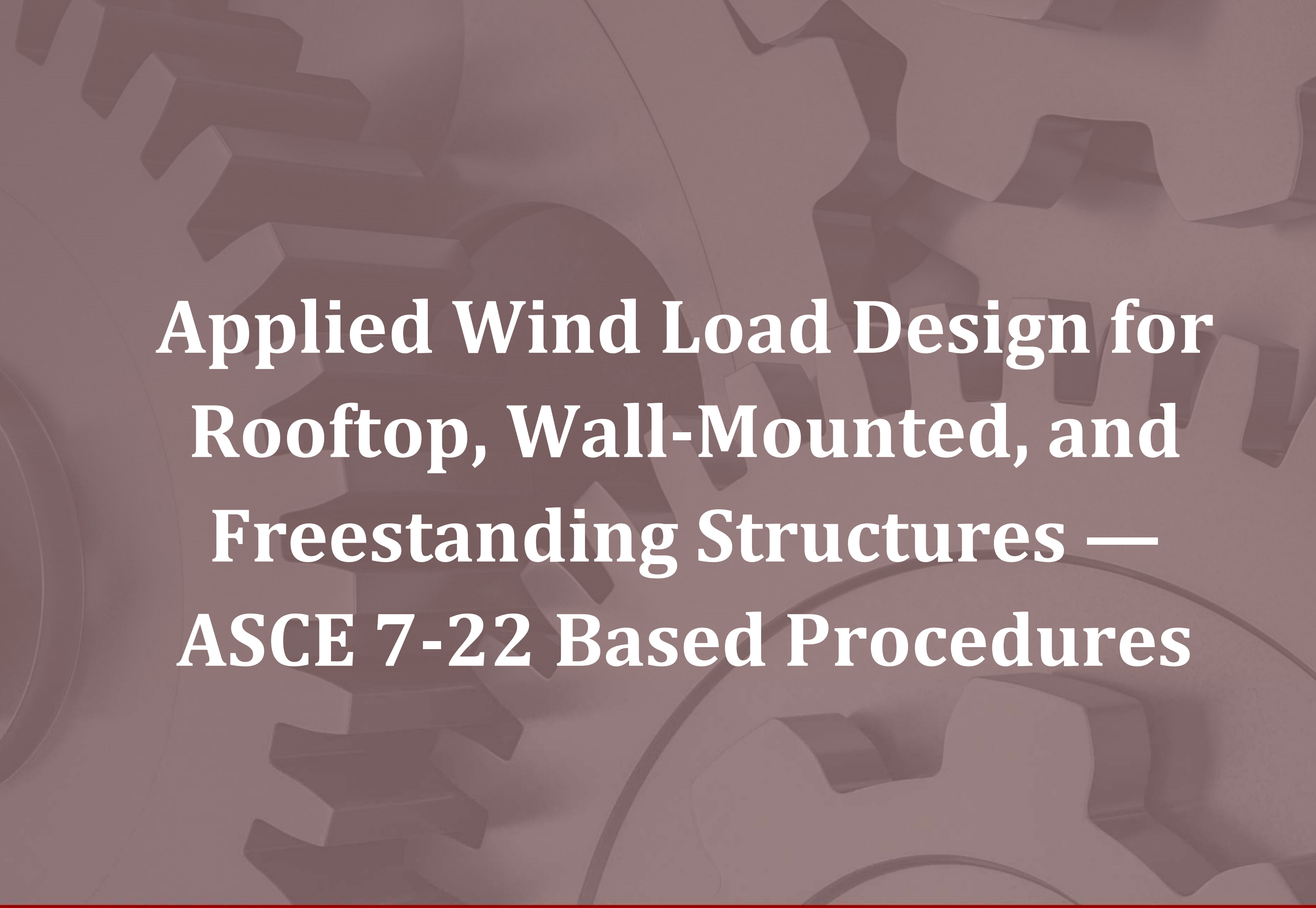

Applied Wind Load Design for Rooftop, Wall-Mounted, and Freestanding Structures — ASCE 7-22 Based Procedures

An Online Continuing Education Course for Engineers

Course Number: S-3033

Credit: 3 Hours / 3 PDH / 3 CPD

Applied Wind Load Design for Rooftop, Wall-Mounted, and Freestanding Structures — ASCE 7-22 Based Procedures

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COURSE OUTLINE / PARTS

Part 1 — Rooftop Appurtenances
Part 2 — Wall-Mounted and Attached Appurtenances
Part 3 — Freestanding and Other Structures (Non-Building)
Part 4 — From Wind Pressure to Design Forces

INTRODUCTION

This course guides practicing structural engineers through wind load determination for building appurtenances and other structures using the detailed provisions of ASCE 7-22.

