ICC SPRING INTERCHANGE

Ever-changing Structural Provisions of our Building Codes- Wind

INTERNATIONAL CODE COUNCIL

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Ever-Changing Structural Provisions of Our Building Codes - Wind

S. K. Ghosh

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www.skghoshassociates.com

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Design Load Standards

1. ANSI A58.1-1972
2. ANSI A58.1-1982
3. ASCE 7-88
4. ASCE 7-93
5. ASCE 7-95
6. ASCE 7-98
7. ASCE 7-02
8. ASCE 7-05 (2006/2009 IBC)

Note: Only seismic provisions changed between ASCE 7-88 and ASCE 7-93

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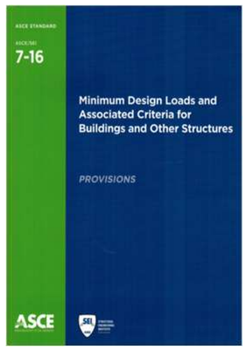
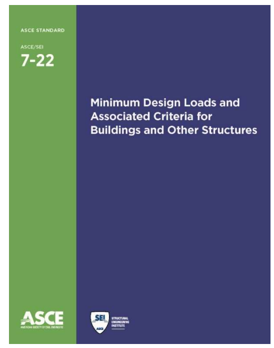
Design Load Standards

9. ASCE 7-10
10. ASCE 7-16
11. ASCE 7-22





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WIND

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Background

- Wind Loading is the effect of the atmosphere passing by a stationary structure attached to the earth's surface.
- Wind Loads are controlled by Atmospheric and Aerodynamic effects.
- The 3 terms in the general equation of wind:

$$p = q \times G \times C_p$$

  - Velocity Pressure, q - Atmospheric Effects.
  - External Pressure Coefficient, C_p – Aerodynamic Effects.
  - Gust Effect Factor, G - Combination of both.

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Atmospheric Effects

- Meteorological Effects
- Boundary Layer Effects

Atmospheric boundary layer - That part of the atmosphere that directly feels the effect of the earth's surface

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Meteorological Effects

- Meteorology provides a description and explanation of the basic features of atmospheric flows.
- Climatology deals with the prediction of storm conditions at a given geographic location.

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Climatological Effects

- Thunderstorms.
- Tornadoes.
- Hurricanes.
- Special Regional Effects.

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Thunderstorms

- Variety of associated wind phenomena.
- Predicted thunderstorm activity controls vast majority of US wind loads.
- Reason most of the inland U.S. has very similar design wind speeds.

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Tornadoes

- Design wind speeds do not include the effects of tornadoes.
- Probability of occurrence at a particular location so low that tornadoes do not appear in the 50-year statistical storm data used to formulate the inland portion of the map.

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Tornadoes

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Hurricanes

- Size and duration makes much higher probability of striking a given coastal location.
- Control design wind speeds along:
  - Atlantic and Gulf coasts.
  - Islands of the Caribbean.
  - Islands of the Pacific.
- Return period greater than 50 years used to be used on the hurricane coast to provide consistent risk of failure.

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Special Wind Regions

- Regional wind effects such as:
  - Wind blowing over mountain ranges
  - Wind blowing through gorges and valleys
- These increase the wind speeds above those shown on the map.
- Consultation with wind engineers or meteorologists may be required.

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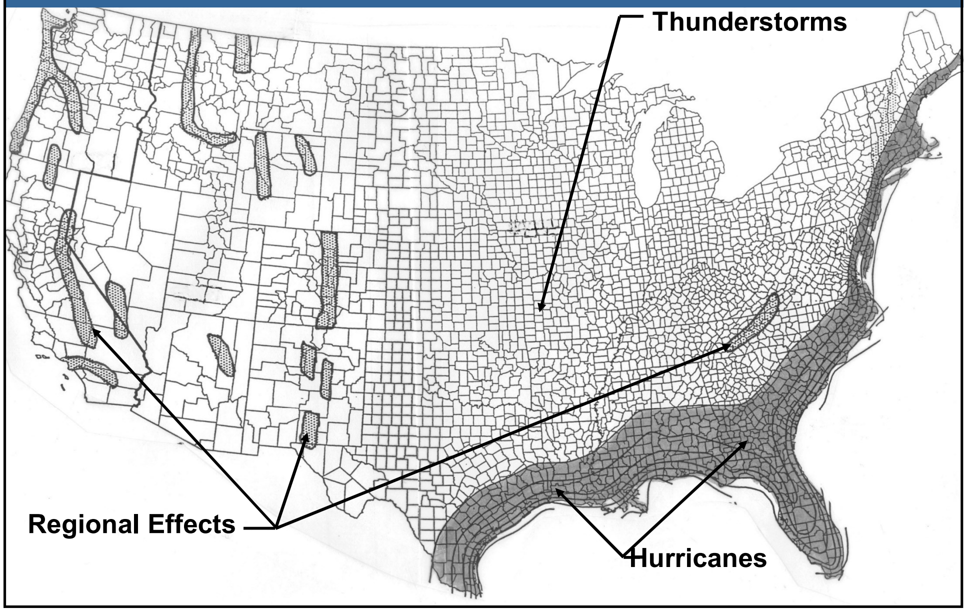
Controlling Factors - Wind Speed



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Velocity Pressure

ASCE 7-98, ASCE 7-02, ASCE 7-05:

$$q = \left(0.00256V^2\right)K_z K_{zt} K_d I$$

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Numerical Constant

The constant 0.00256 reflects the mass density of air for the standard atmosphere, i.e., the temperature of 59^{0}F and sea level pressure of 29.92 in. of mercury, and dimensions associated with wind speed in miles per hour.

Constant = ½ [(0.0765 lb/cu ft) / (32.2 ft/sec^2)]

x [(mi/h) (5280 ft/mi) x (1h/3600sec)]^2

= 0.00256

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Basic Wind Speed

Basic wind speed, *V*: 3-second gust speed at 33 ft (10 m) above the ground in Exposure C and associated with an annual probability of 0.02 of being equaled or exceeded (50-year mean recurrence interval).

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Velocity Pressure

ASCE 7-98, ASCE 7-02, ASCE 7-05:

$$q = \left(0.00256V^2\right)K_z K_{zt} K_d I$$

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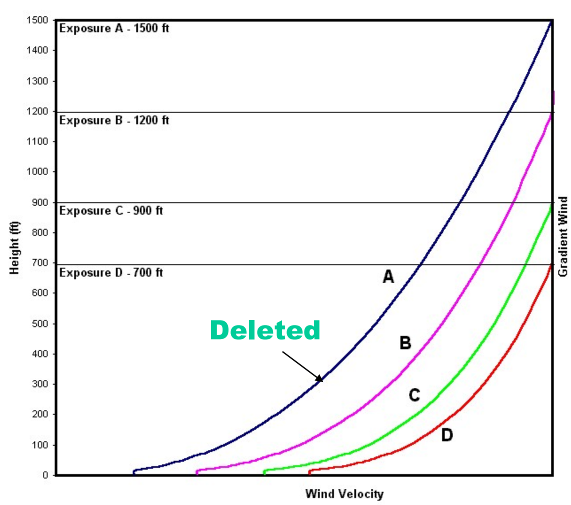
Wind Velocity Profiles & Boundary Layer Thickness



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Exposure Constant

$$K_z = 2.01\left(z / z_g\right)^{2/\alpha}$$

Parabolic Equation of "Power Law" curves.

z is the height above ground.

z_g is the thickness of the boundary layer for each exposure category (B, C, D).

α is the power law exponent for each exposure category, equal to 7.0, 9.5, and 11.5 for Exposures B, C, and D, respectively.

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Velocity Pressure

ASCE 7-98, ASCE 7-02, ASCE 7-05:

$$q = \left(0.00256V^2\right)K_z K_{zt} K_d I$$

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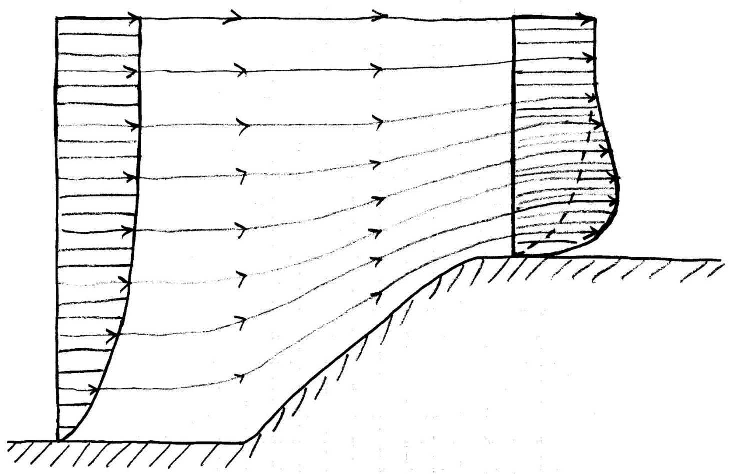
Topographic Wind Speed-up Effect



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Velocity Pressure

ASCE 7-98, ASCE 7-02, ASCE 7-05:

$$q = (0.00256V^2)K_z K_{zt} K_d I$$

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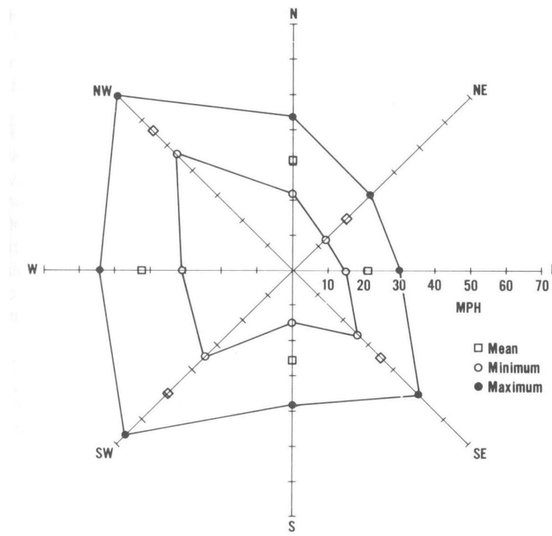
Directionality



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Gust

$p = q \times G \times C_p$

- Rapid fluctuation of wind
- Ordinary structures sensitive to peak gusts of about 1 sec duration.
- Use of fastest-mile wind in design inadequate

  Gust speed, $V_g = G_v V$

- Pressure generated by gust, $p_g = G_p p$

  $p \propto V^2 \quad \therefore G_p = G_v^2$

- Flexible structures more sensitive to gust.

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Gust Effect Factor

- Accounts for the loading effects in the along-wind direction (parallel to the direction of the wind) due to wind turbulence-structure interaction.
- Also accounts for along-wind loading effects due to dynamic amplification for flexible structures.
- Does not account for other dynamic effects such as across-wind loads.

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Gust Effect Factor (*G*)

Starting with ASCE 7-95,

- *G* may be taken as 0.85 for all rigid buildings' MWFRS.
- *G* must be calculated for flexible buildings' MWFRS.
- *G* is included in a combined GC_p term for Low-Rise MWFRS and Components and Cladding.

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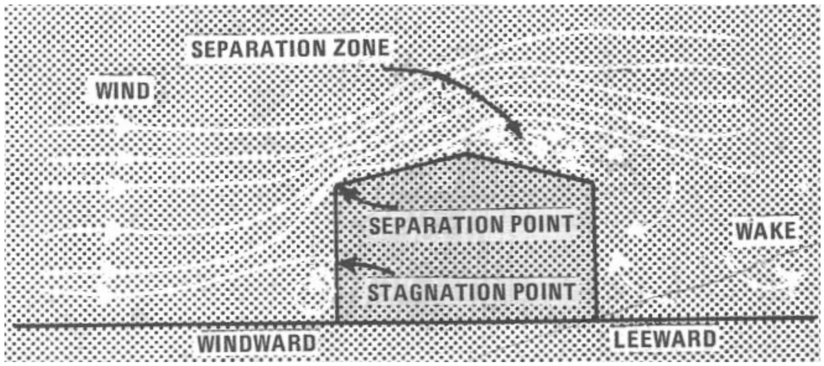
Wind Flow Around Building



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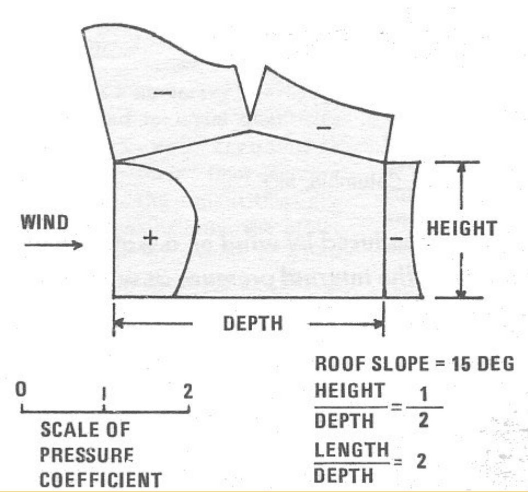
External Pressure due to Wind



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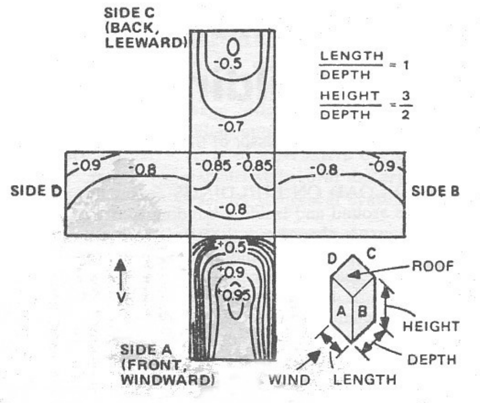
Dimensionless Pressure or Pressure Coefficient

$$C_p = \frac{p - p_a}{(\frac{1}{2})\rho V^2} = \frac{p'}{(\frac{1}{2})\rho V^2}$$

p = actual pressure at any arbitrary point on building, psf



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Pressure Coefficients (C_p)

- C_p determined experimentally in wind tunnel.
- Values vary for different types of building shapes, and for the different methods used in the provisions.
- Consistently lower values for MWFRS coefficients compared to C&C.
- MWFRS correlated between the pressure values on the different surfaces.
- C&C uses worst case values.

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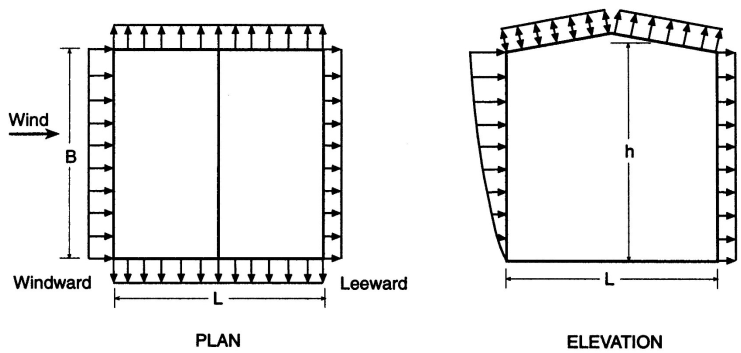
Wind-resistant Design

Wind Pressures on a Building



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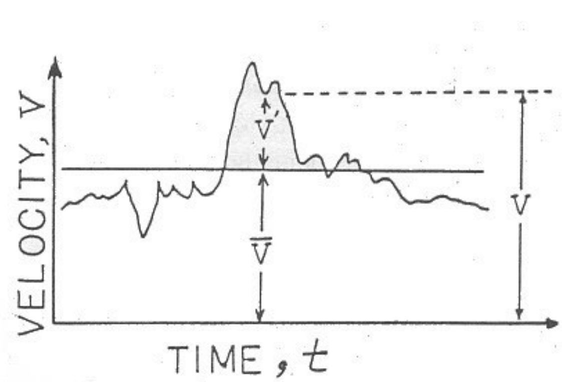
Wind Velocity

Instantaneous velocity of wind at a point as a function of time:



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Fastest-Mile Wind

- Maximum wind speed averaged over one mile of wind passing through the anemometer.

