Wind Loads on Domed and Arched Buildings as Per ASCE7-22

An Online Continuing Education Course for Engineers

Course Number: S-4029

Credit: 4 Hours / 4 PDH / 4 CPD

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1. Introduction:

Wind load is the load of the current of air and gusts during windstorms and hurricanes acting on the structure. The wind load is a function of wind speed in the zone where the structure is located.

The standard (ASCE7-22) develops maps of the “basic wind speed” for all the states of the US based on the building's Risk Category (I, II, III, or IV).

This course starts by determining the primary factors that affect the wind pressure acting on the structure, such as velocity pressure exposure coefficient (k_z), wind directionality factor (k_d), ground elevation factor (k_e), topographic factor (k_{zt}), gust factor (G), external pressure coefficient (GC_p), enclosure classification, and internal pressure coefficient (GC_{pi}).

The course then focuses on determining the Design Wind Pressure acting on MWFRS and C&C of structural members in domed and arched buildings and their appurtenances, such as parapets and overhangs.

At the end of the course, more than 50 solved problems cover all the provisions of the latest edition of ASCE7-22, “Minimum Design Loads and Associated Criteria for Buildings and Other Structures,” regarding the basics of wind loads and wind loads on domed and arched buildings.

This course is a part of a series of independent courses related to wind load determination for different types of structures.

The following is the list of related courses:

1. Wind Load on All-Height Buildings.
2. Wind Load on Open Buildings.
3. Wind Load on Domed and Arched Buildings.
4. Wind Load on Low-Rise Buildings.
5. Wind Load on Circular Non-Building Structures.
6. Wind Load on Solar Panels and Rooftop Equipment
7. Wind Load on Signs and Trussed Towers

For other structural loads covered by ASCE7-22, there is another series of courses that includes the determination of dead loads, live loads, snow loads, crane loads, and seismic loads.

This course covers the following topics:

1. Risk Category.
2. Basic Wind Speed.
3. Velocity pressure exposure coefficient (k_z).
4. Wind directionality factor (k_d).
5. Ground elevation factor (k_e).
6. Topographic factor (k_{zt}).
7. Gust factor (G).
8. Enclosure Classification.
9. External pressure coefficient (GCp).
10. Internal pressure coefficient ($GCpi$).
11. Design Wind Pressure (p) for MWFRS of Domed Roofs.
12. Design Wind Pressure (p) for MWFRS of Arched Roofs.
13. Design Wind Pressure (p) for MWFRS of Parapets in Domed or Arched Roofs.
14. Design Wind Pressure (p) for MWFRS of Overhangs in Domed or Arched Roofs.
15. Design Wind Pressure (p) for C&C of Domed Roofs.
16. Design Wind Pressure (p) for C&C of Arched Roofs.
17. Design Wind Pressure (p) for C&C of Parapets in Domed or Arched Roofs.
18. Design Wind Pressure (p) for C&C of Roof Overhangs in Domed or Arched Roofs.
19. Examples.

2. Risk Category

Each structure shall be assigned a Risk Category level, which depends on the use or occupancy type and the number of occupants.

ASCE7-22 demonstrates the uses or occupancies of each Risk Category as follows:

a. Risk Category (I):

This category includes buildings and other structures that represent a low risk to human life in the event of failure.

It includes greenhouses, temporary buildings, etc.

b. Risk Category (II):

This category includes buildings and other structures except those in Risk Category I, III, & IV.

c. Risk Category (III):

This category includes:

- buildings and other structures whose failure represents a substantial risk to human life in the event of failure,
- buildings and other structures whose failure represents a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure. (Not included in Risk Category IV)
- facilities that accommodate hazardous chemicals, hazardous waste, or explosives.
- facilities that accommodate toxic, explosive substances of a quantity larger than those allowed by the authority of jurisdiction and may cause a threat to the public if released.

d. Risk Category (IV):

This category includes:

- essential facilities, such as police stations, ambulances, electricity stations, fire stations, etc.
- buildings and other structures whose failure represents a substantial risk to the community in the event of failure,
- facilities that accommodate hazardous fuels, hazardous chemicals, and hazardous waste.
- facilities that accommodate sufficient quantities of highly toxic substances of a quantity larger than those allowed by the authority of jurisdiction and may cause a threat to the public if released.
- buildings and other structures required to maintain the functionality of other Risk Category IV structures.

