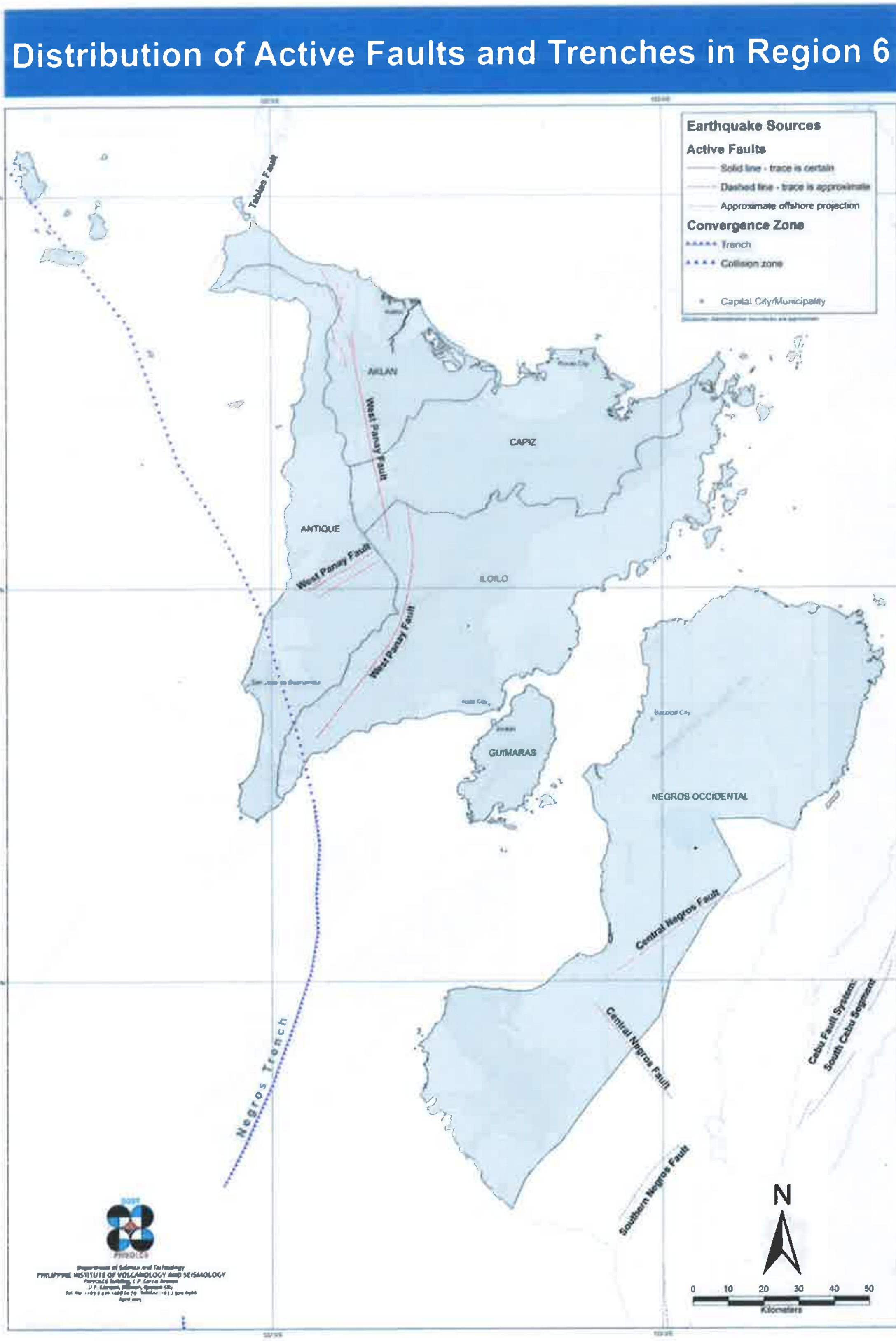


Figure 208-2F Distribution of Active Faults and Trenches in Region 6

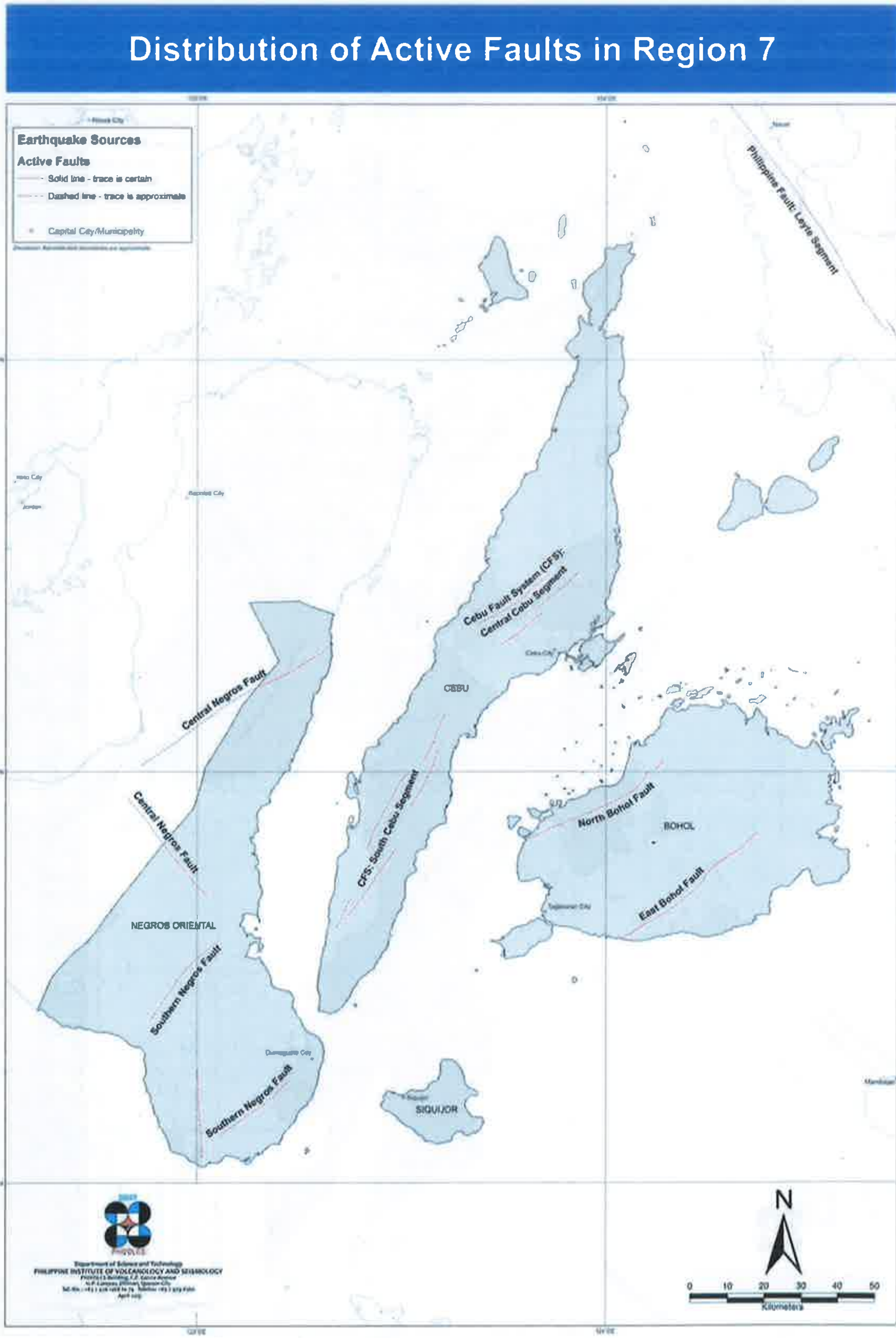


Figure 208-2G Distribution of Active Faults in Region 7

Distribution of Active Faults in Region 8

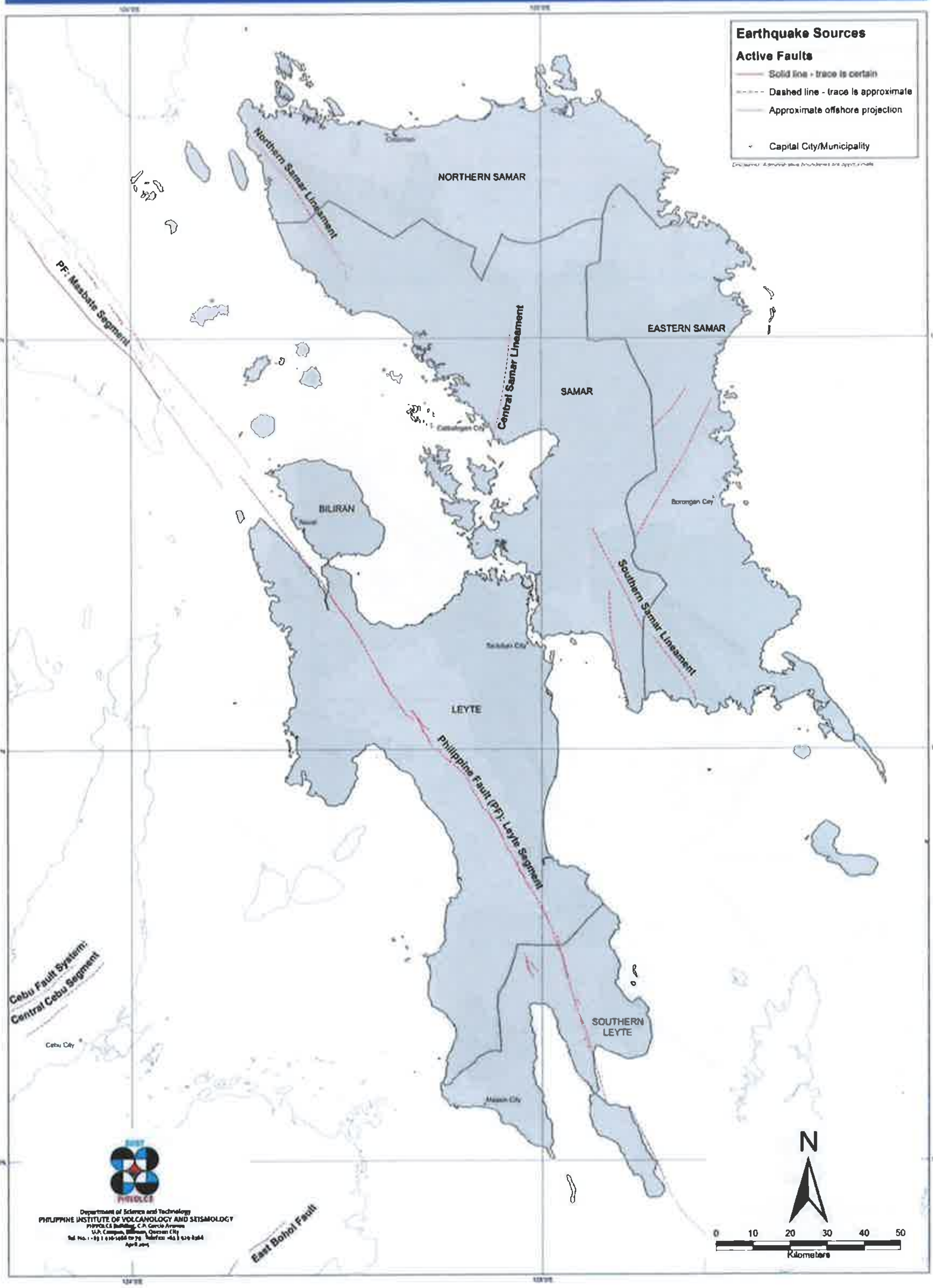


Figure 208-2H Distribution of Active Faults in Region 8

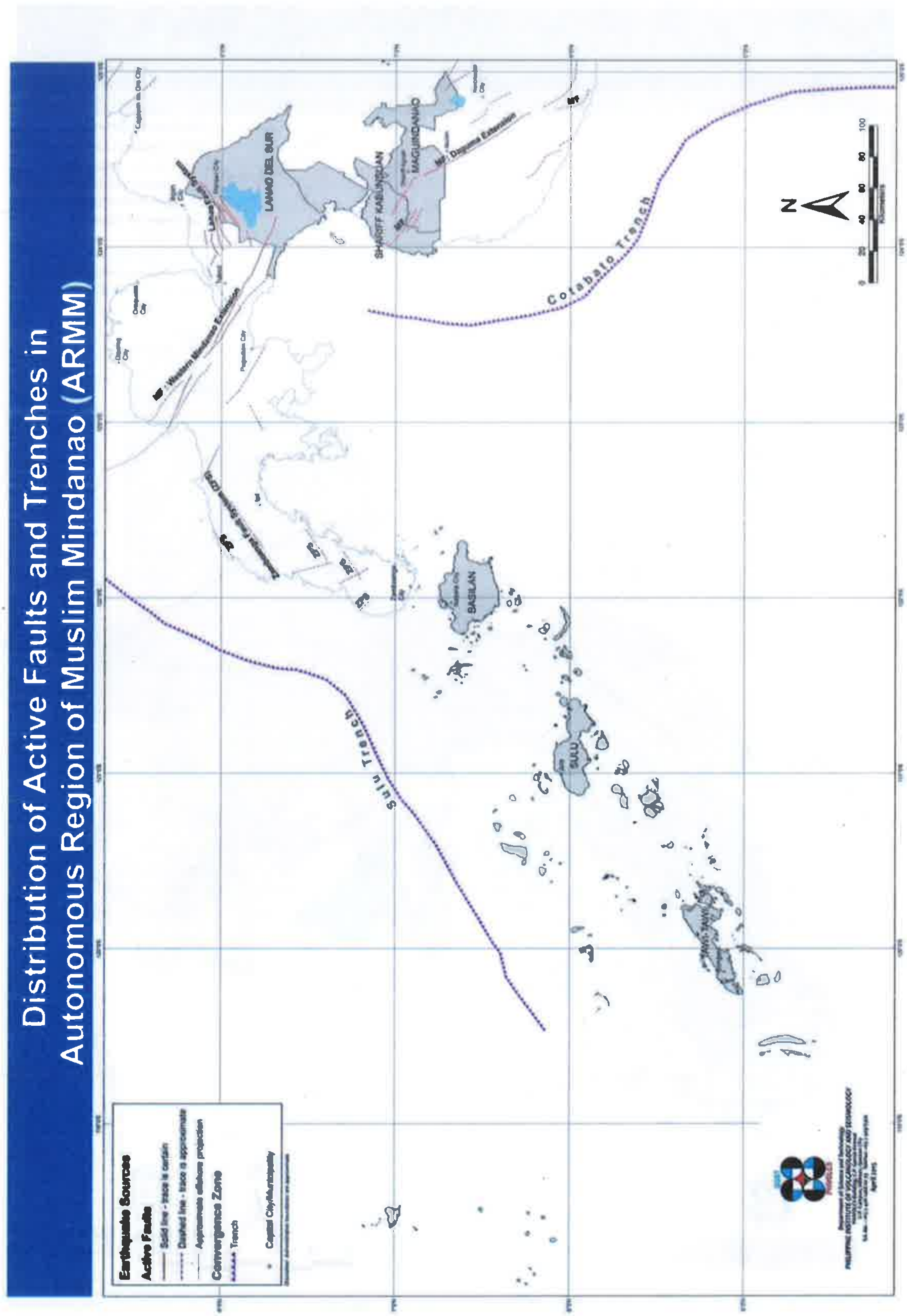


Figure 208-2I Distribution of Active Faults and Trenches in Autonomous Region of Muslim Mindanao (ARMM)