- Averaging time of fastest-mile wind: T(sec) 3600/V_f

  V_f – fastest-mile wind speed in mph

  For V_f = 60 mph – T = 3600/60 = 60 sec

  For V_f = 120 mph – T = 3600/120 = 30 sec

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Return Period

- Also known as mean recurrence interval (MRI).
- In most U.S. inland locations, MRI of 50 years was used for normal-use structures.
- Return period greater than 50 years was used on the hurricane coast to provide consistent risk of failure.
- MRI for critical facilities such as hospitals was 100 years.
- MRI for low-risk buildings such as barns was 25 years.

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Return Period

ANSI A58.1-72:

Mean Recurrence Interval. A basic wind speed with a 50-year MRI shall be used for all permanent structures except those that, in the judgment of the engineer or the authority having jurisdiction, present a high degree of sensitivity to wind and an unusually high degree of hazard to life and property in case of failure. In the latter case, a 100-year mean recurrence interval shall be used. For structures that have no human occupants or where there is negligible risk to human life, a 25-year MRI may be used.

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Return Period

ANSI A58.1-72:

A 50-year MRI design wind speed map and a separate 100-year MRI design wind speed map were provided

A 25-year MRI wind speed map was provided in Appendix (Commentary)

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Unusual Exposures

ANSI A58.1-72:

… For ocean promontories, mountains, gorges, and other unusual exposures, where wind records or experience indicates that the wind speeds given … are inadequate, higher basic wind speeds may be prescribed by the building official. All mountainous and hilly exposures must be carefully examined for such unusual conditions.

Basically the same language continued in ANSI A58.1-82.

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Return Period

ANSI A58.1-82:

Only a 50-year MRI design wind speed map was provided.

Table in Appendix (Commentary) provided 25-year, 50-year, and 100-year MRI wind speed values for locations in the United States.

The table was continued in ASCE 7-88 and ASCE 7-93 despite introduction of Importance Factors

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Importance Factor

- For MRI of 25, 50 , and 100 years -
  3 Maps???? - No!
- MRI was adjusted by using an importance factor, *I*.
- Ratio of difference in velocity pressure from one MRI to another is a fairly consistent ratio for non-hurricane locations.

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Importance Factor, *I*, (Wind Loads)

ASCE 7-88 and ASCE 7-93:

Building Classification	Importance Factor, *I*	
	100 miles from hurricane oceanline and in other areas	At hurricane oceanline
I (Standard Occupancy)	1.00 (50-year MRI)	1.05
II (Assembly Buildings	1.07 (100-year MRI)	1.11
III (Essential Facilities)	1.07 (100-year MRI)	1.11
IV (Low-Risk)	0.95 (25-year MRI)	1.00

Factor applied to wind velocity, not pressure

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Importance Factor, *I*, (Wind Loads)

ASCE 7-95:

Building Classification	Importance Factor, *I*
	100 miles from hurricane oceanline and in other areas
I (Low-Risk)	0.87 (25-year MRI)
II (Standard Occupancy)	1.00 (50-year MRI)
III (Assembly Buildings	1.00 (50-year MRI)
IV (Essential Facilities)	1.15 (100-year MRI)

Factor applied to wind pressure, not velocity

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Importance Factor

ASCE 7-98, ASCE 7-02, ASCE 7-05:

Occupancy Category	Importance Factor (Non-Hurricane Prone Regions with *V* = 85-100 mph and Alaska)	Importance Factor (Hurricane Prone Regions with *V* > 100 mph)
I	0.87	0.77
II	1.00	1.00
III and IV	1.15	1.15

Factor applied to wind pressure, not velocity

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ASCE 7 Wind

ANSI A58.1-72, ANSI A 58.1-82,

ASCE 7-88, ASCE 7-93:

Fastest-Mile Wind Speed, *V*

50-year MRI for standard occupancy structures

Wind speed contours for the entire country

Basic wind speed in most of the country: 70 mph

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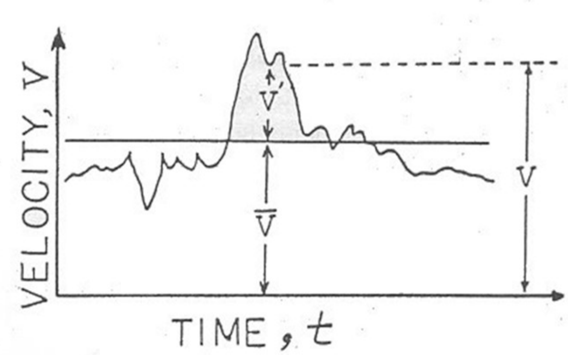
3-second Gust Speed

ASCE 7-95, ASCE 7-98, ASCE 7-02, ASCE 7-05:

50-year MRI 3-sec gust wind speed



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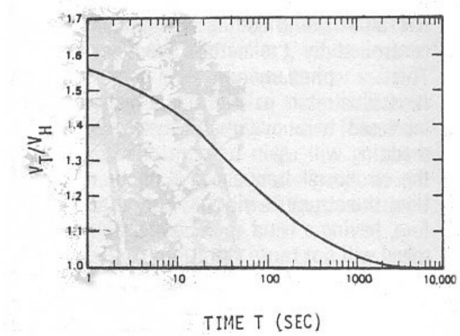
3-second Gust Speed



- V_T = max. wind speed based on averaging time of T sec
- V_H = max. wind speed based on averaging time of 1 hour

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3-second Gust Speed

ASCE 7-95, ASCE 7-98, ASCE 7-02, ASCE 7-05:

Basic wind speed

85 mph in California, Oregon, Washington

90 mph in rest of the country outside of hurricane-prone regions

Higher in hurricane-prone regions

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“Service-Level” Wind

ASCE 7-05:

Load factor on *W* =1.6 in Strength Design

Load factor on *W* =1.0 in ASD.

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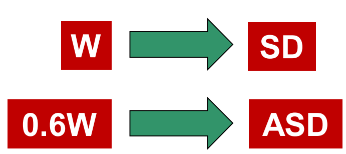
“Strength-Level” Wind

ASCE 7-10:

Load factor on *W* changed to1.0 for Strength Design and 1/1.6 or 0.6 for ASD.

Thus, the design wind speed maps in ASCE 7-10 produce strength-level design wind forces. The mapped design wind speeds are, therefore, higher than in ASCE 7-05.



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ASCE 7-10 Wind

No Importance Factor is used in wind design any more

Basic Wind Speeds: 3 Maps
replace need for Importance Factor

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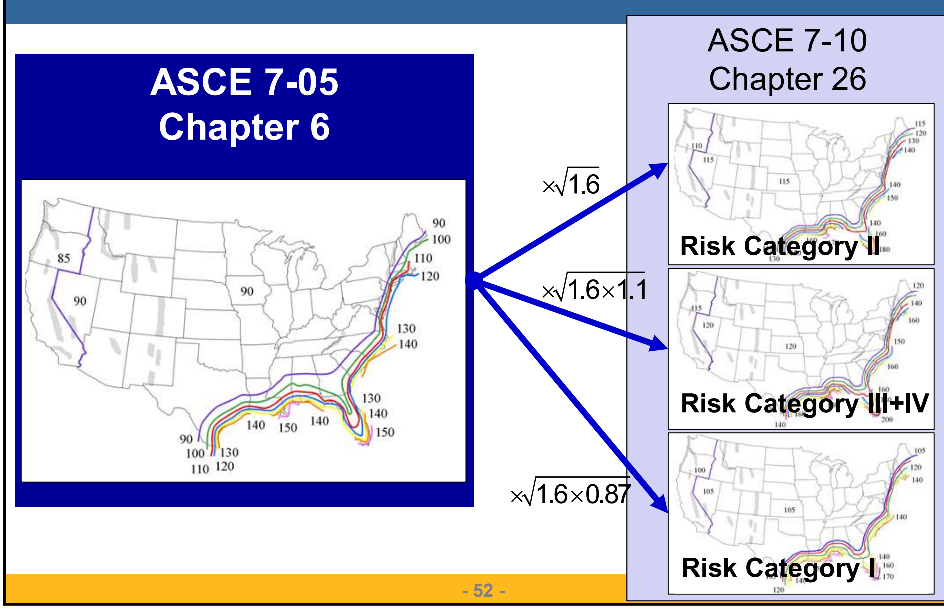
ASCE 7-10 Wind Speed Maps



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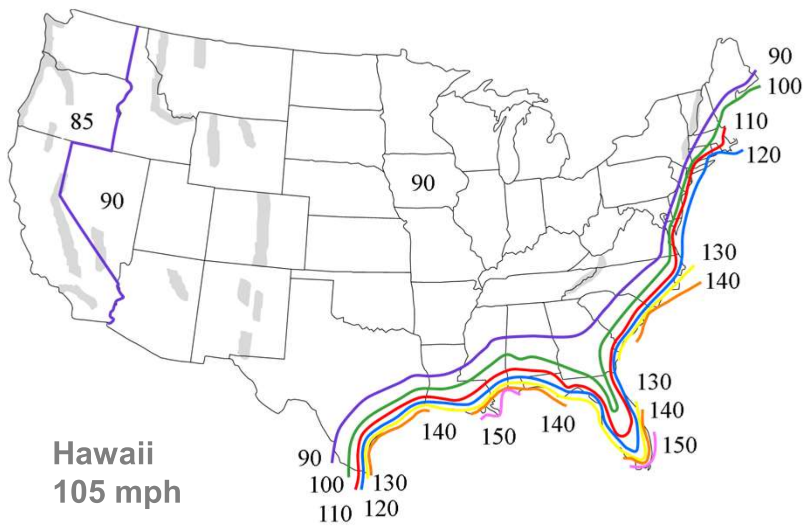
ASCE 7-05 Figure 6-1



Hawaii
105 mph

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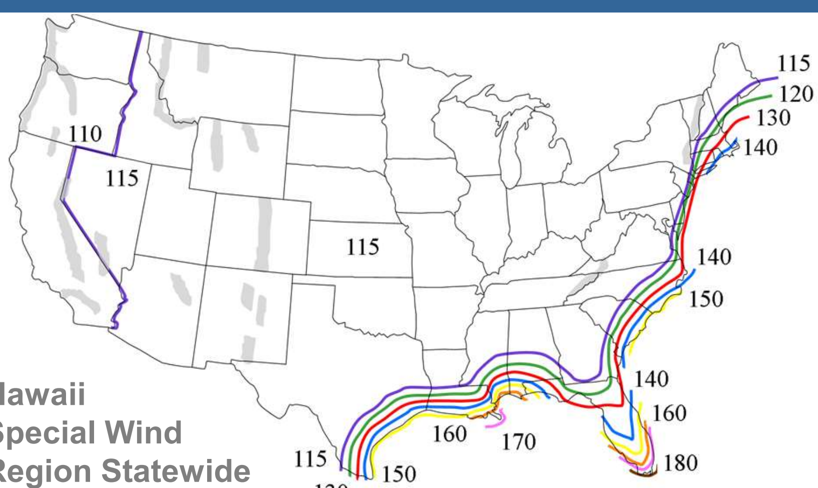
ASCE 7-10 Figure 26.5-1A



Hawaii
Special Wind
Region Statewide
130 mph
(132.8 mph)

Risk Category II - 7% probability of exceedance in 50 years, MRI of 700 years

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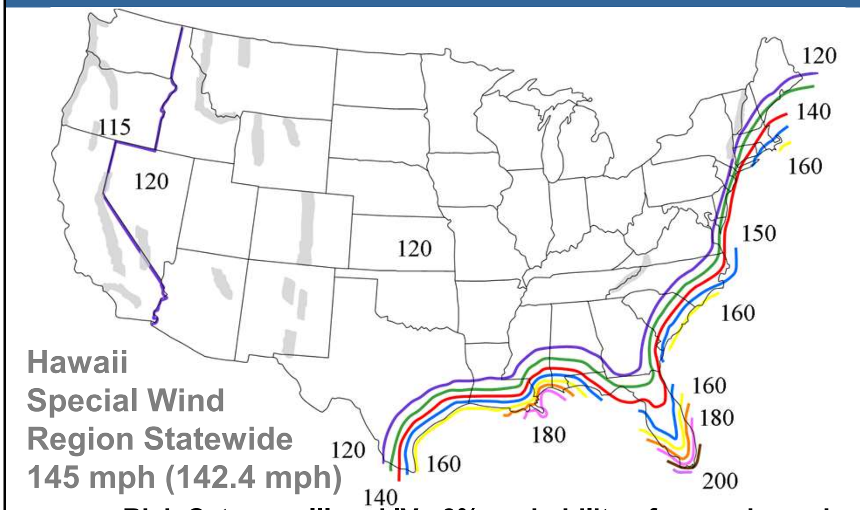
ASCE 7-10: Figure 26.5-1B



Risk Category III and IV - 3% probability of exceedance in 50 years, MRI of 1700 years

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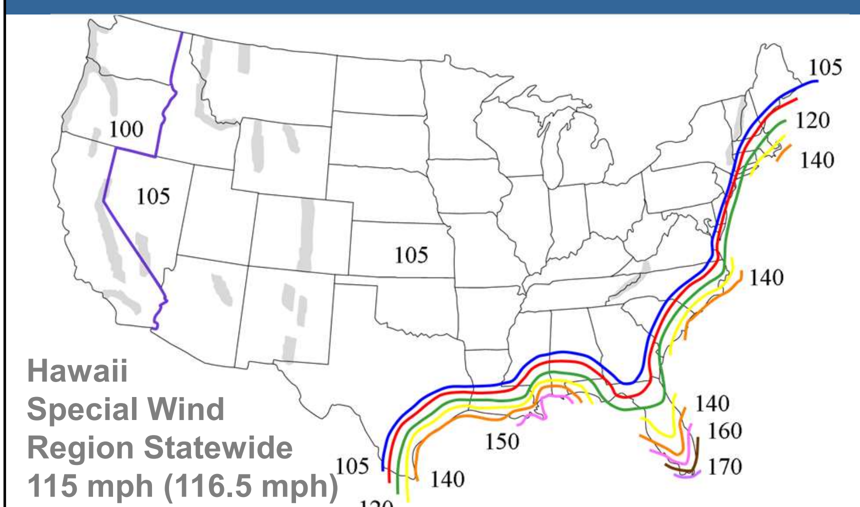
ASCE 7-10: Figure 26.5-1C



