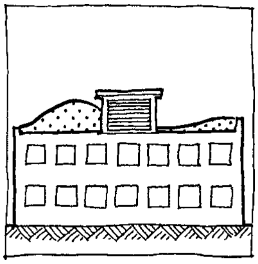


Chapter 8

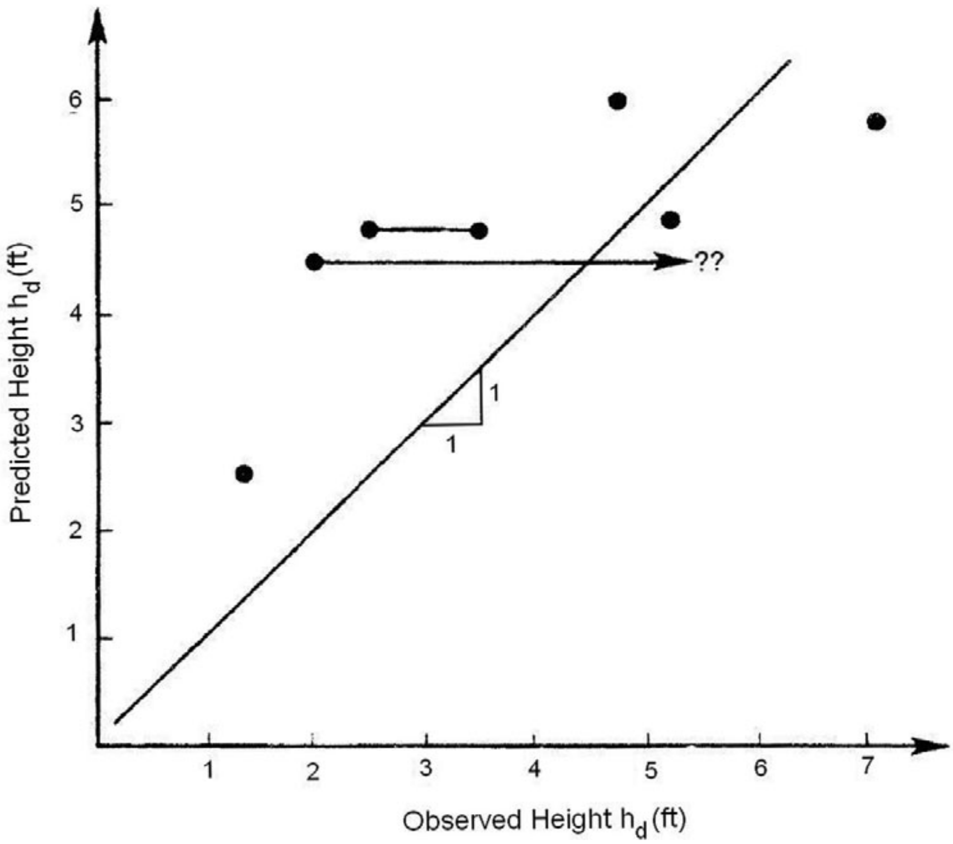
Roof Projections

Snow drifts frequently form at parapet walls and adjacent to rooftop units (RTUs). At a parapet wall, the drift is clearly a windward drift because the snow source is the roof, as opposed to snow originally on the top of the wall itself. For an RTU, the situation is more complex. The drift on the upwind side of the RTU is a windward drift for the same reasons as for parapet walls. The drift on the downwind side is a somewhat reduced leeward drift composed of snow originally on the roof upwind of the RTU plus a small contribution from snow originally on top of the RTU itself. This leeward drift is somewhat reduced because some of the roof snow is captured at the windward drift on the upwind side of the RTU. Hence for wind out of the north, a windward drift forms on the north side of the unit and a somewhat reduced leeward drift on the south side, both made from snow originally to the north of the RTU. For wind out of the south, a windward drift and a leeward drift again form, but now they are made from snow originally to the south of the RTU.