Distribution of Active Faults and Trenches in Region 9

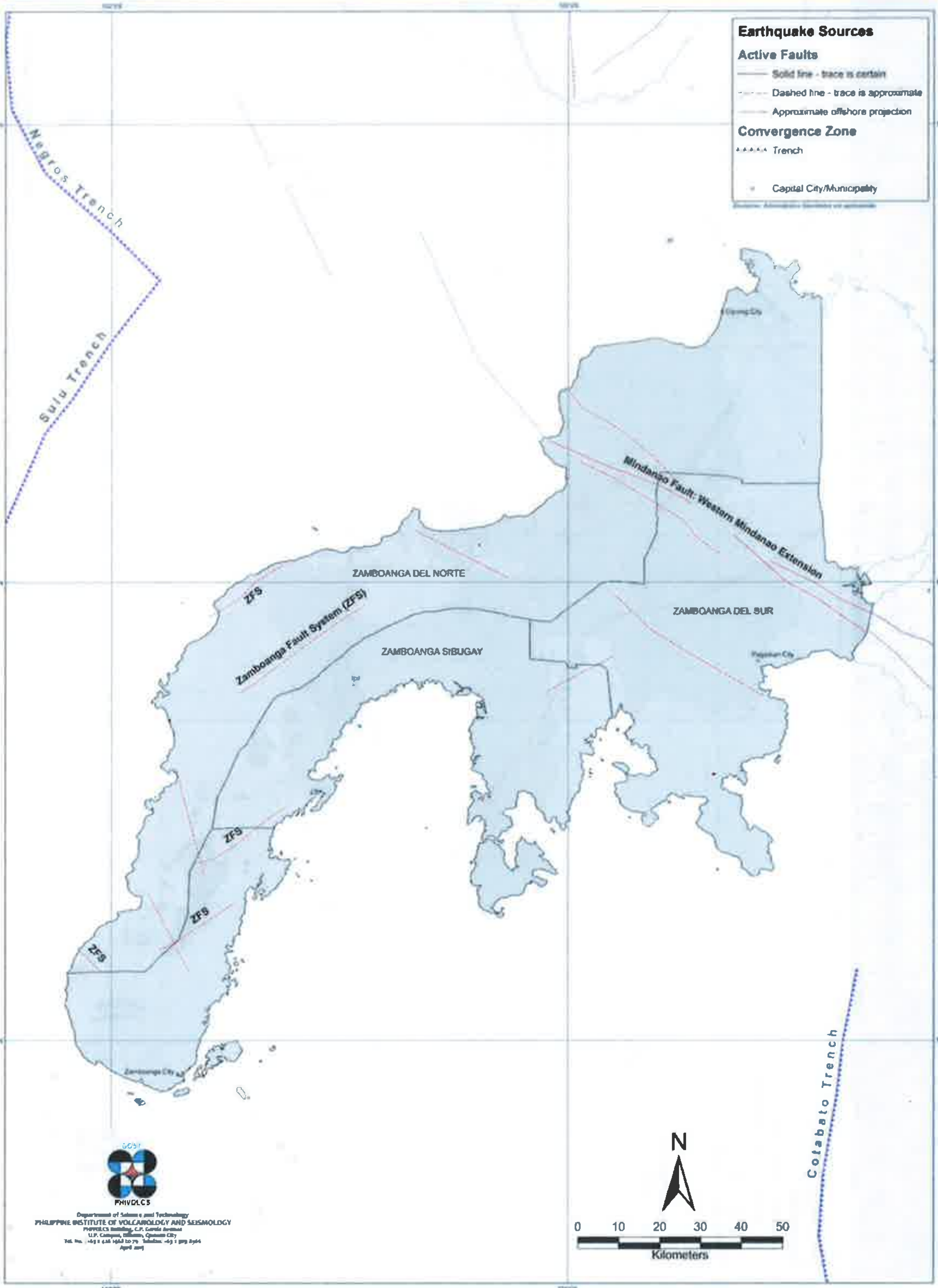


Figure 208-2J Distribution of Active Faults and Trenches in Region 9

Figure 208-2K Distribution of Active Faults and Trenches in Region 10

Distribution of Active Faults and Trenches in Region 11

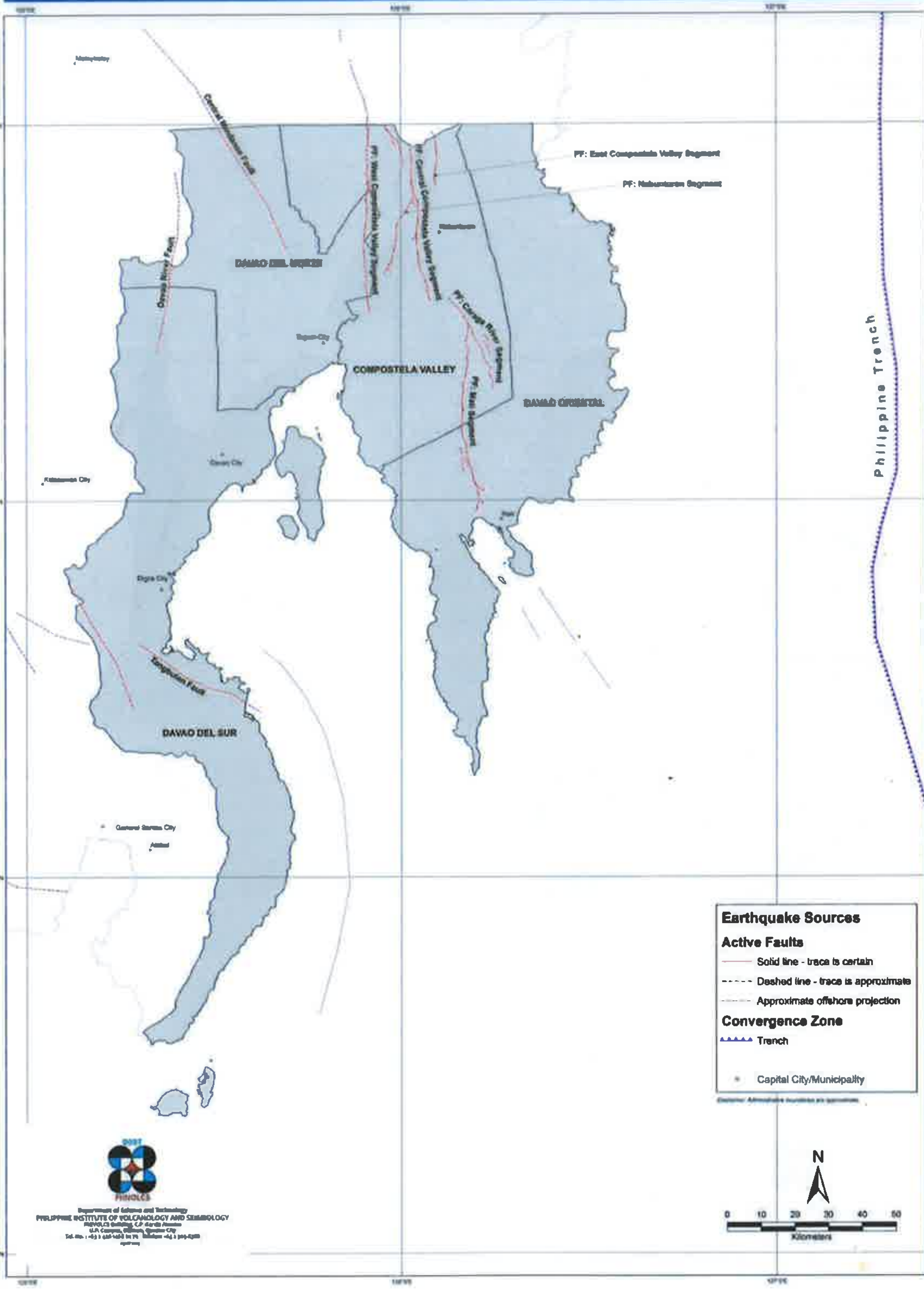


Figure 208-2L Distribution of Active Faults in Region 11

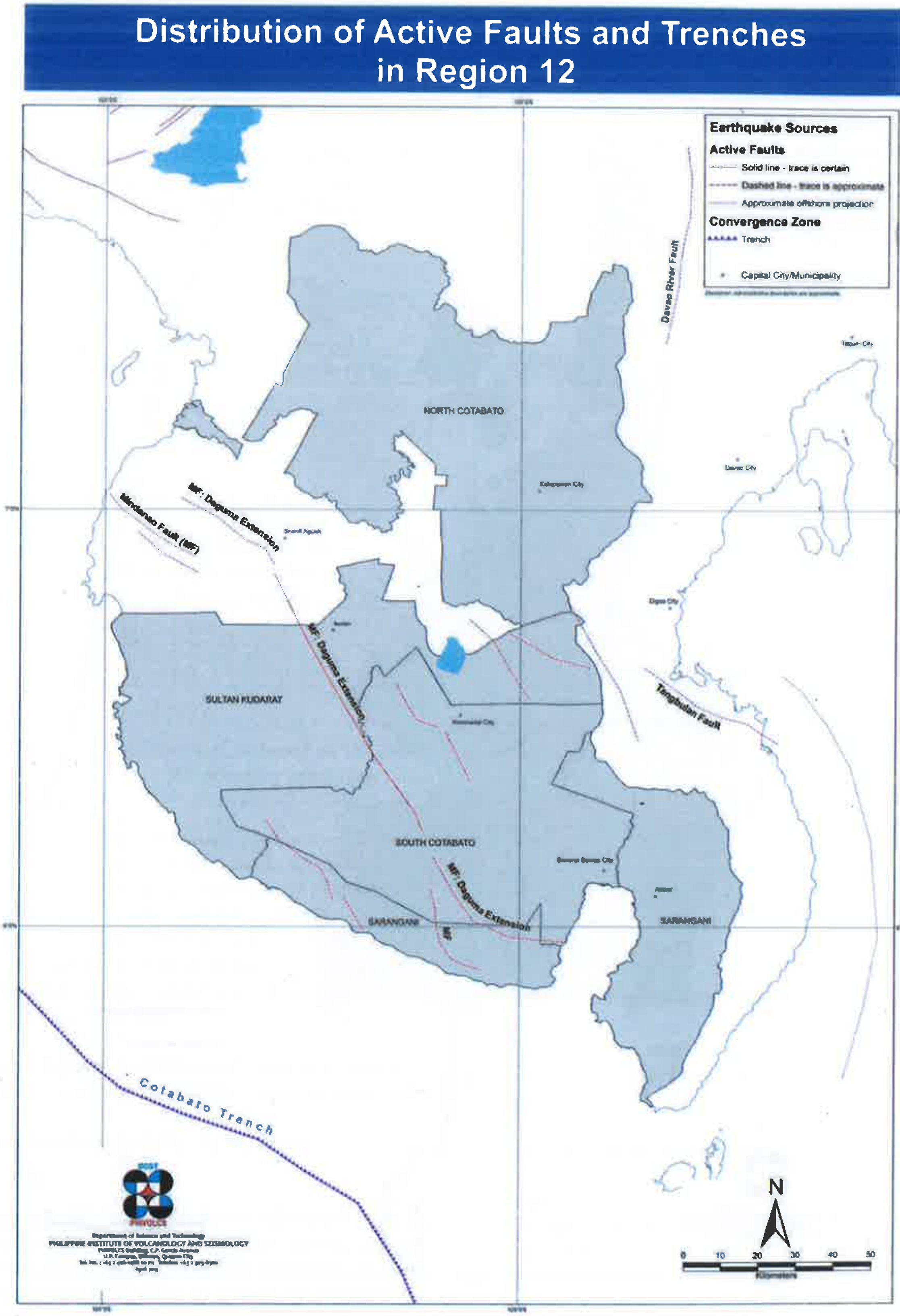


Figure 208-2M Distribution of Active Faults and Trenches in Region 12

Distribution of Active Faults and Trenches in Region 13

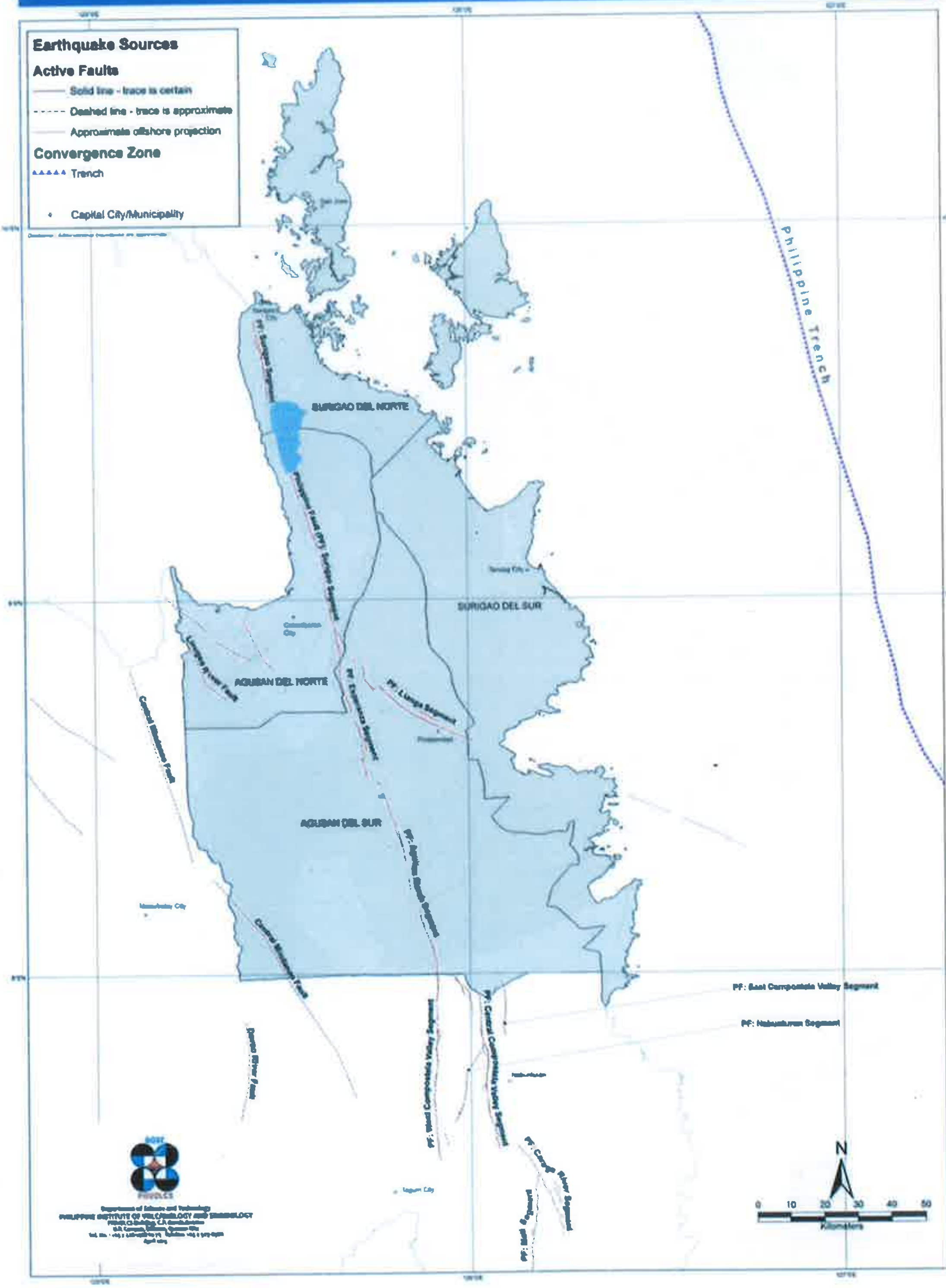


Figure 208-2N Distribution of Active Faults and Trenches in Region 13

208.4.4.3 Seismic Zone 4 Near-Source Factor

In Seismic Zone 4, each site shall be assigned near-source factors in accordance with Tables 208-5 and 208-6 based on the Seismic Source Type as set forth in Section 208.4.4.2.

For high rise structures and essential facilities within 2.0 km of a major fault, a site specific seismic elastic design response spectrum is recommended to be obtained for the specific area.

Table 208-5 Near-Source Factor N_a [1]

Seismic Source Type	Closest Distance To Known Seismic Source[2]		
	≤ 2 km	≤ 5 km	≥ 10 km
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

Table 208-6 Near-Source Factor, N_v [1]

Seismic Source Type	Closest Distance To Known Seismic Source[2]			
	≤ 2 km	5 km	10 km	≥ 15 km
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

Notes for Tables 208.5 and 208.6:

1 *The Near-Source Factor may be based on the linear interpolation of values for distances other than those shown in the table.*

2 *The closest distance to seismic source shall be taken as the minimum distance between the site and the area described by the vertical projection of the source on the surface (i.e., surface projection of fault plane). The surface projection need not include portions of the source at depths of 10 km or greater. The largest value of the Near-Source Factor considering all sources shall be used for design.*

The value of N_a used to determine C_a need not exceed 1.1 for structures complying with all the following conditions:

1. The soil profile type is S_A, S_B, S_C or S_D.
2. $\rho = 1.0$.
3. Except in single-storey structures, residential building accommodating 10 or fewer persons, private garages, carports, sheds and agricultural buildings, moment frame systems designated as part of the lateral-force-resisting system shall be special moment-resisting frames.
4. The exceptions to Section 515.6.5 shall not apply, except for columns in one-storey buildings or columns at the top storey of multistorey buildings.
5. None of the following structural irregularities is present: Type 1, 4 or 5 of Table 208-9, and Type 1 or 4 of Table 208-10.

208.4.4.4 Seismic Response Coefficients

Each structure shall be assigned a seismic coefficient, C_a, in accordance with Table 208-7 and a seismic coefficient, C_v, in accordance with Table 208-8.

Table 208-7 Seismic Coefficient, C_a

Soil Profile Type	Seismic Zone Z	
	$Z = 0.2$	$Z = 0.4$
S_A	0.16	$0.32N_a$
S_B	0.20	$0.40N_a$
S_C	0.24	$0.40N_a$
S_D	0.28	$0.44N_a$
S_E	0.34	$0.44N_a$
S_F	*See Footnote 1 of Table 208-8*	

Table 208-8 Seismic Coefficient, C_v

Soil Profile Type	Seismic Zone Z	
	$Z = 0.2$	$Z = 0.4$
S_A	0.16	$0.32N_V$
S_B	0.20	$0.40N_V$
S_C	0.32	$0.56N_V$
S_D	0.40	$0.64N_V$
S_E	0.64	$0.96N_V$
S_F	*See Footnote 1 of Table 208-8*	

1 *Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients*

208.4.5 Configuration Requirements

Each structure shall be designated as being structurally regular or irregular in accordance with Sections 208.4.5.1 and 208.4.5.2.

