

Review of ASCE 7-05 unbalanced snow load provisions and their effect on building design

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Introduction

Early in the transition to the IBC codes, I was involved in reviewing bid documents originated by an architect. The plans did not have the specific unbalanced snow load information displayed for a contractor to bid. This was not an uncommon experience during this time. In many cases the plan originator inappropriately assumed the truss manufacturer would take responsibility for the design in meeting this condition; unfortunately most of the time this didn't happen. I am sure some buildings were bid and eventually constructed without consideration for this condition. Today, I think everyone — architects, engineers, code officials, contractors, and truss designers — has become more educated on this subject, and I believe a majority of code buildings are designed and built for this condition.



Because the current ASCE 7-02 unbalanced snow load condition often controls the snow load design, and thus the size of building components, it is important to understand a bit more about the ASCE 7 standard history, how each of the versions differ, and what impact each has on the design process. Information on each will be given in this article.

The most current ASCE 7-05 standard is referenced in the new 2006 IBC. IBC 2000 referenced ASCE 7-98 and IBC 2003 referenced ASCE 7-02, the predecessors of 7-05. The purpose of this article is to give a perspective of the historical changes that have taken place in the design area of unbalanced snow loads, and how the most recent change in the 7-05 version will impact your future designs.

This article only addresses gable pitched buildings and does not address curved roofs. A brief comparative build-

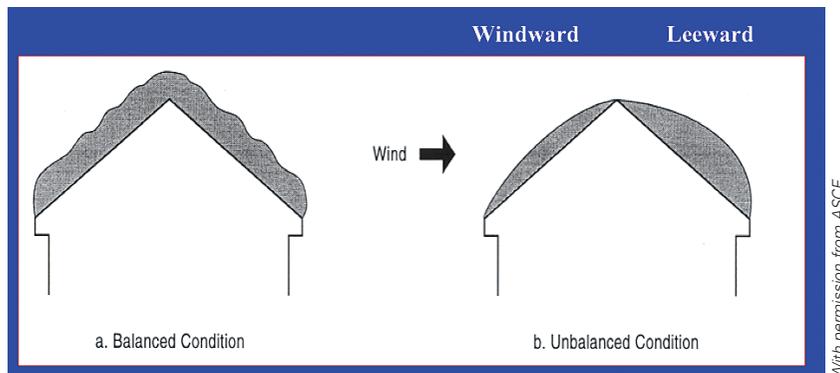


Fig 1. Balanced and unbalanced snow loads

ing example with a summary of the changes made in this area will be shown, along with other suggested design considerations.

What are unbalanced snow loads?



Fig. 2. Snow drift photo

A balanced snow load is one that occurs with a minimum amount of wind that does not cause drifting. Snow falls and settles fairly uniformly over the entire roof. Unbalanced snow loads occur when wind redistributes this balanced snow from one area of the roof to another, from the windward side of the peak to the leeward side (see fig 1 and 2).

How are these loads determined and what factors affect unbalanced snow loads?

The following items affect unbalanced snow loads.

1. The Quantity of the P_s (sloped roof snow load)

P_s is the balanced snow load design value established through two key equations.

$$P_f = .7 * C_e * C_t * I * P_g$$

$$P_s = P_f * C_s$$

Here is a short explanation of these factors. ASCE 7 provides us with a historic ground snow load map that establishes the P_g or ground snow load. This ground snow load is the snow expected to land on the ground. The next step is to find the amount of snow expected to land on a flat roof, P_f . The ground snow load is multiplied by various factors. The first factor accounts for flat roofs collecting **70 percent** of the ground snow based on historical studies that show snow loads being reduced by wind and thermal effects. C_e is the exposure factor that considers various terrains and their effect. C_t is the temperature factor of the building's roof and its effect on retaining snow. Also included in the formula is a factor (Importance Factor) that is independent of how much snow the building will see, but it is a factor that accounts for the probability that the design snow load will be met or exceeded in a given year (0.01 for a hospital to 0.04 for an agricultural building) and is related to the physical use of the building (i.e. a 1.2 value for a hospital is higher than an agricultural building at .8). Finally, to convert this flat roof snow design value to a pitched gable roof value, we use the following formula $P_s = P_f * C_s$. The C_s

roof slope factor is used to adjust for the effects of the material type and geometry of the roof system.

2. Width of the building. Generally, the wider the span, the greater the quantity of snow in the “snow source area” that is available to be drifting over the peak.

3. Length of the roof. ASCE 7-98 unbalanced load calculations included a function of length, making it more three dimensional. It was felt that a large number of wind directions could result in more drifting on a large building (large L/W) but less for a shorter building (small L/W). This philosophy changed in later versions.