For simplicity, ASCE 7 requires a windward drift on each side of the unit, based on the larger of the two fetch distances. Hence, these roof projection drifts follow the same provisions as windward roof step drifts discussed in Chapter 7 of this guide (Section 7.7 of ASCE 7-10). For parapet walls, the drift height is taken as three-quarters of the value given by **Equation G7-3**, where ℓ_u is the roof fetch distance upwind of the wall. The drift height at two opposite sides of an RTU is also three-quarters of the value from **Equation G7-3**, where ℓ_u is now the *larger* of the two roof fetch distances for the direction of interest.

In a review of snow drift case histories, O'Rourke and DeAngelis (2002) demonstrated that the three-quarters factor applied to windward drifts is reasonable. The observed surcharge drift heights for six windward drifts were compared with values predicted by the appropriate ASCE 7 provisions. The resulting graph is presented in **Figure G8-1**. In one case, the observed height of 2 ft filled the space available for drift formation. If the parapet wall had been taller, then a larger drift may have formed. This full-drift situation is shown in **Figure G8-1** by a horizontal line with question marks located to the

Figure G8-1
Comparison of observed windward surcharge drift height with values predicted by ASCE 7.



right-hand side. In another case history, the observed surcharge height was generally characterized as ranging from 2.5 to 3.5 ft.

For three of the case histories, the provisions overpredict the observed values, and for two others, the provisions underpredict the observed values. The ratios of observed to predicted range from 0.53 to 1.23, with a mean of 0.84. For the windward drifts considered, the overload for the *surcharge* was no more than 23%. As noted by O'Rourke and DeAngelis, the overload for the total snow load (balanced plus surcharge) is less, and it is unlikely that a snow overload of 23% would result in significant structural performance problems given the safety factors commonly used in building design.

As with drifts on lower roofs discussed in Chapter 7 of this guide, the sloped roof snow load in Equation 7-2 of ASCE 7 is the balanced load below the roof projection drift load. The sloped roof snow load, p_s, = $0.7C_eC_tI_sC_sp_g$, where p_g is the 50-year Mean Recurrence Interval (MRI) ground snow load. Minimum roof snow loading and rain-on-snow surcharge loads do not influence this balanced load. In addition, if the cross-wind length of the roof projection is small (that is, the plan dimension perpendicular to the direction of wind under consideration is less than 15 ft) then the drift load does not need to be considered for that wind direction. Drifts will form at such roof projections, but the cross-wind plan dimension of the drift and the total drift load (in lbs) is relatively small and can be neglected without affecting the overall integrity of the structural system. The author is not aware of any structural-performance problems related to this 15 ft cutoff for roof projection drifts.