208.4.5.1 Regular Structures

Regular structures have no significant physical discontinuities in plan or vertical configuration or in their lateral-force-resisting systems such as the irregular features described in Section 208.4.5.2.

208.4.5.2 Irregular Structures

1. Irregular structures have significant physical discontinuities in configuration or in their lateral-force-resisting systems. Irregular features include, but are not limited to, those described in Tables 208-9 and 208-10. All structures in occupancy Categories 4 and 5 in Seismic Zone 2 need to be evaluated only for vertical irregularities of Type 5 (Table 208-9) and horizontal irregularities of Type 1 (Table 208-10).
2. Structures having any of the features listed in Table 208-9 shall be designated as if having a vertical irregularity.

Exception:

Where no storey drift ratio under design lateral forces is greater than 1.3 times the storey drift ratio of the storey above, the structure may be deemed to not have the structural irregularities of Type 1 or 2 in Table 208-9. The storey drift ratio for the top two stories need not be considered. The storey drifts for this determination may be calculated neglecting torsional effects.

3. Structures having any of the features listed in Table 208-10 shall be designated as having a plan irregularity.

Table 208-9 Vertical Structural Irregularities

Irregularity Type and Definition	Reference Section
1. Stiffness Irregularity – Soft Storey A soft storey is one in which the lateral stiffness is less than 70 % of that in the storey above or less than 80 percent of the average stiffness of the three stories above.	208.4.8.3 Item 2
2. Weight (Mass) Irregularity Mass irregularity shall be considered to exist where the effective mass of any storey is more than 150 % of the effective mass of an adjacent storey. A roof that is lighter than the floor below need not be considered.	208.4.8.3 Item 2
3. Vertical Geometric Irregularity Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral-force-resisting system in any storey is more than 130 % of that in an adjacent storey. One-storey penthouses need not be considered.	208.4.8.3 Item 2
4. In-Plane Discontinuity In Vertical Lateral-Force-Resisting Element Irregularity An in-plane offset of the lateral-load-resisting elements greater than the length of those elements.	208.5.8.1.5.1
5. Discontinuity In Capacity – Weak Storey Irregularity A weak storey is one in which the storey strength is less than 80 % of that in the storey above. The storey strength is the total strength of all seismic-resisting elements sharing the storey for the direction under consideration.	208.4.9.1

Table 208-10 Horizontal Structural Irregularities

Irregularity Type and Definition	Reference Section
1. **Torsional Irregularity - To Be Considered When Diaphragms Are Not Flexible** Torsional irregularity shall be considered to exist when the maximum storey drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.2 times the average of the storey drifts of the two ends of the structure.	208.7.2.7 Item 6
2. **Re-Entrant Corner Irregularity** Plan configurations of a structure and its lateral-force-resisting system contain re-entrant corners, where both projections of the structure beyond a re-entrant corner are greater than 15 % of the plan dimension of the structure in the given direction.	208.7.2.7 Items 6 and 7
3. **Diaphragm Discontinuity Irregularity** Diaphragms with abrupt discontinuities or variations in stiffness, including those having cutout or open areas greater than 50 % of the gross enclosed area of the diaphragm, or changes in effective diaphragm stiffness of more than 50 % from one storey to the next.	208.7.2.7 Item 6
4. **Out-Of-Plane Offsets Irregularity** Discontinuities in a lateral force path, such as out-of-plane offsets of the vertical elements	208.5.8.5.1 208.7.2.7 Item 6;
5. **Non-parallel Systems Irregularity** The vertical lateral-load-resisting elements are not parallel to or symmetric about the major orthogonal axes of the lateral force-resisting systems.	208.7.1

208.4.6 Structural Systems

Structural systems shall be classified as one of the types listed in Table 208-11 and defined in this section.

208.4.6.1 Bearing Wall System

A structural system without a complete vertical load-carrying space frame. Bearing walls or bracing systems provide support for all or most gravity loads. Resistance to lateral load is provided by shear walls or braced frames.

208.4.6.2 Building Frame System

A structural system with an essentially complete space frame providing support for gravity loads. Resistance to lateral load is provided by shear walls or braced frames.

208.4.6.3 Moment-Resisting Frame System

A structural system with an essentially complete space frame providing support for gravity loads. Moment-resisting frames provide resistance to lateral load primarily by flexural action of members.

208.4.6.4 Dual System

A structural system with the following features:

1. An essentially complete space frame that provides support for gravity loads.
2. Resistance to lateral load is provided by shear walls or braced frames and moment-resisting frames (SMRF, IMRF, MMRWF or steel OMRF). The moment-resisting frames shall be designed to independently resist at least 25 percent of the design base shear.
3. The two systems shall be designed to resist the total design base shear in proportion to their relative rigidities considering the interaction of the dual system at all levels.

208.4.6.5 Cantilevered Column System

A structural system relying on cantilevered column elements for lateral resistance.

208.4.6.6 Undefined Structural System

A structural system not listed in Table 208-11.

208.4.6.7 Non-building Structural System

A structural system conforming to Section 208.8.

208.4.7 Height Limits

Height limits for the various structural systems in Seismic Zone 4 are given in Table 208-11.

Exception:

Regular structures may exceed these limits by not more than 50 percent for unoccupied structures, which are not accessible to the general public.

208.4.8 Selection of Lateral Force Procedure

Any structure may be, and certain structures defined below shall be, designed using the dynamic lateral-force procedures of Section 208.5.3.

208.4.8.1 Simplified Static

The simplified static lateral-force procedure set forth in Section 208.5.1.1 may be used for the following structures of Occupancy Category IV or V:

1. Buildings of any occupancy (including single-family dwellings) not more than three stories in height excluding basements that use light-frame construction.

2. Other buildings not more than two stories in height excluding basements.

208.4.8.2 Static

The static lateral force procedure of Section 208.5 may be used for the following structures:

1. All structures, regular or irregular in Occupancy Categories IV and V in Seismic Zone 2.

2. Regular structures under 75 m in height with lateral force resistance provided by systems listed in Table 208-11, except where Section 208.4.8.3, Item 4, applies.

3. Irregular structures not more than five stories or 20 m in height.

4. Structures having a flexible upper portion supported on a rigid lower portion where both portions of the structure considered separately can be classified as being regular, the average storey stiffness of the lower portion is at least 10 times the average storey stiffness of the upper portion and the period of the entire structure is not greater than 1.1 times the period of the upper portion considered as a separate structure fixed at the base.

208.4.8.3 Dynamic

The dynamic lateral-force procedure of Section 208.5.3 shall be used for all other structures, including the following:

1. Structures 75 m or more in height, except as permitted by Section 208.4.8.2, Item 1.
2. Structures having a stiffness, weight or geometric vertical irregularity of Type 1, 2 or 3, as defined in Table 208-9, or structures having irregular features not described in Table 208-9 or 208-10, except as permitted by Section 208.4.10.3.1.
3. Structures over five stories or 20 m in height in Seismic Zone 4 not having the same structural system throughout their height except as permitted by Section 208.5.3.2.
4. Structures, regular or irregular, located on Soil Profile Type S_F, that have a period greater than 0.7 s. The analysis shall include the effects of the soils at the site and shall conform to Section 208.5.3.2, Item 4.

208.4.8.4 Alternative Procedures

208.4.8.4.1 General

Alternative lateral-force procedures using rational analyses based on well-established principles of mechanics may be used in lieu of those prescribed in these provisions.

208.4.8.4.2 Seismic Isolation

Seismic isolation, energy dissipation and damping systems may be used in the analysis and design of structures when approved by the building official and when special detailing is used to provide results equivalent to those obtained by the use of conventional structural systems.

208.4.9 System Limitations

208.4.9.1 Discontinuity

Structures with a discontinuity in capacity, vertical irregularity Type 5 as defined in Table 208-9, shall not be over two stories or 9 m in height where the weak storey has a calculated strength of less than 65 % of the storey above.

Exception:

Where the weak storey is capable of resisting a total lateral seismic force of $\mathbf{\Omega_o}$ *times the design force prescribed in Section 208.5.*

208.4.9.2 Undefined Structural Systems

For undefined structural systems not listed in Table 208-11, the coefficient $\boldsymbol{R}$ shall be substantiated by approved cyclic test data and analyses. The following items shall be addressed when establishing $\boldsymbol{R}$:

1. Dynamic response characteristics,
2. Lateral force resistance,
3. Over-strength and strain hardening or softening,
4. Strength and stiffness degradation,
5. Energy dissipation characteristics,
6. System ductility, and
7. Redundancy.

208.4.9.3 Irregular Features

All structures having irregular features described in Table 208-9 or 208-10 shall be designed to meet the additional requirements of those sections referenced in the tables.

208.4.10 Determination of Seismic Factors

208.4.10.1 Determination of Ω_o

For specific elements of the structure, as specifically identified in this code, the minimum design strength shall be the product of the seismic force over-strength factor $\mathbf{\Omega_o}$ and the design seismic forces set forth in Section 208.5. For both Allowable Stress Design and Strength Design, the Seismic Force Over-strength Factor, $\mathbf{\Omega_o}$, shall be taken from Table 208-11.

208.4.10.2 Determination of *R*

The value for ***R*** shall be taken from Table 208-11.

208.4.10.3 Combinations of Structural Systems

Where combinations of structural systems are incorporated into the same structure, the requirements of this section shall be satisfied.

208.4.10.3.1 Vertical Combinations

The value of ***R*** used in the design of any storey shall be less than or equal to the value of ***R*** used in the given direction for the storey above.

Exception:

This requirement need not be applied to a storey where the dead weight above that storey is less than 10 percent of the total dead weight of the structure.

Structures may be designed using the procedures of this section under the following conditions:

The entire structure is designed using the lowest ***R*** of the lateral force-resisting systems used, or

1. The following two-stage static analysis procedures may be used for structures conforming to Section 208.4.8.2, Item 4.
   1.1 The flexible upper portion shall be designed as a separate structure, supported laterally by the rigid lower portion, using the appropriate values of ***R*** and $\boldsymbol{\rho}$.

   1.2 The rigid lower portion shall be designed as a separate structure using the appropriate values of ***R*** and $\boldsymbol{\rho}$. The reactions from the upper portion shall be those determined from the analysis of the upper portion amplified by the ratio of the $(\boldsymbol{R/\rho})$ of the upper portion over $(\boldsymbol{R/\rho})$ of the lower portion.

208.4.10.3.2 Combinations along Different Axes

In Seismic Zone 4 where a structure has a bearing wall system in only one direction, the value of ***R*** used for design in the orthogonal direction shall not be greater than that used for the bearing wall system.

Any combination of bearing wall systems, building frame systems, dual systems or moment-resisting frame systems may be used to resist seismic forces in structures less than 50 m in height. Only combinations of dual systems and special moment-resisting frames shall be used to resist seismic forces in structures exceeding 50 m in height in Seismic Zone 4.

208.4.10.3.3 Combinations along the Same Axis

Where a combination of different structural systems is utilized to resist lateral forces in the same direction, the value of *R* used for design in that direction shall not be greater than the least value for any of the systems utilized in that same direction.

208.5 Minimum Design Lateral Forces and Related Effects

208.5.1 Simplified Static Force Procedure

Structures conforming to the requirements of Section 208.4.8.1 may be designed using this procedure.

208.5.1.1 Simplified Design Base Shear

The total design base shear in a given direction shall be determined from the following equation:

$$\boldsymbol{V = \frac{3C_a}{R}W} \qquad (208\text{-}5)$$

where the value of $\boldsymbol{C_a}$ shall be based on Table 208-7 for the soil profile type. When the soil properties are not known in sufficient detail to determine the soil profile type, Type $\boldsymbol{S_D}$ shall be used in Seismic Zone 4, and Type $\boldsymbol{S_E}$ shall be used in Seismic Zone 2. In Seismic Zone 4, the Near-Source Factor, $\boldsymbol{N_a}$, need not be greater than 1.2 if none of the following structural irregularities are present:

1. Type 1, 4 or 5 of Table 208-9, or

2. Type 1 or 4 of Table 208-10.

208.5.1.2 Vertical Distribution

The forces at each level shall be calculated using the following equation:

$$\boldsymbol{F_x = \frac{3C_a}{R}w_i} \qquad (208\text{-}6)$$

where the value of $\boldsymbol{C_a}$ shall be determined as in Section 208.5.1.1.

208.5.1.3 Horizontal Distribution of Shear

The design storey shear, V_x, in any storey is the sum of the forces F_t and F_x above that storey. V_x shall be distributed to the various elements of the vertical lateral force-resisting system in proportion to their rigidities, considering the rigidity of the diaphragm. See Section 208.7.2.3 for rigid elements that are not intended to be part of the lateral force-resisting systems.

Where diaphragms are not flexible, the mass at each level shall be assumed to be displaced from the calculated center of mass in each direction a distance equal to 5 percent of the building dimension at that level perpendicular to the direction of the force under consideration. The effect of this displacement on the storey shear distribution shall be considered.

Diaphragms shall be considered flexible for the purposes of distribution of storey shear and torsional moment when the maximum lateral deformation of the diaphragm is more than two times the average storey drift of the associated storey. This may be determined by comparing the computed midpoint in-plane deflection of the diaphragm itself under lateral load with the storey drift of adjoining vertical-resisting elements under equivalent tributary lateral load.

208.5.1.4 Horizontal Torsional Moments

Provisions shall be made for the increased shears resulting from horizontal torsion where diaphragms are not flexible. The most severe load combination for each element shall be considered for design.

The torsional design moment at a given storey shall be the moment resulting from eccentricities between applied design lateral forces at levels above that storey and the vertical-resisting elements in that storey plus an accidental torsion.

The accidental torsional moment shall be determined by assuming the mass is displaced as required by Section 208.5.1.3.

Where torsional irregularity exists, as defined in Table 208-10, the effects shall be accounted for by increasing the accidental torsion at each level by an amplification factor, A_x, determined from the following equation:

$$A_x = \left[\frac{\delta_{max}}{1.2\delta_{avg}}\right]^2 \qquad (208\text{-}7)$$

where

δ_{avg} = the average of the displacements at the extreme points of the structure at Level x, mm

δ_{max} = the maximum displacement at Level x, mm

The value of A_x need not exceed 3.0

208.5.1.5 Overturning

Every structure shall be designed to resist the overturning effects caused by earthquake forces specified in Section 208.5.2.3. At any level, the overturning moments to be resisted shall be determined using those seismic forces (F_t and F_x) that act on levels above the level under consideration. At any level, the incremental changes of the design overturning moment shall be distributed to the various resisting elements in the manner prescribed in Section 208.5.1.3. Overturning effects on every element shall be carried down to the foundation. See Sections 207.1 and 208.7 for combining gravity and seismic forces.

208.5.1.5.1 Elements Supporting Discontinuous Systems

208.5.1.5.1.1 General

Where any portion of the lateral load-resisting system is discontinuous, such as for vertical irregularity Type 4 in Table 208-9 or plan irregularity Type 4 in Table 208-10, concrete, masonry, steel and wood elements supporting such discontinuous systems shall have the design strength to resist the combination loads resulting from the special seismic load combinations of Section 203.5.

Exceptions:

1. *The quantity E_m in Section 208.6 need not exceed the maximum force that can be transferred to the element by the lateral-force-resisting system.*
2. *Concrete slabs supporting light-frame wood shear wall systems or light-frame steel and wood structural panel shear wall systems.*

For Allowable Stress Design, the design strength may be determined using an allowable stress increase of 1.7 and a resistance factor, ϕ, of 1.0. This increase shall not be combined with the one- third stress increase permitted by Section 203.4, but may be combined with the duration of load increase permitted in Section 615.3.4.

208.5.1.5.1.1.2 Detailing requirements in Seismic Zone 4

In Seismic Zone 4, elements supporting discontinuous systems shall meet the following detailing or member limitations:

1. Reinforced concrete or reinforced masonry elements designed primarily as axial-load members shall comply with Section 421.4.4.5.

2. Reinforced concrete elements designed primarily as flexural members and supporting other than light-frame wood shear wall system or light-frame steel and wood structural panel shear wall systems shall comply with Sections 421.3.2 and 421.3.3. Strength computations for portions of slabs designed as supporting elements shall include only those portions of the slab that comply with the requirements of these sections.

3. Masonry elements designed primarily as axial-load carrying members shall comply with Sections 706.1.12.4, Item 1, and 708.2.6.2.6.

4. Masonry elements designed primarily as flexural members shall comply with Section 708.2.6.2.5.

5. Steel elements designed primarily as axial-load members shall comply with Sections 515.4.2 and 515.4.3.

6. Steel elements designed primarily as flexural members or trusses shall have bracing for both top and bottom beam flanges or chords at the location of the support of the discontinuous system and shall comply with the requirements of Section 515.6.1.3.

7. Wood elements designed primarily as flexural members shall be provided with lateral bracing or solid blocking at each end of the element and at the connection location(s) of the discontinuous system.

208.5.1.5.2 At Foundation

See Sections 208.4.1 and 308.4 for overturning moments to be resisted at the foundation soil interface.

208.5.1.6 Applicability

Sections 208.6.2, 208.6.3, 208.5.2.1, 208.5.2.2, 208.5.2.3, 208.6.4, 208.6.5 and 208.5.3 shall not apply when using the simplified procedure.