Risk Category I - 15% probability of exceedance in 50 years, MRI of 300 years

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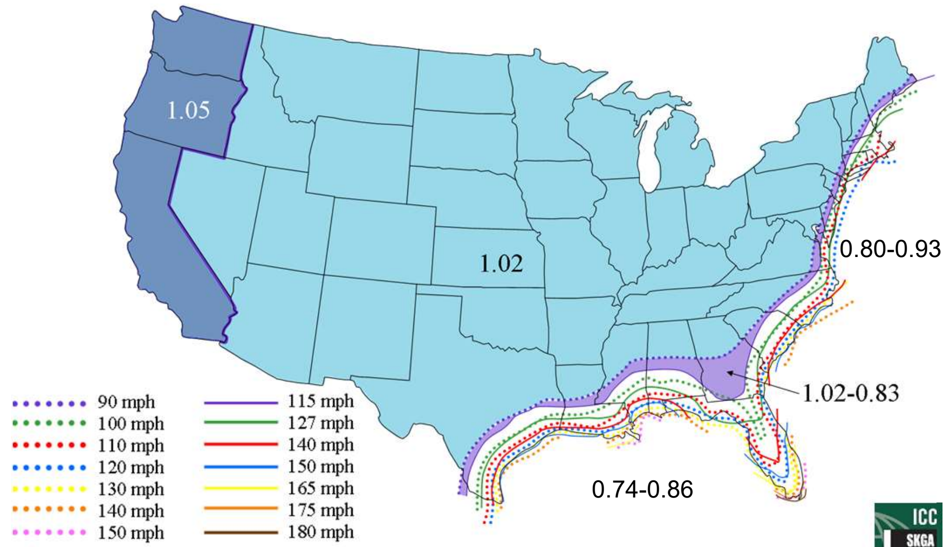
Risk Category II Comparison



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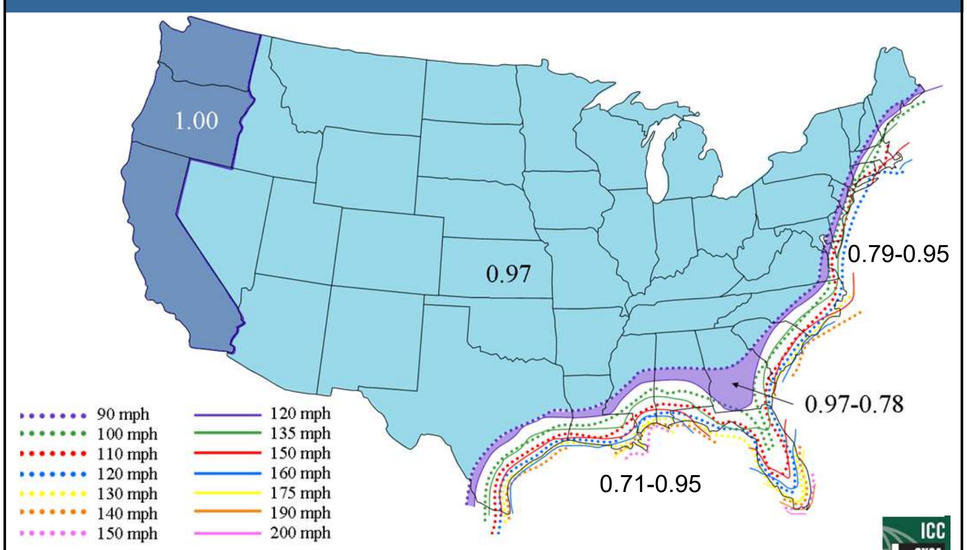
RC III and IV Comparison



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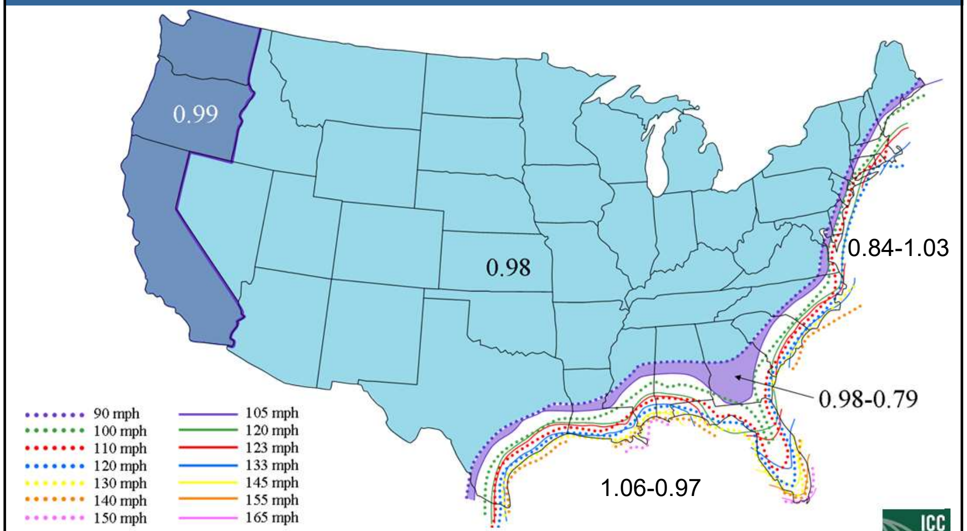
Risk Category I Comparison



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Equations for Velocity Pressure

ANSI A58.1-1 972: $q_{30} = 0.00256V_{30}^2$

ANSI A58.1-1982, ASCE 7-88, ASCE 7-93:

$$q_z = 0.00256\boldsymbol{K_z}(\boldsymbol{I}V)^2$$

ASCE 7-95: $q_z = 0.00256K_z\boldsymbol{K_{zt}}V^2I$

ASCE 7-98, ASCE 7-02, ASCE 7-05:

$$q_z = 0.00256K_zK_{zt}\boldsymbol{K_d}V^2I$$

ASCE 7-10: $q_z = 0.00256K_zK_{zt}K_dV^2$

ASCE 7-16: $q_z = 0.00256K_zK_{zt}K_d\boldsymbol{K_e}V^2$

ASCE 7-22: $q_z = 0.00256K_zK_{zt}K_eV^2$ $p = K_d\,GC_p$

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ASCE 7-16, 7-22 Design Wind Speed Maps

ASCE 7-16:

- ❑ Basic Wind Speed Maps, Figures 26.5-1 A, B, C Replaced
- ❑ New Figure D Introduced

ASCE 7-22:

Basic Wind Speed Maps, Figures 26.5-1 A, B, C Modified

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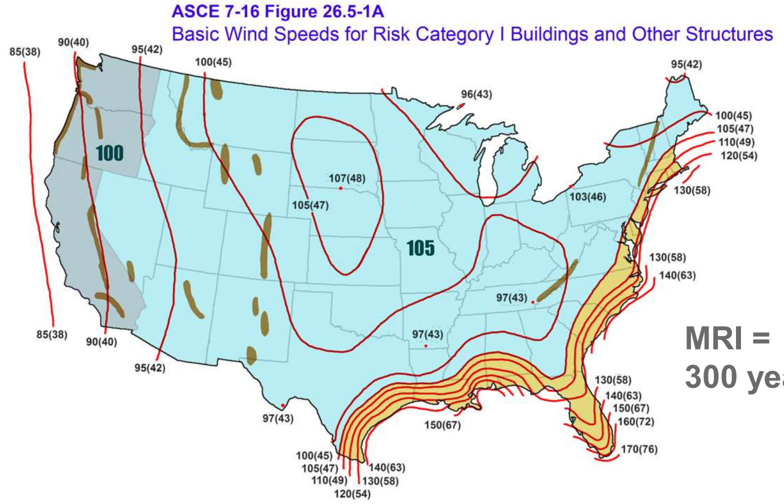
ASCE 7-16 Design Wind Speed Map RC I



MRI = 300 years

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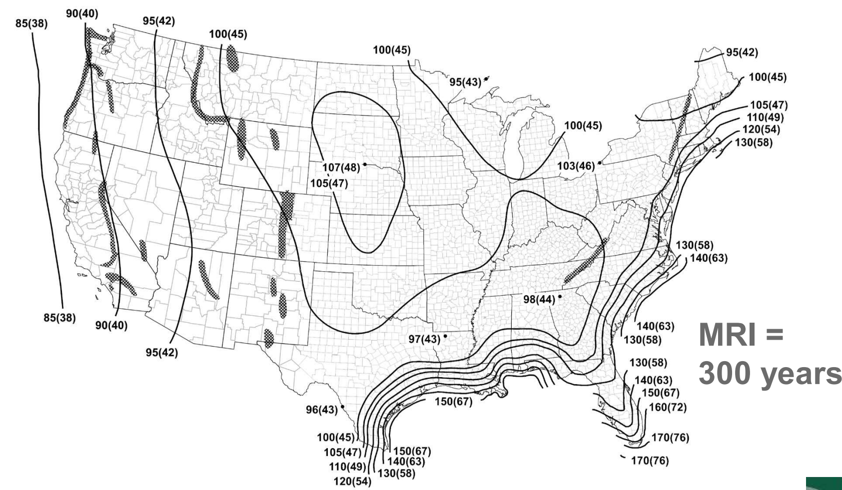
Change 1a: Updated Wind Maps



MRI =
300 years

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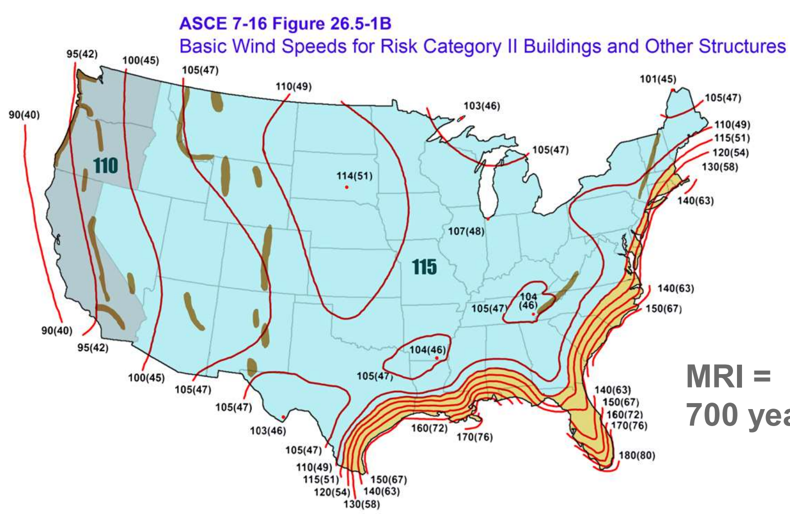
ASCE 7-16 Design Wind Speed Map RC II



MRI =
700 years

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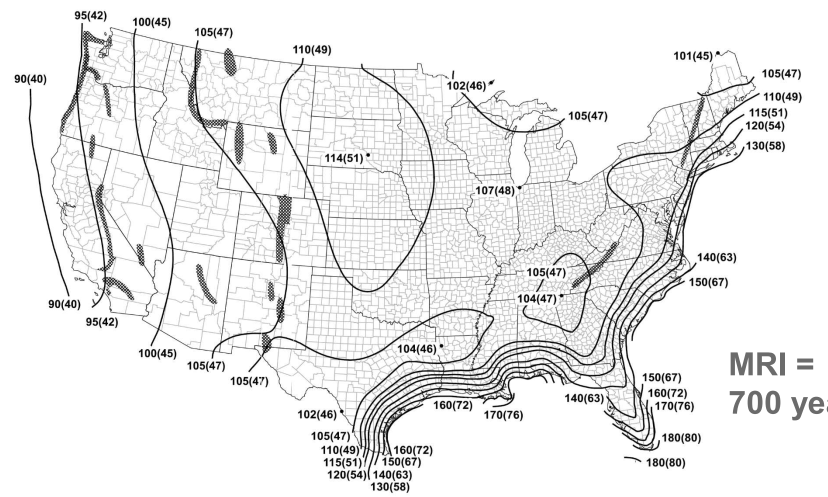
Change 1a: Updated Wind Maps



MRI =
700 years

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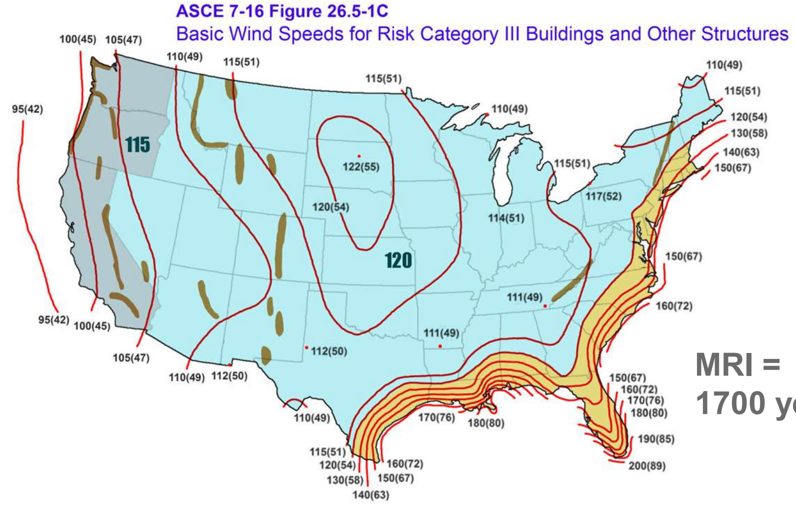
ASCE 7-16 Design Wind Speed Map RC III



MRI =
1700 years

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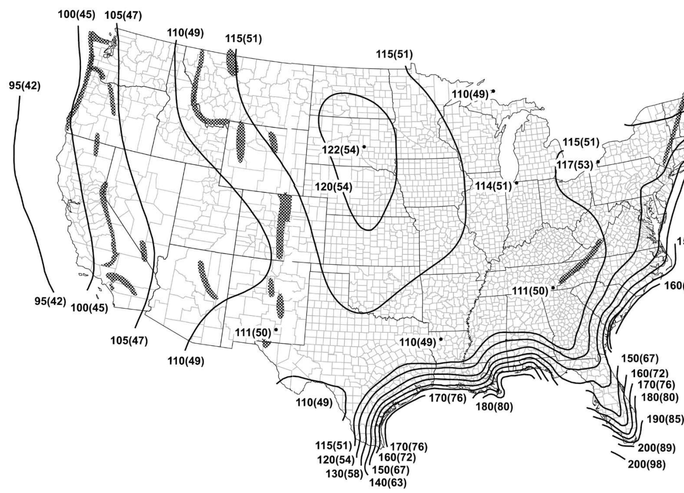
Change 1a: Updated Wind Maps