Example 8-1 Parapet Wall Drift

Problem

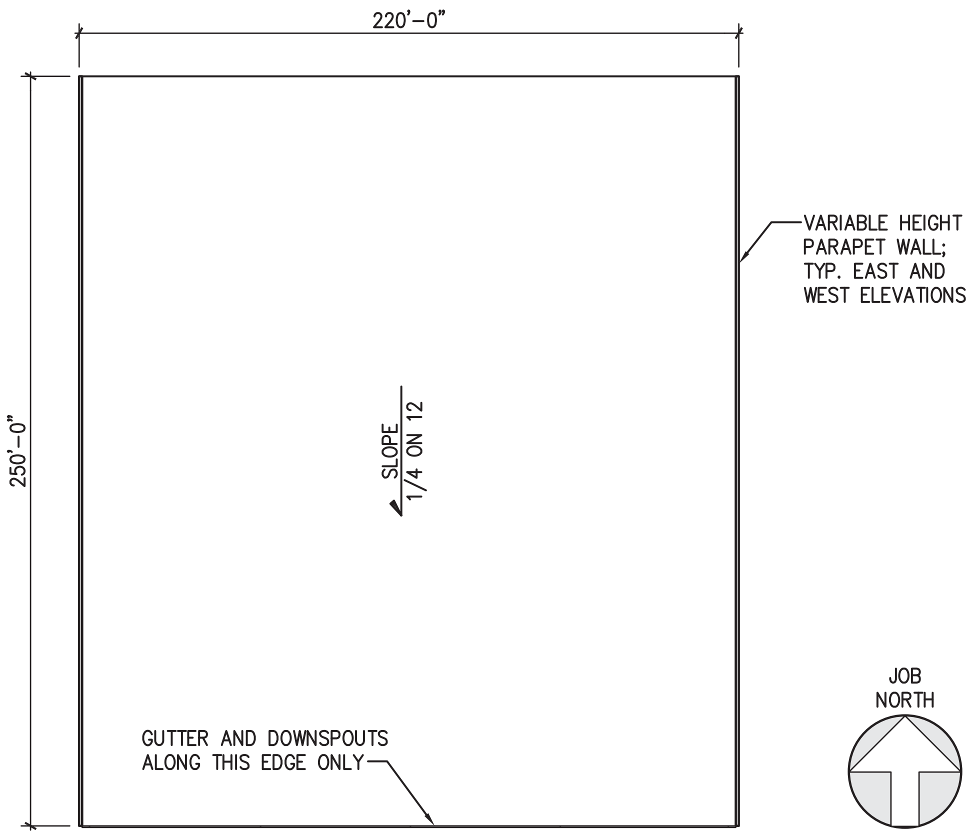
Determine the design snow drift loads for the roof structure shown in **Figure G8-2**. The site is in a suburban area (Terrain Category B) where p_g is 30 lb/ft^2. A line of conifers about 50 ft to the west of the structure serves as an obstruction. That is, the top of the trees is more than 5 ft (50 ft/10) above roof elevation. The structure is a large, heated warehouse deemed to be of ordinary importance. It has parapet walls on the east and west elevations only. The parapet wall is nominally flush with the roof edge at the north elevation.

Solution

Balanced Load

The building is located in Terrain Category B, and the roof is partially exposed (due to the presence of the conifers as well as the parapet wall); therefore, C_e is 1.0 from Table 7-2. From Tables 7-3 and 1-2, $C_t = I_s = 1.0$. For a roof

Figure G8-2
Plan of monoslope roof for Example 8-1.



slope of ¼ on 12, C_s is 1.0 irrespective of the roof's surface or thermal characteristics. Hence, the balanced load is

$$p_s = 0.7C_eC_tC_sI_sp_g = 0.7(1.0)(1.0)(1.0)(1.0)(30\ \text{lb/ft}^2) = 21\ \text{lb/ft}^2$$

Drift Load

The height of the parapet wall at the southeast and southwest corners is

$$h = 250\ \text{ft}\ (¼\ \text{in./ft}) = 62.5\ \text{in.} = 5.2\ \text{ft}$$

The snow density is $\gamma = 0.13p_g + 14 = 0.13(30\ \text{lb/ft}^2) + 14 = 18\ \text{lb/ft}^3$ (Equation 7-3), and the depth of the balanced snow is

$$h_b = \frac{p_s}{\gamma} = \frac{21\ \text{lb/ft}^2}{18\ \text{lb/ft}^3} = 1.17\ \text{ft}$$

The space available for drift formation (the clear height above the balanced snow, h_c, is 5.2 ft – 1.17 ft = 4 ft) is large compared to the balanced snow depth ($h_c/h_b > 0.2$). Therefore, the parapet wall drift must be considered. For an upwind fetch of 220 ft and a ground snow load of 30 lb/ft^2,

$$h_d = 0.75\left[(0.43)\left(\sqrt[3]{220}\right)\left(\sqrt[4]{30+10}\right) - 1.5\right] = 3.8\ \text{ft}$$

The drift height is not limited by the space available for drift formation because the drift height is less than h_c. The maximum drift surcharge load at the parapet wall is

$$p_d = \gamma\, h_d = 18\ \text{lb/ft}^3\ (3.8\ \text{ft}) = 68\ \text{lb/ft}^2$$

