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Searching for Simplicity
The Evolution of Wind Provisions in Standards and Codes in the United States—Part 1

by S. K. Ghosh

5420 Old Orchard Road
Skokie, Illinois 60077-1083
847.966.6200 Fax 847.966.9481

www.cement.org

Searching for simplicity

The evolution of wind provisions in standards and codes in the United States — Part 1

By S. K. Ghosh, Ph.D.

This two-part article will provide an historical overview of the evolution of wind provisions in standards and codes in the United States. From the 1972 edition of the American National Standards Institute's Minimum Design Loads for Buildings and Other Structures (ANSI A58.1) — which later became the American Society of Civil Engineers' Minimum Design Loads for Buildings and Other Structures (ASCE 7) — to the current ASCE 7-05 and the International Code Council's 2006 International Building Code (IBC), one trend is consistent. Through their evolution, the complexity of wind design has been steadily increasing.

Part one of this series will discuss the history of the wind provisions standards in the United States, specifically ANSI A58.1 and ASCE 7. Part two (which will be printed in the January 2007 issue of **Structural Engineer**) will focus on the evolution of wind provisions in the model building codes in the United States, such as the IBC and its three legacy model building codes. In part two of this series, I would like to make a plea for action leading to a way out of this complexity.

Wind provisions in standards

This section traces the evolution of wind provisions in ASCE 7 and its predecessor standard, ANSI A58.1.

ANSI A58.1–1972 — Modern wind design in the United States started with ANSI A58.1–1972. The new provisions represented a quantum jump in sophistication in comparison with codes of practice at that time. However, the provisions were flawed with ambiguities, inconsistencies in terminology, and a format that permitted misinterpretation of certain provisions.

ANSI A58.1-1982 — A revised ANSI A58.1-1982 standard contained an innovative approach to wind forces for components and cladding of buildings. 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.

ASCE 7-88 — The maintenance and update of the ANSI A.58.1 standard was taken over by ASCE in the mid-1980s. 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.

ASCE 7-95 — The first significant updates in the wind provisions since 1982 were made in ASCE 7-95. The most significant among a number of important changes was that three-second gust wind speed rather than fastest-mile wind speed, became the basis of design. The averaging time implicit in fastest-mile wind speed was the time it takes for a mile of wind to pass through the measuring instrument, called an anemometer. This typically ranged between 30 and 60 seconds. The averaging time changed to a fixed three seconds when the three-second gust wind speed was adopted. Since average wind velocity increases as the averaging time decreases, 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. 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.

Among other significant changes, provisions were added for wind speed-up over isolated hills and escarpments by including a topographic-effect factor in the expression for the design wind pressure.

New provisions were added for full and partial loading on the main wind force-resisting system (MWFRS) of buildings with a mean roof height greater than 60 feet, thereby requiring consideration of wind-induced torsion in all buildings other than low-rise buildings. Low-rise buildings for purposes of the wind design provisions are those with mean roof heights up to 60 feet.

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

ASCE 7-98 — In 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.

A wind directionality factor, K_d, was introduced in the expression for the design wind pressure to account for the directionality of wind. Directionality refers to the fact that wind seldom, if ever, strikes along the most critical direction of a building — basically, because it cannot. Wind direction changes from one instant to the next. Wind can be only instantaneous along the most critical direction; at the very next instant, it will not be from the same direction. This fact used to be taken into account through a relatively low load factor of 1.3 on the effect of wind in strength design load combinations. But then ASCE 7 received comments that engineers using allowable stress design (ASD) could not take advantage of the directionality of wind. The ASCE 7 decision to include $K_d = 0.85$ for buildings in the definition of the wind pressure was in response to these comments. In order not to design using lower-factored wind forces 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.

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 feet), regular-shaped simple diaphragm buildings. New definitions were introduced for regular-shaped buildings and simple diaphragm buildings.

The wind design provisions were for the first time 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 feet.

A very important provision was introduced, requiring that glazing in the lower 60 feet 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.

ASCE 7-02 — In ASCE 7-02, the

Table 1: Surface roughness categories of ASCE 7-02 and 7-05

Surface roughness category	Description
B	Urban and suburban areas, wooded areas or other terrain with numerous, closely spaced obstructions having the size of single-family dwellings or larger.
C	Open terrain with scattered obstructions having heights generally less than 30 feet. This category includes flat, open country; grandstands; and all water surfaces in hurricane-prone regions.
D	Flat, unobstructed areas and water surfaces outside hurricane-prone regions. This category includes smooth mud flats, salt flats, and unbroken ice.

