# Snow load design using the 2003 International Building Code

By John R. Henry, P.E.

Early model building codes transcribed design provisions from various sources and standards. More recent editions of the building codes, such as the 1999 Edition of the National Building Code, the 1999 Edition of the Standard Building Code, and the 1997 Edition of the Uniform Building Code, have moved toward adopting standards by reference rather than transcribing standards into the body of the code.

The trend continues with the 2000 and 2003 editions of the International Building Code, and roof snow load design is a good example of this practice.

The 1997 and earlier editions of the UBC had minimal snow load provisions, which essentially required that buildings and other structures exposed to snow be designed for snow loads as determined by the building official. The 1988 UBC introduced an alternate design method in the Appendix that expanded the minimal snow load design provisions. This procedure, which was retained in later editions of the UBC, was based on the ANSI A58.1 Design Standard, the Metal Building Manufacturers Design Standard, Placer and Nevada Counties' (California) Snow Design Ordinance, the Structural Engineers Association of Arizona, and an Ad Hoc Snow Design Committee consisting of engineers and building officials from various western states. In contrast to the UBC, both the NBC and SBC historically have referenced the American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures (ASCE 7) for snow load design. The snow load provisions of the 2000 IBC are based on ASCE 7-98, and the snow load provisions of the 2003 IBC are based on ASCE 7-02, which is the current edition of the standard.

## ASCE 7 snow load design

The snow loads in ASCE 7-98 were developed from records of depths and loads of ground snow at 204 National Weather Service stations where data were recorded for at least 11 years between 1952 and 1992. These records of depth and load were used to estimate the ground snow load and depth having a 2 percent annual probability of exceedance for each location. A relationship was developed between the 2 percent depth and the 2 percent loads, and this relationship was used to estimate the 2 percent (50-year mean recurrence interval) ground snow loads at 9,200 other locations where only snow depths were measured. These depths and the depths at the 204 stations were used to create the map used in ASCE 7-98, which is an updated version of the maps in ASCE 7-93 and ASCE 7-95. Figure 1608.2 of the 2000 IBC is virtually identical to Figure 7-1 of ASCE 7-98.

The importance factor is the mechanism used to adjust the annual probability of being exceeded for different structures based on occupancy, to provide an additional margin of safety. The importance factor for ordinary structures is 1.0, corresponding to the unmodified 2 percent annual probability of being exceeded (50-year mean recurrence interval). The snow load importance factor varies from 0.8 for minor structures and agricultural buildings (4 percent annual probability of being exceeded or 25-year mean recurrence interval) to 1.2 for essential facilities (1 percent annual probability of being exceeded or 100-year mean recurrence interval).

The factors used in the standard to account for thermal, aerodynamics, and geometric properties of various structures and their site characteristics were developed from the National Building Code of Canada and many snow load case studies.

An excellent resource document for snow load design, ASCE 7-02 contains an extensive commentary with a great deal of information on the development of the snow load data as well as a detailed discussion of the intent and proper application of the design procedure outlined in the standard. Section C7.0 of the commentary includes a logical, 12-step methodology summarizing the snow load design procedure. The commentary also includes an extensive bibliography with 55 references.

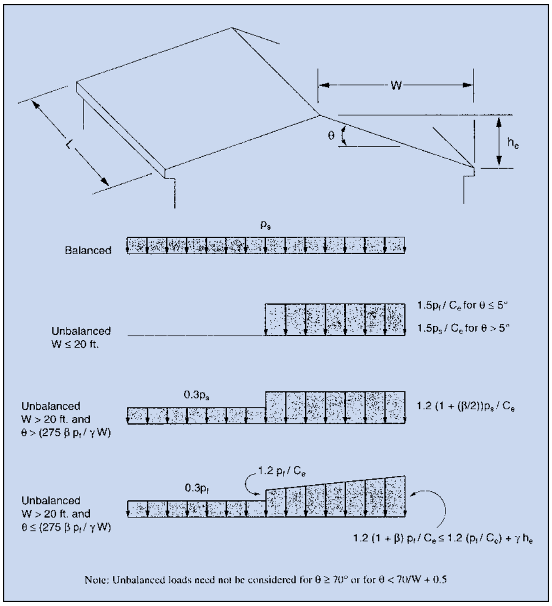
## 2003 IBC snow load design

As indicated, the snow load provisions of the 2003 IBC are based on the ASCE 7-02 standard. The procedure for determining roof snow loads are prescribed in IBC Section 1608, which is based on Section 7 of ASCE 7. Section 1608.1 of the IBC states that design snow loads shall be determined in accordance with Section 7 of ASCE 7, and requires that the design roof load be not less than the roof live load prescribed in Section 1607. For the most part, the section numbers in the IBC correspond to a section in the ASCE 7 standard. ASCE 7 Section 7.10 Rain on snow surcharge and Section 7.11 Ponding instability are covered in IBC Sections 1608.3.4 and 1608.3.5 respectively.