Exception:

For buildings with relatively flexible structural systems, the building official may require consideration of $\boldsymbol{P\Delta}$ *effects and drift in accordance with Sections 208.6.3, 208.6.4 and 208.6.5.* $\boldsymbol{\Delta_s}$ *shall be determined using design seismic forces from Section 208.5.1.1.*

Where used, Δ_M shall be taken equal to 0.01 times the storey height of all stories. In Section 208.7.2.7, Equation 208-22 shall read $\boldsymbol{F_{px} = \frac{3C_a}{R} w_{px}}$ and need not exceed $\boldsymbol{C_a w_{px}}$, but shall not be less than $\boldsymbol{0.5 C_a w_{px}}$. $\boldsymbol{R}$ and $\boldsymbol{\Omega_o}$ shall be taken from Table 208-11.

208.5.2 Static Force Procedure

208.5.2.1 Design Base Shear

The total design base shear in a given direction shall be determined from the following equation:

$$\boldsymbol{V = \frac{C_v I}{RT} W} \tag{208-8}$$

The total design base shear need not exceed the following:

$$\boldsymbol{V = \frac{2.5 C_a I}{R} W} \tag{208-9}$$

The total design base shear shall not be less than the following:

$$\boldsymbol{V = 0.11 C_a I W} \tag{208-10}$$

In addition, for Seismic Zone 4, the total base shear shall also not be less than the following:

$$\boldsymbol{V = \frac{0.8 Z N_v I}{R} W} \tag{208-11}$$

208.5.2.2 Structure Period

The value of T shall be determined from one of the following methods:

1. **Method A:**

For all buildings, the value T may be approximated from the following equation:

$$T = C_t(h_n)^{3/4} \tag{208-12}$$

where

C_t = 0.0853 for steel moment-resisting frames
C_t = 0.0731 for reinforced concrete moment-resisting frames and eccentrically braced frames
C_t = 0.0488 for all other buildings

Alternatively, the value of C_t for structures with concrete or masonry shear walls may be taken as $0.0743/\sqrt{A_c}$.

The value of A_c shall be determined from the following equation:

$$A_c = \sum A_e[0.2 + (D_e/h_n)^2] \tag{208-13}$$

The value of D_e/h_n used in Equation 208-13 shall not exceed 0.9.

2. **Method B:**

The fundamental period T may be calculated using the structural properties and deformational characteristics of the resisting elements in a properly substantiated analysis. The analysis shall be in accordance with the requirements of Section 208.6.2. The value of T from Method B shall not exceed a value 30 percent greater than the value of T obtained from Method A in Seismic Zone 4, and 40 percent in Seismic Zone 2.

The fundamental period T may be computed by using the following equation:

$$T = 2\pi\sqrt{\frac{(\sum_{i=1}^{n} w_i\delta_i^2)}{g(\sum_{i=1}^{n} wf_i\delta_i)}} \tag{208-14}$$

The values of f_i represent any lateral force distributed approximately in accordance with the principles of Equations. 208-15, 208-16 and 208-17 or any other rational distribution. The elastic deflections, δ_i, shall be calculated using the applied lateral forces, f_i.

208.5.2.3 Vertical Distribution of Force

The total force shall be distributed over the height of the structure in conformance with Equations 208-15, 208-16 and 208-17 in the absence of a more rigorous procedure.

$$V = F_t + \sum_{i=1}^{n} F_i \tag{208-15}$$

The concentrated force F_t at the top, which is in addition to F_n, shall be determined from the equation:

$$F_t = 0.07TV \tag{208-16}$$

The value of T used for the purpose of calculating F_t shall be the period that corresponds with the design base shear as computed using Equation 208-4. F_t need not exceed $0.25V$ and may be considered as zero where T is 0.7 s or less. The remaining portion of the base shear shall be distributed over the height of the structure, including Level n, according to the following equation:

$$F_x = \frac{(V - F_t)w_x h_x}{\sum_{i=1}^{n} w_i h_i} \tag{208-17}$$

At each level designated as x, the force F_x shall be applied over the area of the building in accordance with the mass distribution at that level. Structural displacements and design seismic forces shall be calculated as the effect of forces F_x and F_t applied at the appropriate levels above the base.

208.5.3 Dynamic Analysis Procedures

208.5.3.1 General

Dynamic analyses procedures, when used, shall conform to the criteria established in this section. The analysis shall be based on an appropriate ground motion representation and shall be performed using accepted principles of dynamics.

Structures that are designed in accordance with this section shall comply with all other applicable requirements of these provisions.

208.5.3.2 Ground Motion

The ground motion representation shall, as a minimum, be one having a 10-percent probability of being exceeded in 50 years, shall not be reduced by the quantity $\boldsymbol{R}$ and may be one of the following:

1. An elastic design response spectrum constructed in accordance with Figure 208-3, using the values of $\boldsymbol{C_a}$ and $\boldsymbol{C_v}$ consistent with the specific site. The design acceleration ordinates shall be multiplied by the acceleration of gravity, 9.815 m/sec^2.

2. A site-specific elastic design response spectrum based on the geologic, tectonic, seismologic and soil characteristics associated with the specific site. The spectrum shall be developed for a damping ratio of 0.05, unless a different value is shown to be consistent with the anticipated structural behavior at the intensity of shaking established for the site.

3. Ground motion time histories developed for the specific site shall be representative of actual earthquake motions. Response spectra from time histories, either individually or in combination, shall approximate the site design spectrum conforming to Section 208.5.3.2, Item 2.

4. For structures on Soil Profile Type $\boldsymbol{S_F}$, the following requirements shall apply when required by Section 208.4.8.3, Item 4:

   4.1 The ground motion representation shall be developed in accordance with Items 2 and 3.

   4.2 Possible amplification of building response due to the effects of soil-structure interaction and lengthening of building period caused by inelastic behavior shall be considered.

5. The vertical component of ground motion may be defined by scaling corresponding horizontal accelerations by a factor of two- thirds. Alternative factors may be used when substantiated by site-specific data. Where the Near-Source Factor, $\boldsymbol{N_a}$, is greater than **1.0**, site-specific vertical response spectra shall be used in lieu of the factor of two-thirds.

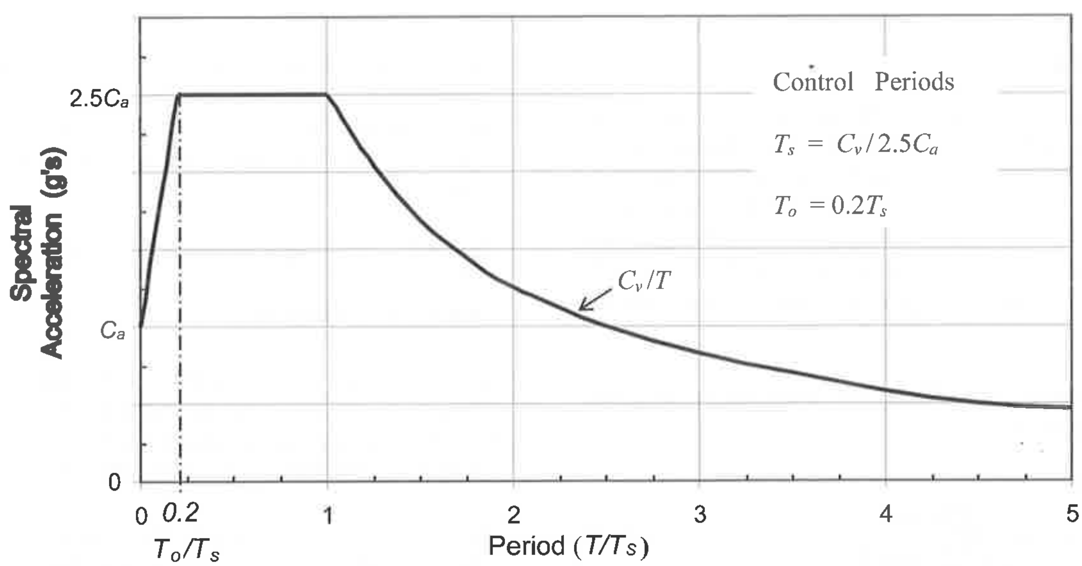


Figure 208-3
Design Response Spectra

208.5.3.3 Mathematical Model

A mathematical model of the physical structure shall represent the spatial distribution of the mass and stiffness of the structure to an extent that is adequate for the calculation of the significant features of its dynamic response. A three-dimensional model shall be used for the dynamic analysis of structures with highly irregular plan configurations such as those having a plan irregularity defined in Table 208-10 and having a rigid or semi-rigid diaphragm. The stiffness properties used in the analysis and general mathematical modeling shall be in accordance with Section 208.6.2.

208.5.3.4 Description of Analysis Procedures

208.5.3.4.1 Response Spectrum Analysis

An elastic dynamic analysis of a structure utilizing the peak dynamic response of all modes having a significant contribution to total structural response. Peak modal responses are calculated using the ordinates of the appropriate response spectrum curve which correspond to the modal periods. Maximum modal contributions are combined in a statistical manner to obtain an approximate total structural response.

208.5.3.4.2 Time History Analysis

An analysis of the dynamic response of a structure at each increment of time when the base is subjected to a specific ground motion time history.

208.5.3.5 Response Spectrum Analysis

208.5.3.5.1 Response Spectrum Representation and Interpretation of Results

The ground motion representation shall be in accordance with Section 208.5.3.2. The corresponding response parameters, including forces, moments and displacements, shall be denoted as Elastic Response Parameters. Elastic Response Parameters may be reduced in accordance with Section 208.5.3.5.4.

The base shear for a given direction, determined using dynamic analysis must not be less than the value obtained by the equivalent lateral force method of Section 208.5.2. In this case, all corresponding response parameters are adjusted proportionately.

208.5.3.5.2 Number of Modes

The requirement of Section 208.5.3.4.1 that all significant modes be included may be satisfied by demonstrating that for the modes considered, at least 90 percent of the participating mass of the structure is included in the calculation of response for each principal horizontal direction.

208.5.3.5.3 Combining Modes

The peak member forces, displacements, storey forces, storey shears and base reactions for each mode shall be combined by recognized methods. When three-dimensional models are used for analysis, modal interaction effects shall be considered when combining modal maxima.

208.5.3.5.4 Reduction of Elastic Response Parameters for Design

Elastic Response Parameters may be reduced for purposes of design in accordance with the following items, with the limitation that in no case shall the Elastic Response Parameters be reduced such that the corresponding design base shear is less than the Elastic Response Base Shear divided by the value of ***R***.

1. For all regular structures where the ground motion representation complies with Section 208.5.3.2, Item 1, Elastic Response Parameters may be reduced such that the corresponding design base shear is not less than 90 percent of the base shear determined in accordance with Section 208.5.2.

2. For all regular structures where the ground motion representation complies with Section 208.5.3.2, Item 2, Elastic Response Parameters may be reduced such that the corresponding design base shear is not less than 80 percent of the base shear determined in accordance with Section 208.5.2.

3. For all irregular structures, regardless of the ground motion representation, Elastic Response Parameters may be reduced such that the corresponding design base shear is not less than 100 percent of the base shear determined in accordance with Section 208.5.2.

The corresponding reduced design seismic forces shall be used for design in accordance with Section 203.

208.5.3.5.5 Directional Effects

Directional effects for horizontal ground motion shall conform to the requirements of Section 208.6. The effects of vertical ground motions on horizontal cantilevers and pre-stressed elements shall be considered in accordance with Section 208.6. Alternately, vertical seismic response may be determined by dynamic response methods; in no case shall the response used for design be less than that obtained by the static method.

208.5.3.5.6 Torsion

The analysis shall account for torsional effects, including accidental torsional effects as prescribed in Section 208.5.1.4. Where three-dimensional models are used for analysis, effects of accidental torsion shall be accounted for by appropriate adjustments in the model such as adjustment of mass locations, or by equivalent static procedures such as provided in Section 208.5.1.3.

208.5.3.5.7 Dual Systems

Where the lateral forces are resisted by a dual system as defined in Section 208.4.6.4, the combined system shall be capable of resisting the base shear determined in accordance with this section. The moment-resisting frame shall conform to Section 208.4.6.4, Item 2, and may be analyzed using either the procedures of Section 208.5.2.3 or those of Section 208.5.3.5.

208.5.3.6 Time History Analysis

208.5.3.6.1 Time History

Time-history analysis shall be performed with pairs of appropriate horizontal ground-motion time- history components that shall be selected and scaled from not less than three recorded events. Appropriate time histories shall have magnitudes, fault distances and source mechanisms that are consistent with those that control the design-basis earthquake (or maximum capable earthquake). Where three appropriate recorded ground-motion time-history pairs are not available, appropriate simulated ground-motion time-history pairs may be used to make up the total number required. For each pair of horizontal ground-motion components, the square root of the sum of the squares (SRSS) of the 5 percent-damped site-specific spectrum of the scaled horizontal components shall be constructed. The motions shall be scaled such that the average value of the SRSS spectra does not fall below 1.4 times the 5 percent-damped spectrum of the design-basis earthquake for periods from $\mathbf{0.2}T$ second to $\mathbf{1.5}T$ seconds. Each pair of time histories shall be applied simultaneously to the model considering torsional effects.

The parameter of interest shall be calculated for each time-history analysis. If three time-history analyses are performed, then the maximum response of the parameter of interest shall be used for design. If seven or more time-history analyses are performed, then the average value of the response parameter of interest may be used for design.

208.5.3.6.2 Elastic Time History Analysis

Elastic time history shall conform to Sections 208.5.3.1, 208.5.3.2, 208.5.3.3, 208.5.3.5.2, 208.5.3.5.4, 208.6.5.3.5.5, 208.6.5.3.5.6, 208.5.3.5.7 and 208.5.3.6.1 and 208.6.6.1. Response parameters from elastic time-history analysis shall be denoted as Elastic Response Parameters. All elements shall be designed using Strength Design. Elastic Response Parameters may be scaled in accordance with Section 208.5.3.5.4.

208.5.3.6.3 Nonlinear Time History Analysis

208.5.3.6.3.1 Nonlinear Time History

Nonlinear time history analysis shall meet the requirements of Section 208.4.8.4, and time histories shall be developed and results determined in accordance with the requirements of Section 208.5.3.6.1. Capacities and characteristics of nonlinear elements shall be modeled consistent with test data or substantiated analysis, considering the Importance Factor. The maximum inelastic response displacement shall not be reduced and shall comply with Section 208.6.5.

208.5.3.6.3.2 Design Review

When nonlinear time-history analysis is used to justify a structural design, a design review of the lateral- force-resisting system shall be performed by an independent engineering team, including persons licensed in the appropriate disciplines and experienced in seismic analysis methods. The lateral-force-resisting system design review shall include, but not be limited to, the following:

1. Reviewing the development of site-specific spectra and ground-motion time histories.
2. Reviewing the preliminary design of the lateral-force-resisting system.
3. Reviewing the final design of the lateral-force-resisting system and all supporting analyses.

The engineer-of-record shall submit with the plans and calculations a statement by all members of the engineering team doing the review stating that the above review has been performed.

208.6 Earthquake Loads and Modeling Requirements

208.6.1 Earthquake Loads

Structures shall be designed for ground motion producing structural response and seismic forces in any horizontal direction. The following earthquake loads shall be used in the load combinations set forth in Section 203:

$$E = \rho E_h + E_v \tag{208-18}$$

$$E_m = \Omega_o E_h \tag{208-19}$$

where

E = the earthquake load on an element of the structure resulting from the combination of the horizontal component, E_h, and the vertical component, E_v

E_h = the earthquake load due to the base shear, V, as set forth in Section 208.5.2 or the design lateral force, F_p, as set forth in Section 208.9

E_m = the estimated maximum earthquake force that can be developed in the structure as set forth in Section 208.6.1, and used in the design of specific elements of the structure, as specifically identified in this section

E_v = the load effect resulting from the vertical component of the earthquake ground motion and is equal to an addition of $0.5C_aID$ to the dead load effect, D, for Strength Design, and may be taken as zero for Allowable Stress Design

Ω_o = the seismic force amplification factor that is required to account for structural overstrength, as set forth in Section 208.4.10.1

ρ = Reliability/Redundancy Factor as given by the following equation:

$$\rho = 2 - \frac{6.1}{r_{max}\sqrt{A_B}} \tag{208-20}$$

where

r_{max} = the maximum element-storey shear ratio. For a given direction of loading, the element-storey shear ratio is the ratio of the design storey shear in the most heavily loaded single element divided by the total design storey shear.

For any given Storey Level i, the element-storey shear ratio is denoted as r_i. The maximum element-storey shear ratio r_{max} is defined as the largest of the element storey shear ratios, r_i, which occurs in any of the storey levels at or below the two-thirds height level of the building.

For braced frames, the value of r_i is equal to the maximum horizontal force component in a single brace element divided by the total storey shear.

For moment frames, r_i shall be taken as the maximum of the sum of the shears in any two adjacent columns in a moment frame bay divided by the storey shear. For columns common to two bays with moment-resisting connections on opposite sides at Level i in the direction under consideration, 70 percent of the shear in that column may be used in the column shear summation.