4. Roof pitch. Low-sloped, narrow roofs and very high-pitched buildings see little snow drift. The pitch limits for unbalanced snow load conditions have varied with different versions of ASCE-7, as this table shows. W is defined as the horizontal distance from the eave to the peak.

Version	Lower limit	Upper limit
7-93, and 7-95	15 degrees	70 degrees
7-98	$70/W+.5$	70 degrees
7-02	$70/W+.5$	70 degrees
7-05	higher of $70/W+.5$ or 2.38 degrees	70 degrees

History of ASCE 7 unbalanced load formulas

It almost appears we have come full circle on the design criteria for unbalanced snow loads as formulated in the historical versions of ASCE 7. Prior formulas for this condition are as follows. Please note that I have not gone to the extent of defining the variables cited in the figures, but will leave that to the reader to review from the appropriate ASCE standard.

ASCE 7-93 and ASCE 7-95

ASCE 7-93 called for a windward load of 0# with a leeward load of 1.5 times P_s/C_e . ASCE 7-95 became slightly more liberal and decreased this leeward load to 1.3 from 1.5. Neither 7-93 nor 7-95 unbalanced design conditions created the most severe leeward wall design

reaction. In all cases the balanced load applied over the complete span resulted in the critical case. The increased roof leeward load did require a review of components and cladding design in the heavier loaded areas and sometimes caused member size increases especially with the 7-93 version.

ASCE 7-98

ASCE 7-98 radically changed these unbalanced snow load provisions. 7-98 based the unbalanced snow load calculation on an aspect ratio of the building length (L) to the width (W , horizontal distance from the roof peak to the eave). This provided for higher snow drift for a long, narrow building with a low pitch, which early field studies identified as likely candidates for snow drift. Suddenly, unbalanced versus balanced snow loads were controlling the main truss and leeward building frame vertical design reactions, therefore increasing sizes of

trusses, purlins, headers, footings, and sometimes columns.

Because of this dramatic change, industry action sought relief of this provision. Northern, heavier snow load states such as Wisconsin adopted the provisions of the unbalanced snow load design of the Canadian National Building code. This code to this day uses nearly identical formulas as ASCE 7-93 for unbalanced snow load condition.

ASCE 7-02

The 7-02 version of unbalanced snow loads saw two changes that relaxed the more conservative unbalanced loading requirements on spans over 40 feet ($W>20$ feet). The two snow load cases and equations for $W>20$ feet in figure 3 were dependent on building length whereas in figure 4 drifting load was resolved into

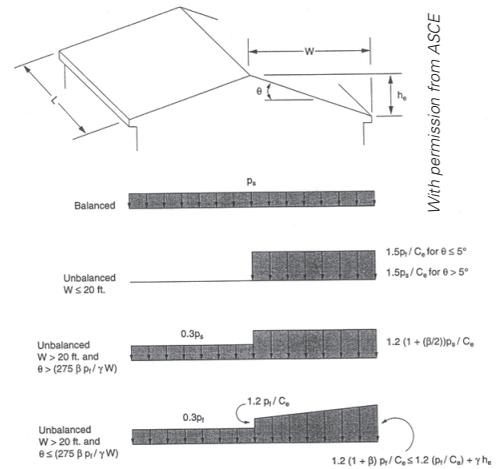


Fig 3. ASCE 7-98

one load case in which the leeward load was dependent upon the ground snow load. This change dramatically reduced the leeward reaction on longer length and span buildings. The buildings less than 40 feet retained the design model of zero windward loads and a leeward load of $1.5 P_s/C_e$, the same formula for the 7-93 version.

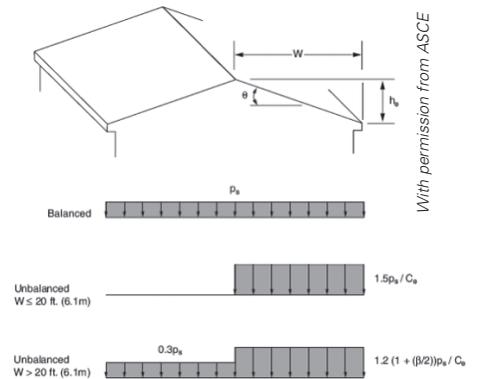


Fig 4. ASCE 7-02

ASCE 7-05

The prior ASCE 7 formulas were derived from analysis of full-scale case histories. Per ASCE News “the 7-05 gable roof drift provisions are based on a computer simulation and the results from a water flume experiment carried out at Rensselaer Polytechnic Institute. Michael O’Rourke, a professor of civil engineering at RPI, and his team of graduate students employed a water flume to simulate snow drifting and used crushed walnut shells to model snow particles on a building roof. The flow of water in the flume modeled the wind.”