The determination of the structure's risk category is used to select the corresponding wind speed map in ASCE7-22-Figure 26.5-1A to Figure 26.5-1D.

3. Basic Wind Speed (*V*)

The wind speed used in structural design differs among the standards of structural loads. There are four types of wind speed:

- 3 Second-gust wind speed: the wind speed is the peak wind speed measured from an average gust with 3 3-second recording period during the “design windstorm.”
- Mean-hourly wind speed: The wind speed is the peak wind speed measured from an average gust with a one-hour recording period during the “design windstorm.”

- 10-minute wind speed: The wind speed is the peak wind speed measured from an average gust with a 10-minute recording period during the “design windstorm.”
- Fastest mile wind speed: the wind speed is the peak wind speed measured from an average gust without a certain recording period during the “design windstorm.”

In accordance with ASCE7-22-Section 26.2, the basic wind speed is a 3-second wind speed measured at 33 ft above the ground in Exposure C. This speed is used to calculate wind pressure acting on structures.

The exposure categories are explained in section (4-a).

Basic wind speeds for the United States are figures in maps in ASCE7-22 Figures (26.5-1A) to (26.5-1D).

Figure (26.5-1A) provides wind speed for structures with Risk Category (I).
Figure (26.5-1B) provides wind speed for structures with Risk Category (II).
Figure (26.5-1C) provides wind speed for structures with Risk Category (III).
Figure (26.5-1D) provides wind speed for structures with Risk Category (IV).

The design wind speed is increased for structures with higher “Risk Categories.” This is because the return period for a structure with a higher “Risk Category” is longer than its counterpart with a lower “Risk Category.” The return period is the inverse of the probability of occurrence of the storm used to determine the basic wind speed.

For a Risk Category “I,” the return period is 300 years; this means that the storm is probable to occur once per 300 years. Therefore, the probability of such a storm is 0.33%.

Table (01) indicates the return period and probability of each Risk Category.

Table (01). Return Period and Probability of Risk Categories

Risk Category	Return Period (years)	Probability
I	300	0.33%
II	700	0.14%
III	1,700	0.06%
IV	3,000	0.033%

It shall be mentioned that the basic wind speed in ASCE7-22 is determined at the ultimate strength level, which means that the load factor of wind load in load combinations is 1.00 for the LRFD method and 0.60 for the ASD method.

4. Velocity Wind Pressure (q):

The general equation of velocity wind pressure (q) is:

$$q_z = 0.00256 K_z K_{zt} K_e V^2 (\text{lb/ft}^2); V, \text{mi/h} \qquad \text{(ASCE7-22-Eq.26.10-1)}$$

The velocity pressure (q) is the pressure of the wind in the zone under consideration, regardless of the shape and vibration properties of the structure. It is determined using the following factors:

1. Basic Wind Speed (V).
2. Surface exposure and velocity pressure exposure coefficient (k_z).
3. Topographic factor (k_{zt}).
4. Ground elevation factor (k_e).

a) *Surface Exposure:* The wind load intensity is affected by the ground surface roughness at the upwind direction, this is affected by natural topography, vegetation, and constructed facility. ASCE7-22 classifies the wind exposures in the upwind direction into three categories:

Category B:

Urban and suburban areas, wooded areas, or other terrains with numerous, closely spaced obstructions with single-family dwellings or larger.