For shear walls, r_i shall be taken as the maximum value of the product of the wall shear multiplied by $3/l_w$ and divided by the total storey shear, where l_w is the length of the wall in meter.

For dual systems, r_i shall be taken as the maximum value of r_i as defined above considering all lateral-load-resisting elements. The lateral loads shall be distributed to elements based on relative rigidities considering the interaction of the dual system. For dual systems, the value of ρ need not exceed 80 percent of the value calculated above.

ρ shall not be taken less than 1.0 and need not be greater than 1.5. For special moment-resisting frames, except when used in dual systems, ρ shall not exceed 1.25. The number of bays of special moment-resisting frames shall be increased to reduce r, such that ρ is less than or equal to 1.25.

Exception:
A_B may be taken as the average floor area in the upper setback portion of the building where a larger base area exists at the ground floor.

When calculating drift, or when the structure is located in Seismic Zone 2, ρ shall be taken equal to 1.0.

The ground motion producing lateral response and design seismic forces may be assumed to act non-concurrently in the direction of each principal axis of the structure, except as required by Section 208.7.2.

Seismic dead load, W, is the total dead load and applicable portions of other loads listed below.

1. In storage and warehouse occupancies, a minimum of 25 percent of the floor live load shall be applicable.

2. Where a partition load is used in the floor design, a load of not less than 0.5 kN/m^2 shall be included.

3. Total weight of permanent equipment shall be included.

208.6.2 Modeling Requirements

The mathematical model of the physical structure shall include all elements of the lateral-force-resisting system. The model shall also include the stiffness and strength of elements, which are significant to the distribution of forces, and shall represent the spatial distribution of the mass and stiffness of the structure. In addition, the model shall comply with the following:

1. Stiffness properties of reinforced concrete and masonry elements shall consider the effects of cracked sections.

2. For steel moment frame systems, the contribution of panel zone deformations to overall storey drift shall be included.

208.6.3 $P\Delta$ Effects

The resulting member forces and moments and the storey drifts induced by $\boldsymbol{P\Delta}$ effects shall be considered in the evaluation of overall structural frame stability and shall be evaluated using the forces producing the displacements of Δ_S. $\boldsymbol{P\Delta}$ need not be considered when the ratio of secondary moment to primary moment does not exceed 0.10; the ratio may be evaluated for any storey as the product of the total dead and floor live loads, as required in Section 203, above the storey times the seismic drift in that storey divided by the product of the seismic shear in that storey times the height of that storey. In Seismic Zone 4, $\boldsymbol{P\Delta}$ need not be considered when the storey drift ratio does not exceed $\boldsymbol{0.02/R}$.

208.6.4 Drift

Drift or horizontal displacements of the structure shall be computed where required by this code. For both Allowable Stress Design and Strength Design, the Maximum Inelastic Response Displacement, Δ_M, of the structure caused by the Design Basis Ground Motion shall be determined in accordance with this section. The drifts corresponding to the design seismic forces of Section 208.5.2.1 or Section 208.5.3.5, Δ_S, shall be determined in accordance with Section 208.6.4.1. To determine Δ_M, these drifts shall be amplified in accordance with Section 208.6.4.2.

208.6.4.1 Determination of Δ_S

A static, elastic analysis of the lateral force-resisting system shall be prepared using the design seismic forces from Section 208.5.2.1. Alternatively, dynamic analysis may be performed in accordance with Section 208.5.3. Where Allowable Stress Design is used and where drift is being computed, the load combinations of Section 203.3 shall be used. The mathematical model shall comply with Section 208.6.2. The resulting deformations, denoted as Δ_S, shall be determined at all critical locations in the structure. Calculated drift shall include translational and torsional deflections.

208.6.4.2 Determination of Δ_M

The Maximum Inelastic Response Displacement, Δ_M, shall be computed as follows:

$$\boldsymbol{\Delta_M = 0.7R\Delta_s} \qquad (208\text{-}21)$$

Exception:

Alternatively, Δ_m may be computed by nonlinear time history analysis in accordance with Section 208.5.3.6.3.

The analysis used to determine the Maximum Inelastic Response Displacement Δ_M shall consider $\boldsymbol{P\Delta}$ effects.

208.6.5 Storey Drift Limitation

Storey drifts shall be computed using the Maximum Inelastic Response Displacement, Δ_M.

208.6.5.1 Calculated

Calculated storey drift using Δ_M shall not exceed 0.025 times the storey height for structures having a fundamental period of less than 0.7 sec. For structures having a fundamental period of 0.7 sec or greater, the calculated storey drift shall not exceed 0.020 times the storey height.

Exceptions:

1. *These drift limits may be exceeded when it is demonstrated that greater drift can be tolerated by both structural elements and nonstructural elements that could affect life safety. The drift used in this assessment shall be based upon the Maximum Inelastic Response Displacement, Δ_M.*

2. *There shall be no drift limit in single-storey steel-framed structures whose primary use is limited to storage, factories or workshops. Minor accessory uses shall be allowed. Structures on which this exception is used shall not have equipment attached to*

the structural frame or shall have such equipment detailed to accommodate the additional drift. Walls that are laterally supported by the steel frame shall be designed to accommodate the drift in accordance with Section 208.7.2.3.

208.6.5.2 Limitations

The design lateral forces used to determine the calculated drift may disregard the limitations of Equations. 208-11 and 208-10 and may be based on the period determined from Equations. 208-14 neglecting the 30 or 40 percent limitations of Section 208.5.2.2.

208.6.6 Vertical Component

The following requirements apply in Seismic Zone 4 only. Horizontal cantilever components shall be designed for a net upward force of $\mathbf{0.7}\boldsymbol{C_a I W_p}$.

In addition to all other applicable load combinations, horizontal pre-stressed components shall be designed using not more than 50 percent of the dead load for the gravity load, alone or in combination with the lateral force effects.

208.7 Detailed Systems Design Requirements

208.7.1 General

All structural framing systems shall comply with the requirements of Section 208.4. Only the elements of the designated seismic-force-resisting system shall be used to resist design forces. The individual components shall be designed to resist the prescribed design seismic forces acting on them. The components shall also comply with the specific requirements for the material contained in Chapters 4 through 7. In addition, such framing systems and components shall comply with the detailed system design requirements contained in Section 208.7.

All building components in Seismic Zones 2 and 4 shall be designed to resist the effects of the seismic forces prescribed herein and the effects of gravity loadings from dead and floor live loads.

Consideration shall be given to design for uplift effects caused by seismic loads.

In Seismic Zones 2 and 4, provision shall be made for the effects of earthquake forces acting in a direction other than the principal axes in each of the following circumstances:

1. The structure has plan irregularity Type 5 as given in Table 208-10.

2. The structure has plan irregularity Type 1 as given in Table 208-10 for both major axes.

3. A column of a structure forms part of two or more intersecting lateral-force-resisting systems.

Exception:

If the axial load in the column due to seismic forces acting in either direction is less than 20 percent of the column axial load capacity.

The requirement that orthogonal effects be considered may be satisfied by designing such elements for 100 percent of the prescribed design seismic forces in one direction plus 30 percent of the prescribed design seismic forces in the perpendicular direction. The combination requiring the greater component strength shall be used for design. Alternatively, the effects of the two orthogonal directions may be combined on a square root of the sum of the squares (SRSS) basis. When the SRSS method of combining directional effects is used, each term computed shall be assigned the sign that will result in the most conservative result.

8.7.2 Structural Framing Systems

ur types of general building framing systems defined in ction 208.4.6 are recognized in these provisions and own in Table 208-11. Each type is subdivided by the pes of vertical elements used to resist lateral seismic rces. Special framing requirements are given in this ction and in Chapters 4 through 7.

8.7.2.1 Detailing for Combinations of Systems

r components common to different structural systems, e more restrictive detailing requirements shall be used.

8.7.2.2 Connections

onnections that resist design seismic forces shall be signed and detailed on the drawings.

8.7.2.3 Deformation Compatibility

l structural framing elements and their connections, not quired by design to be part of the lateral-force-resisting stem, shall be designed and/or detailed to be adequate to aintain support of design dead plus live loads when bjected to the expected deformations caused by seismic rces. $P\Delta$ effects on such elements shall be considered. pected deformations shall be determined as the greater of the Maximum Inelastic Response Displacement, Δ_M, considering $P\Delta$ effects determined in accordance with Section 208.6.4.2 or the deformation induced by a storey drift of 0.0025 times the storey height. When computing expected deformations, the stiffening effect of those elements not part of the lateral-force-resisting system shall be neglected.

For elements not part of the lateral-force-resisting system, the forces inducted by the expected deformation may be considered as ultimate or factored forces. When computing the forces induced by expected deformations, the restraining effect of adjoining rigid structures and nonstructural elements shall be considered and a rational value of member and restraint stiffness shall be used. Inelastic deformations of members and connections may be considered in the evaluation, provided the assumed calculated capacities are consistent with member and connection design and detailing.

For concrete and masonry elements that are part of the lateral- force-resisting system, the assumed flexural and shear stiffness properties shall not exceed one half of the gross section properties unless a rational cracked-section analysis is performed. Additional deformations that may result from foundation flexibility and diaphragm deflections shall be considered. For concrete elements not part of the lateral-force-resisting system, see Section 421.9.

Table 208-11A Earthquake-Force-Resisting Structural Systems of Concrete

Basic Seismic-Force Resisting System	***R***	Ω_o	**System Limitation and Building Height Limitation by Seismic Zone, m**	
			Zone 2	**Zone 4**
A. Bearing Wall Systems				
• Special reinforced concrete shear walls	4.5	2.8	NL	50
• Ordinary reinforced concrete shear walls	4.5	2.8	NL	NP
B. Building Frame Systems				
• Special reinforced concrete shear walls or braced frames (shear walls)	5.0	2.8	NL	75
• Ordinary reinforced concrete shear walls or braced frames	5.6	2.2	NL	NP
• Intermediate precast shear walls or braced frames	5.0	2.5	NL	10
C. Moment-Resisting Frame Systems				
• Special reinforced concrete moment frames	8.5	2.8	NL	NL
• Intermediate reinforced concrete moment frames	5.5	2.8	NL	NP
• Ordinary reinforced concrete moment frames	3.5	2.8	NL	NP
D. Dual Systems				
• Special reinforced concrete shear walls	8.5	2.8	NL	NL
• Ordinary reinforced concrete shear walls	6.5	2.8	NL	NP
E. Dual System with Intermediate Moment Frames				
• Special reinforced concrete shear walls	6.5	2.8	NL	50
• Ordinary reinforced concrete shear walls	5.5	2.8	NL	NP
• Shear wall frame interactive system with ordinary reinforced concrete moment frames and ordinary reinforced concrete shear walls	4.2	2.8	NP	NP
F. Cantilevered Column Building Systems				
• Cantilevered column elements	2.2	2.0	NL	10
G. Shear Wall- Frame Interaction Systems	5.5	2.8	NL	50

Table 208-11B Earthquake-Force-Resisting Structural Systems of Steel

Basic Seismic-Force Resisting System	R	Ω_o	System Limitation and Building Height Limitation by Seismic Zone, m	
			Zone 2	Zone 4
A. Bearing Wall Systems				
• Light steel-framed bearing walls with tension-only bracing	2.8	2.2	NL	20
• Braced frames where bracing carries gravity load	4.4	2.2	NL	50
• Light framed walls sheathed with steel sheets structural panels rated for shear resistance or steel sheets	5.5	2.8	NL	20
• Light-framed walls with shear panels of all other light materials	4.5	2.8	NL	20
• Light-framed wall systems using flat strap bracing	2.8	2.2	NL	NP
B. Building Frame Systems				
• Steel eccentrically braced frames (EBF), moment-resisting connections at columns away from links	8.0	2.8	NL	30
• Steel eccentrically braced frames (EBF), non-moment-resisting connections at columns away from links	6.0	2.2	NL	30
• Special concentrically braced frames (SCBF)	6.0	2.2	NL	30
• Ordinary concentrically braced frames (OCBF)	3.2	2.2	NL	NP
• Light-framed walls sheathed with steel sheet structural panels / sheet steel panels	6.5	2.8	NL	20
• Light frame walls with shear panels of all other materials	2.5	2.8	NL	NP
• Buckling-restrained braced frames (BRBF), non-moment-resisting beam-column connection	7.0	2.8	NL	30
• Buckling-restrained braced frames, moment-resisting beam-column connections	8.0	2.8	NL	30
• Special steel plate shear walls (SPSW)	7.0	2.8	NL	30
C. Moment-Resisting Frame Systems				
• Special moment-resisting frame (SMRF)	8.0	3.0	NL	NL
• Intermediate steel moment frames (IMF)	4.5	3.0	NL	NP
• Ordinary moment frames (OMF)	3.5	3.0	NL	NP
• Special truss moment frames (STMF)	6.5	3.0	NL	NP
• Special composite steel and concrete moment frames	8.0	3.0	NL	NL
• Intermediate composite moment frames	5.0	3.0	NL	NP
• Composite partially restrained moment frames	6.0	3.0	50	NP
• Ordinary composite moment frames	3.0	3.0	NP	NP
D. Dual Systems with Special Moment Frames				
• Steel eccentrically braced frames	8.0	2.8	NL	NL
• Special steel concentrically braced frames	7.0	2.8	NL	NL
• Composite steel and concrete eccentrically braced frame	8.0	2.8	NL	NL

Table 208-11B (continued) Earthquake-Force-Resisting Structural Systems of Steel

Basic Seismic-Force Resisting System	***R***	Ω_O	**System Limitation and Building Height Limitation by Seismic Zone, m**	
			Zone 2	**Zone 4**
• Composite steel and concrete concentrically braced frame	6.0	2.8	NL	NL
• Composite steel plate shear walls	7.5	2.8	NL	NL
• Buckling-restrained braced frame	8.0	2.8	NL	NL
• Special steel plate shear walls	8.0	2.8	NL	NL
• Masonry shear wall with steel OMRF	4.2	2.8	NL	50
• Steel EBF with steel SMRF	8.5	2.8	NL	NL
• Steel EBF with steel OMRF	4.2	2.8	NL	50
• Special concentrically braced frames with steel SMRF	7.5	2.8	NL	NL
• Special concentrically braced frames with steel OMRF	4.2	2.8	NL	50
E. Dual System with Intermediate Moment Frames				
• Special steel concentrically braced frame	6.0	2.8	NL	NP
• Composite steel and concrete concentrically braced frame	5.5	2.8	NL	NP
• Ordinary composite braced frame	3.5	2.8	NL	NP
• Ordinary composite reinforced concrete shear walls with steel elements	5.0	3.0	NL	NP
F. Cantilevered Column Building Systems				
• Special steel moment frames	2.2	2.0	10	10
• Intermediate steel moment frames	1.2	2.0	10	NP
• Ordinary steel moment frames	1.0	2.0	10	NP
• Cantilevered column elements	2.2	2.0	NL	10
G. Steel Systems not Specifically Detailed for Seismic Resistance, Excluding Cantilever Systems	3.0	3.0	NL	NP

Table 208-11C Earthquake-Force-Resisting Structural Systems of Masonry

Basic Seismic-Force Resisting System	R	Ω_o	System Limitation and Building Height Limitation by Seismic Zone, m	
			Zone 2	Zone 4
A. Bearing Wall Systems				
• Masonry shear walls	4.5	2.8	NL	50
B. Building Frame Systems				
• Masonry shear walls	5.5	2.8	NL	50
C. Moment-Resisting Frame Systems				
• Masonry moment-resisting wall frames (MMRWF)	6.5	2.8	NL	50
D. Dual Systems				
• Masonry shear walls with SMRF	5.5	2.8	NL	50
• Masonry shear walls with steel OMRF	4.2	2.8	NL	50
• Masonry shear walls with concrete IMRF	4.2	2.8	NL	NP
• Masonry shear walls with masonry MMRWF	6.0	2.8	NL	50

Table 208-11D Earthquake-Force-Resisting Structural Systems of Wood

Basic Seismic-Force Resisting System	R	Ω_o	System Limitation and Building Height Limitation by Seismic Zone (meters)	
			Zone 2	Zone 4
A. Bearing Wall Systems				
• Light-framed walls with shear panels: wood structural panel walls for structures three stories or less	5.5	2.8	NL	20
• Heavy timber braced frames where bracing carries gravity load	2.8	2.2	NL	20
• All other light framed walls	NA	NA		
B. Building Frame Systems				
• Ordinary heavy timber-braced frames	5.6	2.2	NL	20

208.7.2.3.1 Adjoining Rigid Elements

Moment-resisting frames and shear walls may be enclosed by or adjoined by more rigid elements; provided it can be shown that the participation or failure of the more rigid elements will not impair the vertical and lateral- load-resisting ability of the gravity load and lateral-force-resisting systems. The effects of adjoining rigid elements shall be considered when assessing whether a structure shall be designated regular or irregular in Section 208.4.5.