MRI =
1700 years

ICC SKGA

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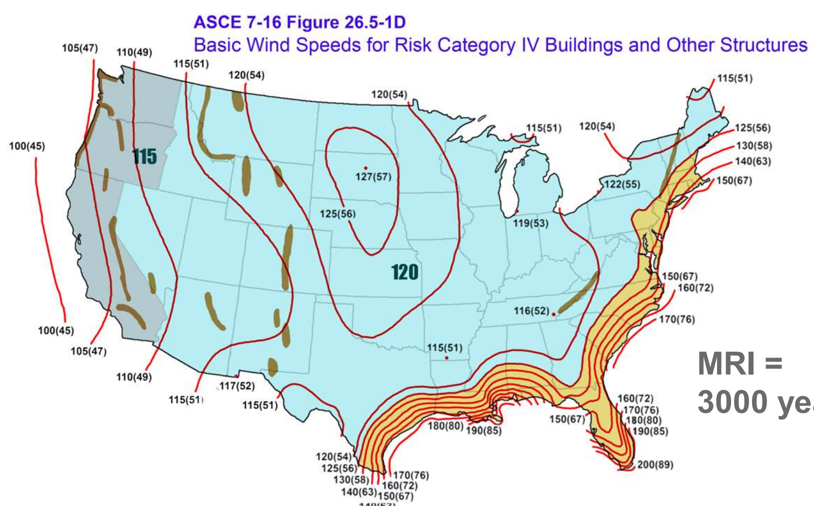
ASCE 7-16 Design Wind Speed Map RC IV



MRI =
3000 years

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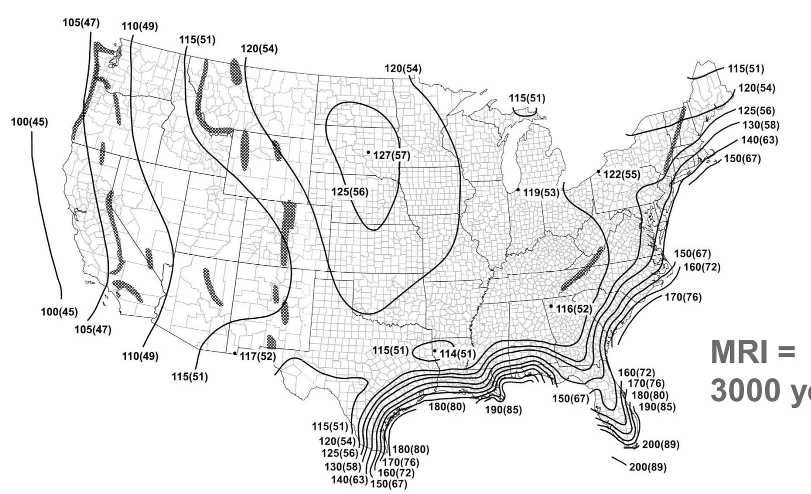
Change 1a: Updated Wind Maps



MRI = 3000 years

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26 Effective Wind Speed Maps for Hawaii

In the 2016 edition, microzoned "effective" wind speed maps for Hawaii were added in accordance with the strength design return periods including the effect of topography. The Hawaii Effective Wind Speeds are algebraically formulated to include the macroscale and mesoscale terrain-normalized values of K_{zt} and K_d (Chock et al 2005), i.e., $V_{effective}$ is the Basic Windspeed V multiplied by $\sqrt{(K_{zt} \times K_d/0.85)}$, so that the engineer is permitted to more conveniently use the standard values of K_{zt} of 1.0 and K_d as given in Table 26.6-1.

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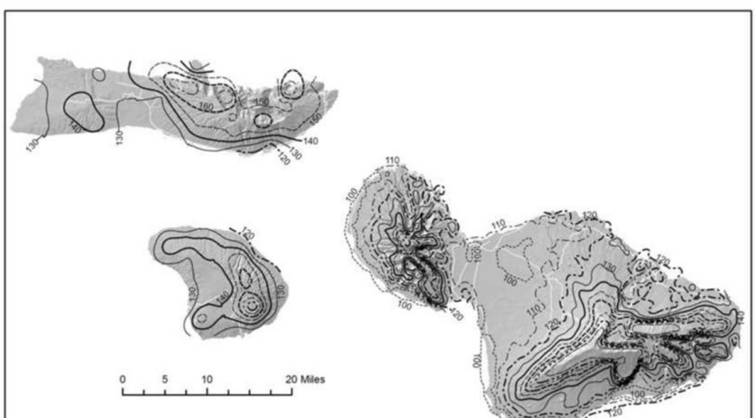
26 Effective Wind Speed Maps for Hawaii

Note that local site conditions of finer toposcale, such as ocean promontories and local escarpments, should still be examined. Spatial resolution scales for digital modeling, including terrain effects, are as follows:

Scale	Spatial Resolution
Toposcale	10–200 m
Mesoscale	200 m–5 km
Macroscale	5–500 km

Effective Wind Speed Maps for Maui, Molokai, and Lanai



Effective Wind Speed Contour for the Islands of Maui, Molokai and Lanai (ASCE 7-2016) for MWFRS, Risk Category I

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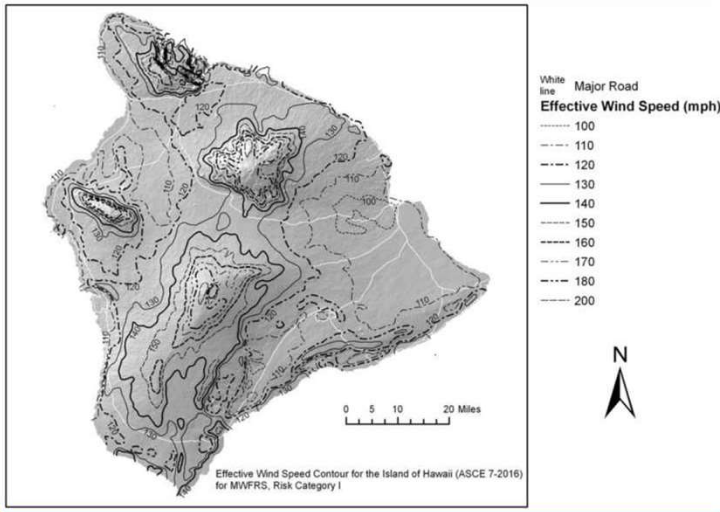
Effective Wind Speed Maps for Hawaii



Effective Wind Speed Contour for the Island of Hawaii (ASCE 7-2016) for MWFRS, Risk Category I

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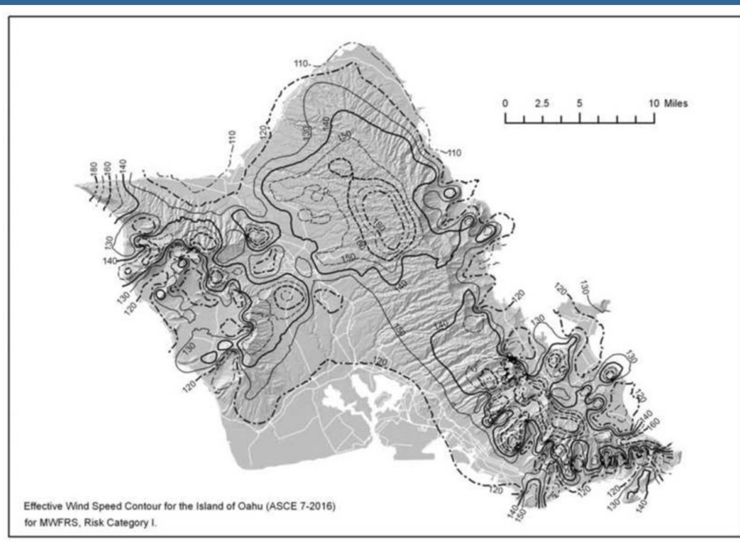
Effective Wind Speed Maps for Oahu



Effective Wind Speed Contour for the Island of Oahu (ASCE 7-2016) for MWFRS, Risk Category I.

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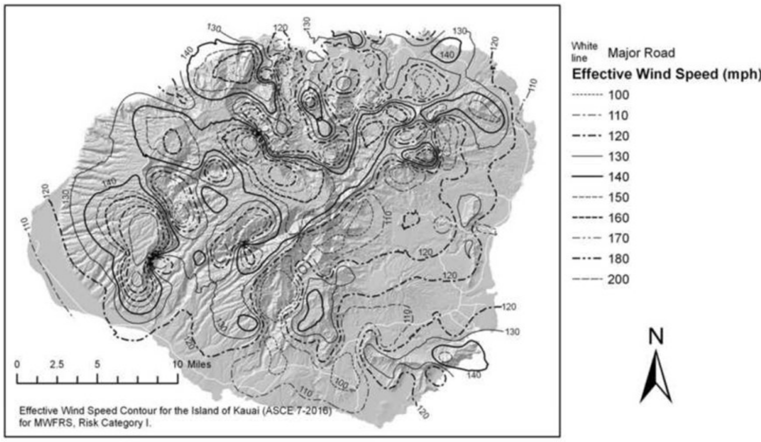
Effective Wind Speed Maps for Kauai



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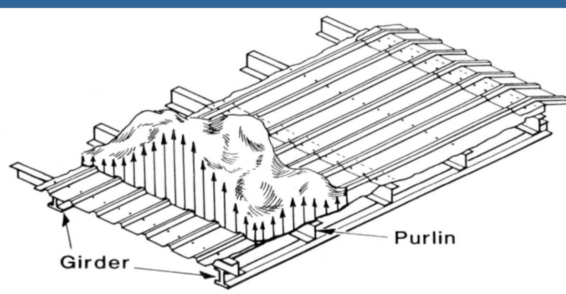
C&C Pressure Coefficients



- Area Based Values for Components & Cladding
- For component and cladding elements, the effective area = the span length × effective width that need not be less than one-third the span length.
- For cladding fasteners, effective area ≤ tributary area

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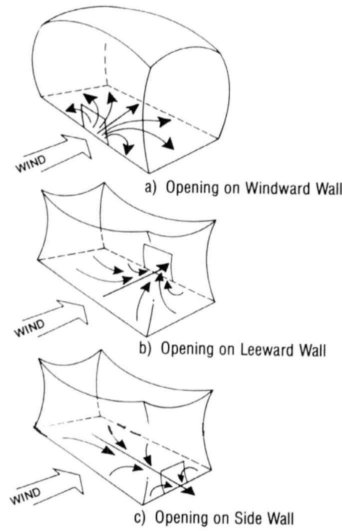
Internal Pressure



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Enclosure Classification

- Buildings with openings large enough to effect the internal pressure, and with a background porosity low enough to allow that pressure to build up, are classified as partially enclosed.
- Buildings which are at least 80% open on every wall are classified as open.

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Enclosure Classification (cont'd)

- Everything else is classified as enclosed. [This changed in ASCE 7-16, with the introduction of a partially open classification – almost a cosmetic change]
- A building may have large openings which would allow pressure to enter, but also have enough background porosity that the pressure escapes as fast as it enters. In this case the building is still classified as enclosed.

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Basic Wind Equation

- For buildings with External and Internal Pressure:

$$p = qGC_p - q_iGC_{pi}$$

q_i = Velocity pressure calculated for internal pressure.

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Evolution of Wind Provisions in U.S. Codes and Standards

- Early building Codes:
  - Uniform pressure of 10 psf and 20 psf below and above 40 ft respectively.
  - Lateral loads only- No uplift provisions.
  - As late as 50 years ago, uplift provisions bore little resemblance to the magnitude of the values used today.

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Evolution of Wind Provisions in U.S. Codes and Standards

ANSI A58.1–1972 — Modern wind design in the United States started with ANSI A58.1–1972.

- The provisions represented a quantum jump in sophistication in comparison with codes of practice at that time.
- The provisions were flawed with ambiguities, inconsistencies in terminology, and a format that permitted misinterpretation of certain provisions.

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Evolution of Wind Provisions in U.S. Codes and Standards

ANSI A58.1–1982 —

- Revised standard contained an innovative approach to wind forces for components and cladding. The wind-load specification was based on understanding the aerodynamics of wind pressure around building corners, eaves, and ridge areas, as well as the effects of area averaging on pressures.
- This standard was largely free of the ambiguities and inconsistencies of ANSI A58.1-1972 and began to be adopted by model code organizations.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-88 — The first minimum-loads standard to appear under ASCE's banner was ASCE 7-88, in which only minor changes and modifications were made in the wind provisions of ANSI A58.1-1982.

ASCE 7-93 — No changes whatsoever were made to the wind provisions in the next edition of the standard, ASCE 7-93.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-95 — The most significant since 1982; a number of important changes made.

- 3-sec gust wind speed became the basis of design. The design wind speed, which for the vast majority of the country had been 70 miles per hour (mph), now became 90 mph, except in the West (roughly in the Pacific time zone), where it typically became 85 mph.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-95 — Important changes (Contd.)

- In order not to end up with significantly greater design wind pressures as a result of this change, numerous adjustments had to be made to coefficients. Some of the more important of these included velocity pressure exposure coefficients, gust-effect factors, and internal and external pressure coefficients that included gust effects.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-95 — Important changes (Contd.)

- Provisions were added for wind speed-up over isolated hills and escarpments by including a topographic-effect factor in the expression for velocity pressure.
- New provisions were added for full and partial loading on the MWFRS of buildings with a mean roof height greater than 60 ft, thereby requiring consideration of wind-induced torsion in all buildings other than low-rise buildings.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-95 — Important changes (Contd.)

- An alternate (low-rise, analytical) procedure was added for determining external loads on the MWFRSs of buildings having mean roof height not exceeding 60 ft. This procedure had been adopted into the Standard Building Code (SBC) from the Metal Building Manufacturers' Association (MBMA) manual and was based on testing carried out at the University of Western Ontario, in London, Ontario, many years earlier.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-98 —

- The basic wind-speed map was updated based on new analysis of hurricane wind speeds. As a result, wind speeds became significantly lower in inland Florida.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-98 —

- A wind-directionality factor, K_d, was introduced in the expression for the design wind pressure to account for the directionality of wind. Directionality used to be taken into account through a relatively low load factor of 1.3 on the effect of wind in strength design. the 1.3 load factor on wind was adjusted up. A load factor of 1.3/0.85 = 1.53 would have maintained status quo exactly. However, it was rounded up to 1.6, which resulted in an effective 5 percent increase in the wind-load factor. For ASD, the effect of this change was 15 percent lower wind forces.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-98 —

- The definitions of Exposures C and D were changed slightly to allow the shorelines in hurricane-prone regions to be classified as Exposure C rather than Exposure D.
- A simplified design procedure was introduced for the first time for relatively common low-rise (mean roof height not exceeding 30 ft), regular-shaped, simple diaphragm buildings. New definitions were introduced for regular-shaped buildings and simple diaphragm buildings.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-98 —

- For the first time, the wind design provisions were organized by the method of design: Method 1 – Simplified Procedure; Method 2 – Analytical Procedure; and Method 3 – Wind Tunnel Procedure. Method 2 contained two separate and distinct procedures under the same heading — the general analytical procedure, applicable to buildings of all heights, and the low-rise analytical procedure, applicable to buildings having mean roof height not exceeding 60 ft.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-98 —

- A very important provision was introduced, requiring that glazing in the lower 60 ft of Category II, III, or IV buildings (all buildings except those representing a low hazard to human life in the event of failure) sited in wind-borne debris regions be impact-resistant glazing or protected with an impact-resistant covering, or such glazing that receives positive external pressure be assumed to be openings. "Wind-borne debris region" was defined in ASCE 7-98.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-02 —

- In ASCE 7-02, the simplified design procedure, Method 1, of ASCE 7-98 was discarded. The simplified design procedure in Section 1609.6 of the 2000 IBC, with only a few relatively minor modifications, was adopted instead. This simplified procedure is based on the low-rise analytical procedure of ASCE 7 and bears strong resemblance to it. Its applicability is broader than that of the simplified design procedure in ASCE 7-98.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-02 —

- ASCE 7-02 required that a ground-surface roughness within each 45-degree sector be determined for a distance upwind of the site. Three surface-roughness categories were defined as shown in *Table 1*.
- Three exposure categories were defined in terms of the three roughness categories. The former Exposure A (centers of large cities) was deleted.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-02 —

- Provisions for calculating wind loads on parapets were added.
- Consideration of wind-induced torsion was now required for all buildings, not just buildings having mean roof height exceeding 60 ft.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-05 —

- ASCE 7-02 required Exposure D to extend inland from the shoreline for a distance of 660 ft or 10 times the height of the building, whichever was greater. ASCE 7-05 required Exposure D to extend into downwind areas of Surface Roughness B or C for a distance of 600 ft or 20 times the height of the building, whichever is greater. Other controlling distances were rounded off to the nearest 100 ft.

