Leeward Drift: For a wind out of the north, the upwind fetch for the resulting leeward drift is the length of the upper roof (ℓ_u = 100 ft). Hence, the surcharge drift height is

$$h_d = 0.43\sqrt[3]{\ell_u}\sqrt[4]{p_g + 10} - 1.5 = 0.43\,(100\text{ ft})^{1/3}\,(40\text{ lb/ft}^2 + 10)^{1/4} - 1.5 = 3.8\text{ ft}$$

Windward Drift: For a wind out of the south, the upwind fetch for the resulting windward drift is 170 ft. Hence, the surcharge drift height is

$$\begin{aligned} h_d &= 0.75[0.43\sqrt[3]{\ell_u}\sqrt[4]{p_g + 10} - 1.5] \\ &= 0.75[0.43(170)^{1/3}(40\text{ lb/ft}^2 + 10)^{1/4} - 1.5] = 3.6\text{ ft} \end{aligned}$$

Thus, the leeward drift controls, and h_d is 3.8 ft. Because the drift is not full ($h_c > h_d$), the drift width is four times the drift height

$$w = 4h_d = 4(3.8\text{ ft}) = 15\text{ ft}$$

The maximum *surcharge* drift load is the drift height times the snow density

$$p_d = h_d\gamma = 3.8\text{ ft}\,(19\text{ lb/ft}^3) = 72\text{ lb/ft}^2$$

The total load at the step is the balanced load on the lower roof plus the drift surcharge ($34 + 72 = 106$ lb/ft^2), as shown in **Fig. G7-11**.

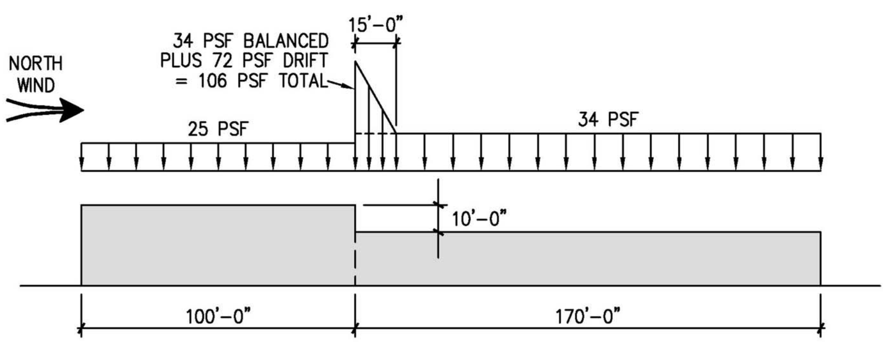
Due to the comparatively large ground snow load ($p_g > 20$ lb/ft^2), the minimum roof snow load (Section 7.3.4) is $20I_s$, or 20 lb/ft^2, for both the upper and lower roofs. Hence that separate load case does not govern. Also due to the large ground snow load, the rain-on-snow surcharge does not apply (see Section 7.10).

Example 7-2. Roof Step Drift, Limited Height

Problem

Solve the same problem as Example 7-1, except the elevation difference at the roof step is 4 ft.

***Fig. G7-11.* Roof step snow load for Example 7-1**



Solution

The depth of the balanced snow on the lower roof remains 1.8 ft, but now the clear height, h_c, = 4.0 ft − 1.8 ft = 2.2 ft. Note that h_c/h_b = 2.2 ft/1.8 ft = 1.2 > 0.2; therefore, drift loads need to be considered. In this case, the drift surcharge height will be limited by $h_c(h_d = 3.8 \text{ ft} > h_c)$, and the maximum surcharge drift load is

$$p_d = h_c\,\gamma = 2.2 \text{ ft}\,(19 \text{ lb/ft}^3) = 42 \text{ lb/ft}^2$$

The balanced load on the lower roof remains 34 lb/ft². Thus, the total (balanced plus drift) snow load at the roof step is 76 lb/ft² (34 lb/ft² + 42 lb/ft²). Because the drift is full, the width is increased. Recalling that the unlimited leeward drift height (ℓ_u = 100 ft, p_g = 40 lb/ft²) was 3.8 ft from Example 7-1, the drift width is

$$w = 4h_d^2/h_c = 4(3.8 \text{ ft})^2/2.2 \text{ ft} = 26 \text{ ft}$$

But the drift slope need not exceed a rise-to-run of 1:8 (aerodynamically streamlined); thus

$$w_{\max} = 8h_c = 8(2.2 \text{ ft}) = 18 \text{ ft}$$

In this case, $8h_c$ controls, and the design snow loads are shown in **Fig. G7-12**.