ASCE Section 7.12, which covers requirements for snow loads on existing roofs caused by building alterations or new additions, is not included in the IBC. Additionally, some language in the IBC differs from ASCE 7. For example, the IBC uses the term "building official" when ASCE 7 uses "authority having jurisdiction."

One difference between the code and the standard is the table referenced for the importance factor for snow loads, $I_s$. This factor is based on the building categories listed in IBC Table 1604.5, along with the importance factors for seismic and wind. There are some differences in the descriptions and terminology used in ASCE 7 Table 1-1 and IBC Table 1604.5. Since IBC Section 1608.3.3 specifically references Table 1604.5 for importance factors, it is important that code users use the IBC table for building categories and their corresponding importance factor.

In addition to the figures and tables used to determine the various snow load design factors, ASCE 7 also includes numerous, helpful figures illustrating balanced and unbalanced loading conditions, partial (alternate span) loading for continuous beams and cantilevers, and drifting snow configurations for various roof types.



Note: Unbalanced loads need not be considered for θ ≥ 70° or for θ < 70/W + 0.5

## Roof snow load factors

The following are the factors used to determine roof snow loads.

Ground snow load — The ground snow load, $p_g$, is shown in IBC Figure 1608.2 for the United States and Table 1608.2 for Alaska. In areas identified as "CS" on the map, site-specific case studies should be made based on an extreme value statistical analysis to determine the 2 percent annual probability of exceedance (50-year mean recurrence interval). See also ASCE 7 Figure 7-1. The standard further indicates that where available, local records and experience should be used to establish ground snow load values.

Snow exposure factor — The snow exposure factor, $C_e$, is obtained from IBC Table 1608.3.1 (ASCE 7 Table 7-2). The exposure factor depends on the terrain category, which is defined in IBC Section 1609.4 (ASCE 7 Section 6.5.6), and the roof exposure. The terms used to describe exposure are fully exposed, partially exposed, and sheltered, and they are defined in footnote "b" of IBC Table 1608.3.1. The exposure factor, which is intended to account for the fact that less snow is present on most roofs than on the ground (due to wind), ranges from 0.7 for fully exposed areas above the tree line in windswept mountainous areas to 1.3 in sheltered areas in terrain (exposure) category A. It should be noted that, although exposure category A is still listed in ASCE 7, Table 7.2, it has been eliminated in ASCE 7-02 and the 2003 IBC for the design of structures.

Thermal factor — The thermal factor, $C_t$, is obtained from IBC Table 1608.3.2 (ASCE 7 Table-3); it depends on the anticipated thermal conditions of the roof during winter. In general, more snow accumulates on cold roofs than on warm roofs. The thermal factor varies between 0.85 for continuously heated greenhouses to 1.2 for unheated structures. Significantly different snow loads result from shingled (non-slippery) versus plain steel (slippery) roof surfaces.

Importance factor — The snow load importance factor, $I_s$, must be obtained from IBC Table 1604.5, based on the occupancy category of the building. The importance factor for wind, seismic, or snow load design is intended to provide additional margin of safety in certain occupancies by adjusting the annual probability of exceedance for the particular load under consideration. The net effect is that design loads are magnified or decreased, depending on the specific use of the structure. The importance factor for ordinary structures is 1.0, and varies from 0.8 for minor structures and agricultural buildings to 1.2 for essential facilities such as police and fire stations, hospitals, aviation control towers, emergency response facilities.

Flat roof snow load — The flat roof snow load, $p_f$, is calculated in pounds per square foot (psf) from Section 7.3 of ASCE 7 and is given by Equation 7-1:

$$p_f = 0.7C_eC_tI_sp_g$$

0.7 is the combined exposure reduction factor for ground-to-roof conversion for normal conditions. For $C_t = 1.0$ and $I_s = 1.0$, Equation 7-1 produces ground-to-roof snow load reductions that range from 0.49 to 0.91 for $C_e = 0.7$ to 1.3, respectively. The design engineer must use considerable judgment to properly use the adjustment factors. Also, note that the proper application of the factors should be based on conditions that are likely to exist during the life of the structure.