The total maximum roof snow load (balanced plus drift) is

$$21\ \text{lb/ft}^2 + 68\ \text{lb/ft}^2 = 89\ \text{lb/ft}^2$$

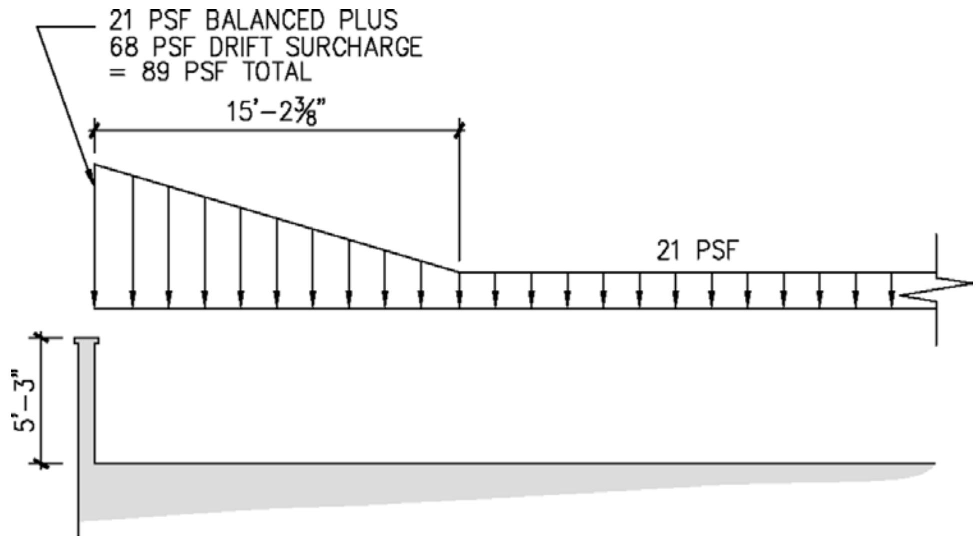
and the horizontal extent is

$$w = 4\, h_d = 4(3.8\ \text{ft}) = 15.2\ \text{ft}$$

The resulting parapet wall drift load at the southwest corner is shown in **Figure G8-3**. The design drift at the southeast corner is similar. Since both drifts have the same snow source area, it is unlikely that both design drifts would occur simultaneously. The issue of the possible simultaneous occurrence of drifts on all four sides of an RTU is discussed in Chapter 13 of this guide.

The ground snow load in this case is large enough that the minimum snow load for low sloped roofs ($p_m = I_s(20\ \text{lb/ft}^2) = 20\ \text{lb/ft}^2$) is less than the balanced load and thus does not govern. Similarly, the ground snow load is large enough that the rain-on-snow surcharge does not apply (see Section 7.10).

Figure G8-3
Parapet wall drift at southwest corner for Example 8-1.



If the roof is a continuous-beam system (for example, a metal building system roof with lapped purlins), then the roof also needs to be checked for the partial load provisions in Section 7.5. The resultant partial load would be considered a separate load case from the balanced-plus-drift load case determined above.

Example 8-2 Rooftop Unit (RTU) Drift

Problem

Solve the same problem as Example 8-1, except a 4 ft × 12 ft × 20 ft RTU is located as shown in **Figure G8-4** and the roof has no parapets.