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Evolution of Wind Provisions in U.S. Codes and Standards

ASCE 7-05 —

- Glazing in wind-borne debris regions that receive positive external pressure could no longer be treated as openings for design purposes, instead of making it impact-resistant or protected.
- Provisions for wind loads on parapets were updated. Values of the Combined Net Pressure Coefficient were updated from +1.8 and -1.1 to +1.5 and -1.0 for windward and leeward parapets, respectively.

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ASCE 7-10 Reorganization of Wind Provisions

- ASCE 7-05: Chapter 6 contained all wind provisions
- ASCE 7-10:
  - 6 new Chapters (Chapters 26-31)
  - User Notes added
  - Intent was to clarify the applicability of the wind provisions

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Reorganization of Wind Provisions

(ASCE 7-05: Red; ASCE 7-10: Dark Gray)

Method 1 – Envelope Procedure MWFRS, C&C
(Simplified Method 2 Low-Rise)

Method 2

- All-Heights – Directional Procedure MWFRS, C&C
- Low-Rise – Envelope Procedure MWFRS, C&C

Method 3 – Wind Tunnel Procedure

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Reorganization of Wind Provisions
(ASCE 7-05: Red; ASCE 7-10: Dark Gray)

Chapter 26 – General Requirements

Chapter 27 – MWFRS Directional Procedure
Method 2 All-Heights, new simplified version - MWFRS

Chapter 28 – MWFRS Envelope Procedure
Method 2 Low-Rise, Method 1 - MWFRS

Chapter 29 – MWFRS Other Structures and Appurtenances

Chapter 30 – C&C **Method 2 All-Heights, Method 1, new simplified version of Method 2 All-Heights – C&C**

Chapter 31 – Wind Tunnel Procedure **Method 3**

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ASCE 7-10 Section 26.7.2 Surface Roughness Categories

Surface Roughness C: Open terrain with scattered obstructions having heights generally less than 30 ft. This category includes flat open country, and grasslands, and ~~all water surfaces in hurricane prone regions~~.

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

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ACE 7-10 Section 26.7.2 Surface Roughness Categories

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ASCE 7-10 Section 26.7.2 Surface Roughness Categories

- Water surfaces in hurricane-prone regions are moved from Surface Roughness C to Surface Roughness D.
- Older research and modeling suggested roughness of ocean approached Surface Roughness C with increase in wind speed.
- New research suggests otherwise - roughness of ocean does not continue to increase with increasing wind speed.

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Rigid vs. Flexible Buildings

BUILDING OR OTHER STRUCTURE, FLEXIBLE: Slender buildings and other structures that have a fundamental natural frequency less than 1 Hz (T_1>1 sec).

BUILDING OR OTHER STRUCTURE, RIGID: A building or other structure whose fundamental frequency is greater than or equal to 1 Hz.1 (T_1≤1 sec)

$$T_1(\text{sec}) = 1/f_1(\text{sec}^{-1} \text{ or Hz})$$

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ASCE 7-10 Section 26.9.2 Frequency Determination

- In ASCE 7-05, several expressions for computing approximate fundamental frequency , n_1, of a building were suggested in C6.5.8.
- Some of those expressions were now included within the body of ASCE 7-10
- Expressions provide conservative lower-bound estimates of n_1, which is needed to distinguish between rigid and flexible buildings.
- Low-Rise Buildings, as defined in 26.2, are permitted to be considered rigid.

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ASCE 7-10 Section 26.9.2 Frequency Determination

26.9.2.1. As an alternative to performing an analysis to determine n_1, the approximate building natural frequency, n_a, shall be permitted to be calculated in accordance with 26.9.3 for structural steel, concrete, or masonry buildings meeting the following requirements:

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ASCE 7-10 Section 26.9.2 Frequency Determination

26.9.2.1 May use n_a for n_1 if

1. Building height is less than or equal to 300 ft, and
2. Building height is less than 4 times its effective length, L_{eff}.

$$L_{eff} = \frac{\sum_{i=1}^{n} h_i L_i}{\sum_{i=1}^{n} h_i} \qquad (26.9\text{-}1)$$

summations are over height of building where
h_i is height above grade of level i
L_i is building length at level i parallel to wind direction

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ASCE 7-10 Section 26.9.3 Approximate Natural Frequency

- Structural steel moment-resisting-frame buildings:

$$n_a = 22.2/h^{0.8} \qquad (26.9\text{-}2)$$

- Concrete moment-resisting-frame buildings:

$$n_a = 43.5/h^{0.9} \qquad (26.9\text{-}3)$$

- Structural steel and concrete buildings with other lateral-force-resisting system:

$$n_a = 75/h \qquad (26.9\text{-}4)$$

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ASCE 7-10 Section 26.9.3 Approximate Natural Frequency

- Concrete or masonry shear wall buildings

$$n_a = 385(C_w)^{0.5}/h \qquad (26.9\text{-}5)$$

where

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

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ASCE 7-10 Section 26.9.3
Approximate Natural Frequency

h = mean roof height (ft)

n = number of shear walls in building effective in resisting lateral forces in direction under consideration

A_B = base area of structure (ft^2)

A_i = horizontal cross-section area of shear wall "i" (ft^2)

D_i = length of shear wall "i" (ft)

h_i = height of shear wall "i" (ft)

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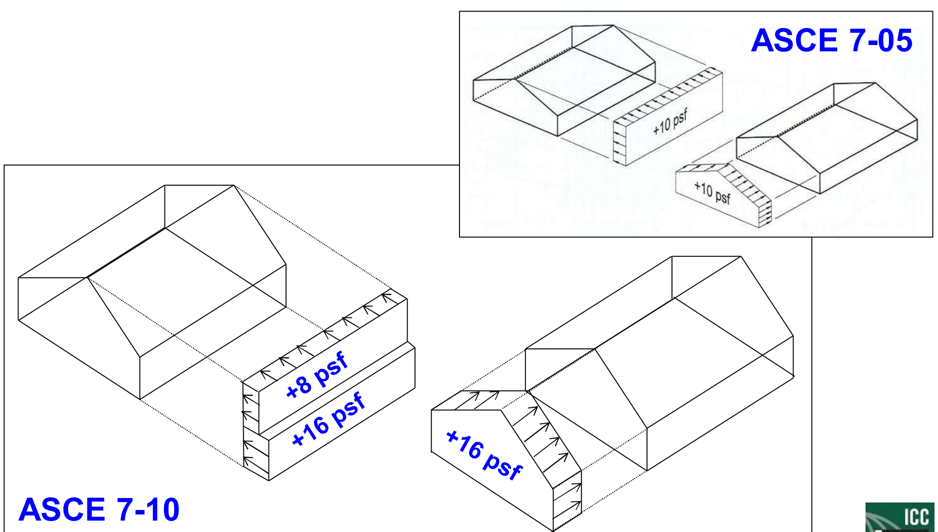
27.4.7, 28.4.4, 28.6.4
Minimum Design Wind Loads



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ASCE 7-16 Velocity Pressure

$q_z = 0.00256 K_z K_{zt} K_d \boldsymbol{K_e} V^2$ (lb/ft²); V in mph (26.10-1)

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ASCE 7-16 Elevation Factor

26.9 Ground Elevation above Sea Level

The effect on air density caused by elevation of the ground level at the project site above sea level is accounted for by the factor K_e, obtained from Table 26.9-1.

Ground Elevation above Sea Level	K_e
0	1.00
1000	0.96
2000	0.93
3000	0.90
4000	0.86
5000	0.83
6000	0.80

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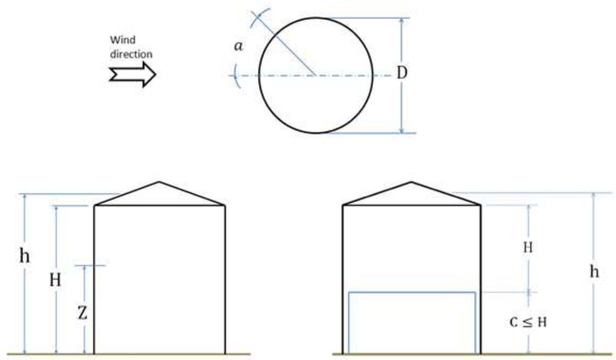
ASCE 7-16 Circular Bins, Silos, and Tanks

29.4.2 Design Wind Loads: Circular Bins, Silos, and Tanks with *h* ≤ 120 ft, *D* ≤ 120 ft, and 0.25 ≤ *H*/*D* ≤ 4.



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ASCE 7-16 Circular Bins, Silos, and Tanks

29.4.2 Design Wind Loads: Circular Bins, Silos, and Tanks with *h* ≤ 120 ft, *D* ≤ 120 ft, and 0.25 ≤ *H*/*D* ≤ 4.

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ASCE 7-16 Rooftop Solar Collectors

29.4.3 Rooftop Solar Arrays for Buildings of All Heights with Flat Roofs or Gable or Hip Roofs with Slopes Less Than 7°.

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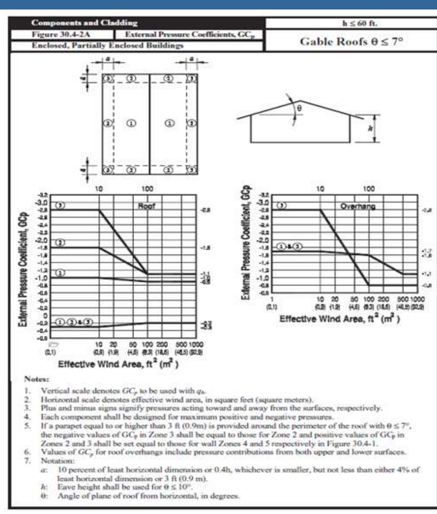
ASCE 7-16 30 Components and Cladding - Gable Roofs (Low-Rise Analytical)



ASCE 7-10

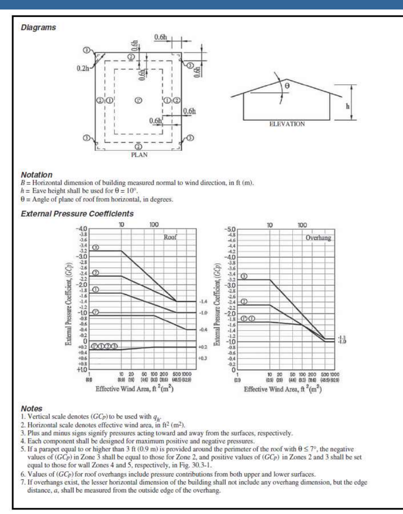


FIGURE 30.3-2A Components and Cladding [$h \leq 60$ ft ($h \leq 18.3$ m)]: External Pressure Coefficients, (GC_p), for Enclosed and Partially Enclosed Buildings—Gable Roofs, $\theta \leq 7°$

ASCE 7-16

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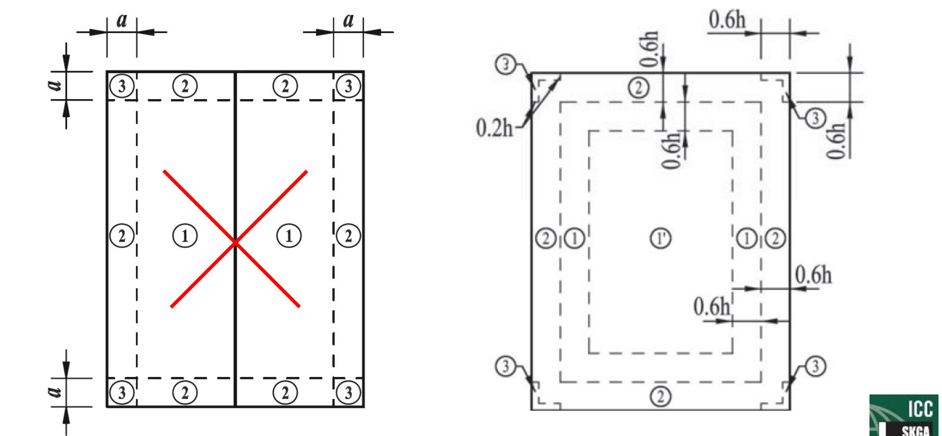
ASCE 7-16 30 Components and Cladding - Gable Roofs (Low-Rise Analytical)

Components and Cladding | **$h \leq 60$ ft**
Figure 30.43-2A | **External Pressure Coefficients, GC_p** | **Gable Roofs $\theta \leq 7°$**
Enclosed, Partially Enclosed Buildings



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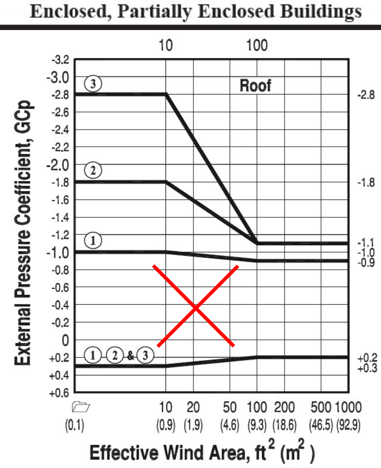
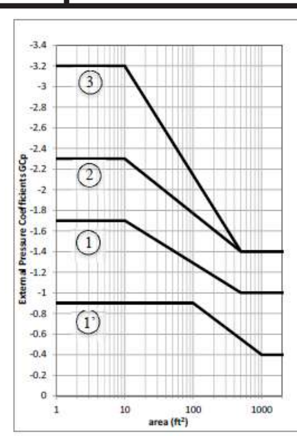
ASCE 7-16 30 Components and Cladding - Gable Roofs (Low-Rise Analytical)

Components and Cladding | **$h \leq 60$ ft**
Figure 30.43-2A | **External Pressure Coefficients, GC_p** | **Gable Roofs $\theta \leq 7°$**
Enclosed, Partially Enclosed Buildings





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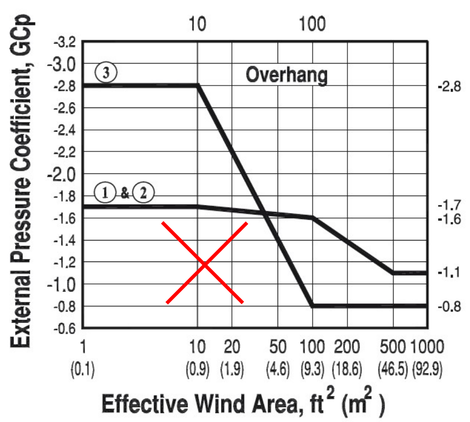
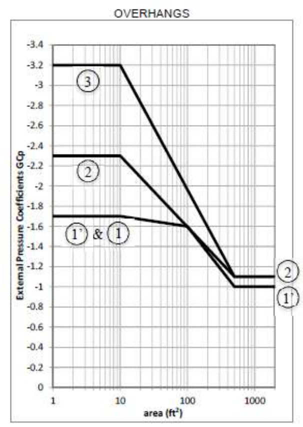
ASCE 7-16 30 Components and Cladding - Gable Roofs (Low-Rise Analytical)