IBC Section 1603.1.3 requires the flat-roof snow load, ($p_f$), the snow exposure factor ($C_e$), the snow load importance factor ($I_s$) and the thermal factor ($C_t$) be shown on the construction documents. It is not sufficient to only indicate the ground snow load levels on, for example, a truss design drawing.

Minimum flat roof snow load for low slope roofs — A minimum flat roof snow load applies to monoslope, hip, gable, and curved roofs with the following characteristics: monoslope roofs with slopes less than 15 degrees, hip or gable roofs with slopes less than or equal to 70/W + 0.5 (where W is the horizontal distance, in feet, from the eave to the ridge), and curved roofs with a vertical angle from eave to ridge less than 10 degrees. If the ground snow load is 20 psf or less, then $p_f = I_sp_g$. If the ground snow load is greater than 20 psf, then $p_f = 20I_s$. See ASCE 7, Sections 7.3 and 7.3.4.

Sloped roof snow load — For roofs with slopes greater than 5 degrees, the flat roof snow load is adjusted with the slope factor, $C_s$, determined from Section 7.4 of the standard. Since the accumulation of snow decreases as the slope of roof increases, this reduction primarily relates to wind action. Sloped roofs may shed snow by sliding and drainage of melt water. The amount of snow that sheds is related to the temperature of the roof and the slipperiness of the roof covering material. Hence, the slope factor depends on three parameters: the pitch of the roof, the type of roof covering material, and the roof's thermal conditions.

The slope factor is determined from ASCE 7 Figure 7-2a for warm roofs and Figures 7-2b and 7-2c for cold roofs. Cold roofs are those with $C_t$ greater than 1.0 from Table 7-3. See ASCE 7 Sections 7.4.1 and 7.4.2 for more on warm and cold roofs.

Once the appropriate figure is selected based on the thermal

## Step-by-step snow load design example

The following example illustrates the step-by step procedure for determining roof snow loads under the provisions outlined in IBC Section 1608, based on Section 7 of ASCE 7-02.

Given: A print shop building located in a suburban area of Green Bay, Wis. The building is 100 feet long by 60 feet wide with an 8:12 pitch gable roof and trusses spanning 60 feet. The roof covering material is composition shingles; the attic is vented and insulated with an R>25. (Although the 8:12 pitch is steeper than generally encountered in most post-frame buildings, the example still illustrates correctly the snow load calculation procedures for post-frame buildings.)

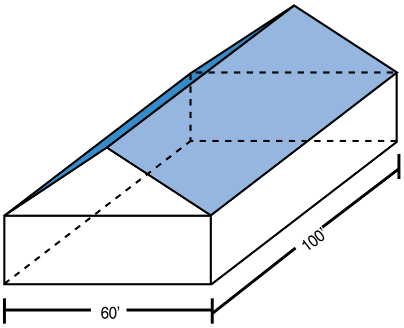
Step 1: The ground snow load from IBC Figure 1608.2 for Green Bay, Wis. is $p_g = 40$ psf.

Step 2: Determine the snow exposure factor, $C_e$, from IBC Table 1608.3.1 (ASCE 7 Table 7-2).

$C_e = 1.0$ for exposure category B, partially exposed roof.

Step 3: Determine the thermal factor, $C_t$, from IBC Table 1608.3.2 (ASCE 7 Table-3). $C_t = 1.1$ for heated structures with ventilated roofs, R > 25.

Step 4: Determine the snow load importance factor, $I_s$, from IBC Table 1604.5. For Category II ordinary structures, $I_s = 1.0$.



Step 5: Determine the flat roof snow load, $p_f$, in accordance with Equation 7-1.

$p_f = 0.7C_eC_tI_sp_g$
$= 0.7(1.0)(1.1)(1.0)(40)$
$= 30.8$ psf

Step 6: Determine if the minimum flat roof snow load applies in accordance with Sections 7.3 and 7.3.4. Since $p_g = 40$ psf and factor $I_s = 1.0$, the minimum flat roof snow load is 20 x 1.0 = 20 psf. Therefore, $p_f = 30.8$ psf governs.

Step 7: Determine the sloped roof snow load by adjusting the flat roof snow load by the slope factor, Cs, in accordance with Section 7.4. The slope of the roof in degrees, $\theta = \arctan(8/12) = 33.7$ degrees. Since $C_t = 1.1$, $C_s$ is determined from Figure 7.2b. $C_s = 1.0$.