A schematic representation of this

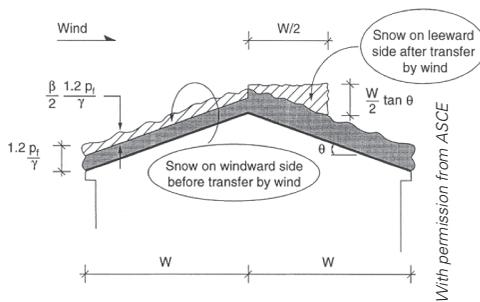


Fig 5. Snow drift model

loading is depicted in figure 5. The expected shape of a gable roof drift is nominally a triangle located close to the ridge line

Balanced and unbalanced loading diagrams for ASCE 7-05 are presented in figure 6.

Per ASCE 7-05 standard, “research suggested that the size of this triangular gable roof drift is comparable to a leeward roof step drift with the same snow source area. For certain simple structural systems, for example, wood or light gauge roof rafter systems with either a ridge board or a supporting ridge beam, with small eave to ridge distances, the drift is represented by a uniform load of $I \times P_g$ from eave to ridge. For all other gable roofs, the drift is represented by a rectangular distribution located adjacent to the ridge. The location of the centroid for the rectangular distribution is identical to that for the expected triangular distribution.” The intensity is the average of that for the expected triangular distribution. The formula for the intensity of this rectangular area is $h_d^* \gamma / (S)^{.5}$.

In the ASCE 7-02 standard the following definitions state: h_d is the height of

the snow drift and is calculated by the formula $.43 (lu)^{.33} (P_g + 10)^{.25} - 1.5$, where lu is equal to W , the eave to ridge distance. Note that in standard ASCE 7-05, figure 7-9 (not shown here) the graph and equation for determining drift height h_d , states that lu shall not be less than 25. Per communication with snow loads standards committee chairman O'Rourke this stipulation is eliminated for purposes of calculation for unbalanced loads. γ is the snow density and is defined as $.13 P_g + 14$. S is the roof slope run for a rise of one. The horizontal width of the drift surcharge is $8/3 h_d / (S)^{.5}$.

In addition to the drift load, the design snow load on the windward side is $0.3 P_s$, which is based upon case histories and did not change from 7-02. The leeward snow load consists of the value P_s with the rectangular drift load calculated, as noted earlier. The lower roof pitch angle limit of $Q = 70/W + .5$, with W in feet, has an additional lower limit of 2.38 degrees to consider, whichever is larger. This change was intended to exclude very wide, low-slope roofs, such as membrane roofs, on which significant unbalanced loads have not been observed.

Note: There are two significant items surrounding the background of these formulas:

1. The second case $I \times P_g$ load generally results in larger maximum rafter moment and shear than the expected triangular drift distribution, plus balanced load.

2. The ASCE 7 committee also felt that study of case histories showed that significant drifts didn't form on roofs with slopes less than 1/2:12 (2.38 degrees).

The new formulas provide results very similar to 7-95. The second load case rafter analysis generally depending on importance factor produces a smaller leeward reaction load than the reaction from the third load case of the rectangular drift area model. The leeward wall reactions of load case 3 used with truss designs generally result in values below the reactions of the balanced load, thus eliminating the need to upsize footings, columns, headers, and trusses. Truss chords and webs near the drift load could possibly be affected,

depending on the size and severity of the load. One must still review the heavier drift load area of the building for design of components such as purlins and roof steel cladding.

Comparison example

To further show the extent of these changes, the following example in figures 7, 8, and 9 show the leeward wall reaction results of unbalanced snow loads. These reactions are obtained by summing moments of loads about the windward wall. The results are the leeward wall loads per foot of building length on a typical 50x100 gable-pitched building with a 4:12 roof pitch, shingled roof, importance factor of 1, C_t temperature factor of 1.2, C_e exposure factor of 1.0, and a ground snow load of 50 psf. Note that the design factors, and thus the balanced roof load for all versions of ASCE-7, have remained the same. The bar graph in figure 10 summarizes the results. It is left to the reader to review the formulas and criteria from the appropriate ASCE 7 version to review the numbers shown.