Components and Cladding		$h \le 60$ ft
Figure 30.43-2A	External Pressure Coefficients, GC_p	Gable Roofs $\theta \le 7°$
Enclosed, Partially Enclosed Buildings		





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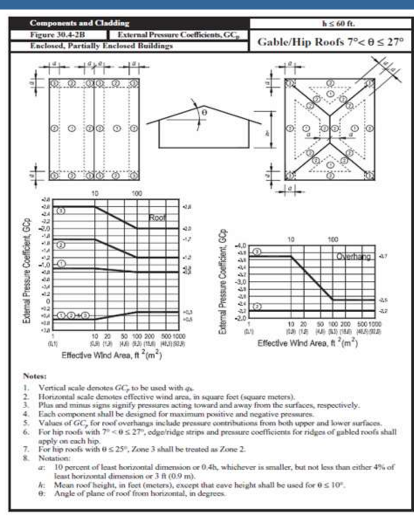
ASCE 7-16 30 C & C - Gable/Hip Roofs (Low-Rise Analytical)



ASCE 7-10

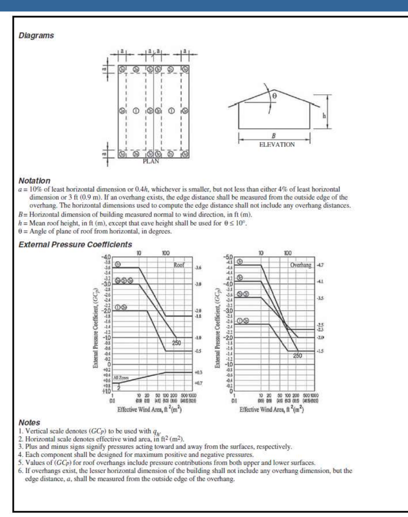


FIGURE 30.3-2B Components and Cladding [$h \le 60$ ft ($h \le 18.3$ m)]: External Pressure Coefficients, (GC_p), for Enclosed and Partially Enclosed Buildings—Gable Roofs, $7° < \theta \le 20°$

ASCE 7-16

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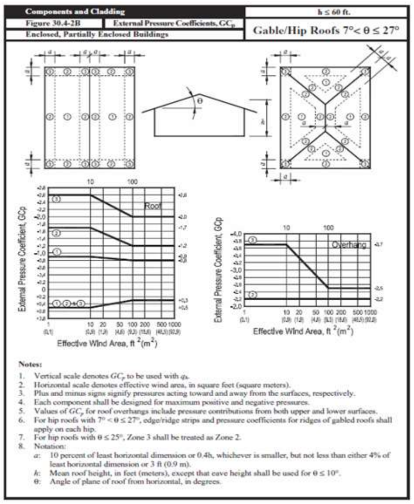
ASCE 7-16 30 C & C - Gable/Hip Roofs (Low-Rise Analytical)



ASCE 7-10

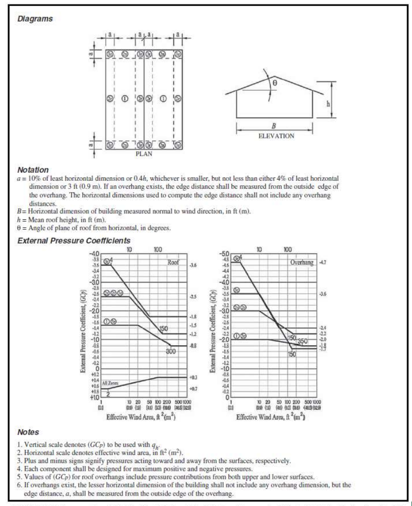


FIGURE 30.3-2C Components and Cladding [h ≤ 60 ft (h ≤ 18.3 m)]: External Pressure Coefficients, (GC_p), for Enclosed and Partially Enclosed Buildings—Gable Roofs, 20° < θ ≤ 27°

ASCE 7-16

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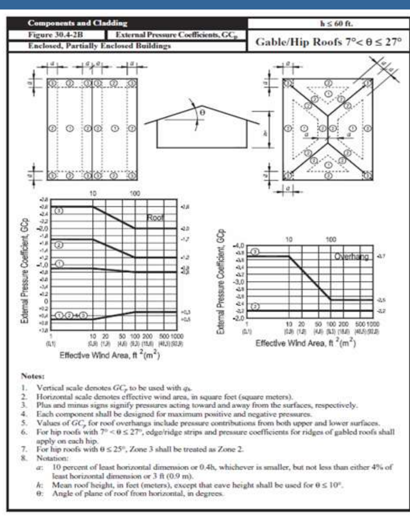
ASCE 7-16 30 C & C - Gable/Hip Roofs (Low-Rise Analytical)



ASCE 7-10

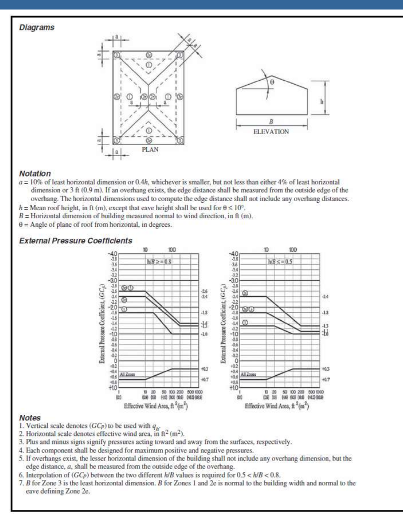


FIGURE 30.3-2E Components and Cladding [h ≤ 60 ft (h ≤ 18.3 m)]: External Pressure Coefficients, (GC_p), for Enclosed and Partially Enclosed Buildings—Hip Roofs, 7° < θ ≤ 20° (Roof)

ASCE 7-16

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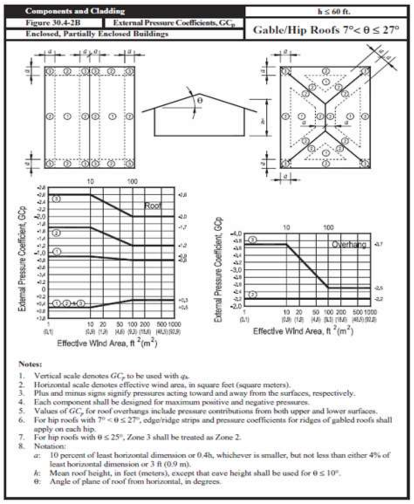
30 Components and Cladding Hip Roofs



ASCE 7-10

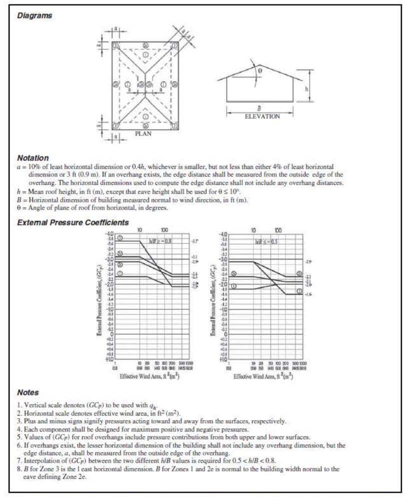


FIGURE 30.3-2F Components and Cladding [h ≤ 60 ft (h ≤ 18.3 m)]: External Pressure Coefficients, (GC_p), for Enclosed and Partially Enclosed Buildings—Hip Roofs, 7° < θ ≤ 20° (Overhang)

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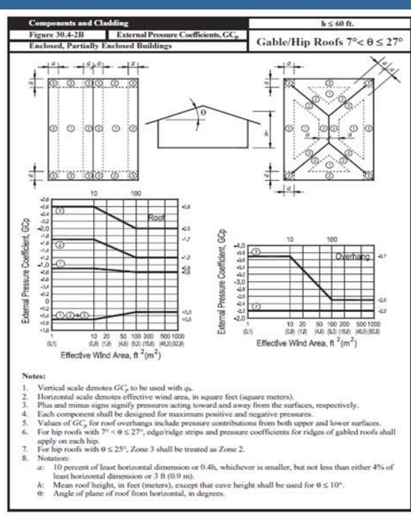
ASCE 7-16 30 C & C - Hip Roofs (Low-Rise Analytical)



ASCE 7-10

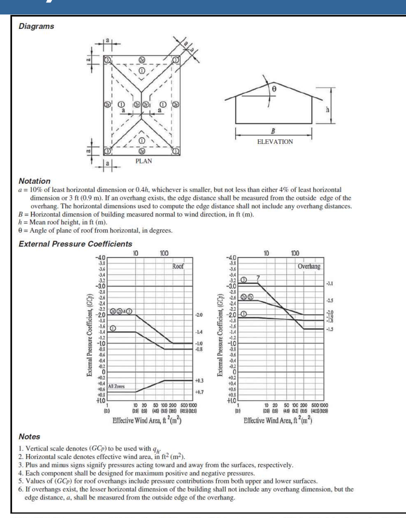


FIGURE 30.3-2G Components and Cladding [h ≤ 60 ft (h ≤ 18.3 m)]: External Pressure Coefficients, (GC_p), for Enclosed and Partially Enclosed Buildings—Hip Roofs, 20° < θ ≤ 27° (Roof and Overhang)

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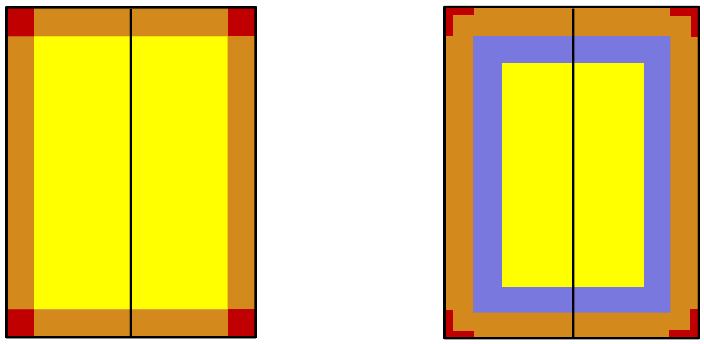
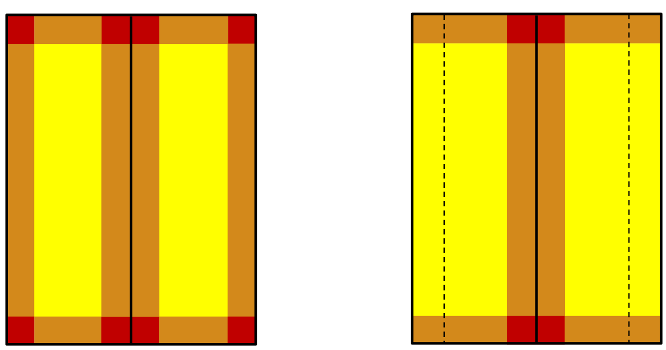
ASCE 7-10 Fig. 30.4-2A / ASCE 7-16 Fig. 30.3-2A
Gable Roof – h < 60 ft, θ ≤ 7°



GC_P values for 10 ft^2 effective wind area

ASCE 7-10		ASCE 7-16	
	-2.8		-3.2
	-1.8		-2.3
	-1.0		-1.7
	-1.0		-0.9

ASCE 7-10 Fig. 30.4-2B / ASCE 7-16 Fig. 30.3-2B
Gable Roof – h < 60 ft, 7° < θ ≤ 20°



GC_P values for 10 ft^2 effective wind area

ASCE 7-10		ASCE 7-16	
	-2.6		-3.6
	-1.7		-3.0
	-0.9		-2.0

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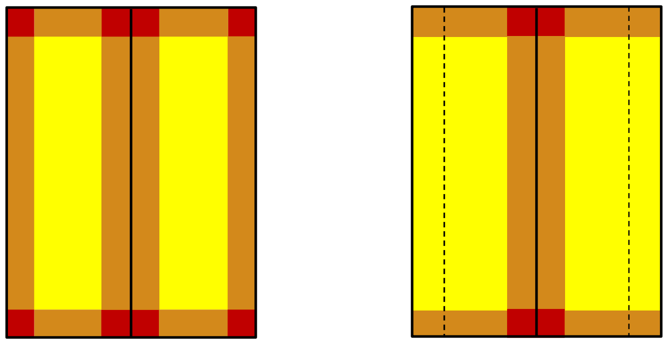
ASCE 7-10 Fig. 30.4-2B / ASCE 7-16 Fig. 30.3-2C Gable Roof – h < 60 ft, 20° < θ ≤ 27°



GC$_P$ values for 10 ft^2 effective wind area

ASCE 7-10		ASCE 7-16	
	-2.6		-3.6
	-1.7		-2.5
	-0.9		-1.5

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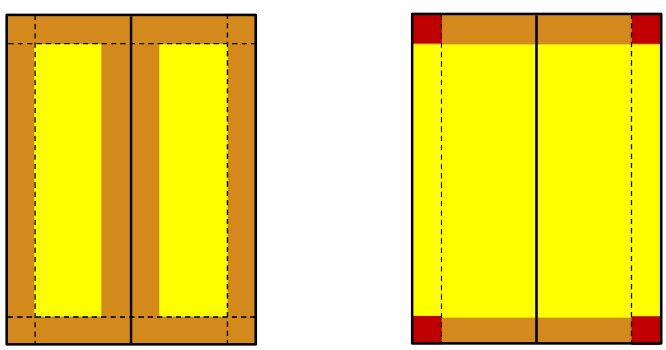
ASCE 7-10 Fig. 30.4-2C / ASCE 7-16 Fig. 30.3-2D Gable Roof – h < 60 ft, 27° < θ ≤ 45°



GC$_P$ values for 10 ft^2 effective wind area

ASCE 7-10		ASCE 7-16	
	-1.2		-3.2
	-1.2		-2.0
	-1.0		-1.8

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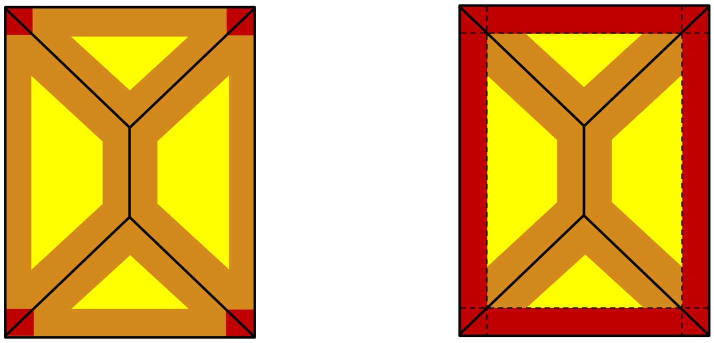
ASCE 7-10 Fig. 30.4-2B / ASCE 7-16 Fig. 30.3-2E
Hip Roof – h < 60 ft, 7° < θ ≤ 20°



