CODE UPDATES

code developments
and announcements

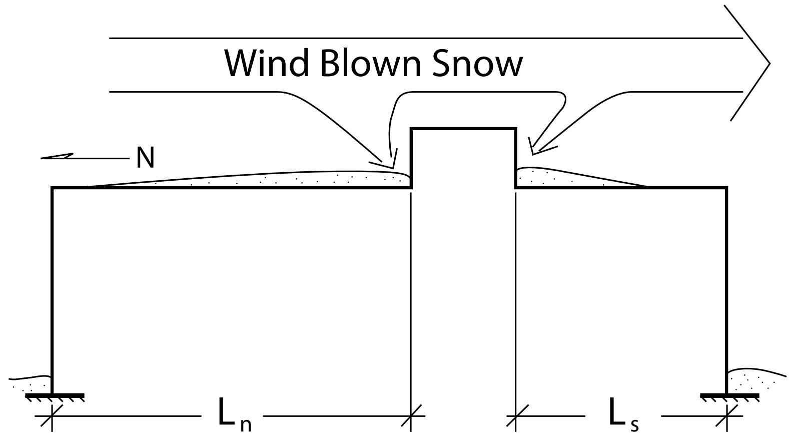

Figure 1: RTU Drifting-North Wind.

Snow & Rain Provisions in ASCE 7-10

What's New and Different

By Michael O'Rourke, Ph.D., P.E.

The American Society of Civil Engineers' ASCE 7-10 load standard is now available and, as one would expect, some things have changed. Although the snow and rain chapters are nominally the same size as before (14 pages in both 7-05 and 7-10.), some changes are subtle while others are not-so-subtle. In this article, the most substantive changes are discussed along with the reasoning behind them.

Minimum Roof Snow Load

The minimum roof load provisions have been a source of confusion for some time. In ASCE 7-10, as in ASCE 7-05, the minimum roof load is the importance factor I times the smaller of 20 psf or the ground snow load, p_g. The confusion is not the magnitude of the minimum load but whether it is to be used in combination with drift loads, sliding loads and the like. The answer to this last question is no.

The situation envisioned by the minimum load provision corresponds to the roof snow load immediately after a single large snowfall without wind. Under these conditions, neither the exposure factor C_e (no wind), the thermal factor C_t (no time for thermal effects to develop) nor the slope factor C_s (no time for sliding to develop) apply. As a result, the roof snow load is the same as the ground snow load. Finally, the "single large snowfall" is taken to be I•p_g or I•20 psi whichever is smaller. That is, for locations with comparatively low values of p_g, one could get the 50 year ground snow load in a single large snowfall. However, even for locations with comparatively high values of p_g, a single large snowfall is not expected to result in a ground snow load of more than 20 psf.

Over time, wind and thermal effects come into play and the roof load morphs into the balanced load, p_s. It is this balanced load, which includes the exposure, thermal and slope factors, that is consistent with drifting and the like.

In ASCE 7-10, this intent is hopefully clarified by using a new symbol, p_m, for the minimum roof load to avoid confusion with the flat roof load p_f and by identifying the sloped roof snow load p_s as the "balanced" snow load. Finally, for further clarification, the following note was added at the end of Section 7.3.4:

> *"This minimum roof snow load is a separate uniform load case. It need not be used in determining or in combination with drifts, sliding, unbalanced or partial loads."*

RTU Drifts

Another area of confusion has been drift loading at Roof Top Units (RTUs). In ASCE 7-05, it is clear that the drift in question is a windward drift (three quarters of the height of the leeward drift from ASCE 7-05 Figure 7-9). The confusion involved the appropriate fetch distance. For example, considering the RTU sketched in *Figure 1*; some engineers thought that the drift immediately south of the RTU should be based upon the fetch distance, L_s.

In ASCE 7-10, the situation is clarified

> *"For roof projections, l_u, shall be taken equal to the greater of the length of the roof upwind and downwind of the projection."*

That is, irrespective of the location of interest being upwind or downwind of the RTU, a windward drift (¾ factor) using the larger of L_n or L_s as the fetch distance is prescribed.