208.7.2.3.2 Exterior Elements

Exterior non-bearing, non-shear wall panels or elements that are attached to or enclose the exterior shall be designed to resist the forces per Equation 208-27 or 208-28 and shall accommodate movements of the structure based on Δ_M and temperature changes. Such elements shall be supported by means of cast-in-place concrete or by mechanical connections and fasteners in accordance with the following provisions:

1. Connections and panel joints shall allow for a relative movement between stories of not less than two times storey drift caused by wind, the calculated storey drift based on Δ_M or 12.7 mm, whichever is greater.
2. Connections to permit movement in the plane of the panel for storey drift shall be sliding connections using slotted or oversize holes, connections that permit movement by bending of steel, or other connections providing equivalent sliding and ductility capacity.
3. Bodies of connections shall have sufficient ductility and rotation capacity to preclude fracture of the concrete or brittle failures at or near welds.

4. The body of the connection shall be designed for the force determined by Equation 208-28, where $R_p = 3.0$ and $a_p = 1.0$.

5. All fasteners in the connecting system, such as bolts, inserts, welds and dowels, shall be designed for the forces determined by Equation 208-28, where $R_p = 1.0$ and $a_p = 1.0$.

6. Fasteners embedded in concrete shall be attached to, or hooked around, reinforcing steel or otherwise terminated to effectively transfer forces to the reinforcing steel.

208.7.2.3.3 Ties and Continuity

All parts of a structure shall be interconnected and the connections shall be capable of transmitting the seismic force induced by the parts being connected. As a minimum, any smaller portion of the building shall be tied to the remainder of the building with elements having at least strength to resist $0.5C_aI$ times the weight of the smaller portion.

A positive connection for resisting horizontal force acting parallel to the member shall be provided for each beam, girder or truss. This force shall not be less than $0.3C_aI$ times the dead plus live load.

208.7.2.4 Collector Elements

Collector elements shall be provided that are capable of transferring the seismic forces originating in other portions of the structure to the element providing the resistance to those forces.

Collector elements, splices and their connections to resisting elements shall resist the forces determined in accordance with Equation 208-22. In addition, collector elements, splices, and their connections to resisting elements shall have the design strength to resist the combined loads resulting from the special seismic load of Section 203.5.

Exception:

In structures, or portions thereof, braced entirely by light-frame wood shear walls or light-frame steel and wood structural panel shear wall systems, collector elements, splices and connections to resisting elements need only be designed to resist forces in accordance with Equation 208-22.

The quantity E_M need not exceed the maximum force that can be transferred to the collector by the diaphragm and other elements of the lateral-force-resisting system. For Allowable Stress Design, the design strength may be determined using an allowable stress increase of 1.7 and a resistance factor, θ, of 1.0. This increase shall not be combined with the one-third stress increase permitted by Section 203.4, but may be combined with the duration of load increase permitted in Section 615.3.4.

208.7.2.5 Concrete Frames

Concrete frames required by design to be part of the lateral-force-resisting system shall conform to the following:

1. In Seismic Zone 4 they shall be special moment-resisting frames.

2. In Seismic Zone 2 they shall, as a minimum, be intermediate moment-resisting frames.

208.7.2.6 Anchorage of Concrete or Masonry Walls

Concrete or masonry walls shall be anchored to all floors and roofs that provide out-of-plane lateral support of the wall. The anchorage shall provide a positive direct connection between the wall and floor or roof construction capable of resisting the larger of the horizontal forces specified in this section and Sections 206.4 and 208.9. In addition, in Seismic Zone 4, diaphragm to wall anchorage using embedded straps shall have the straps attached to or hooked around the reinforcing steel or otherwise terminated to effectively transfer forces to the reinforcing steel. Requirements for developing anchorage forces in diaphragms are given in Section 208.7.2.6. Diaphragm deformation shall be considered in the design of the supported walls.

208.7.2.6.1 Out-of-Plane Wall Anchorage to Flexible Diaphragms

This section shall apply in Seismic Zone 4 where flexible diaphragms, as defined in Section 208.5.1.3, provide lateral support for walls.

1. Elements of the wall anchorage system shall be designed for the forces specified in Section 208.9 where $R_p = 3.0$ and $a_p = 1.5$.

2. In Seismic Zone 4, the value of F_p used for the design of the elements of the wall anchorage system shall not be less than 6.1 kN per lineal meter of wall substituted for E.

3. See Section 206.4 for minimum design forces in other seismic zones.

4. When elements of the wall anchorage system are not loaded concentrically or are not perpendicular to the wall, the system shall be designed to resist all components of the forces induced by the eccentricity.

5. When pilasters are present in the wall, the anchorage force at the pilasters shall be calculated considering the additional load transferred from the wall panels to the pilasters. However, the minimum anchorage force at a floor or roof shall be that specified in Section 208.7.2.7, Item 2.

6. The strength design forces for steel elements of the wall anchorage system shall be 1.4 times the forces otherwise required by this section.

7. The strength design forces for wood elements of the wall anchorage system shall be 0.85 times the force otherwise required by this section and these wood elements shall have a minimum actual net thickness of 63.5 mm.

208.7.2.7 Diaphragms

1. The deflection in the plane of the diaphragm shall not exceed the permissible deflection of the attached elements. Permissible deflection shall be that deflection that will permit the attached element to maintain its structural integrity under the individual loading and continue to support the prescribed loads.

2. Floor and roof diaphragms shall be designed to resist the forces determined in accordance with the following equation:

$$F_{px} = \frac{F_t + \sum_{i=x}^{n} F_i}{\sum_{i=x}^{n} w_i} w_{px} \qquad (208\text{-}22)$$

The force F_{px} determined from Equation 208-22 need not exceed $1.0C_a I w_{px}$, but shall not be less than $0.5C_a I w_{px}$.

When the diaphragm is required to transfer design seismic forces from the vertical-resisting elements above the diaphragm to other vertical-resisting elements below the diaphragm due to offset in the placement of the elements or to changes in stiffness in the vertical elements, these forces shall be added to those determined from Equation 208-22.

3. Design seismic forces for flexible diaphragms providing lateral supports for walls or frames of masonry or concrete shall be determined using Equation 208-22 based on the load determined in accordance with Section 208.5.2 using a R not exceeding 4.

4. Diaphragms supporting concrete or masonry walls shall have continuous ties or struts between diaphragm chords to distribute the anchorage forces specified in Section 208.7.2.7. Added chords of subdiaphragms may be used to form subdiaphragms to transmit the anchorage forces to the main continuous crossties. The maximum length-to-width ratio of the wood structural sub-diaphragm shall be 2½:1.

5. Where wood diaphragms are used to laterally support concrete or masonry walls, the anchorage shall conform to Section 208.7.2.7. In Seismic Zone 2 and 4, anchorage shall not be accomplished by use of toenails or nails subject to withdrawal, wood ledgers or framing shall not be used in cross-grain bending or cross-grain tension, and the continuous ties required by Item 4 shall be in addition to the diaphragm sheathing.

6. Connections of diaphragms to the vertical elements in structures in Seismic Zone 4, having a plan irregularity of Type 1, 2, 3 or 4 in Table 208-10, shall be designed without considering either the one-third increase or the duration of load increase considered in allowable stresses for elements resisting earthquake forces.

7. In structures in Seismic Zone 4 having a plan irregularity of Type 2 in Table 208-10, diaphragm chords and drag members shall be designed considering independent movement of the projecting wings of the structure. Each of these diaphragm elements shall be designed for the more severe of the following two assumptions:

   a. Motion of the projecting wings in the same direction.

   b. Motion of the projecting wings in opposing directions.

Exception:

This requirement may be deemed satisfied if the procedures of Section 208.5.3 in conjunction with a three-dimensional model have been used to determine the lateral seismic forces for design.

208.7.2.8 Framing below the Base

The strength and stiffness of the framing between the base and the foundation shall not be less than that of the superstructure. The special detailing requirements of Chapters 4, 5 and 7, as appropriate, shall apply to columns supporting discontinuous lateral-force-resisting elements and to SMRF, IMRF, EBF, STMF and MMRWF system elements below the base, which are required to transmit the forces resulting from lateral loads to the foundation.

208.7.2.9 Building Separations

All structures shall be separated from adjoining structures. Separations shall allow for the displacement Δ_m. Adjacent buildings on the same property shall be separated by at least Δ_{MT} where

$$\Delta_{MT} = \sqrt{(\Delta_{M1}) + (\Delta_{M2})^2} \qquad (208\text{-}23)$$

and Δ_{M1} and Δ_{M2} are the displacements of the adjacent buildings.

When a structure adjoins a property line not common to a public way, that structure shall also be set back from the property line by at least the displacement Δ_M of that structure.

Exception:

Smaller separations or property line setbacks may be permitted when justified by rational analyses based on maximum expected ground motions.

208.8 Non-Building Structures

208.8.1 General

208.8.1.1 Scope

Non-building structures include all self- supporting structures other than buildings that carry gravity loads and resist the effects of earthquakes. Non-building structures shall be designed to provide the strength required to resist the displacements induced by the minimum lateral forces specified in this section. Design shall conform to the applicable provisions of other sections as modified by the provisions contained in Section 208.8.

208.8.1.2 Criteria

The minimum design seismic forces prescribed in this section are at a level that produces displacements in a fixed base, elastic model of the structure, comparable to those expected of the real structure when responding to the Design Basis Ground Motion. Reductions in these forces using the coefficient R is permitted where the design of non-building structures provides sufficient strength and ductility, consistent with the provisions specified herein for buildings, to resist the effects of seismic ground motions as represented by these design forces.

When applicable, design strengths and other detailed design criteria shall be obtained from other sections or their referenced standards. The design of non-building structures shall use the load combinations or factors specified in Section 203.3 or 203.4. For non-building structures designed using Section 208.8.3, 208.8.4 or 208.8.5, the Reliability/Redundancy Factor, ρ, may be taken as 1.0.

When applicable design strengths and other design criteria are not contained in or referenced by this code, such criteria shall be obtained from approved national standards.

208.8.1.3 Weight *W*

The weight, W, for non-building structures shall include all dead loads as defined for buildings in Section 208.6.1. For purposes of calculating design seismic forces in non-building structures, W shall also include all normal operating contents for items such as tanks, vessels, bins and piping.

208.8.1.4 Period

The fundamental period of the structure shall be determined by rational methods such as by using Method B in Section 208.5.2.2.

208.8.1.5 Drift

The drift limitations of Section 208.6.5 need not apply to non-building structures. Drift limitations shall be established for structural or nonstructural elements whose failure would cause life hazards. $P\Delta$ effects shall be considered for structures whose calculated drifts exceed the values in Section 208.6.3.

Table 208-12 R and Ω_O Factors for Non-building Structures

STRUCTURE TYPE	R	Ω_O
1. Vessels, including tanks and pressurized spheres, on braced or unbraced legs.	2.2	2.0
2. Cast-in-place concrete silos and chimneys having walls continuous to the foundations	3.6	2.0
3. Distributed mass cantilever structures such as stacks, chimneys, silos and skirt-supported vertical vessels.	2.9	2.0
4. Trussed towers (freestanding or guyed), guyed stacks and chimneys.	2.9	2.0
5. Cantilevered column-type structures.	2.2	2.0
6. Cooling towers.	3.6	2.0
7. Bins and hoppers on braced or unbraced legs.	2.9	2.0
8. Storage racks.	3.6	2.0
9. Signs and billboards.	3.6	2.0
10. Amusement structures and monuments.	2.2	2.0
11. All other self-supporting structures not otherwise covered.	2.9	2.0

208.8.1.6 Interaction Effects

In Seismic Zone 4, structures that support flexible nonstructural elements whose combined weight exceeds 25 percent of the weight of the structure shall be designed considering interaction effects between the structure and the supported elements.

208.8.2 Lateral Force

Lateral-force procedures for non-building structures with structural systems similar to buildings (those with structural systems which are listed in Table 208-11) shall be selected in accordance with the provisions of Section 208.4.

Exception:

Intermediate moment-resisting frames (IMRF) may be used in Seismic Zone 4 for non-building structures in Occupancy Categories III and IV if (1) the structure is less than 15 m in height and (2) the value R used in reducing calculated member forces and moments does not exceed 2.8.

208.8.3 Rigid Structures

Rigid structures (those with period T less than 0.06 s) and their anchorages shall be designed for the lateral force obtained from Equation 208-24.

$$V = 0.7C_a IW \quad (208\text{-}24)$$

The force V shall be distributed according to the distribution of mass and shall be assumed to act in any horizontal direction.

208.8.4 Tanks with Supported Bottoms

Flat bottom tanks or other tanks with supported bottoms, founded at or below grade, shall be designed to resist the seismic forces calculated using the procedures in Section 208.9 for rigid structures considering the entire weight of the tank and its contents. Alternatively, such tanks may be designed using one of the two procedures described below:

1. A response spectrum analysis that includes consideration of the actual ground motion anticipated at the site and the inertial effects of the contained fluid.
2. A design basis prescribed for the particular type of tank by an approved national standard, provided that the seismic zones and occupancy categories shall be in conformance with the provisions of Sections 208.4.4.2 and 208.4.4.3, respectively.

208.8.5 Other Non-building Structures

Non-building structures that are not covered by Section 208.8.3 and 208.8.4 shall be designed to resist design seismic forces not less than those determined in accordance with the provisions in Section 208.5 with the following additions and exceptions:

1. The factors R and Ω_o shall be as set forth in Table 208-12. The total design base shear determined in accordance with Section 208.5.2 shall not be less than the following:

$$V = 0.56C_a IW \quad (208\text{-}25)$$

Additionally, for Seismic Zone 4, the total base shear shall also not be less than the following:

$$V = \frac{1.6ZN_v I}{R} W \quad (208\text{-}26)$$

2. The vertical distribution of the design seismic forces in structures covered by this section may be determined by using the provisions of Section 208.5.2.3 or by using the procedures of Section 208.5.3.

   Exception:

   For irregular structures assigned to Occupancy Categories I and II that cannot be modeled as a single mass, the procedures of Section 208.5.3 shall be used.

3. Where an approved national standard provides a basis for the earthquake-resistant design of a particular type of non-building structure covered by this section, such a standard may be used, subject to the limitations in this section:

The seismic zones and occupancy categories shall be in conformance with the provisions of Sections 208.4.4 and 208.4.2, respectively.

The values for total lateral force and total base overturning moment used in design shall not be less than 80 percent of the values that would be obtained using these provisions.

208.9 Lateral Force on Elements of Structures, Nonstructural Components and Equipment Supported by Structures

208.9.1 General

Elements of structures and their attachments, permanent nonstructural components and their attachments, and the attachments for permanent equipment supported by a structure shall be designed to resist the total design seismic forces prescribed in Section 208.9.2.

Attachments for floor- or roof-mounted equipment weighing less than 1.8 kN, and furniture need not be designed.

Attachments shall include anchorages and required bracing. Friction resulting from gravity loads shall not be considered to provide resistance to seismic forces.

When the structural failure of the lateral-force-resisting systems of non-rigid equipment would cause a life hazard, such systems shall be designed to resist the seismic forces prescribed in Section 208.9.2.

When permissible design strengths and other acceptance criteria are not contained in or referenced by this code, such criteria shall be obtained from approved national standards subject to the approval of the building official.

208.9.2 Design for Total Lateral Force

The total design lateral seismic force, F_p, shall be determined from the following equation:

$$F_p = 4C_a I_p W_p \tag{208-27}$$

Alternatively, F_p may be calculated using the following equation:

$$F_p = \frac{a_p C_a I_p}{R_p}\left(1 + 3\frac{h_x}{h_y}\right)W_p \tag{208-28}$$

Except that F_p shall not be less than $0.7C_a I_p W_p$ and need not be more than $4C_a I_p W_p$.

where

h_x	=	the element or component attachment elevation with respect to grade. h_x shall not be taken less than 0.0.
h_r	=	the structure roof elevation with respect to grade.
a_p	=	the in-structure Component Amplification Factor that varies from 1.0 to 2.5.

A value for a_p shall be selected from Table 208-13. Alternatively, this factor may be determined based on the dynamic properties or empirical data of the component and the structure that supports it. The value shall not be taken less than 1.0.

R_p is the Component Response Modification Factor that shall be taken from Table 208-13, except that R_p for anchorages shall equal 1.5 for shallow expansion anchor bolts, shallow chemical anchors or shallow cast-in-place anchors. Shallow anchors are those with an embedment length-to-diameter ratio of less than 8. When anchorage is constructed of non-ductile materials, or by use of adhesive, R_p shall equal 1.0.

The design lateral forces determined using Equation 208-27 or 208-19 shall be distributed in proportion to the mass distribution of the element or component.

Forces determined using Equation 208-27 or 208-28 shall be used to design members and connections that transfer these forces to the seismic-resisting systems. Members and connection design shall use the load combinations and factors specified in Section 203.3 or 203.4. The Reliability/Redundancy Factor, ρ, may be taken equal to 1.0.

For applicable forces and Component Response Modification Factors in connectors for exterior panels and diaphragms, refer to Sections 208.7.2.3 and 208.7.2.7.

Forces shall be applied in the horizontal directions, which result in the most critical loadings for design.