GC_P values for 10 ft² effective wind area

ASCE 7-10		ASCE 7-16		
			h/*B* ≥ 0.8	*h*/*B* ≤ 0.5
Red	-2.6	Red	-2.6	-1.8
Orange	-1.7	Orange	-2.4	-2.4
Yellow	-0.9	Yellow	-1.8	-1.3

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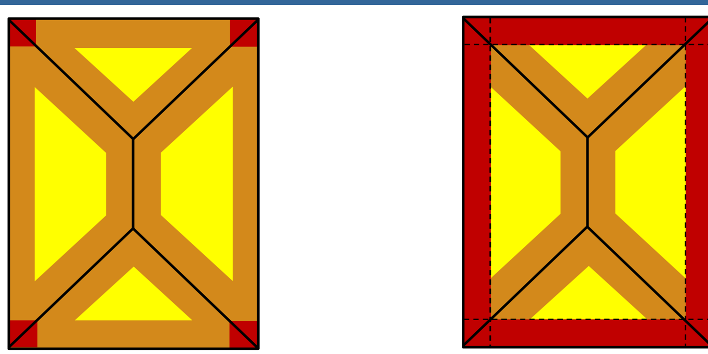
ASCE 7-10 Fig. 30.4-2B / ASCE 7-16 Fig. 30.3-2G
Hip Roof – h < 60 ft, 20° < θ ≤ 27°



GC_P values for 10 ft² effective wind area

ASCE 7-10		ASCE 7-16	
Red	-2.6	Red	-2.0
Orange	-1.7	Orange	-2.0
Yellow	-0.9	Yellow	-1.4

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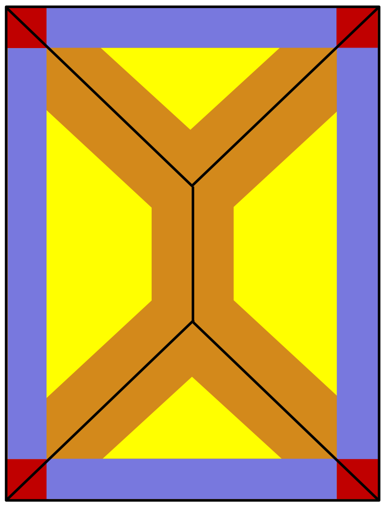
ASCE 7-16 Fig. 30.3-2H (New Figure)
Hip Roof – h < 60 ft, 27° < θ ≤ 45°



GC_P values for 10 ft^2 effective wind area and θ = 45°

ASCE 7-16	
Red	-2.50
Orange	-2.35
Purple	-1.80
Yellow	-1.50

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ASCE 7-22 Major Changes

1. Wind maps and the geodatabase for contiguous US are updated
2. Determination of Topographic Factor, K_{zt}, is updated
3. Determination of velocity pressure exposure coefficient, K_z, is revised
4. "Simple Diaphragm Building" is deleted, and two simplified methods applicable to simple diaphragm buildings are also deleted

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ASCE 7-22 Major Changes (Contd.)

5. New provisions for "Elevated Buildings" are added
6. New Chapter 32 on Tornado Loads is added

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Performance-Based Procedures

26.1.3 Performance-Based Procedures Wind design of buildings and other structures using performance-based procedures shall be permitted subject to the approval of the Authority Having Jurisdiction. The performance-based wind design procedures used shall, at a minimum, conform to Section 1.3.1.3.

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ASCE 7-22: Updated Wind Maps and Geodatabase

a. Wind speed maps for the contiguous US have been updated. There is no discussion of those changes in the Commentary.

b. Wind maps for Hawaii, Puerto Rico, and US Virgin Islands have been deleted from ASCE 7 and are available only on the ASCE Geodatabase at the ASCE Hazard Tools website.

c. Site-specific values for selected Special Wind Regions in the contiguous United States have been included in the ASCE 7 Wind Design Geodatabase.

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ASCE 7-22: Special Wind Region Included in ASCE Geodatabase

ASCE 7 Hazard Tool

This web-based application offers a better way to look up key design parameters specified by ASCE 7. Easy to use mapping features allow you to quickly retrieve precise hazard data for wind, earthquake motion, flood, snow, rain, ice, and tsunami.

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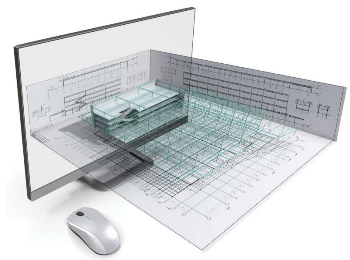
ASCE 7-22: Special Wind Region Included in ASCE Geodatabase



- This online platform is now free to use
- It replicates the provisions and commentary of ASCE 7-10, 7-16 and 7-22 with enhanced features that make it easier for engineers to work with the standard.

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ASCE 7-22: Revised Topographic Factor, K_{zt}

- Previously, it was permitted to neglect the topographic effect when there was an upwind topographic feature of similar size within a certain distance.
- However, a study has shown that little sheltering can be expected from such an upwind feature.
- Also, more studies are required to properly quantify such sheltering effect.
- As a result, in ASCE 7-22, topographic effect is to be considered even in the presence of upwind topographic features of similar height.

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ASCE 7-22: Revised Velocity Pressure Exposure Coefficient, K_z

K_z = ~~2.01~~ 2.41$(15 / z_g)^{2/\alpha}$ …for $z < 15$ ft

K_z = ~~2.01~~ 2.41$(z / z_g)^{2/\alpha}$ …..for $15 \text{ ft} \le z \le z_g$

$K_z = 2.41$ …..for $z_g \le z \le 3280$ ft

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ASCE 7-22: Revised Velocity Pressure Exposure Coefficient, K_z

Table 26.11-1. Terrain Exposure Constants (Partial)

Exposure	α	z_g (ft)
B	~~7.0~~ 7.5	~~1200~~ 3280
C	~~9.5~~ 9.8	~~900~~ 2460
D	11.5	~~700~~ 1935

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ASCE 7-22: Revised Velocity Pressure Exposure Coefficient, K_z

Comparison of K_z for Exposure B

z (ft)	ASCE 7-16	ASCE 7-22	z (ft)	ASCE 7-16	ASCE 7-22
0-15	0.57	0.57	120	1.04	1.00
20	0.62	0.62	140	1.09	1.04
25	0.67	0.66	160	1.13	1.08
30	0.70	0.69	180	1.17	1.11
40	0.76	0.74	200	1.20	1.14
50	0.81	0.79	250	1.28	1.21
60	0.85	0.83	300	1.35	1.27
70	0.89	0.86	350	1.41	1.33
80	0.93	0.90	400	1.47	1.38
90	0.96	0.92	450	1.52	1.42
100	0.99	0.95	500	1.57	1.46

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ASCE 7-22: Revised Velocity Pressure Exposure Coefficient, K_z

Comparison of K_z for Exposure C

z (ft)	ASCE 7-16	ASCE 7-22	z (ft)	ASCE 7-16	ASCE 7-22
0-15	0.85	0.85	120	1.32	1.30
20	0.90	0.90	140	1.36	1.34
25	0.95	0.94	160	1.40	1.38
30	0.98	0.98	180	1.43	1.41
40	1.04	1.04	200	1.46	1.44
50	1.09	1.09	250	1.53	1.51
60	1.14	1.13	300	1.59	1.57
70	1.17	1.17	350	1.65	1.62
80	1.21	1.20	400	1.69	1.66
90	1.24	1.23	450	1.74	1.70
100	1.27	1.25	500	1.78	1.74

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ASCE 7-22: Revised Velocity Pressure Exposure Coefficient, K_z

Comparison of K_z for Exposure D

z (ft)	ASCE 7-16	ASCE 7-22	z (ft)	ASCE 7-16	ASCE 7-22
0-15	1.03	1.04	120	1.48	1.49
20	1.08	1.09	140	1.52	1.53
25	1.13	1.13	160	1.55	1.56
30	1.16	1.17	180	1.59	1.59
40	1.22	1.23	200	1.62	1.62
50	1.27	1.28	250	1.68	1.69
60	1.31	1.32	300	1.73	1.74
70	1.35	1.35	350	1.78	1.79
80	1.38	1.38	400	1.82	1.83
90	1.41	1.41	450	1.86	1.87
100	1.43	1.44	500	1.90	1.90

ASCE 7-22: Relocation of Directionality Factor, K_d

The directionality factor, K_d, has been removed from the expression of velocity pressure, q_z or q_h. It is now included in the expressions for wind pressures in Chapters 27 through 30.

$$q_z = 0.00256 K_z K_{zt} \cancel{K_d} K_e V^2 \qquad (26.10\text{-}1)$$

$$p = q\,\underline{K_d}\,GC_p - q_i\,\underline{K_d}\,(GC_p) \qquad (27.3\text{-}1)$$

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ASCE 7-22: Definition of "Simple Diaphragm Building" Deleted

Section 26.2

~~BUILDING, SIMPLE DIAPHRAGM: A building in which both windward and leeward wind loads are transmitted by roof and vertically spanning wall assemblies, through continuous floor and roof diaphragms, to the MWFRS.~~

- ASCE 7-22 does not include any provision specific to simple diaphragm buildings anymore.

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ASCE 7-22: Two Simplified Design Procedures Deleted

Simplified envelope procedure applicable to Simple Diaphragm Low-Rise Buildings is deleted

- ~~CHAPTER 28 PART 2: ENCLOSED SIMPLE DIAPHRAGM LOW-RISE BUILDINGS~~
- ~~CHAPTER 30 PART 2: LOW-RISE BUILDINGS (SIMPLIFIED)~~

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ASCE 7-22: Two Simplified Design Procedures Deleted

Simplified directional procedure applicable to Simple Diaphragm Buildings with *h* ≤ 160 ft is deleted

- ~~CHAPTER 27 PART 2: ENCLOSED SIMPLE DIAPHRAGM BUILDINGS WITH h ≤ 160 ft~~
- ~~CHAPTER 30 PART 4: BUILDINGS WITH 60 ft < h ≤ 160 ft (SIMPLIFIED)~~

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Change 5: New Provisions for Elevated Buildings

Section 26.2 **Definitions**

<u>**BUILDING, ELEVATED:** A building supported on structural elements where wind can pass beneath the building.</u>

<u>***27.3.1.1 Elevated Buildings*** The MWFRS loads for rigid or flexible elevated buildings meeting both of the following geometric limitations, for any principal wind direction, shall be determined in accordance with this section for that principal direction……….</u>

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Change 5: New Provisions for Elevated Buildings

CHAPTER 30 PART 1: LOW-RISE BUILDINGS

30.3.2.1 Bottom Horizontal Surface of Elevated Buildings.

CHAPTER 30 PART 2: BUILDINGS WITH *h* > 60 ft

30.4.2.1 Bottom Horizontal Surface of Elevated Buildings.

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ASCE 7-22: New Chapter 32 for Tornado Loads

26.1.1 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 Chapters 26 through 31.

Risk Category III and IV buildings and other structures, including the MWFRS and all C&C thereof, shall also be designed and constructed to resist tornado loads determined in accordance with Chapter 32, as applicable.

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ASCE 7-22 : New Chapter 32 for Tornado Loads

CHAPTER 32 TORNADO LOADS

32.1.1 Scope Buildings and other structures classified as Risk Category III or IV and located in the tornado-prone region as shown in Figure 32.1-1, including the main wind force resisting system (MWFRS) and all components and cladding (C&C) thereof, shall be designed and constructed to resist the greater of the tornado loads determined in accordance with the provisions of this chapter or the wind loads determined in accordance with Chapters 26 through 31, using the load combinations provided in Chapter 2.

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ASCE 7-22 : New Chapter 32 for Tornado Loads

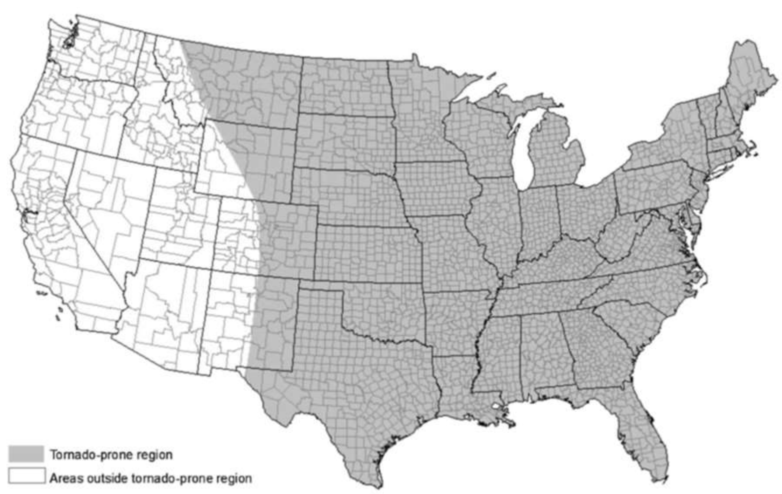

Figure 32.1-1. Tornado-prone region.

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ASCE 7-22: Revised GC_p for Gable Roofs

- Figures 30.3-2B, 30.3-2C and 30.3-2D are updated through a reduction in the number of roof zones and revisions in the GC_p chart.
- The provisions for roof overhangs are deleted from the figures in favor of referencing Section 30.7.