Example 7-3. Roof Step Drift, Low Ground Snow Load

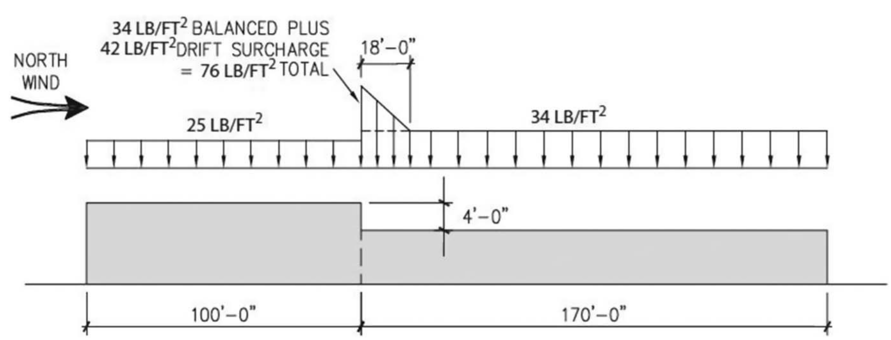
Problem

Solve the same problem as Example 7-1 with p_g = 15 lb/ft².

Solution

Balanced Loads: For the upper roof, the values of C_e = 0.9 and $C_t = C_s = I_s$ = 1.0 are still valid. For the ground load of 15 lb/ft², the balanced snow

Fig. G7-12. **Roof step snow loading for Example 7-2**



load on the upper-level roof is

$$p_s = 0.7C_eC_tC_sI_sp_g = 0.7(0.9)(1.0)^3(15\ \text{lb/ft}^2) = 9.5\ \text{lb/ft}^2\ (\text{round to }10\ \text{lb/ft}^2)$$

The minimum snow load for low sloped roofs from Section 7.3.4 is $I_sp_g = 1.0(15\ \text{lb/ft}^2) = 15\ \text{lb/ft}^2$.

For the lower roof, the values of $C_e = 1.0$, $C_t = 1.2$, $C_s = 1.0$, and $I_s = 1.0$ are still valid. For the ground snow load of 15 lb/ft^2, the balanced load on the lower roof is

$$p_s = 0.7C_eC_tC_sI_sp_g = 0.7(1.0)(1.2)(1.0)(1.0)(15\ \text{lb/ft}^2) = 12.6\ (\text{round to }13\ \text{lb/ft}^2)$$

Drift Loads: The balanced snow depth on the lower roof is determined from p_s and the snow density [Eq. (7-3)]

$$h_b = \frac{p_s}{\gamma} = \frac{13}{0.13(15)+14} = 0.82\ \text{ft}$$

The surcharge height for the leeward drift (wind from the north) is

$$h_d = 0.43\sqrt[3]{\ell_u}\sqrt[4]{p_g+10} - 1.5 = 0.43(100\ \text{ft})^{1/3}(15\ \text{lb/ft}^2+10)^{1/4} - 1.5 = 2.96\ \text{ft}$$

and the corresponding value for the windward drift (wind from the south) is

$$\begin{aligned} h_d &= 0.75[0.43\sqrt[3]{\ell_u}\sqrt[4]{p_g+10} - 1.5] \\ &= 0.75[0.43(170\ \text{ft})^{1/3}(15\ \text{lb/ft}^2+10)^{1/4} - 1.5] = 2.87\ \text{ft} \end{aligned}$$

As with Example 7-1, the leeward drift height is larger. Because the leeward drift height is less than the clear height ($h_d = 2.96$ ft $< h_c = 10.0$ ft $- 0.82$ ft $= 9.18$ ft), the width is equal to four times the surcharge height

$$w = 4h_d = 4(2.96\ \text{ft}) = 11.8\ \text{ft}$$

and the drift surcharge load is

$$p_d = h_d\gamma = (2.96\ \text{ft})[(0.13\times 15\ \text{lb/ft}^2) + 14\ \text{lb/ft}^3] = 47.2\ \text{lb/ft}^2$$

Because the ground snow load is comparatively small ($p_g < 20\ \text{lb/ft}^2$), minimum roof snow loads (Section 7.3) need to be considered. The minimum roof snow load for both the upper and lower roofs is I_sp_g or 15 lb/ft^2. Similarly, because the ground snow load is small, the roof slope is small (1/4 on 12), and the eave-to-ridge distance is large ($W = 80$ ft), the rain-on-snow surcharge applies (see Chapter 10 of this guide). The rain-on-snow surcharge of 5 lb/ft^2 is added to the sloped roof snow loads.

For the upper roof, the sloped roof snow load is 10 lb/ft^2 and the rain-on-snow surcharge is 5 lb/ft^2, for a total of 15 lb/ft^2. For the lower roof, the sloped roof snow load is 13 lb/ft^2 plus 5 lb/ft^2 rain-on-snow, for a total of 18 lb/ft^2. For both roof levels, the sum of the rain-on-snow surcharge and the sloped roof snow load is greater than or equal to the minimum roof snow load. Therefore, the rain-on-snow augmented load governs.