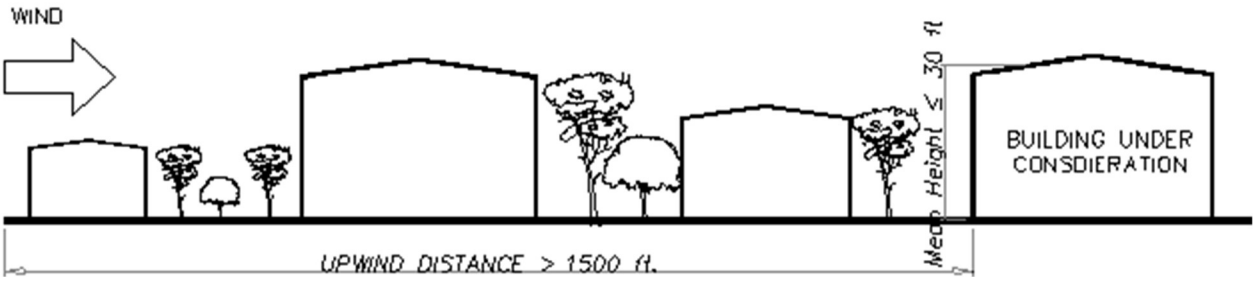
This category also includes cities with skyscrapers and high-rise buildings. The main determinator of this category is the spacing between the obstructions, such as buildings, trees, mountains, and others.

The designer can assign this category to buildings in cities crowded with closed-spaced buildings and other structures or high ones.

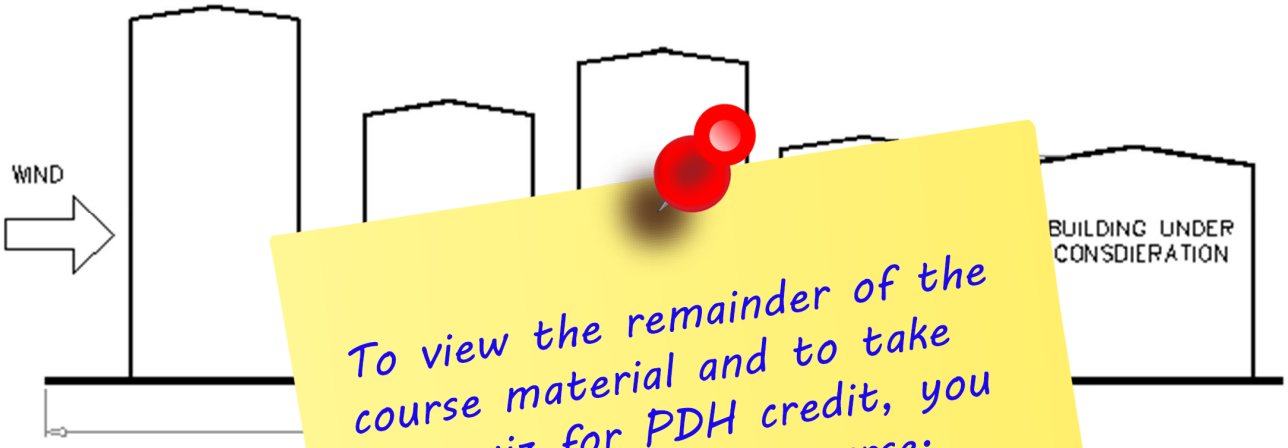
Types of buildings located in this category:

- Buildings and other structures with a mean roof height less than or equal to 30 ft (9.1 m) located in a ground surface roughness of category (B) that prevails in the upwind direction for a distance greater than 1500 ft (457 m), as shown in figure (01).

- Buildings and other structures with a mean roof height greater than 30 ft (9.1 m) located in a ground surface roughness category (B) that prevails in the upwind direction for a distance greater than 2600 ft (792 m) or 20 times the height of the building or the structure, whichever is greater, as shown in figure (02).



SUBURBAN AREA WITH COSELY-SPACED WITH SINGLE FAMILTY DWELLINGS



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