Solution

Balanced Load

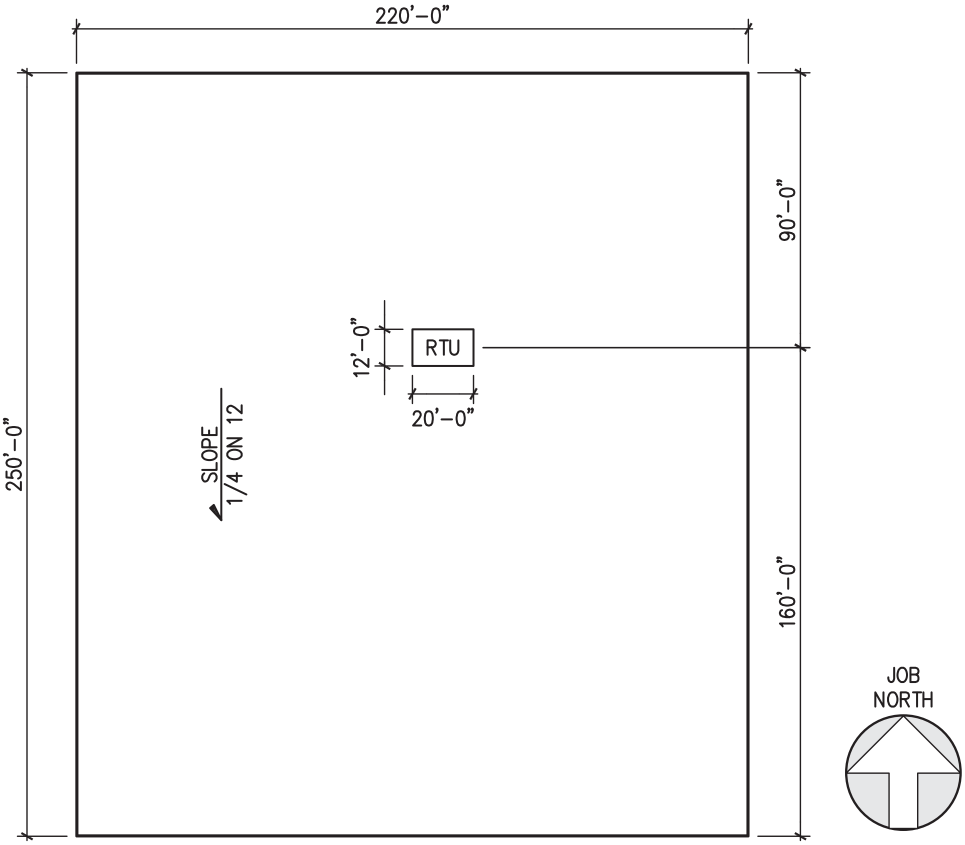
Although the parapets have been removed, the stand of conifers is still in close proximity, so C_e, C_t, I_s, and p_f are the same as in Example 8-1 ($p_s = 21$ lb/ft^2 and $h_b = 1.17$ ft).

Drift

The clear height to the top of the RTU is $h_c = 4.0$ ft – 1.17 ft = 2.8 ft and $h_c/h_b > 0.2$. Therefore, a roof projection drift needs to be considered. Since the cross-wind dimension of the RTU is only 12 ft, which is less than the 15 ft minimum for an east–west wind, drifting along the east and west sides of the RTU need not be considered. For a north–south wind, the larger of the upwind fetch distances is 160 ft. Hence,

$$h_d = 0.75\left[(0.43)\left(\sqrt[3]{160}\right)\left(\sqrt[4]{30+10}\right) - 1.5\right] = 3.3\text{ ft}$$

Figure G8-4
Plan view of monoslope roof for Example 8-2.



Since this drift height is greater than the clear height, h_c, the drift width, w, is larger than $4h_d$. Using the "equating the areas" relation from Section 7.7.1, the drift width is

$$w = 4h_d^2/h_c = 4(3.3\text{ ft})^2/2.8\text{ ft} = 15.6\text{ ft}$$

Yet from the "aerodynamically streamlined drift" relation, the drift width cannot exceed

$$w \leq 8h_c = 8(2.8\text{ ft}) = 22.4\text{ ft}$$

In this case, the "equating the area" relation controls, and the total maximum load (balanced plus drift) is

$$p_{\max} = h_{\text{RTU}} \times \gamma = 4.0\text{ ft}(18\text{ lb/ft}^3) = 72\text{ lb/ft}^2$$