It is unclear which load case governs for the lower roof, so both the uniform load case and the balanced-plus-drift load case require evaluation. The resulting design load cases are shown in **Fig. G7-13**.

Example 7-4. Roof Step Drift, Adjacent Structure

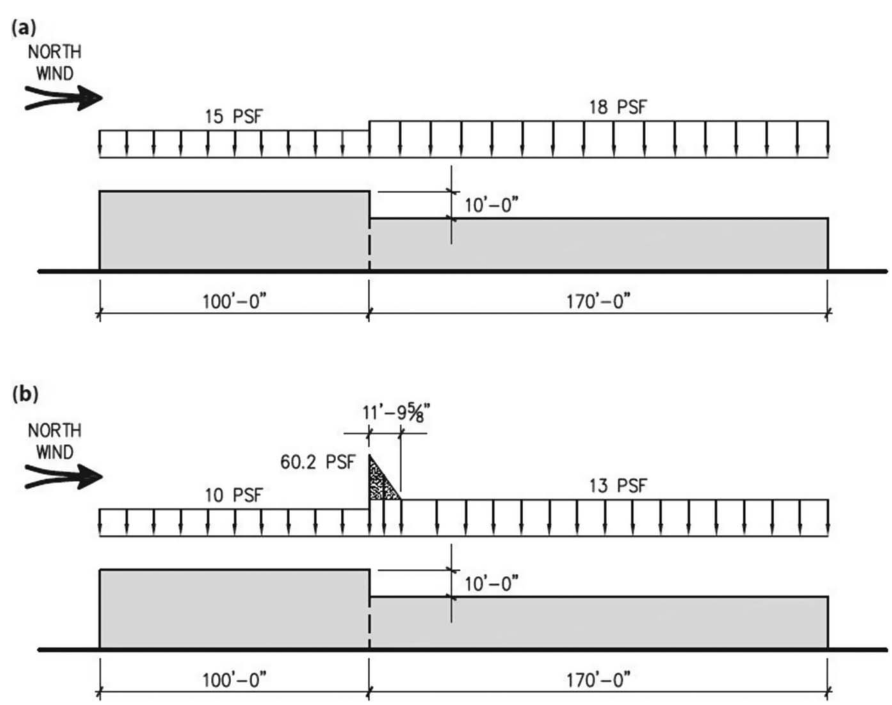
Problem

Solve the same problem as Example 7-1, except the unheated storage facility is separated from the heated, unventilated roof facility by 8 ft.

Solution

The balanced load on the unheated space remains unchanged at 34 lb/ft^2. Although the heated space no longer adjoins to the unheated space, it still serves as an obstruction (refer to the footnotes for Table 7.3-1). Given h_o = 10 ft and the separation distance of 8 ft < $10h_o$ = 100 ft, the heated space qualifies as an obstruction for the roof of the unheated storage facility.

***Fig. G7-13*. Two load cases for step roof in Example 7-3: (a) uniform load case; (b) balanced plus drift load case**



Because the separation distance $s = 8$ ft is less than 20 ft and less than $6h = 60$ ft, drifts need to be considered. The unmodified leeward and windward drift heights for a roof step without a separation are still 3.8 and 3.6 ft, respectively. Hence, the leeward drift governs in this case. The drift height is the smaller of $h_d = 3.8$ ft and $(6h - s)/6$, which is

$$(6h - s)/6 = (6 \times 10 - 8)/6 = 8.66 \text{ ft}$$

Hence, the surcharge height is 3.8 ft and the peak surcharge load is 3.8 ft (19 lb/ft^3) = 72 lb/ft^2 using the snow density of 19 lb/ft^3 from Example 7-1. The horizontal extent of the drift surcharge is the smaller of $6h_d = 22.8$ ft and $6h - s = 52$ ft.

In summary, the drift on the adjacent roof consists of a triangular surcharge with a peak load of 72 lb/ft^2 and a horizontal extent of 22.8 ft. Note that this drift has a larger horizontal extent than that in Example 7-1, which is an artifact of the simplifying assumptions, specifically the 1:6 drift slope, used for the adjacent drift.

Example 7-5. Roof Steps in Series

Problem

Determine the height of the leeward drift atop Roof C in **Fig. G7-9** if the ground snow load is 20 lb/ft^2.

Solution

The effective fetch distance for two leeward roof steps in series is

$$\ell = 120 + 0.75(100) = 195 \text{ ft}$$

and the height of the drift is determined from **Eq. (G7-3)** for a ground load of 20 lb/ft^2, as follows:

$$h_d = 0.43 \sqrt[3]{\ell_u} \sqrt[4]{p_g + 10} - 1.5 = 0.43 \sqrt[3]{195} \sqrt[4]{20 + 10} - 1.5 = 4.32 \text{ ft}$$

Note that if one were to completely neglect the influence of the step between Roofs A and B, the fetch distance would be 220 ft and the corresponding leeward drift height atop Roof C would be 4.56 ft.