Table 2: Exposure categories of ASCE 7-02 and 7-05

Exposure category	Description
B	Surface Roughness B prevails in the upwind direction for at least 2,630 feet or 10 times the building height, whichever is greater.
C	All cases where Exposure B or D does not apply.
D	Surface Roughness D prevails in the upwind direction for at least 5,000 feet or 10 times the building height, whichever is greater. Exposure D extends inland from the shoreline a distance of 660 feet or 10 times the building height, whichever is greater.

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.

buildings having mean roof height exceeding 60 feet.

In the table of roof pressure coefficients for the design of the MWFRS by the general analytical procedure, a low-suction coefficient of 0.18 was added for the windward roof in all cases where only a high-suction coefficient was provided earlier. The intent of the new low-suction coefficient is to require the roof to be designed for zero or a slightly positive (inward acting)

By and large, changes in ANSI A58.1/ASCE 7 have not been consistently in the direction of lower or higher design wind pressures. If there is a consistent trend to the changes, it is that the complexity of wind design has been steadily increasing.

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, as shown in Table 2. The former Exposure A (centers of large cities) was deleted.

Method 2, Analytical Procedure, for (MWFRS of) low-rise buildings was revised to provide clarification. The different load cases were clearly delineated.

New pressure coefficients were provided for determination of wind loads on domed-roof buildings.

Provisions for calculating wind loads on parapets were added.

The design load cases for the MWFRSs of buildings designed by the general analytical procedure (as distinct from the low-rise analytical procedure) were different in ASCE 7-98 than in ASCE 7-02. Consideration of wind-induced torsion was now required for all buildings, not just

pressure, depending upon whether the building is enclosed or partially enclosed, respectively.

ASCE 7-05 — Several changes are made in the set of conditions that must be met by a building for its MWFRS to be qualified to be designed by Method 1 - Simplified Procedure. The restriction that the building not be subjected to topographic effects is omitted. Topographic effects are now accounted for in the simplified design procedure by including a topographic effect factor in the calculation of the design wind pressure.

The conditions that must be met by a building for its components and claddings to be eligible to be designed by Method 1 are not changed, except that the restriction concerning topographic effects is lifted, as in the case of the MWFRS.

Simplified design wind pressures and net design wind pressures can now be calculated for basic wind speeds of 105, 125, and 145 mph.

ASCE 7-05 now explicitly states that the basic wind speeds estimated from regional climatic data for special wind regions outside hurricane-prone areas can be lower than those given in ASCE 7-05 Figure 6-1. For estimation of basic wind speeds from regional wind data in special wind regions outside hurricane-prone areas, a minimum criterion is specified.

ASCE 7-02 required Exposure D to extend inland from the shoreline for a distance of 660 feet or 10 times the height of the building, whichever was greater. ASCE 7-05 requires Exposure D to extend into downwind areas of Surface Roughness B or C for a distance of 600 feet or 20 times the height of the building, whichever is greater. The multiplier of building height by which a certain terrain category has to extend in the upwind and the downwind direction of the building for qualification of an Exposure Category is changed from 10 to 20, as indicated above in the specific case of Exposure Category D. Other controlling distances are rounded off to the nearest 100 feet.

A definition for eve height is added. Footnote 8 to Figure 6-10 (Low-Rise Analytical Procedure), which concerns delineation of boundary between windward zone pressures and leeward zone pressures, has been clarified.

Glazing in wind-borne debris regions that receive positive external pressure can no longer be treated as an opening for design purposes, instead of making it impact-resistant or protected.

Provisions for wind loads on parapets are updated. Values of the Combined Net Pressure Coefficient are updated from +1.8 and -1.1 to +1.5 and -1.0 for windward and leeward parapets, respectively. Application of the provisions to low-slope roofs has been clarified.

Design wind loads on free-standing walls and solid signs are revised.

Design wind loads on open buildings with monoslope roofs are revised. Design wind loads on open buildings with pitched, or troughed roofs are provided for the first time.

New provisions are added for rooftop structures and equipment when the roof height of the building is less than 60 feet.

Wind-borne debris requirements are clarified as being applicable to Method 3 (Wind Tunnel Procedure). The requirements are the same as those for Method 2 (Analytical Procedure).