The sloped roof snow load is, $p_s = 30.8$ psf (balanced snow load).

Step 8: Unbalanced loading from the effects of wind loading on hip and gable roofs must be considered in accordance with Section 7.6.1. Unbalanced snow load need not be considered for $\theta \geq 70$ degrees or for $\theta < (70/W + 0.5)$ degrees.

(70/30 + 0.5) = 2.38 degrees. Since $\theta > 2.38$ degrees and $\theta < 70$ degrees, the unbalanced loading condition must be considered.

(W=30) > 20 feet. The parameter $\beta$ is a function of L/W. L/W = 100/30 = 3.33.

$\beta = 0.33 + 0.167\ (L/W) = 0.33 + 0.167\ (3.33) = 0.89$

The roof must be designed for an unbalanced snow load per Figure 7-5 as follows:

Windward load = $p_W = 0.3p_s = 0.3(30.8) = 9$ psf

Leeward load = $p_L = 1.2(1 + \beta/2)\ p_s / C_e = 1.2(1 + 0.89/2)(30.8)/(1.0) = 53$ psf

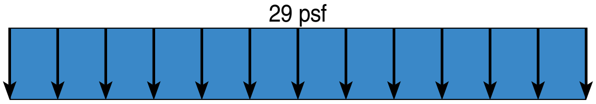
The density of snow, $\gamma$, is given by Equation 7-4.

$\gamma = 0.13p_g + 14 = 0.13(40) + 14 = 19.2$ pcf

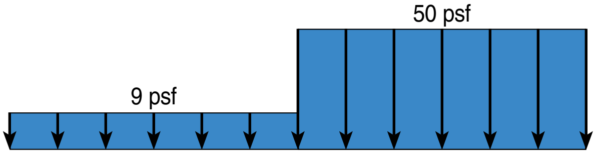
The depth of unbalanced snow on the windward roof is d = 9/19.2 = 0.5 feet.

The depth of unbalanced snow on the leeward roof is d = 53/19.2 = 2.8 feet.

The balanced and unbalanced loading conditions are shown in the figure below



Balanced snow load



Unbalanced snow load

conditions of the roof, $C_s$ is determined using the slope of the roof in degrees (or pitch) and either the dashed line for unobstructed slippery surfaces or the solid line for all other surfaces. It should be noted that Section 7.4 states that the sloped roof snow load is assumed to act on the horizontal projection of the roof surface.

Portions of curved roofs with a slope greater than 70 degrees need not be designed for snow loads; in this case, $C_s = 0$. For multiple folded plate, sawtooth, or barrel vault roofs, no reduction is permitted and $C_s = 1.0$.

### Calculations for loading conditions and drifting configurations

Once the roof snow load is determined, various types of loading conditions and possible drifting configurations must be considered.

Partial loading — Partial loading

must be considered for continuous beams, cantilevers, or similar structural systems in accordance with Section 7.5 of ASCE 7. Partial loading consists of alternate span loading with full (balanced) snow load on a given span and one half the full snow load on adjacent spans. Section 7.5 includes three load cases for proper application of the full and half snow load conditions. Partial loading need not be considered for members spanning perpendicular to the ridge in gable roofs where the slope is greater than 70/W + 0.5, w in ft. See ASCE 7 Figure 7-4.

IBC Table 1604.5
Importance Factor, $I_s$
(Snow Loads)

| Category | $I_s$ |
|---|---|
| I | 1.0 |
| II | 1.1 |
| III | 1.2 |
| IV | 0.8 |

Unbalanced loading — Unbalanced loading from the effects of snow drifting due to wind effects must be considered. Roof types and the applicable section of the standard are as follows: hip and gable roofs, Section 7.6.1; curved roofs, Section 7.6.2; multiple folded plate, sawtooth, or barrel vault roofs, Section 7.6.3; and dome roofs, Section 7.6.4. Y

In calculating drift geometry, it is necessary to consider both the depth of the snow, h (feet), and the pressure of the snow, p (psf). These factors are related by the formula p/g = h. Equation 7-4 gives snow density, , as a function of the ground snow load. The standard requires that both balanced and unbalanced snow loads be considered as separate loading conditions. See Figures 7-3, 7-5, and 7-6.

Drifting on lower roofs — Drifts on lower roofs must be considered in accordance with Section 7.7. The same method used to determine drifts on lower roofs must be used to consider drift loads caused by higher structures or adjacent terrain features within 20 feet of a roof in accordance with Section 7.7.2. When analyzing drifting, both windward and leeward drifts must be considered, and the design is to be based on the governing drift condition. See Figure 7-8.