In way of explanation, consider an example with wind out of the north as shown in *Figure 1*. Clearly the drift immediately north of the

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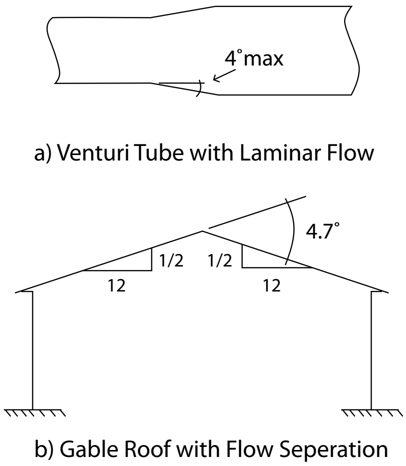

Figure 2: Venturi Tube and Gable Roof Geometry.

RTU is the windward drift for an upwind fetch distance of L_n. The drift to the south of the RTU is a leeward drift for a fetch distance somewhat less than L_n. The fetch is less because some of the wind blown snow is captured in the upstream drift. Since a leeward drift for a reduced fetch is not greatly different than a windward drift for an un-reduced fetch, for simplicity it was decided to require the same drift on both sides.

Thermal Factor

In most cases, the roof snow load without drifting or sliding is less than or equal to the ground snow load. This is consistent with the ASCE 7-05 provisions for the sloped roof load (or the "balanced" load). That is, for an importance factor of I = 1.0, the largest balanced load – one for a sheltered (C_e = 1.2) unheated (C_t = 1.2) roof – is 1.008 p_g (0.7 x 1.2 x 1.2 = 1.008).

There are, however, some cases where the balanced roof load was observed to be **larger** than the ground snow load. For example, as noted in a report by the Structural Engineers Association of Washington (SEAW), the peak ground snow load in the Greater Yakima area was 31 pounds per square foot (psf) during the 1996-97 Holiday Storm, while the measured roof load on Freezer Buildings and Cold Rooms was roughly 35 psf.

This observation is generally consistent with heat transfer and conditions leading to retention of a snow pack. That is, in relation to the temperature at the bottom of a snow pack and hence the potential for melting, the worst case is a roof snow pack on a heated building – hot air below and ambient air above. At the other extreme is a freezer building with cold air below and ambient air above. Between these two extremes are the ground snowpack with warm earth below and ambient air above, and a loading dock roof with ambient air above and below.

In ASCE 7-05, a thermal factor of C_t = 1.2 was specified for both unheated structures and structures intentionally kept below freezing. Based upon the SEAW observations and differences in heat transfer characteristics, in ASCE 7-10 we have:

Thermal Conditions	C_t
Unheated and open air structures	1.2
Structures intentionally kept below freezing	1.3

That is, freezer buildings now have their own group with a new C_t of 1.3, while loading docks are grouped with unheated buildings with a C_t of 1.2.

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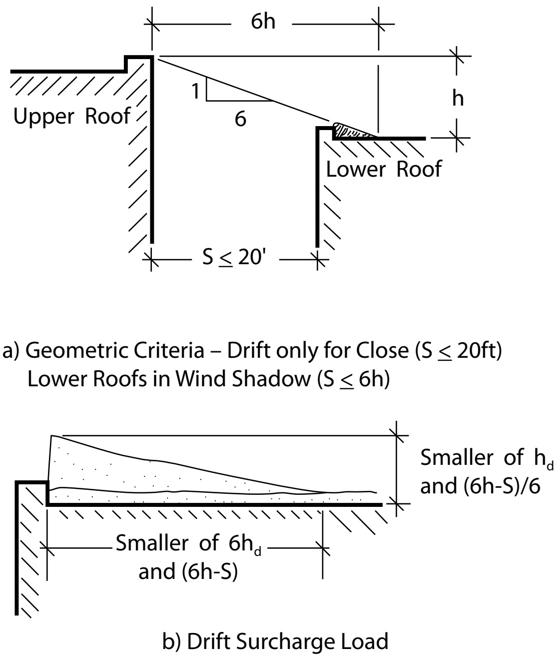

Figure 3: Leeward Drift on Separated Roofs.