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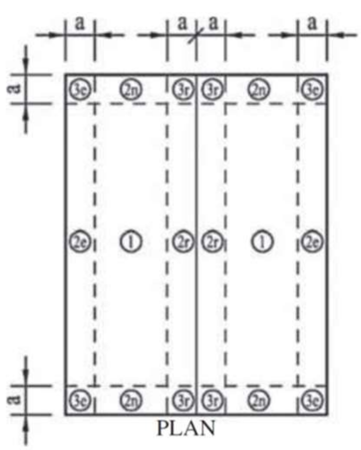
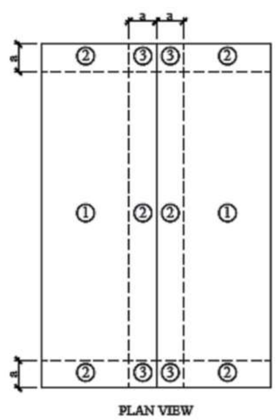
ASCE 7-22: Revised GC_p for Gable Roofs

Figure 30.3-2B for 7° < θ ≤ 20°



ASCE 7-16



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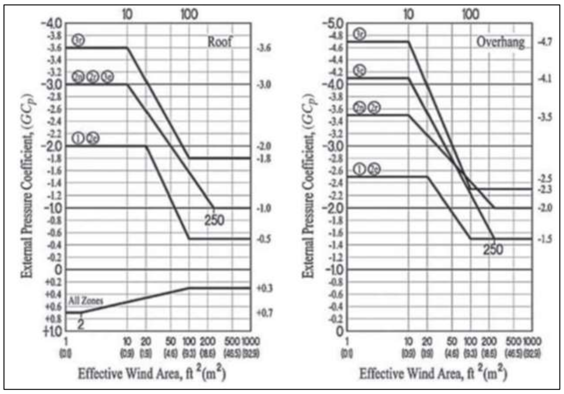
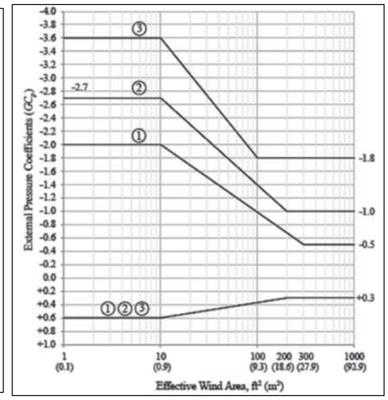
ASCE 7-22: Revised GC_p for Gable Roofs

Figure 30.3-2B for 7° < θ ≤ 20°



ASCE 7-16



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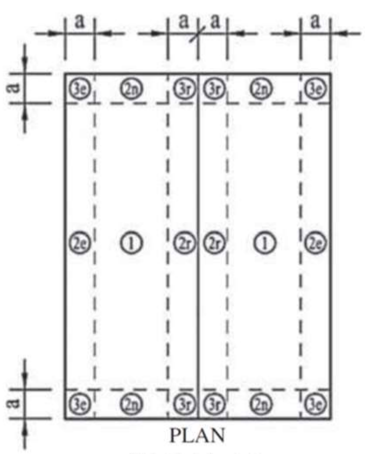
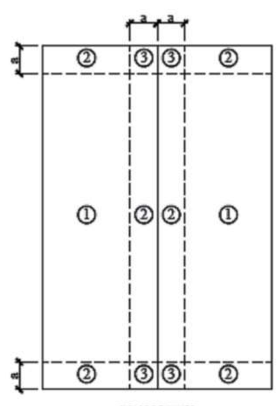
ASCE 7-22: Revised GC_p for Gable Roofs

Figure 30.3-2C for 20° < θ ≤ 27°



ASCE 7-16



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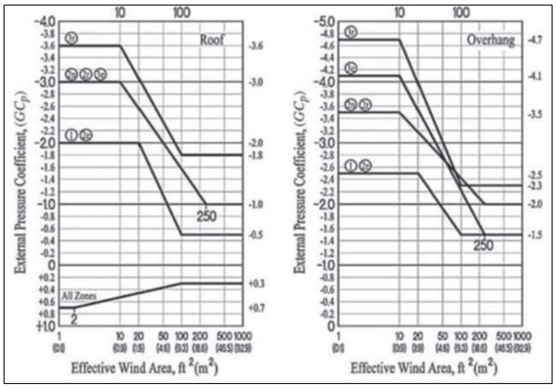
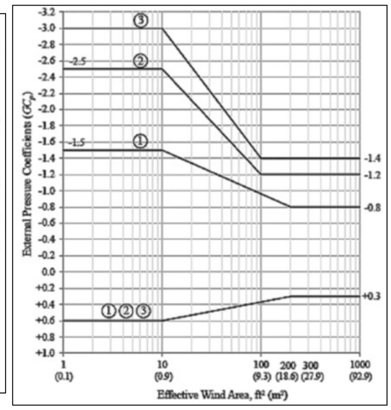
ASCE 7-22: Revised GC_p for Gable Roofs

Figure 30.3-2C for 20° < θ ≤ 27°



ASCE 7-16



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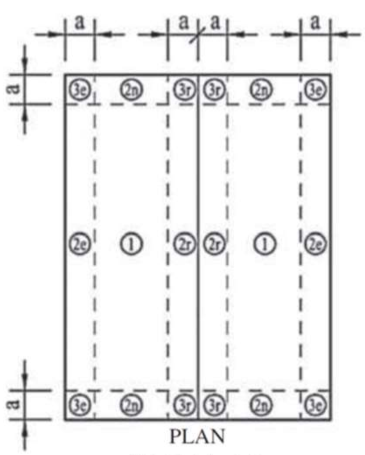
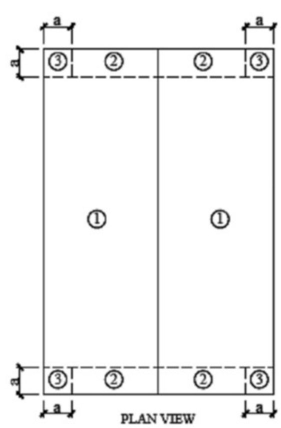
ASCE 7-22: Revised GC_p for Gable Roofs

Figure 30.3-2D for 27° < θ ≤ 45°



ASCE 7-16



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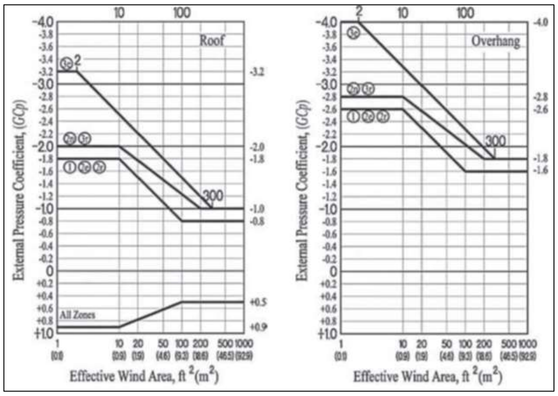
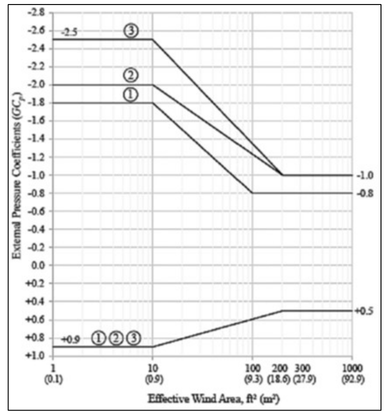
ASCE 7-22: Revised GC_p for Gable Roofs

Figure 30.3-2D for 27° < θ ≤ 45°



ASCE 7-16



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Revised GC_p for Hip Roofs

- ASCE 7-16 Figures 30.3-2E through 30.3-2I are condensed in ASCE 7-22 into three Figures 30.3-2E through 30.3-2G.
- The figures are updated by a reduction in the number of roof zones and revisions in the GC_p chart.
- The provisions for roof overhangs are deleted from the figures in favor of referencing Section 30.7.

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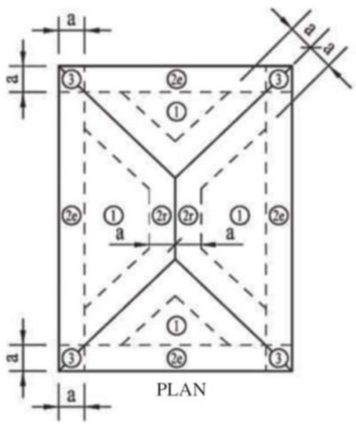
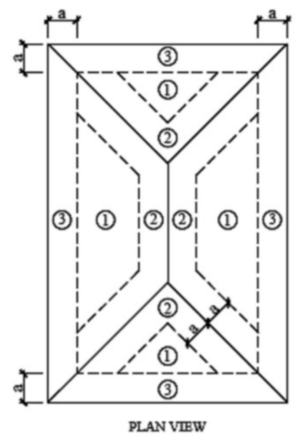
Revised GC_p for Hip Roofs

Roof Zones (All Roof Angles)



ASCE 7-16



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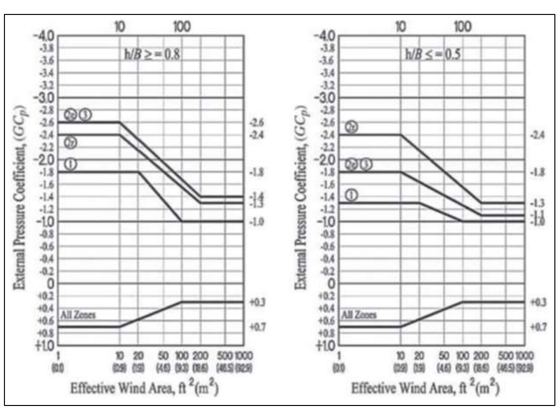
Revised GC_p for Hip Roofs

Figure 30.3-2E for 7° < θ ≤ 20° (Roof)



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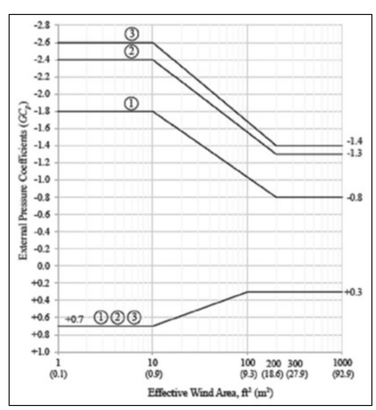

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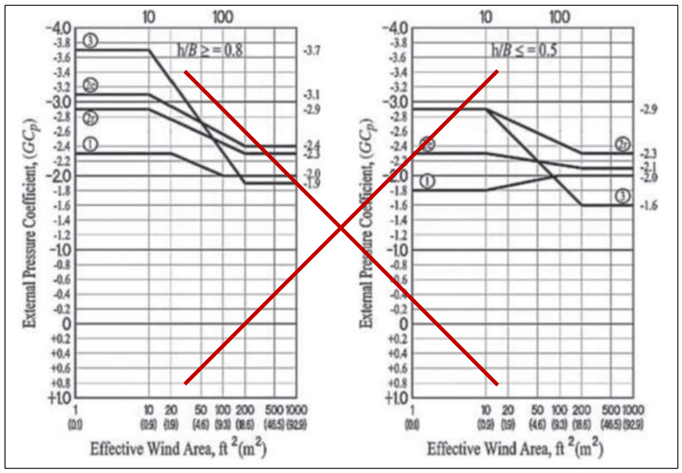
Revised GC_p for Hip Roofs

ASCE 7-16 Figure 30.3-2F for 7° < θ ≤ 20° (Overhang)



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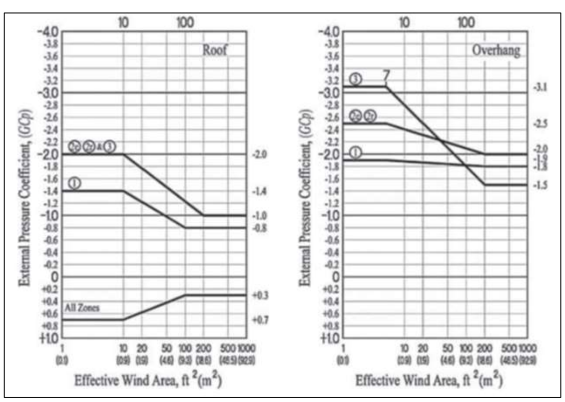
Revised GC_p for Hip Roofs

Figure 30.3-2 ~~G~~ F for 20° < θ ≤ 27° (Roof ~~and Overhang~~)



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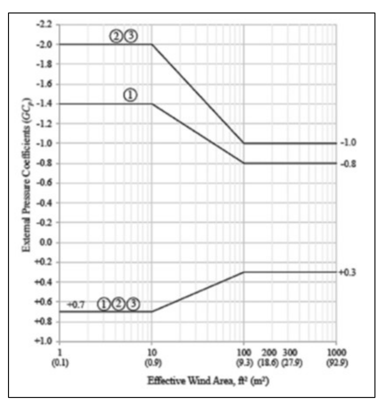

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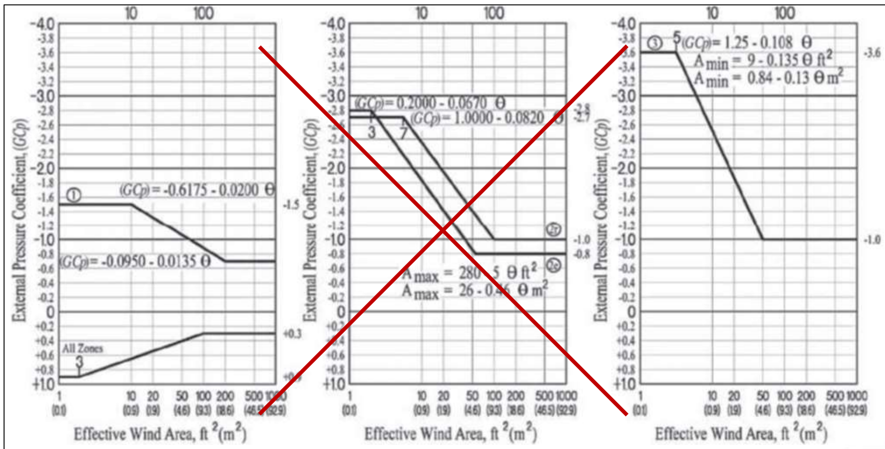
Revised GC_p for Hip Roofs

~~ASCE 7-16 Figure 30.3-2H for 27° < θ ≤ 45° (Roof)~~



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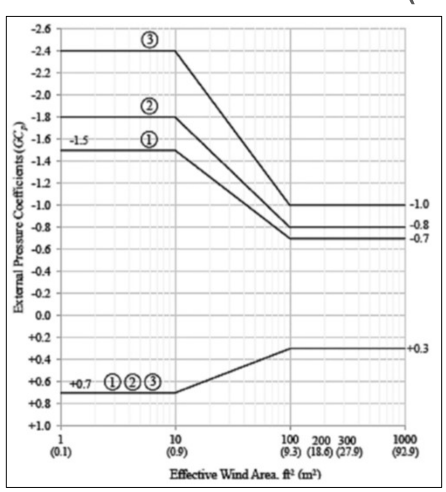
Revised GC_p for Hip Roofs

ASCE 7-22 Figure 30.3-2G for 27° < θ ≤ 45° (Roof)



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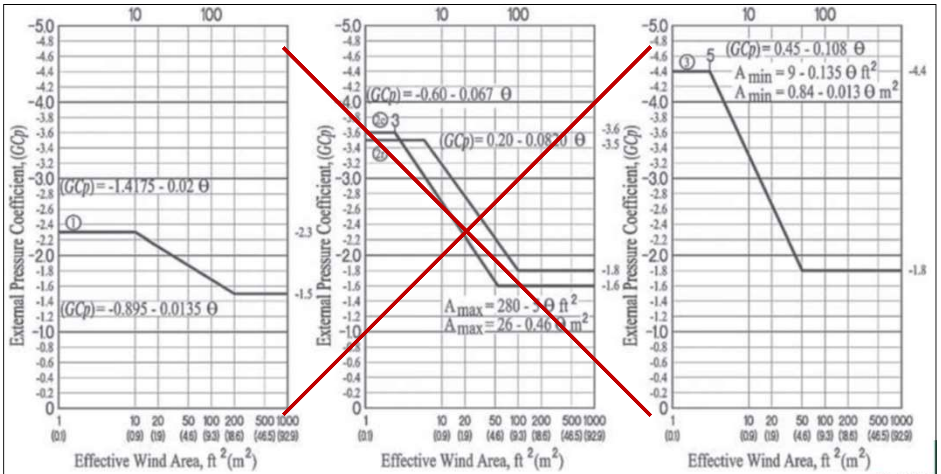
Revised GC_p for Hip Roofs

~~ASCE 7-16 Figure 30.3-2I for 27° < θ ≤ 45° (Overhang)~~



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~~30.11~~ <u>30.9</u> Attached Canopies on Buildings ~~with *h* ≤ 60 ft (*h* ≤ 18.3 m)~~

- This section now applies to buildings with *h* ≥ 60 ft as well.
- Two new Figures 30.9-2A and 30.9-2B are also added as part of this revision.

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Thank You!!

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