Drifts at roof projections — The method used to determine drifts on lower roofs must be used to consider drift loads at roof projections and parapet walls in accordance with Section 7.8. See Figures 7-7 and 7-8.

Sliding snow — The effects of snow sliding off a high roof onto a lower roof must be considered for roof slopes greater than 1/4:12 with slippery roof coverings and for roof slopes greater than 2:12 for other roof coverings. Sliding snow loads are to be superimposed on the balanced snow load.

Rain-on-snow surcharge and ponding instability — Finally, there are also requirements for consideration of rain-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on-snow surcharge and ponding instability. Roofs with a slope of less than 1/2 inch per foot located in areas where a ground snow load is 20 psf or less (and greater than zero) must be designed for an additional rain-on-snow surcharge load of 5 psf. For roofs with a slope of less than 1/4 inch per foot, deflections caused by full snow load must be considered when determining the possibility of ponding from rain-on-snow or water from melted snow.

Existing roofs — Where alterations or additions are made to an existing building, the roof must be evaluated for increased snow load effects. Where a roof higher than an adjacent building roof is constructed within 20 feet, the existing building owner or agent must be advised as to the potential increased snow loading from the new roof structure.

## Snow load design: step-by-step

The following method is a step-by-step procedure for determining roof snow loads under the provisions outlined in IBC Section 1608, based on Section 7 of ASCE 7-98.

Step 1: Determine the ground snow load from IBC Figure 1608.2 for the United States or Table 1608.2 for Alaska.

Step 2: Determine the snow exposure factor, $C_e$, from IBC Table 1608.3.1 (ASCE 7 Table 7-2).

Step 3: Determine the thermal factor, $C_t$, from IBC Table 1608.3.2 (ASCE 7 Table-3).

Step 4: Determine the snow load importance factor for the particular building, $I_s$, from IBC Table 1604.5.

Step 5: Determine the flat roof snow load, $p_f$, in accordance with ASCE 7 Equation 7-1.

$$p_f = 0.7 C_e C_t I_s p_g$$

Step 6: Determine if the minimum flat roof snow load applies in accordance with Sections 7.3 and 7.3.4.

Step 7: Determine the sloped roof snow load by adjusting the flat roof snow load for roof slope by the slope factor in accordance with Section 7.4. Depending on the slope of the roof, the flat or sloped roof snow load is the design snow load to be used in the various loading conditions and configurations.

Step 8: Consider partial loading for continuous beams or similar structural systems where alternate span loading could create maximum loading conditions in accordance with Section 7.5.

Step 9: Consider drift loads on lower roofs in accordance with Section 7.7.

Step 10: Consider drift loads at roof projections and parapet walls in accordance with Section 7.8.

Step 11: Consider the effects of sliding snow on lower roofs in accordance with Section 7.9.

Step 12: Determine if the requirements for rain-on-snow surcharge apply in accordance with Section 7.10.

Step 13: Determine if the requirements for ponding instability apply in accordance with Section 7.11.

Step 14: Determine the design loads on each structural component.

After the design snow loading is determined, the final step is to design the roof and supporting structure to resist the design snow load. The final design depends on the structural material and the design procedure to be used. The roof system and structure may be constructed of aluminum, concrete, masonry, steel, or wood, and the design procedure may be either an allowable stress design (ASD) or a strength design (SD/LRFD) procedure. The IBC permits both procedures for all structural materials using the applicable design standard. Note, however, that appendix A, alternate design method (aka working stress design) has been deleted from the 2002 ACI-318 Building Code Requirements for Structural Concrete.

Depending on the procedure used, the final design of the structural elements will involve the use of ASD load combinations in IBC Section 1605.3, or SD/LRFD load combinations in IBC Section 1605.2. There are two different sets of ASD load combinations in the IBC: the basic load combinations of IBC Section 1605.3.1, which originated with ASCE 7; and the alternative basic load combinations of IBC Section 1605.3.2, which originated with the UBC. Either set of ASD load combinations may be used at the discretion of the engineer, provided the same set of load combinations is used consistently throughout the design of the structure. ■

This is an updated version of an article that originally appeared in the August, 2002 issue of Structural Engineer magazine as “Snow Load Design Using the 2000 International Building Code,” and has been updated by the principal author to reflect changes in the 2003 IBC/ ASCE 7-02. The article is reprinted with permission, Copyright 2002 by Structural Engineer (Telephone: (404) 497-7890). All rights reserved.

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