Unbalanced Loads

It seems that each new version of ASCE 7 brings changes to the unbalanced load provision. ASCE 7-10 is no exception. However, the good news is that the changes make the provision simpler (more engineer friendly) and more realistic in terms of the applicable roof geometrics.

Upper Bound Slope – Unbalanced Loads

In ASCE 7-05, unbalanced loads were required for hip and gable roofs with slopes up to 70 degrees. This limit is the same as that for balanced loads. That is, the slope factor C_s is zero for roof slopes of 70 degrees and higher, and the thinking was if fresh fallen snow doesn't "stick" to such steep roofs then the drift loads would similarly not accumulate on them.

Underlying this approach is the assumption that, in terms of an angle of repose, drifted snow behaves like fresh fallen snow. However, two independent sets of observations suggest differently. One set is from the Tahoe-Truckee Engineers Association (TTEA). Located in a truly beautiful part of Northern California which gets large amounts of snow, roof snow loading is a particularly important consideration for TTEA. Their observations suggest that unbalanced loads (across-the-ridge drifts) only form on roof slopes of 6 on 12 or less.

The other set are observations of the rise-to-run of roof step drifts taken from insurance company files. The vast majority of roof step drifts had a rise-to-run of one vertical to two horizontal (1V: 2H) or less.

Both sets of observations suggest that the angle of repose of **drifted** snow is about 26 degrees, substantially less than that for fresh fallen snow. It is possible that windblown snow particles become more rounded as a result of the transport process. Whatever the actual scientific reason, the committees choose a somewhat conservative approach.

"For hip and gable roofs with slope exceeding 7 on 12 (30.2)…unbalanced loads are not required to be applied."

Lower Bound Slope- Unbalanced Loads

The lower bound slope, below which unbalanced loads need not be considered, has varied over the years. In the original load standard ASCE 7-88, the limit was 15 degrees. In ASCE 7-02, an empirical curve fit relation:

$$angle = \frac{70}{W} + 0.5 \qquad \text{Equation 1}$$

was introduced where the angle is in degrees and the eave to ridge distance *W* is in feet. This was modified in ASCE 7-05 to exclude roofs with slopes less than ½ on 12 since there was no empirical evidence of drifting on such shallow, near flat roofs.

Note that evidence from fluid mechanics, specifically the behavior of Venturi tubes, is consistent with the ½ on 12 roof slope limit. In order to achieve laminar flow, the maximum angular deviation at a Venturi tube can be no more than about 4 degrees, as shown in *Figure 2 (page 37)*. Laminar flow means no flow separation and no areas of aerodynamic shade. For the gable with ½ on 12 slope, also shown in *Figure 2*, the total angular deviation from the windward to leeward roof surfaces is 4.7 degrees. That is, based on the Venturi Tube analog, one expects flow separation, areas of aerodynamics shade and drifting for the ½ on 12 roof (4.7° > 4.0°) while one expects no flow separation, no aerodynamic shade and no drifting for a ⅜ on 12 roof slope (3.58° < 4°).

Based on the evidence from fluid mechanics and a desire to simplify matters, the empirical relation in *Equation 1* was eliminated from the ASCE 7-10 provision.

"For hip and gable roofs….with a slope less than 2.38 (½ on 12) unbalanced snow loads are not required to be applied."