Discussion of changes from ANSI A58.1-1972 to ASCE 7-05

Of all the changes from ANSI A58.1-1972 through ASCE 7-05, there are only a few that are in the direction of less conservatism in design. The first of these is the adoption of the low-rise analytical procedure in ASCE 7-95 as an alternative design approach for the MWFRS. This procedure can reduce design wind pressures significantly. While generalizations are difficult since so many variables influence the determination of design wind pressures for a specific building, use of the alternate procedure can result in the total wind load being approximately 30 to 35 percent less than would be calculated using the primary procedure. It ought to be remembered that the low-rise analytical procedure was part of the Standard Building Code long before it was adopted by ASCE 7 and is based on comprehensive testing done at the University of Western Ontario.

In areas where the basic wind speed is low, the relative lack of conservatism of the low-rise procedure is mitigated somewhat by the requirement that all MWFRS be designed for a minimum pressure of 10 pounds per square foot applied to the area of the building projected onto a vertical plane. However, this provision is widely ignored and is not rigorously enforced by local jurisdictions. It needs to be taken more seriously by practitioners as well as local jurisdictions.

The second change was the introduction of the directionality factor, K_d, in ASCE 7-98. This led to a round-up of the wind load factor from 1.53 to 1.60 in strength design, which is conservative. However, this also decreased the design wind forces when using ASD methods, which are widely used in the design of structures made of materials other than concrete. Also, the three-second gust speed map of ASCE 7-95 was prepared from data accumulated by the National Weather Service and not converted from the fastest-mile wind speed map of ASCE 7-93. While in most areas, 70 mph fastest-mile wind speed became three-second gust speed of 85 or 90 mph, and so forth, in certain areas such as Denver, the numbers remained virtually unchanged. This meant that design wind pressures in those areas went down as ASCE 7-95 was adopted, even while using strength design, with the rounded-up load factor of 1.6 incorporated.

The only other change possibly in the direction of less conservatism was the redrawing of the basic wind speed map in ASCE 7-98, which decreased the basic wind speeds in inland Florida. Obviously, when National Weather Service data indicate that a change is warranted, ASCE 7 has no reason to resist making that change.

Conclusion

By and large, the changes in ANSI A58.1/ASCE 7 have not been consistently in the direction of lower or higher design wind pressures. If there is a consistent trend to the changes, it is that the complexity of wind design has been steadily increasing. ■

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S.K. Ghosh, Ph.D., is the president of S.K. Ghosh Associates, Inc., a structural, seismic, and code consulting firm located in Palatine, Ill., and Laguna Niguel, Calif. He is active in the development and interpretation of national structural code provisions and can be contacted at skghosh@aol.com or via www.skghoshassociates.com.

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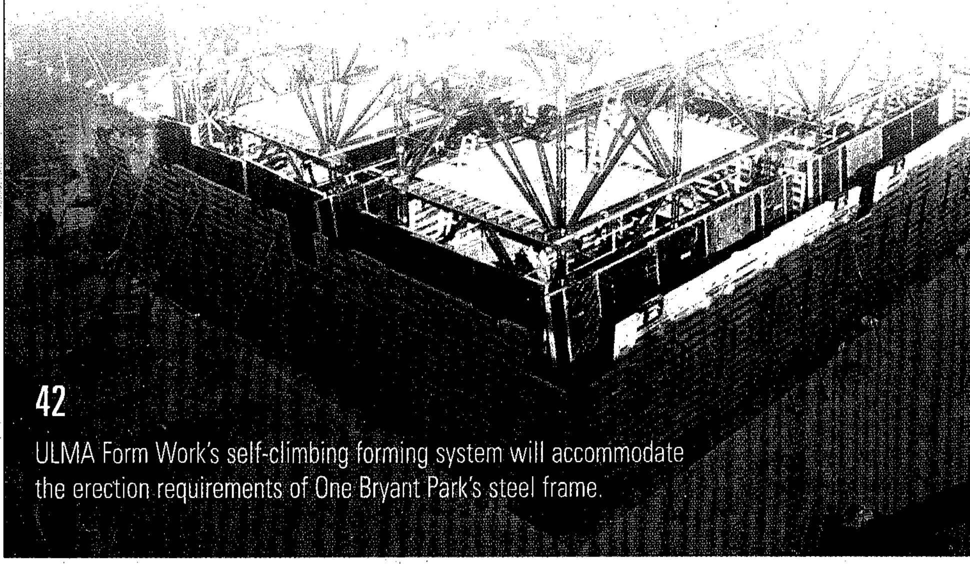

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