Examples include direct references to chapters, sections, tables, and figures, with step-by-step calculations illustrating limit state design pressures for strength design applications. Where allowable stress design is used, adjustments are noted according to ASCE 7-22 load factors.

Designed as a practical, desk-side reference, this course helps engineers apply code provisions confidently, avoid common mistakes, and handle rooftop, wall-mounted, and freestanding elements that often govern project decisions.

PART 1 — ROOFTOP APPURTENANCES

Wind Load Evaluation for Rooftop Elements in Accordance with ASCE 7-22

Rooftop-mounted appurtenances have been repeatedly identified as critical initiation points for wind-induced damage in low-rise and mid-rise buildings (Fig.1). Post-event reconnaissance reports issued by FEMA, ASCE, and state emergency management agencies following recent hurricanes and severe straight-line wind events consistently document a common failure sequence. Localized failure of rooftop equipment or attachments frequently precedes roof membrane uplift, progressive deck distress, loss of enclosure integrity, and, in some cases, secondary structural damage. These observations indicate that rooftop appurtenance failures are seldom governed by insufficient material strength of the component itself. Instead, they are most often attributed to unconservative wind pressure assumptions, incomplete consideration of internal pressure effects, or discontinuities in the load path between the appurtenance and the primary structural system.

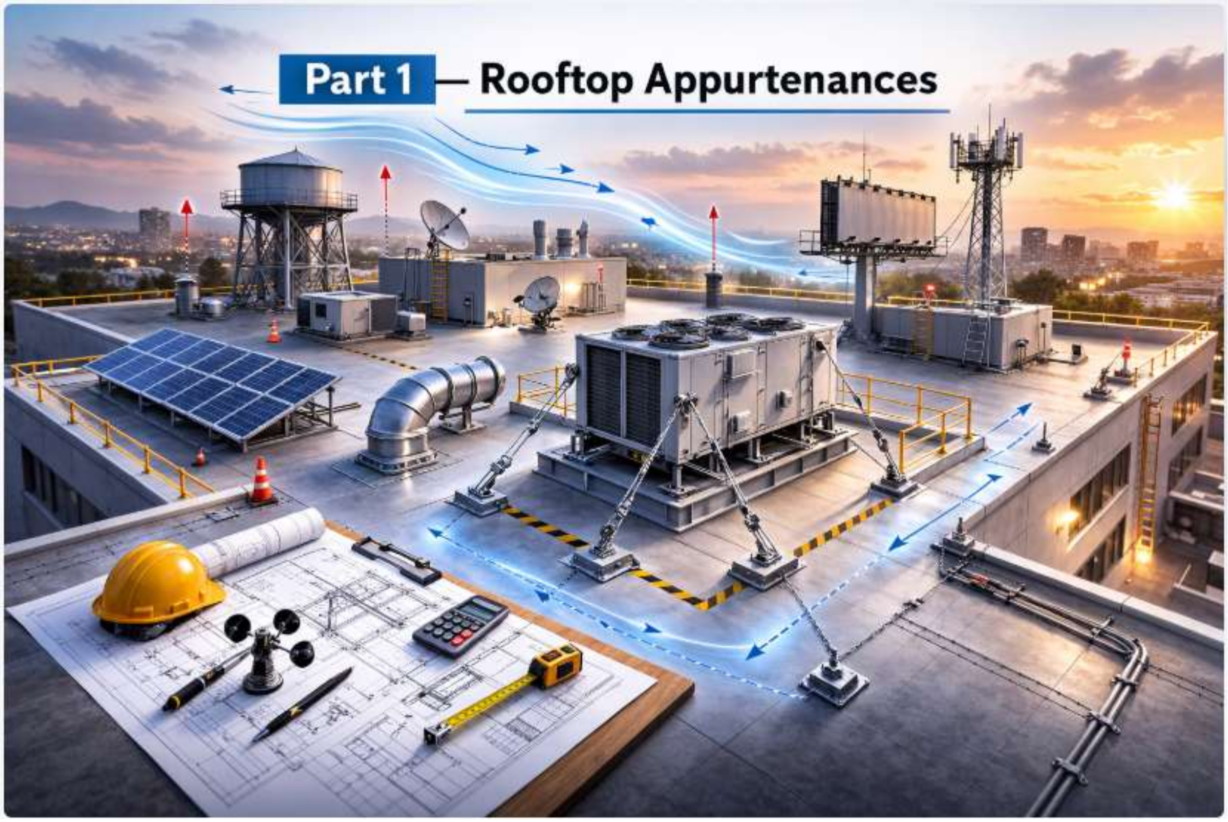

Fig. 1 — Typical Rooftop Appurtenances Subjected to Wind Loading per ASCE 7-22

ASCE 7-22 explicitly addresses this vulnerability by classifying rooftop appurtenances as components and cladding subject to localized wind pressures that commonly exceed those used for the main wind-force-resisting system. The code intent is clear: rooftop-mounted elements must be evaluated independently using pressure coefficients that reflect local flow behavior at roof edges and corners, rather than relying on global roof pressures or gravity-based attachment assumptions.