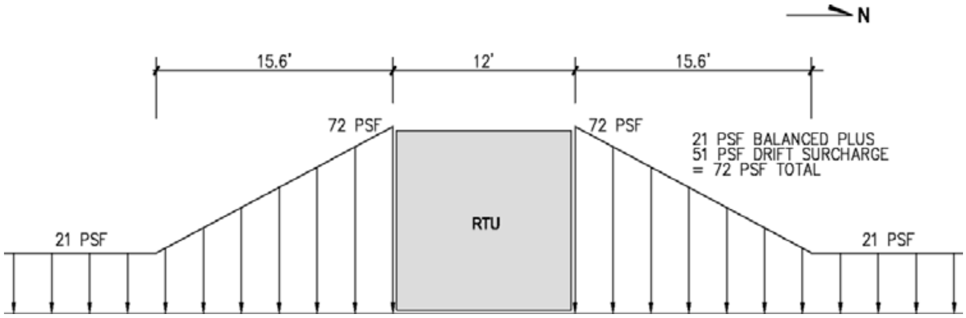
The resulting load at the RTU is sketched in **Figure G8-5**.

Example 8-3 Parapet Wall Drift, Low Ground Snow Load

Problem

Solve the same problem as Example 8-1, except that p_g is 15 lb/ft^2.

Figure G8-5
RTU drift for Example 8-2.



Solution

Balanced Load

In Example 8-1, p_g is 30 lb/ft^2 and the balanced load is 21 lb/ft^2 for the structure. The balanced load is proportional to the ground snow load; therefore, the new balanced load is

$$p_s = \frac{15\ \text{lb/ft}^2}{30\ \text{lb/ft}^2}(21\ \text{lb/ft}^2) = 10.5\ \text{lb/ft}^2\ (\text{round to } 11\ \text{lb/ft}^2)$$

Of course, the new balanced load could also have been calculated directly from Equation 7-2. Recalling from Example 8-1 that $C_e = C_t = C_s = I_s = 1.0$,

$$p_s = 0.7C_eC_tC_sI_sp_g = 0.7(1.0)(1.0)(1.0)(1.0)(15\ \text{lb/ft}^2) = 10.5\ \text{lb/ft}^2$$
$$(\text{round to } 11\ \text{lb/ft}^2)$$

The roof geometry has not changed, and the parapet wall height, h, at the southeast and southwest corners is still 5.2 ft.

The new snow density, γ, is

$$\gamma = 0.13p_g + 14 = 0.13(15\ \text{lb/ft}^2) + 14 = 15.9\ \text{lb/ft}^3\ (\text{round to } 16\ \text{lb/ft}^3),$$

and the depth of the balanced load below the parapet wall drift becomes

$$h_b = \frac{p_s}{\gamma} = \frac{11\ \text{lb/ft}^2}{16\ \text{lb/ft}^3} = 0.69\ \text{ft (round to 0.7 ft)}$$

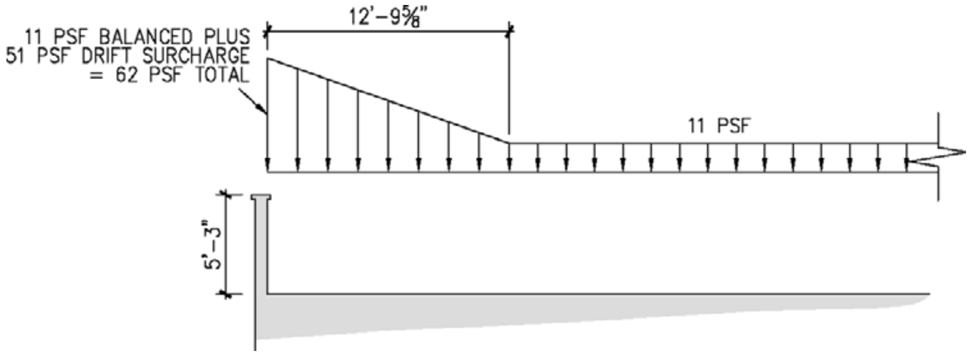
Therefore, enough space is available ($h_c = 5.2$ ft − 0.7 ft = 4.5 ft) for formation of a significant drift ($h_c/h_b > 0.2$).