Lower Bound Eave to Ridge Distance-Unbalanced Load

The empirical relationship between drift height h_d, ground snow load p_g, and upwind fetch distance l_u, in *Equation 2* (Figure 7.9 of ASCE 7) was originally developed from a database of leeward roof step drifts.

$$h_d = 0.43\sqrt[3]{\ell_u}\,\sqrt[4]{Pg+10} - 1.5 \qquad \text{Equation 2}$$

In the database, the fetch distances were typically hundreds of feet. This may well have led to the fact that the relation is problematic for much shorter fetch distances. For example, one calculates **negative** drift heights for small fetch distances and low ground snow loads. With this undesirable feature in mind, a minimum fetch distance of 25 feet was specified. For the roof step geometry, an upwind fetch of 25 feet or less is unusual and designers did not question the lower bound fetch distance of 25 feet.

In ASCE 7-05, the drift height relation in *Equation 2* also was used to determine unbalanced loads on hip and gable roofs. The

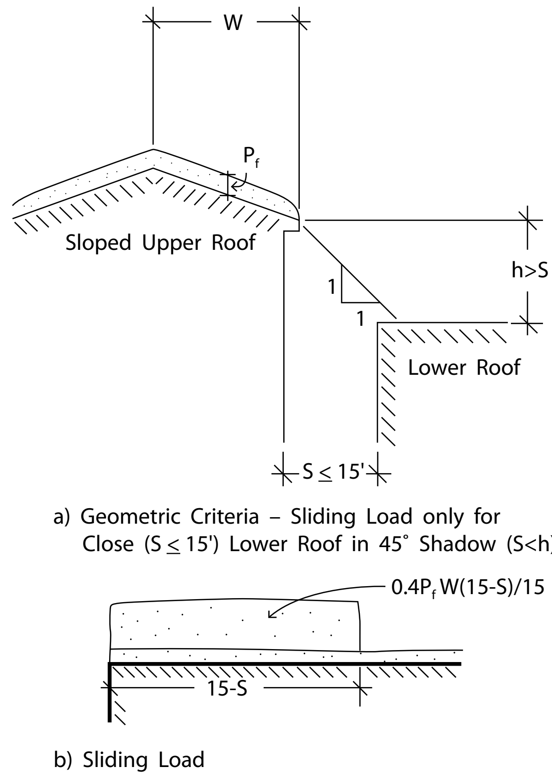

Figure 4: Sliding Load on Separated Roof.

windward eave to ridge distance then became the upwind fetch with the same lower bound of 25 feet. However, for the gable roof geometry, an eave to ridge distance of 25 feet or less is quite common. Designers questioned the lower bound value since it controlled for the majority of single family residences.

Simply eliminating the lower bound was not an option due to the aforementioned problems with *Equation 2*. Due to the lack of available case histories, the Snow and Rain Subcommittee commissioned a small study of simulated drifts using a numerical technique developed originally by Cocca (Masters Thesis, Rensselaer, 2006). An analysis of the simulated drifts convinced the Subcommittee that lowering the limit by five feet was consistent with safety margins associated with larger fetch distances. As a result Section 7.6.1 now reads:

> *"For W less than 20 ft, use W = L_u = 20 ft. in Fig 7-9."*

Separated Structures

If two roofs are close enough, the lower may be subject to additional drifts or sliding loads due to the presence of the higher separated roof.

Drift Loads – Separated Structures

In ASCE 7-05, a truncated drift was specified for the lower level roof if the roof separation distance *s* was less than 20 feet. In ASCE 7-10, the separation distance criterion is retained and an additional geometric criterion is introduced. Specifically, a leeward drift on the lower level roof is required only if the lower roof is in the aerodynamic or wind shadow of the upper level roof. The wind shadow region is assumed to trail downward from the upper level roof at a slope of 1V: 6H. As shown in *Figure 3*, the leeward drift height is the smaller of h_d and *(6h-s)/6*. The first is the drift height based upon the upper roof fetch distance, while the second is based upon a snow drift filling the wind shadow space on the lower level roof. The rise-to-run of the drift is assumed to match the slope of the wind shadow boundary; hence, the horizontal extent is the smaller of $6h_d$ or *(6h-s)*.

For windward drifts, the drift is truncated by simply eliminating the portion of the drift between the edges of the two roofs.