Minimum design wind pressures shall not be taken less than those specified in ASCE 7-22 §30.1.4. Risk Category selection directly influences basic wind speed per Figures 26.5-1A through 26.5-1C and must be verified at project initiation.

Where rooftop elements contribute to the Main Wind-Force-Resisting System (MWFRS), evaluation shall follow ASCE 7-22 Chapter 27 rather than Chapter 30. Misclassification between MWFRS and Components & Cladding remains a frequent source of review comments in permit submissions.

Enclosure Classification and Internal Pressure Effects

The wind load evaluation process for rooftop elements begins with enclosure classification, as defined in ASCE 7-22 Chapter 26. Enclosure classification directly influences internal pressure coefficients and therefore governs the net pressure acting normal to rooftop-mounted components. In practical design and forensic review, a significant proportion of commercial and industrial buildings qualify as partially enclosed due to the presence of large overhead doors, loading dock openings, glazing failures, or extensive louvered wall areas on windward elevations.

When a building behaves as partially enclosed, positive internal pressurization may develop under windward exposure. This internal pressure acts simultaneously with external suction on rooftop components, producing amplified net uplift demands. Field investigations have repeatedly shown that rooftop units located near roof edges or corners experience the most severe demand combinations when partial enclosure coincides with localized suction effects. Failure to properly account for internal pressure has been identified as a recurring deficiency in both original designs and post-construction evaluations.

Roof Zones, Exposure, and Velocity Pressure

Wind pressures acting on rooftop appurtenances are highly sensitive to roof zoning and exposure category. ASCE 7-22 Chapter 30 recognizes that flow separation and vortex formation near roof edges and corners generate substantially higher suction pressures than those acting on interior roof zones. These localized effects are particularly pronounced for low-rise structures, where the roof height is comparable to the atmospheric boundary layer thickness.

Exposure category further influences the magnitude of the velocity pressure evaluated at roof height. In accordance with ASCE 7-22 Chapter 26, the velocity pressure must be determined using the appropriate exposure coefficient, topographic factor, and directionality factor, and then carried consistently into the component and cladding provisions of Chapter 30. Inconsistent use of velocity pressure between Chapters 26 and 30 remains a common source of error in practice.

Worked Example — Uplift Demand on a Rooftop HVAC Unit

Consider a packaged rooftop HVAC unit installed on a low-rise commercial building with a mean roof height of 12 m. The structure is located in Exposure C and is classified as partially enclosed. The unit has a projected plan area of 7.2 m² and is installed within an edge roof zone.

The velocity pressure at roof height is evaluated in accordance with ASCE 7-22 §26.10 as

$$q_h = 0.613\ Kz\ Kzt\ Kd\ V^2$$

Using SI units throughout, and assuming a basic wind speed $V = 42$ m/s, the exposure coefficient at roof height is taken as $K_z = 1.03$. The topographic factor K_{zt} is taken as 1.0, and the directionality factor K_d is taken as 0.85. Substituting these values yields:

$$q_z = 0.613 \times 1.03 \times 1.0 \times 0.85 \times 42^2 = 1.00 \text{ kPa}$$

When the basic wind speed V is expressed in meters per second, the coefficient 0.613 yields the velocity pressure directly in SI base units of N/m^2 (Pa). For practical structural design applications where pressures are carried forward in kN/m^2, the computed value may be converted by dividing by 1000, or the coefficient 0.000613 may be used to obtain velocity pressure directly in kN/m^2 without intermediate unit conversion.

For rooftop components and cladding located within an edge roof zone, ASCE 7-22 Chapter 30 specifies an external pressure coefficient of $GC_p = -2.8$. Given the partially enclosed classification, the applicable internal pressure coefficient is $GC_{pi} = +0.55$.

The resulting net design pressure acting normal to the rooftop unit is therefore:

$$p = q_h (GC_p - GC_{pi})$$

$$p = 1.00 \times (-2.8 - 0.55) = -3.35 \text{ kPa}$$

The corresponding uplift force acting on the unit is obtained by multiplying the net pressure by the projected plan area:

$$F = |p|\ A$$

$$F = 3.35 \times 7.2 = 24.1 \text{ kN}$$

This uplift demand exceeds the self-weight of most packaged rooftop units of comparable size, indicating that anchorage design governs performance. Load combinations shall be applied in accordance with ASCE 7-22 Section 2.3 (LRFD) or Section 2.4 (ASD) [Corrected load combination reference] and Chapter 2. For allowable stress design, the governing combination is typically 1.0D + 1.0W.