For our upwind fetch of 220 ft and our ground snow load of 15 lb/ft^2,

$$h_d = 0.75\left[0.43\left(\sqrt[3]{220}\right)\left(\sqrt[4]{15+10}\right) - 1.5\right] = 3.2\ \text{ft}$$

Note that the new surcharge drift height is less than that for Example 8-1 but not significantly less, specifically 84% of the previous value of 3.8 ft. Although h_d is an increasing function of p_g, the increase is not proportional to p_g.

Figure G8-6
Parapet wall drift at southwest corner for Example 8-3.



As in Example 8-1, the drift height, h_d, is less than h_c (3.2 ft < 4.5 ft). The surcharge height is not limited by the space available for drift formation, and the width or horizontal extent from the parapet is four times the surcharge height.

$$w = 4h_d = 4(3.2\ \text{ft}) = 12.8\ \text{ft}$$

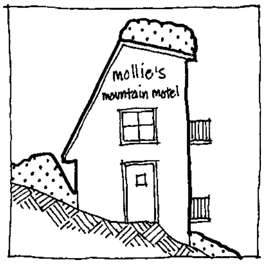
The maximum drift surcharge load is

$$p_d = h_d\,\gamma = 3.2\ \text{ft}\ (16\ \text{lb/ft}^3) = 51.2\ \text{lb/ft}^2\ (\text{round to } 51\ \text{lb/ft}^2)$$

Thus, the total maximum load (balanced plus drift surcharge) at the parapet wall is 11 lb/ft^2 + 51 lb/ft^2 = 62 lb/ft^2. The resulting load at the southwest corner is sketched in **Figure G8-6**.

For this example, the ground snow load is small enough that the minimum roof snow load or the rain-on-snow enhanced uniform load may govern. Finally, if the roof is a continuous-beam system, various partial load cases must be checked also.

Note: Drifting is frequently a problem with a new or enlarged RTU on an existing roof. Since reinforcing an existing roof is often complicated and expensive, it might be desirable to raise the base of the replacement RTU high enough above the roof level so that windward drifts do not form. An example is described in Chapter 13 (Question 3).



Chapter 9

Sliding Snow Loads

As shown in Chapter 4, there are theoretical differences between the design snow load on a nominally flat roof and on a sloped roof. On sloped roofs, snow simply slides off or, for very steep slopes, does not stick in the first place. For example, **Figure G9-1** shows a common case of snow sliding onto a lower roof.

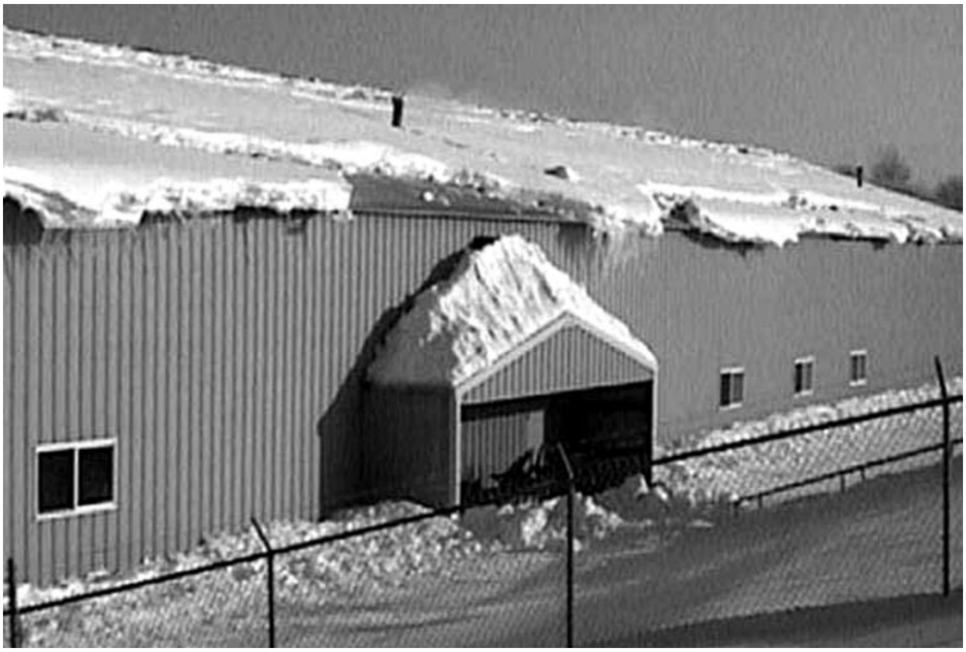
From a structural standpoint, snow sliding off a roof is beneficial as long as the sliding snow does not collect in an undesirable location. The roof geometry and the immediately adjacent site plan should be such that the snow sliding off a roof does not pose a hazard to people, parked cars, or other nearby objects. Clever designers in snowy climates often locate the main entrance at an end wall of a gable roof structure (e.g., a north or south wall for a north–south ridgeline) to avoid snow sliding onto people. If a main entrance is located along a side wall (east or west wall for a north–south ridgeline), then the designer often places a small gable roof above the entrance to deflect sliding snow to either side. This small cross-gable roof, however, can lead to large ice dams.