Sliding Loads- Separated Structures

In ASCE 7-05, a sliding load was required for a lower roof if the slope of the upper level roof was steep enough (greater than ¼ on 12 for slippery upper roof surfaces and greater than 2 on 12 for non-slippery upper roof surfaces). The load per unit length was specified to be $0.4p_f \bullet W$, where *W* is the upper roof eave to ridge distance and the horizontal extent was specified to be 15 feet.

In ASCE 7-10, the sliding load provisions were expanded to include separated roofs. The lower roof is subject to a truncated sliding load if the separation distance is less than 15 feet and the elevation difference is greater than the horizontal separation distance. The first geometric criterion is based upon the 15 foot horizontal extent for attached roofs, while the second is based upon a 1V:1H sliding load shadow. As shown in *Figure 4*, the truncated load per unit length is $0.4p_fW(15\text{-}s)/15$.

To clarify the application of sliding loads for both attached and separated roofs, ASCE 7-10 notes:

> *"Sliding loads shall be superimposed on the balanced snow load and need not be used in combination with drift, unbalanced, partial or rain-on-snow loads."*

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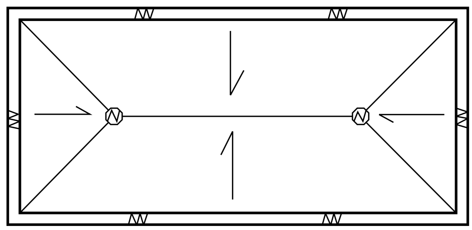

a) Plan View – Roof with Interior Primary Drains and Secondary Drains in Parapet Walls

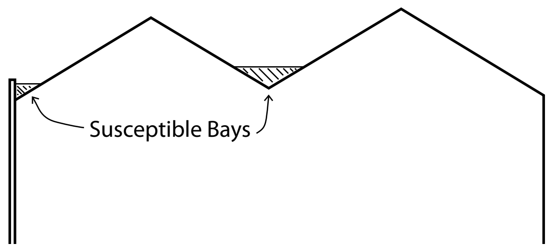

Figure 5: Susceptible Bays.

Ponding

In ASCE 7-05, a ponding analysis with primary drains assumed blocked was required for roofs with slopes less than ¼ on 12. For a ¼ on 12 roof slope, even a "generous" maximum allowable deflection criterion of the span/100 results in the roof low point being located **above** the eave. That is, the ¼ on 12 rule works in precluding standing water if the eaves are free draining. However, irrespective of roof slope, one gets standing water for other roof geometries. *Figure 5* shows two such roof geometries that are susceptible to ponding problems. In the first, the roof has perimeter parapet walls with secondary drains and a roof surface that slopes downward toward primary interior drains. If the primary drains are assumed to be blocked, one gets standing water even if the roof is much steeper than ¼ on 12. The second figure has a similar problem adjacent to the parapet wall to the left and the valley in the center.

In recognition of potential standing water problems for roofs without free draining eaves, ASCE 7-10 requires a ponding instability analysis for so-called "susceptible bays."

"Bays with a roof slope less than ¼ in./ft. or on which water is impounded upon them (in whole or in part) when the primary drain system is blocked, but the secondary system is functional, shall be designated as susceptible bays. Roof surfaces with a slope of at least ¼ in per ft. (1.19°) towards points of free drainage need not to be considered a susceptible bay."

Summary

This article summarizes the most substantive changes to the Snow and Rain provisions of ASCE 7-10. The changes to the Minimum Load and the RTU Drift provisions were intended to clarify the existing provision. A new Thermal factor category was established for a freezer building and cold rooms. The revised lower and upper bound roof slopes for unbalanced loads are straight forward, easier to apply and based on observed behavior. For separated structures, drift loads are no longer required for the lower roof outside the wind shadow region, while sliding loads are now required for lower roofs within a 45-degree sliding load shadow of the upper sloped roof. Finally, the change to the Ponding provision was intended to alert users to the fact that certain roof geometrics require a ponding analysis irrespective of the roof slope.▪