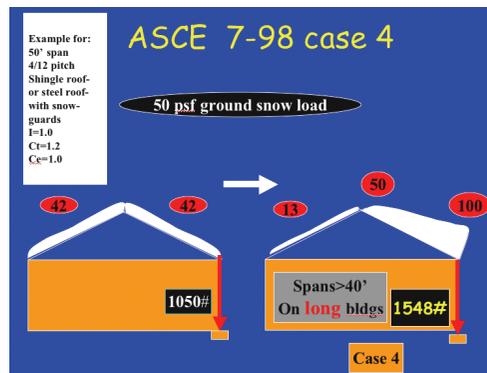


Fig. 7

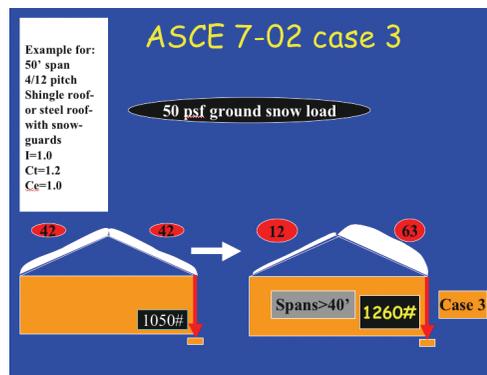


Fig. 8

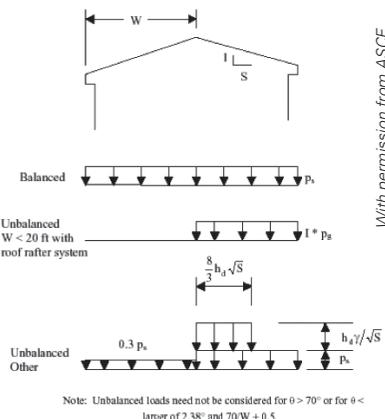


Fig 6. ASCE 7-05

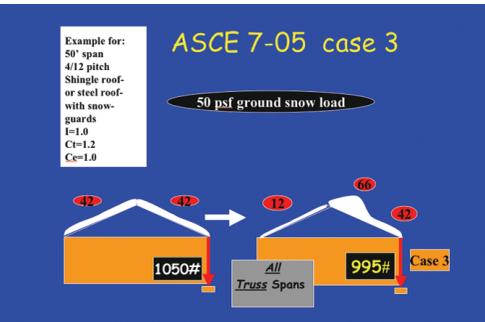


Fig. 9

Leeward wall reaction per lineal foot for unbalanced roof load for the 50x100 example.

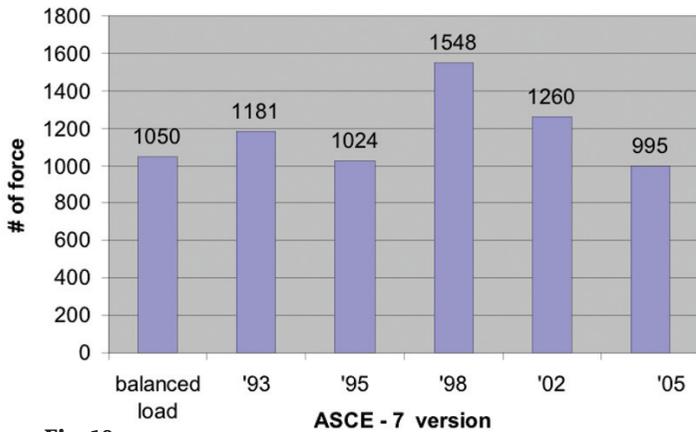


Fig. 10

Other associated design considerations

1. As noted earlier the basic adjustment factors, .7, Ce, Ct, I, Pg, and Cs used in obtaining the Pf (flat roof snow load design values) and Ps (roof snow load design value) have not changed from 7-93 through 7-05.

2. Irrespective of the ASCE 7 version, it should be noted that Cs (roof slope factor) produces values ranging from 60

to 90 percent for common roof pitches of 4, 6, and 8 in 12, dependent on the Ct values used (1.0, 1.1, 1.2). For these same conditions, shingled roofs produce values from 93 to 100 percent. The Cs factor for steel roofs can reduce design roof snow loads Ps considerably. Designers must be aware that if roof snow guards are attached to the roofing as in fig 11 to slow or eliminate the sliding snow, the designer must treat the steel roofing as

in the same category as shingles since more snow is retained on the roof. Keep this in mind when selling and designing steel roofs that may have these guards applied at a later date. Without consideration, one might be as much as 40 percent short of the required design value on a 8:12 roof pitch.