Snow that slides off a roof and collects against a wall is another concern: the snow pile exerts a lateral load on the wall. Some metal-building manufacturers offer snow girts as an option for such situations. Although ASCE 7-10 does not address this issue, Chapter 13 of this guide offers suggestions for estimating the lateral load. ASCE 7-10 does, however, have design load provisions for snow that slides onto an adjacent roof. These are discussed below.

9.1 Adjacent Roofs

At first glance, one might think that the load that slides onto a lower roof should be the complement of the sloped roof load, p_s, and that the sliding load plus the sloped roof snow load should equal the flat roof load, p_f. If this were the case, the sliding load on the lower roof would be proportional to $1 - C_s$, where C_s is the slope factor for the upper roof. This approach appears

Figure G9-1
Snow sliding onto a lower roof
Source: Courtesy of Leo Shirek.



to be compatible with physics and makes sense intuitively. Following the 1 – C_s approach, low-sloped upper roofs would produce small sliding loads and steeply sloped upper roofs would produce large sliding loads. The following example, however, demonstrates why the 1 – C_s approach is flawed.

Consider a case when the only significant snowfall for a winter season occurs on February 1, resulting in 15 lb/ft^2 of snow on a sloped roof. The weather remains cold and cloudy for the next few days, and then it becomes warm and sunny. Upon the arrival of the mild conditions, the upper-roof snow begins to melt, and all the snow slides en masse onto the lower level roof on February 6. In this case, the sliding snow load is proportional to the sloped roof snow load. The annual maximum load on the upper roof of 15 lb/ft^2 occurred between February 1 and February 6. The sliding load on the lower roof, which arrived on February 6, was due to the same 15 lb/ft^2 originally on the upper roof. The 1 – C_s principle is flawed because it neglects the aspect of time; an extant upper roof snow might be sliding load snow in the future.

This example could lead to an "equality" concept, whereby the sliding snow load on the lower roof is proportional to C_s for the upper roof. However, this reasoning also is flawed. Consider a steep roof subject to a number of snowfalls over the course of a winter. Each snowfall initially sticks to the steeply sloped roof, but its stability is precarious and eventually a gust of wind or a slamming door causes the upper roof snow to slide onto a lower roof. In this case, the load on the upper roof is never very large, but the accumulated sliding load could be substantial. The "equality" concept is flawed because more than one sliding event may occur over the course of a winter season, and the design snow load for the steep upper roof may be small compared to the accumulated sliding load on the lower roof.

Because there is not sufficient case-history information to establish a more detailed approach that includes C_s, ASCE 7-10 prescribes a simple approach