Table 208-13 Horizontal Force Factors, a_p and R_p for Elements of Structures and Nonstructural Components and Equipment

Category	Element or Component	a_p	R_p	Footnote
1. Elements of Structures	1. Walls including the following			
	a. Unbraced (cantilevered) parapets	2.5	3.0	
	b. Exterior walls at or above the ground floor and parapets braced above their centers of gravity	1.0	3.0	2
	c. All interior-bearing and non-bearing walls	1.0	3.0	2
	2. Penthouse (except when framed by an extension of the structural frame)	2.5	4.0	
	3. Connections for prefabricated structural elements other walls. See also Section 208.7.2	1.0	3.0	3

Table 208-13 (continued)

Category	Element or Component	a_p	R_p	Footnote
2. Nonstructural Components	1. Exterior and interior ornamentations and appendages.			
	a. Laterally braced or anchored to the structural frame at a point below their centers of mass	2.5	3.0	
	b. Laterally braced or anchored to the structural frame at or above their centers of mass	1.0	3.0	
	2. Signs and billboards	2.5	3.0	
	3. Storage racks (include contents) over 1.8 m tall.	2.5	4.0	4
	4.Permanent floor-supported cabinets and book stacks more than 1.8 m in height (include contents)	1.0	3.0	*5*
	5.Anchorage and lateral bracing for suspended ceilings and light fixtures	1.0	3.0	*3, 6, 7, 8*
	6.Access floor systems	1.0	3.0	*4, 5, 9*
	7. Masonry or concrete fences over 1.8 m high	1.0	3.0	
	8. Partitions.	1.0	3.0	

Table 208-13 (continued)

Category	Element or Component	a_p	R_p	Footnote
3. Equipment	1. Tanks and vessels (include contents), including support systems.	1.0	3.0	
	2. Electrical, mechanical and plumbing equipment and associated conduit and ductwork and piping.	1.0	3.0	*5, 10, 11, 12, 13, 14, 15, 16*
	3. Any flexible equipment laterally braced or anchored to the structural frame at a point below their center of mass	2.5	3.0	*5, 10, 14, 15, 16*
	4.Anchorage of emergency power supply systems and essential communications equipment. Anchorage and support systems for battery racks and fuel tanks necessary for operation of emergency equipment. See also Section 208.7.2	1.0	3.0	*17, 18*
	5. Temporary containers with flammable or hazardous materials.	1.0	3.0	*19*

Table 208-13 (continued)

Category	Element or Component	a_p	R_p	Footnote
4. Other Components	1. Rigid components with ductile material and attachments.	1.0	3.0	*1*
	2. Rigid components with nonductile material or attachments	1.0	1.5	*1*
	3. Flexible components with ductile material and attachments.	2.5	3.0	*1*
	4. Flexible components with nonductile material or attachments.	2.5	1.5	*1*

Notes for Table 208.13

[1] *See Section 208.2 for definitions of flexible components and rigid components.*

[2] *See Section 208.8.7.2.3 and 208.7.2.7 for concrete and masonry walls and Section 208.9.2 for connections for panel connectors for panels.*

[3] *Applies to Seismic Zones 2 and 4 only.*

[4] *Ground supported steel storage racks may be designed using the provisions of Sections 208.8. Load and resistance factor design may be used for the design of cold-formed steel members, provided seismic design forces are equal to or greater than those specified in Section 208.9.2 or 208.8.3 as appropriate.*

[5] *Only anchorage or restraints need be designed.*

[6] *Ceiling weight shall include all light fixtures and other equipment or partitions that are laterally supported by the ceiling. For purposes of determining the seismic force, a ceiling weight of not less than 0.2 kPa shall be used.*

[7] *Ceilings constructed of lath and plaster or gypsum board screw or nail attached to suspended members that support a ceiling at one level extending from wall to wall need not be analyzed, provided the walls are not over 15 meters apart.*

[8] *Light fixtures and mechanical services installed in metal suspension systems for acoustical tile and lay-in panel ceilings shall be independently supported from*

the structure above as specified in UBC Standard 25-2, Part III.

[9] *W_P for access floor systems shall be the dead load of the access floor system plus 25 percent of the floor live load plus a 0.5 kPa partition load allowance.*

[10] *Equipment includes, but is not limited to, boilers, chillers, heat exchangers, pumps, air-handling units, cooling towers, control panels, motors, switchgear, transformers and life-safety equipment. It shall include major conduit, ducting and piping, which services such machinery and equipment and fire sprinkler systems. See Section 208.9.2 for additional requirements for determining a_p for nonrigid or flexibly mounted equipment.*

[11] *Seismic restraints may be omitted from piping and duct supports if all the following conditions are satisfied:*

[11.1] *Lateral motion of the piping or duct will not cause damaging impact with other systems.*

[11.2] *The piping or duct is made of ductile material with ductile connections.*

[11.3] *Lateral motion of the piping or duct does not cause impact of fragile appurtenances (e.g., sprinkler heads) with any other equipment, piping or structural member.*

[11.4] *Lateral motion of the piping or duct does not cause loss of system vertical support.*

[11.5] *Rod-hung supports of less than 300 mm in length have top connections that cannot develop moments.*

[11.6] *Support members cantilevered up from the floor are checked for stability.*

[12] *Seismic restraints may be omitted from electrical raceways, such as cable trays, conduit and bus ducts, if all the following conditions are satisfied:*

[12.1] *Lateral motion of the raceway will not cause damaging impact with other systems.*

[12.2] *Lateral motion of the raceway does not cause loss of system vertical support.*

[12.3] *Rod-hung supports of less than 300 mm in length have top connections that cannot develop moments.*

[12.4] *Support members cantilevered up from the floor are checked for stability.*

[13] *Piping, ducts and electrical raceways, which must be functional following an earthquake, spanning between different buildings or structural systems shall be sufficiently flexible to withstand relative motion of support points assuming out-of-phase motions.*

[14] *Vibration isolators supporting equipment shall be designed for lateral loads or restrained from displacing laterally by other means. Restraint shall also be provided, which limits vertical displacement, such that lateral restraints do not become disengaged. a_p and R_p for equipment supported on vibration isolators shall be taken as 2.5 and 1.5, respectively, except that if the isolation mounting frame is supported by shallow or expansion anchors, the design forces for the anchors calculated by Equations. 208-27, or 208-28 (including limits), shall be additionally multiplied by factor of 2.0.*

[15] *Equipment anchorage shall not be designed such that loads are resisted by gravity friction (e.g., friction clips).*

[16] *Expansion anchors, which are required to resist seismic loads in tension, shall not be used where operational vibrating loads are present.*

[17] *Movement of components within electrical cabinets, rack-and skid-mounted equipment and portions of skid-mounted electromechanical equipment that may cause damage to other components by displacing, shall be restricted by attachment to anchored equipment or support frames.*

[18] *Batteries on racks shall be restrained against movement in all direction due to earthquake forces.*

[19] *Seismic restraints may include straps, chains, bolts, barriers or other mechanisms that prevent sliding, falling and breach of containment of flammable and toxic materials. Friction forces may not be used to resist lateral loads in the restraints unless positive uplift restraint is provided which ensures that the friction forces act continuously.*

208.9.3 Specifying Lateral Forces

Design specifications for equipment shall either specify the design lateral forces prescribed herein or reference these provisions.

208.9.4 Relative Motion of Equipment Attachments

For equipment in Categories I and II buildings as defined in Table 103-1, the lateral-force design shall consider the effects of relative motion of the points of attachment to the structure, using the drift based upon Δ_M.

208.9.5 Alternative Designs

Where an approved national standard or approved physical test data provide a basis for the earthquake-resistant design of a particular type of equipment or other nonstructural component, such a standard or data may be accepted as a basis for design of the items with the following limitations:

1. These provisions shall provide minimum values for the design of the anchorage and the members and connections that transfer the forces to the seismic-resisting system.

2. The force, F_p, and the overturning moment used in the design of the nonstructural component shall not be less than 80 percent of the values that would be obtained using these provisions.

208.10 Alternative Earthquake Load Procedure

The earthquake load procedure of latest edition of ASCE/SEI 7 prior to the release of this code may be used in determining the earthquake loads as an alternative procedure subject to reliable research work commissioned by the owner or the engineer-on-record to provide for all data required due to the non-availability of PHIVOLCS-issued spectral acceleration maps for all areas in the Philippines.

The engineer-on-record shall be responsible for the spectral acceleration and other related data not issued by PHIVOLCS used in the determination of the earthquake loads. This alternative earthquake load procedure shall be subject to Peer Review and approval of the Building Official.

SECTION 209
SOIL LATERAL LOADS

209.1 General

Basement, foundation and retaining walls shall be designed to resist lateral soil loads. Soil loads specified in Table 209-1 shall be used as the minimum design lateral soil loads unless specified otherwise in a soil investigation report approved by the building official. Basement walls and other walls in which horizontal movement is restricted at the top shall be designed for at-rest pressure. Retaining walls free to move and rotate at the top are permitted to be designed for active pressure. Design lateral pressure from surcharge loads shall be added to the lateral earth pressure load. Design lateral pressure shall be increased if soils with expansion potential are present at the site.

Exception:

Basement walls extending not more than 2.4 m below grade and supporting flexible floor systems shall be permitted to be designed for active pressure.

Table 209-1 - Soil Lateral Load

Description of Backfill Material [c]	**Unified Soil Classification**	**Design Lateral Soil Load** [a] **kPa per m depth**	
		Active pressure	At-rest pressure
Well-graded, clean gravels; gravel-sand mixes	GW	5	10
Poorly graded clean gravels; gravel-sand mixes	GP	5	10
Silty gravels, poorly graded gravel-sand mixes	GM	6	10
Clayey gravels, poorly graded gravel-and-clay mixes	GC	7	10
Well-graded, clean sands; gravelly sand mixes	SW	5	10
Poorly graded clean sands; sand-gravel mixes	SP	5	10
Silty sands, poorly graded sand-silt mixes	SM	7	10
Sand-silt clay mix with plastic fines	SM-SC	7	16
Clayey sands, poorly graded sand-clay mixes	SC	10	16
Inorganic silts and clayey silts	ML	7	16
Mixture of inorganic silt and clay	ML-CL	10	16
Inorganic clays of low to medium plasticity	CL	10	16
Organic silts and silt clays, low plasticity	OL	Note b	Note b
Inorganic clayey silts, elastic silts	MH	Note b	Note b
Inorganic clays of high plasticity	CH	Note b	Note b
Organic clays and silty clays	OH	Note b	Note b

[a] *Design lateral soil loads are given for moist conditions for the specified soils at their optimum densities. Actual field conditions shall govern. Submerged or saturated soil pressures shall include the weight of the buoyant soil plus the hydrostatic loads.*

[b] *Unsuitable as backfill material.*

[c] *The definition and classification of soil materials shall be in accordance with ASTM D 2487.*

SECTION 210
RAIN LOADS

210.1 Roof Drainage

Roof drainage systems shall be designed in accordance with the provisions of the code having jurisdiction in the area. The flow capacity of secondary (overflow) drains or scuppers shall not be less than that of the primary drains or scuppers.

210.2 Design Rain Loads

Each portion of a roof shall be designed to sustain the load of rainwater that will accumulate on it if the primary drainage system for that portion is blocked plus the uniform load caused by water that rises above the inlet of the secondary drainage system at its design flow.

$$R = 0.009(8d_s + d_h) \qquad (210\text{-}1)$$

where

d_h = additional depth of water on the undeflected roof above the inlet of secondary drainage system at its design flow (i.e., the hydraulic head), mm

d_s = depth of water on the undeflected roof up to the inlet of secondary drainage system when the primary drainage system is blocked (i.e., the static head), mm

R = rain load on the undeflected roof, kPa

When the phrase "undeflected roof" is used, deflections from loads (including dead loads) shall not be considered when determining the amount of rain on the roof.

210.3 Ponding Instability

For roofs with a slope less than 6 mm per 300 mm, the design calculations shall include verification of adequate stiffness to preclude progressive deflection.

210.4 Controlled Drainage

Roofs equipped with hardware to control the rate of drainage shall be equipped with a secondary drainage system at a higher elevation that limits accumulation of water on the roof above that elevation. Such roofs shall be designed to sustain the load of rainwater that will accumulate on them to the elevation of the secondary drainage system plus the uniform load caused by water that rises above the inlet of the secondary drainage system at its design flow determined from Section 210.2. Such roofs shall also be checked for ponding instability in accordance with Section 210.3.

SECTION 211
FLOOD LOADS

211.1 General

Within flood hazard areas as established in Section 211.3, all new construction of buildings, structures and portions of buildings and structures, including substantial improvement and restoration of substantial damage to buildings and structures, shall be designed and constructed to resist the effects of flood hazards and flood loads. For buildings that are located in more than one flood hazard area, the provisions associated with the most restrictive flood hazard area shall apply.

211.2 Definitions

The following words and terms shall, for the purposes of this section, have the meanings shown herein.

BASE FLOOD refers to flood having a 1-percent chance of being equaled or exceeded in any given year.

BASE FLOOD ELEVATION (BFE) is the elevation of the base flood, m, including wave height, relative to the datum to be set by the specific national or local government agency.

BASEMENT is the portion of a building having its floor subgrade (below ground level) on all sides.

DESIGN FLOOD is the flood associated with the greater of the following two areas:

1. Area with a flood plain subject to a 1-percent or greater chance of flooding in any year; or
2. Area designated as a flood hazard area on a community's flood hazard map, or otherwise legally designated.

DESIGN FLOOD ELEVATION (DFE) is the elevation of the "design flood," including wave height, m, relative to the datum specified on the community's legally designated flood hazard map. The design flood elevation shall be the elevation of the highest existing grade of the perimeter of the building plus the depth specified on the flood hazard map.

DRY FLOODPROOFING is a combination of design modifications that results in a building or structure, including the attendant utility and sanitary facilities, being water tight with walls substantially impermeable to the passage of water and with structural components having the capacity to resist loads as identified in the code.

EXISTING CONSTRUCTION refers to buildings and structures for which the "start of construction" commenced before the effective date of the ordinance or standard. "Existing construction" is also referred to as "existing structures."

EXISTING STRUCTURE See "Existing construction."

FLOOD or FLOODING is a general and temporary condition of partial or complete inundation of normally dry land from:

1. The overflow of inland or tidal waters.
2. The unusual and rapid accumulation or runoff of surface waters from any source.

FLOOD DAMAGE-RESISTANT MATERIALS are construction material capable of withstanding direct and prolonged contact with floodwaters without sustaining any damage that requires more than cosmetic repair.

FLOOD HAZARD AREA refers to the greater of the following two areas:

1. The area within a flood plain subject to a 1-percent or greater chance of flooding in any year.
2. The area designated as a flood hazard area on a community's flood hazard map, or otherwise legally designated.

FLOOD HAZARD AREA SUBJECT TO HIGH VELOCITY-WAVE ACTION refers to area within the flood hazard area that is subject to high velocity wave action.

FLOODWAY is the channel of the river, creek or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.

LOWEST FLOOR refers to the floor of the lowest enclosed area, including basement, but excluding any unfinished or flood-resistant enclosure, usable solely for vehicle parking, building access or limited storage provided that such enclosure is not built so as to render the structure in violation of this section.

START OF CONSTRUCTION refers to the date of permit issuance for new construction and substantial improvements to existing structures, provided the actual start of construction, repair, reconstruction, rehabilitation, addition, placement or other improvement is within 180 days after the date of issuance. The actual start of construction means the first placement of permanent construction of a building (including a manufactured home) on a site, such as the pouring of a slab or footings, installation of pilings or construction of columns. Permanent construction does not include land preparation (such as clearing, excavation, grading or filling), the installation of streets or walkways, excavation for a basement, footings, piers or foundations, the erection of temporary forms or the installation of accessory buildings such as garages or sheds not occupied as dwelling units or not part of the main building. For a substantial improvement, the actual "start of construction" means the first alteration of any wall, ceiling, floor or other structural part of a building, whether or not that alteration affects the external dimensions of the building.

SUBSTANTIAL DAMAGE refers to damage to any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

SUBSTANTIAL IMPROVEMENT refers to any repair, reconstruction, rehabilitation, addition or improvement of a building or structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the improvement or repair is started. If the structure has sustained substantial damage, any repairs are considered substantial improvement regardless of the actual repair work performed. The term does not, however, include either:

1. Any project for improvement of a building required to correct existing health, sanitary or safety code violations identified by the building official and that are the minimum necessary to assure safe living conditions.

2. Any alteration of a historic structure provided that the alteration will not preclude the structure's continued designation as a historic structure.

211.3 Design Requirements

211.3.1 Design Loads

Structural systems of buildings or other structures shall be designed, constructed, connected, and anchored to resist flotation, collapse, and permanent lateral displacement due to action of flood loads associated with the design flood (see Section 211.3.3) and other loads in accordance with the load combinations of Section 203.

211.3.2 Erosion and Scour

The effects of erosion and scour shall be included in the calculation of loads on buildings and other structures in flood hazard areas.

211.3.3 Loads on Breakaway Walls

Walls and partitions required by ASCE/SEI 24, to break away, including their connections to the structure, shall be designed for the largest of the following loads acting perpendicular to the plane of the wall:

1. The wind load specified in Section 207.

2. The earthquake load specified in Section 208.

3. 0.48 kPa.