The wind directionality factor $K_d = 0.85$ is applied in accordance with ASCE 7-22 §26.6. Zone-specific adjustments referenced in Chapter 30 modify pressure coefficients and do not replace the global directionality factor unless explicitly stated by the code.

Minimum Design Pressure Enforcement

ASCE 7-22 Section 30.1.4 establishes a mandatory lower bound for component and cladding wind pressures. The calculated pressure obtained from the coefficient-based procedure shall not be less than the prescribed minimum design wind pressure, regardless of exposure category, roof height, or zone location. In practice, this provision becomes critical in low-rise structures located in Exposure B, where computed pressures may fall below the minimum threshold, particularly within interior roof zones.

The professional obligation does not end at computing pressure coefficients and velocity pressure. The engineer shall explicitly verify that the resulting design pressure satisfies the minimum requirement of the code before converting it into anchor forces or connection demands. Failure to enforce minimum pressure provisions is frequently observed in peer reviews and post-event forensic evaluations, especially for rooftop mechanical units assumed to be located in sheltered regions.

Where the calculated pressure magnitude is less than the minimum required by ASCE 7-22 §30.1.4, the minimum pressure shall govern the design. This governing pressure shall then be carried forward through load combinations and anchorage verification in accordance with Chapter 2 of ASCE 7-22 and ACI 318-22 Chapter 17.

Professional Consideration:
Minimum pressure enforcement is not a conservatism adjustment; it is a mandatory code boundary condition intended to prevent underestimation of localized wind effects on rooftop components.

Equipment Screens and Vertical Rooftop Elements

Vertical rooftop elements, such as equipment screens and parapet-mounted barriers, differ fundamentally from rooftop units due to their orientation and exposure to lateral drag forces. When installed near roof edges, these elements are subjected to amplified pressures caused by accelerated flow and local vortex shedding. Post-event damage surveys frequently show that failures initiate at the screen-to-roof connection rather than within the screen framing itself.

This observed behavior highlights the importance of verifying the complete load path from the screen through its anchorage and into the supporting roof diaphragm or structural framing. Designs that focus exclusively on member capacity without explicit consideration of load transfer mechanisms have repeatedly been shown to be vulnerable under extreme wind events.

Worked Example — Flush-Mounted Solar Panels Adjacent to a Roof Edge

Consider a flush-mounted solar panel array installed adjacent to a parapet within an edge roof zone. Although the panels have a low profile, ASCE 7-22 Chapter 30 indicates that localized suction pressures may govern attachment design.

Using the previously evaluated velocity pressure of $q_h = 1.20$ kPa, the external pressure coefficient for low-profile rooftop components is taken as $GC_p = -1.9$. The internal pressure coefficient remains $GC_{pi} = +0.55$

The resulting net uplift pressure is:

$$p = qh\ (GCp - GCpi) = 1.20\ (-1.9 - 0.55) = -2.94\ \text{kPa}$$

Clarification: This example intentionally applies Cp and Cpi with explicit gust factor G. This is distinct from the GCp/GCpi method used in other sections. Each load case shall consistently adopt only one formulation.

Implementation Note: This equation uses GCp and GCpi, which already include the gust-effect factor G. The gust factor shall not be applied separately in this load case. Where Cp and Cpi are used instead, G must be applied explicitly. The two formulations shall not be mixed within a single load evaluation.

$$p = q_h\left(GC_p - GC_{pi}\right) = 1.20\ (-1.9 - 0.55) = -2.94\ \text{kPa}$$

For a tributary panel area of 1.6 m², the uplift forc ting on an individual nel is:

F = |p| A = 2.94 × 1.6 = 4.7

In typical installa ements, and embedment
depth into the su d combinations shall
again be applied i (ASD) [Corrected load
combination refer

Peer reviews and p ies in rooftop
appurtenance desig of interior roof
pressure coefficients hment without
verification of uplift r ce-level conditions,
can become critical u m material-related;
they most often stem ure types, and
incomplete anchorage ation of load paths
for rooftop-mounted el her than
secondary checks, ensu and related standards.
Systematic application o reliable structural performance and reflects practical
engineering judgment in peer review, and post-construction verification.

Part 2 — Wall-Mounted and Attached Appurtenances

Practical Wind Load Design in Accordance with ASCE 7-22

Wall-mounted appurtenances, including louvers, exterior ducts, architectural sunshades, mechanical supports, and attached canopies (Fig. 2), are frequently treated as secondary elements relative to the primary structural frame. However, post-event investigations and plan review experience consistently demonstrate that these components often govern localized wind performance of the building envelope.