3. As figure 12 indicates, ASCE 7-02 generates higher percentage unbalanced snow load increases on leeward wall columns for lower ground snow load designs irrespective of roof pitch. For the higher 60#, 50#, and 40# snow loads, the leeward unbalanced roof load factor is 1.5 of the balanced load. This 50 percent increase is a lower percentage of the total unbalanced

load as compared to the lower ground snow load design. The 20 psf has a leeward load factor of 1.8. This 80 percent increase is a larger percentage of the total load. In concept, it is more likely on smaller loaded buildings that a larger percentage of the windward snow is blown across the peak.

4. If using ASCE 7-05 and the third loading case used for truss design, the leeward wall reaction is always lower than the balanced load wall reaction on a conventional gable pitched building with supports at the wall line. For other buildings with varying pitch, the percentages in figure 13 will vary only slightly.

5. Irrespective of the ASCE-7 version, when considering any unbalanced load with a gable-pitched building with a ridge that is offset, leaving both a longer and shorter distance from the eave to the peak, calculate the snow drift for wind from either side. In most cases, depending upon roof pitch of each side of the roof, using the longer length W for the windward side will provide for the most critical loaded condition. The snow drift will come from a larger snow source area that is contributing to the supply of snow drifting over the ridge.

6. Monopitch buildings many times are built with the intent of adding another monopitch building later to create a gable-pitched building. When proposing this type of structure, discuss this potential situation with your customer to avoid a future snow drift problem.

7. Today most truss design software



Fig. 11 Snowguards

7-02 Leeward Roof load as a % of the Ps balanced roof load for all applicable roof pitches on > 40' span buildings at designated Pg ground snow loads

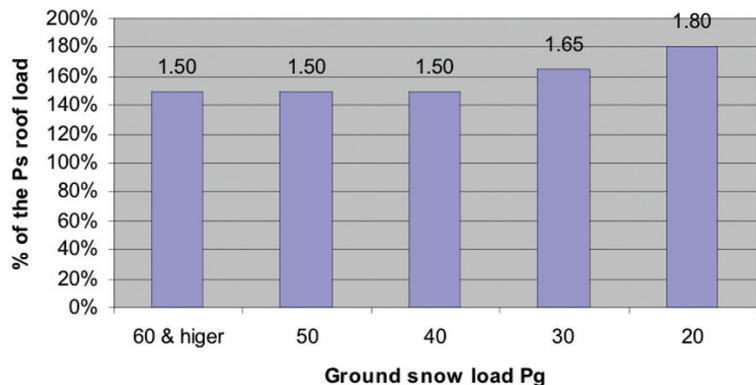


Fig. 12 ASCE 7-02 leeward wall loads

4/12 Unbalanced Leeward vertical wall reaction percentage of a Balanced load leeward wall reaction for various Pg ground snow loads.

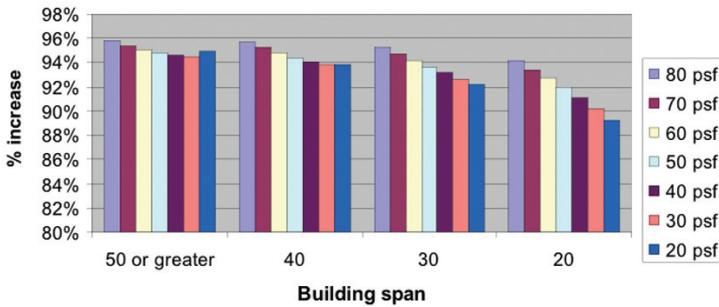


Fig. 13 ASCE 7-05 leeward wall loads

contains provisions for unbalanced snow load design. Some software programs are more flexible than others and most require input loads. Be sure to input loads as they are modeled, and make sure to follow the appropriate ASCE 7 standard and code referenced.

Conclusions

Predicting unbalanced snow loads is not an exact science, but from personal experience I have seen more buildings experience drift loads similar to the new ASCE 7-05 triangular shape model than the 7-98 and 7-02 models. It is refreshing to see the use of new techniques for

establishing the newest design formulas, which I feel are more accurate than the previous versions. Coincidentally, this change to the new 7-05 model produces less conservative results than the 7-98 and 7-02 versions, but similar results to early versions of ASCE 7. Given the prior good building performance record our industry has seen from that design time frame, this is a welcome change. ■

Leo Shirek is Manager of Research and Development for Wick Buildings, Mazomanie, Wis., and a member of the NFBA Technical and Research Committee.

References and acknowledgments:

ASCE standards 7-93,7-95,7-98,7-02, and 7-05, *Minimum Design Loads for Buildings and Other Structures*. American Society of Civil Engineers, Reston, Va.

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Michael O'Rourke and Peter D.Wrenn. *ASCE Snow loads: A guide to the understanding of snow load provisions of ASCE 7-02.*

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