The loading at which breakaway walls are intended to collapse shall not exceed 0.96 kPa unless the design meets the following conditions:

1. Breakaway wall collapse is designed to result from a flood load less than that which occurs during the base flood.

2. The supporting foundation and the elevated portion of the building shall be designed against collapse, permanent lateral displacement, and other structural damage due to the effects of flood loads in combination with other loads as specified in Section 203.

211.4 Loads During Flooding

211.4.1 Load Basis

In flood hazard areas, the structural design shall be based on the design flood.

211.4.2 Hydrostatic Loads

Hydrostatic loads caused by a depth of water to the level of the DFE shall be applied over all surfaces involved, both above and below ground level, except that for surfaces exposed to free water, the design depth shall be increased by 0.30 m. Reduced uplift and lateral loads on surfaces of enclosed spaces below the DFE shall apply only if provision is made for entry and exit of floodwater.

211.4.3 Hydrodynamic Loads

Dynamic effects of moving water shall be determined by a detailed analysis utilizing basic concepts of fluid mechanics.

Exception:

Where water velocities do not exceed 3.05 mls, dynamic effects of moving water shall be permitted to be converted into equivalent hydrostatic loads by increasing the DFE for design purposes by an equivalent surcharge depth, dh, on the headwater side and above the ground level only, equal to

$$d_h = \frac{aV^2}{2g} \tag{211-1}$$

where

V = average velocity of water, m/s
g = acceleration due to gravity, 9.81 m/s^2
a = coefficient of drag or shape factor (not less than 1.25)

The equivalent surcharge depth shall be added to the DFE design depth and the resultant hydrostatic pressures applied to, and uniformly distributed across, the vertical projected area of the building or structure that is perpendicular to the flow. Surfaces parallel to the flow or surfaces wetted by the tail water shall be subject to the hydrostatic pressures for depths to the DFE only.

211.4.4 Wave Loads

Wave loads shall be determined by one of the following three methods: (1) by using the analytical procedures outlined in this section, (2) by more advanced numerical modeling procedures, or (3) by laboratory test procedures (physical modeling).

Wave loads are those loads that result from water waves propagating over the water surface and striking a building or other structure. Design and construction of buildings and other structures subject to wave loads shall account for the following loads: waves breaking on any portion of the building or structure; uplift forces caused by shoaling waves beneath a building or structure, or portion thereof; wave run-up striking any portion of the building or structure; wave-induced drag and inertia forces; and wave-induced scour at the base of a building or structure, or its foundation. Wave loads shall be included for both V-Zones and A-Zones. In V-Zones, waves are 0.91 m high, or higher; in .coastal floodplains landward of the V-Zone, waves are less than 0.91 m.

Nonbreaking and broken wave loads shall be calculated using the procedures described in Sections 211.4.2 and 211.4.3 that show how to calculate hydrostatic and hydrodynamic loads.

Breaking wave loads shall be calculated using the procedures described in Sections 211.4.4.1 through 211.4.4.4. Breaking wave heights used in the procedures described in Sections 211.4.4.1 through 211.4.4.4 shall be calculated for V-Zones and Coastal A-Zones using Equations 211-2 and 211-3.

$$H_b = 0.78d_s \qquad (211\text{-}2)$$

where

H_b = breaking wave height, m
d_s = local still water depth, m

The local still water depth shall be calculated using Equation 211-3, unless more advanced procedures or laboratory tests permitted by this section are used.

$$d_s = 0.65(BFE - G) \qquad (211\text{-}3)$$

where

G = ground elevation, m

211.4.4.1 Breaking Wave Loads on Vertical Pilings and Columns

The net force resulting from a breaking wave acting on a rigid vertical pile or column shall be assumed to act at the still water elevation and shall be calculated by the following:

$$F_D = 0.5\gamma_\omega C_D D H_b^2 \qquad (211\text{-}4)$$

where

F_D = net wave force, kN
= unit weight of water, in lb per cubic kN/m³, = 9.80 kN/m³ for fresh water and 10.05 kN/m³ for salt water
γ_ω = unit weight of water, kN/m³, 9.80 kN/m³ for fresh water and 10.05 kN/m³ for salt water
C_D = coefficient of drag for breaking waves, = 1.75 for round piles or columns, and = 2.25 for square piles or columns
D = pile or column diameter, m for circular sections, or for a square pile or column, 1.4 times the width of the pile or column, m
H_b = breaking wave height, m

211.4.4.2 Breaking Wave Loads on Vertical Walls

Maximum pressures and net forces resulting from a normally incident breaking wave (depth-limited in size, with $H_b = 0.78d_s$) acting on a rigid vertical wall shall be calculated by the following:

$$P_{max} = C_p\gamma_\omega d_s + 1.2\gamma_\omega d_s \qquad (211\text{-}5)$$

and

$$F_t = 1.1C_p\gamma_\omega d_s^2 + 2.4\gamma_\omega d_s^2 \qquad (211\text{-}6)$$

where

P_{max} = maximum combined dynamic $(C_p\gamma_\omega d_s)$ and static $(1.2\gamma_\omega d_s)$ wave pressures, also referred to as shock pressures, kN/m²
F_t = net breaking wave force per unit length of structure, also referred to as shock, impulse, or wave impact force, kN/m, acting near the still water elevation
C_p = dynamic pressure coefficient $(1.6 < C_p < 3.5)$ (see Table 211-1)
γ_ω = unit weight of water, kN/m3, 9.80 kN/m³ for fresh water and 10.05 kN/m³ for salt water
d_s = still water depth, m at base of building or other structure where the wave breaks

This procedure assumes the vertical wall causes a reflected or standing wave against the waterward side of the wall with the crest of the wave at a height of 1.2d, above the still water level. Thus, the dynamic static and total pressure distributions against the wall are as shown in Figure 211-1.

This procedure also assumes the space behind the vertical wall is dry, with no fluid balancing the static component of the wave force on the outside of the wall. If free water exists behind the wall, a portion of the hydrostatic component of the wave pressure and force disappears (see Figure 211-2) and the net force shall be computed by Equation 211-7 (the maximum combined wave pressure is still computed with Equation 211-5).

$$F_t = 1.1C_p\gamma_\omega d_s^2 + 1.9\gamma_\omega d_s^2 \qquad (211\text{-}7)$$

where

F_t = net breaking wave force per unit length of structure, also referred to as shock, impulse, or wave impact force, kN/m, acting near the still water elevation

C_p	=	dynamic pressure coefficient ($1.6 < C_p < 3.5$) (see Table 211-1)
γ_ω	=	unit weight of water, kN/m³, = 9.80 kN/m³ for fresh water and 10.05 kN/m³ for salt water
d_s	=	still water depth, m at base of building or other structure where the wave breaks

211.4.4.3 Breaking Wave Loads on Non-vertical Walls

Breaking wave forces given by Equations 211-6 and 211-7 shall be modified in instances where the walls or surfaces upon which the breaking waves act are non-vertical. The horizontal component of breaking wave force shall be given by

$$F_{nv} = F_t sin^2\alpha \qquad (211\text{-}8)$$

where

F_{nv}	=	horizontal component of breaking wave force, kN/m
F_t	=	net breaking wave force acting on a vertical surface, kN/m
α	=	vertical angle between non-vertical surface and the horizontal

211..4.4.4 Breaking Wave Loads from Obliquely Incident Waves

Breaking wave forces given by Equations 211-6 and 211-7 shall be modified in instances where waves are obliquely incident. Breaking wave forces from non-normally incident waves shall be given by

$$F_{oi} = F_t sin^2\alpha \qquad (211\text{-}9)$$

where

F_{oi}	=	horizontal component of obliquely incident breaking wave force, kN/m
α	=	net breaking wave force (normally incident waves) acting on a vertical surface, kN/m

211.4.5 Impact Loads

Impact loads are those that result from debris, ice, and any object transported by floodwaters striking against buildings and structures, or parts thereof. Impact loads shall be determined using a rational approach as concentrated loads acting horizontally at the most critical location at or below the DFE.

211.5 Establishment of Flood Hazard Areas

To establish flood hazard areas, the governing body shall adopt a flood hazard map and supporting data. The flood hazard map shall include, at a minimum, areas of special flood hazard where records are available.

211.6 Design and Construction

The design and construction of buildings and structures located in flood hazard areas, including flood hazard areas subject to high velocity wave action.

211.7 Flood Hazard Documentation

The following documentation shall be prepared and sealed by an engineer-of-record and submitted to the building official:

1. For construction in flood hazard areas not subject to high-velocity wave action:

   1.1 The elevation of the lowest floor, including the basement, as required by the lowest floor elevation.

   1.2 For fully enclosed areas below the design flood elevation where provisions to allow for the automatic entry and exit of floodwaters do not meet the minimum requirements, construction documents shall include a statement that the design will provide for equalization of hydrostatic flood forces.

   1.3 For dry flood-proofed nonresidential buildings, construction documents shall include a statement that the dry flood-proofing is designed.

2. For construction in flood hazard areas subject to high-velocity wave action:

   2.1 The elevation of the bottom of the lowest horizontal structural member as required by the lowest floor elevation.

   2.2 Construction documents shall include a statement that the building is designed, including that the pile or column foundation and building or structure to be attached thereto is designed to be anchored to resist flotation, collapse and lateral movement due to the effects of wind and flood loads acting simultaneously on all building components, and other load requirements of Section 203.

2.3 For breakaway walls designed to resist a nominal load of less than 0.5 kPa or more than 1.0 kPa, construction documents shall include a statement that the breakaway wall is designed.

Table 211-1 Value of Dynamic Pressure Coefficient, C_p

Building Category	C_p
I	1.6
II	2.8
II	3.2
IV	3.5

211.8 Consensus Standards and Other Referenced Documents

This section lists the consensus standards and other documents which are adopted by reference within this chapter:

ASCE/SEI
American Society of Civil Engineers
Structural Engineering Institute
1801 Alexander Bell Drive
Reston, VA 20191-4400

ASCE/SEI 24
Section 5.3.3
Flood Resistant Design and Construction, 1998

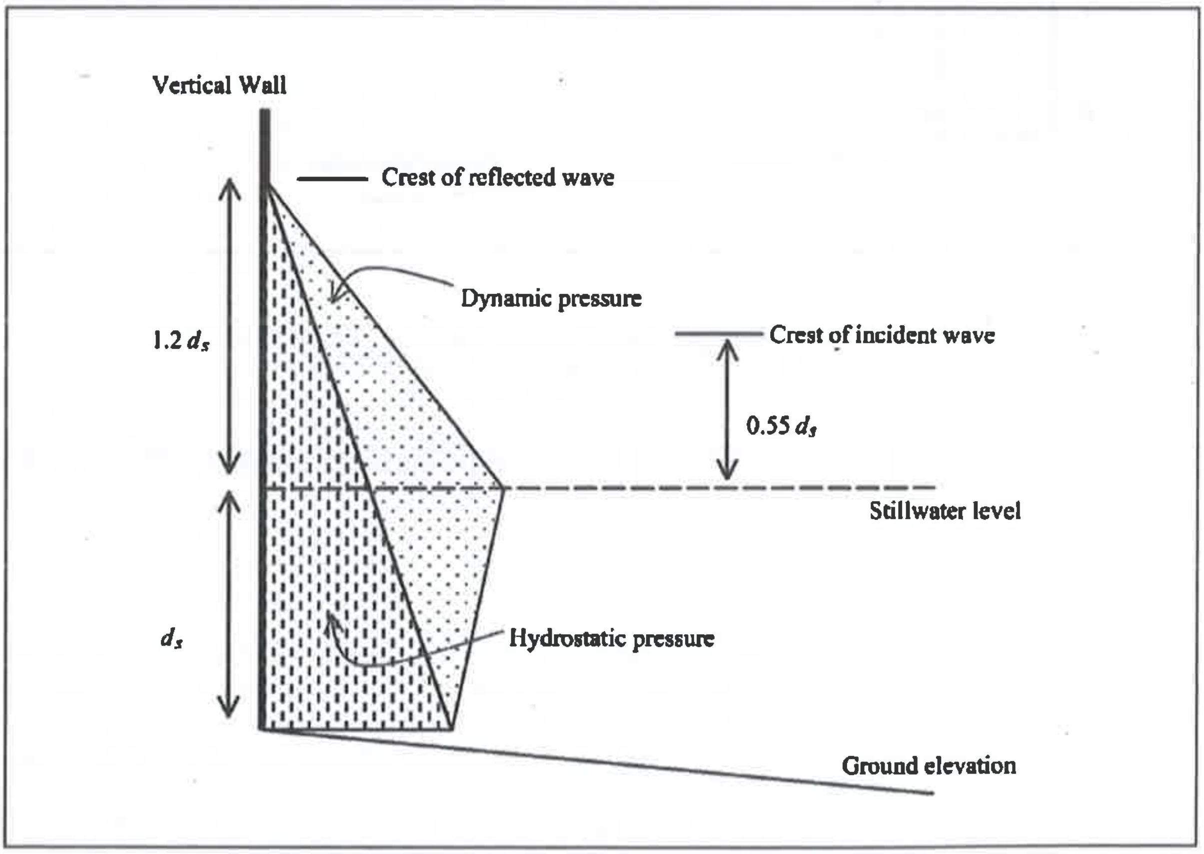


Figure 211-1
Normally Incident Breaking Wave Pressures Against a Vertical Wall
(Space Behind Vertical Wall Is Dry)

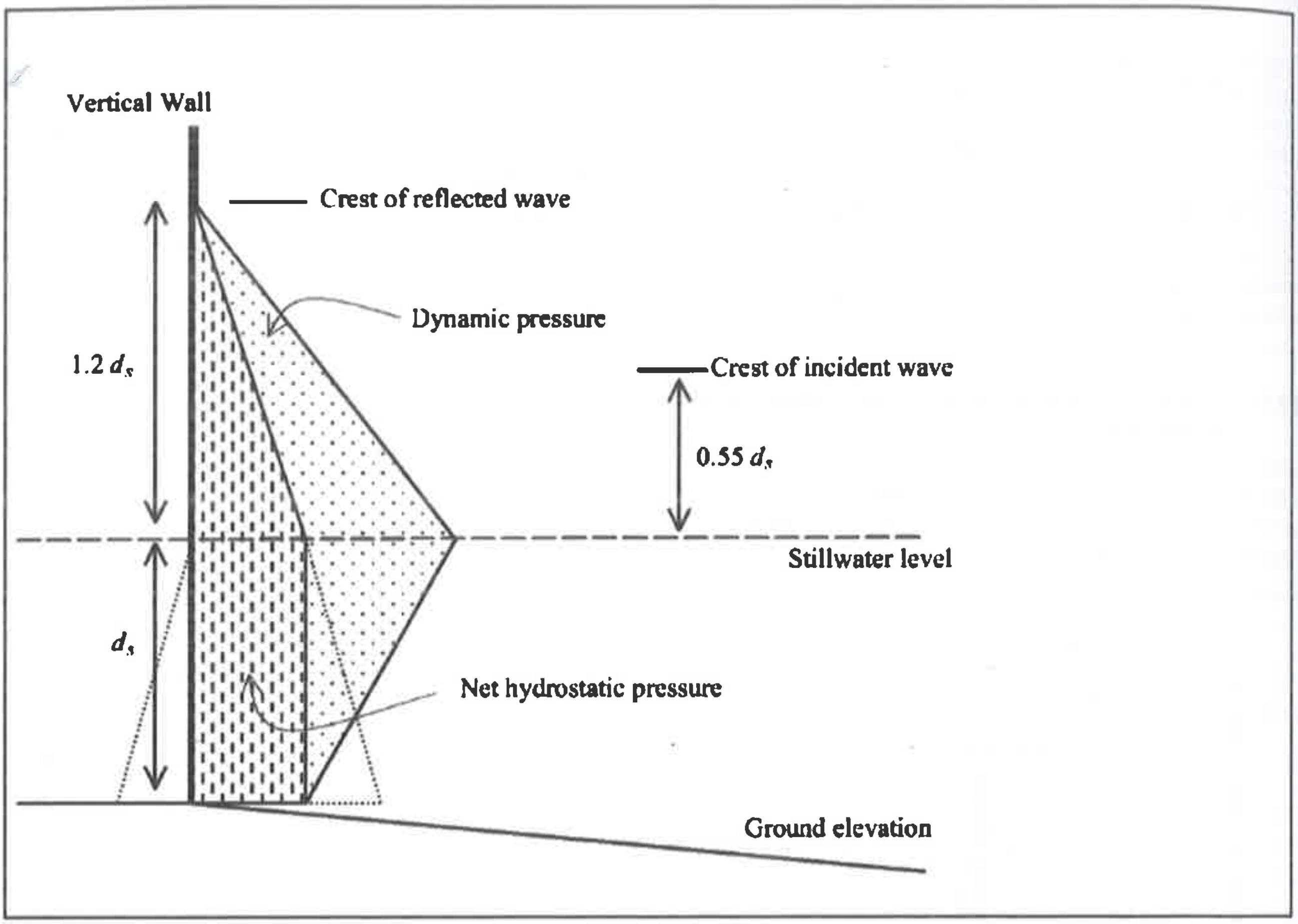


Figure 211-2
Normally Incident Breaking Wave Pressures Against a Vertical Wall
(Still Water Level Equal on Both Sides of Wall)