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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, not 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 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, we have a windward drift on the north side of the unit and a somewhat reduced leeward drift on the south side, both from snow originally to the north of the unit. For wind out of the south, we again have windward and leeward drifts, but now due to snow originally to the south of the unit. 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 7-16). For parapet walls, the drift height is taken as three-quarters of the value given by **Eq. (G7-3)**, where ℓ_u is the roof fetch distance upwind of the wall. The drift height at two opposite sides of a RTU is also three-quarters of the value from **Eq. (G7-3)**, where ℓ_u is now the *larger* of the two roof fetch distances for the direction of interest.

As alluded to in Chapter 7, there are significant differences between leeward drifts at roof steps and windward drifts at a parapet wall, roof projection, or roof step. Leeward drifts have a triangular shape; windward drifts begin with a quadrilateral shape and, given a sufficient upwind snow source and wind, may morph into a triangular shape.

Another difference is the available case-history information. As noted by O'Rourke and DeAngelis (2002), the database on which **Eq. (G7-1)** and **(G7-3)** were based contained 255 triangular drifts (a mix of leeward and full windward) and 50 quadrilateral drifts (nonfull windward). The triangular drifts were significantly larger than the quadrilaterals. For example, **Fig. G8-1** shows a comparison of the predicted surcharge drift height for triangular and quadrilateral drifts. The predicted heights led to the use of a 0.5 factor for windward drifts to convert a leeward drift height in **Eq. (G7-3)** into a windward drift height, in the 1988, 1993, and 1995 editions of the ASCE 7 load standard. That is, windward drifts were presumed to have a quadrilateral shape. A subsequent analysis of true windward drifts (both quadrilateral and triangular) led to the currently used 0.75 factor to convert leeward drift height into windward drift height, which was introduced in the 1998 version of the standard. **Fig. G8-2** shows a comparison of observed and predicted windward drift heights using the current 0.75 factor. In one case, the observed height of 2 ft filled the space available for drift formation. If the parapet wall had been taller, a larger drift may have formed. This full-drift situation is shown in **Fig. G8-2** by a horizontal line with question marks located on the right-hand side. In another case history, the observed surcharge height was generally characterized as ranging from 2.5 to 3.5 ft. A comparison of the small number of data points in **Fig. G8-2** to the large number in **Fig. G7-4** suggests less confidence in the windward relation.

The final significant difference between leeward and windward drifts involves trapping efficiency and growth with time. **Fig. G8-3** shows a leeward drift at three points in time. At time t_1, the triangular drift height is less than the space available and the rise-to-run is approximately 1:4. At time t_2, the drift has just filled the space available at the wall, and at time t_3, the drift has filled in at the toe

Fig. G8-1. **Predicted surcharge height for triangular and quadrilateral drifts**

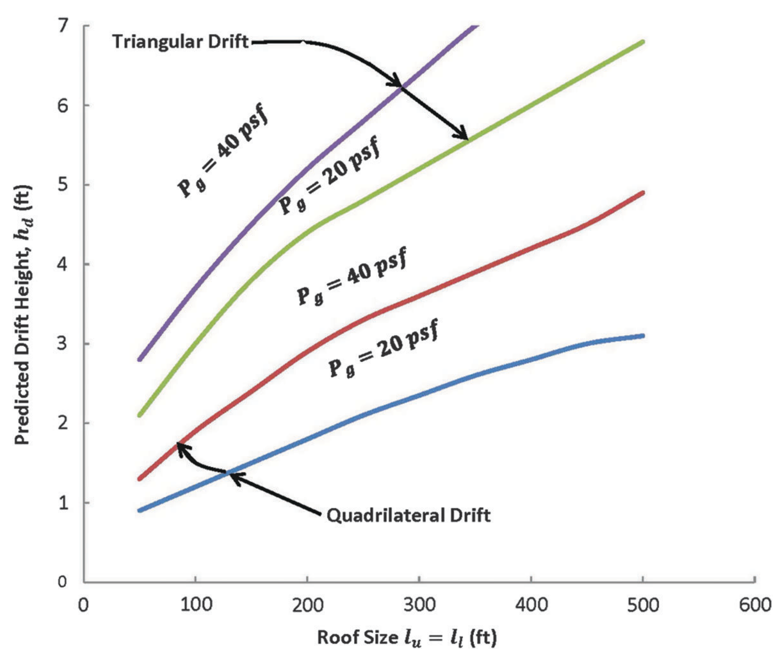


Fig. G8-2. **Comparison of observed windward surcharge drift height with values predicted by ASCE 7-10**

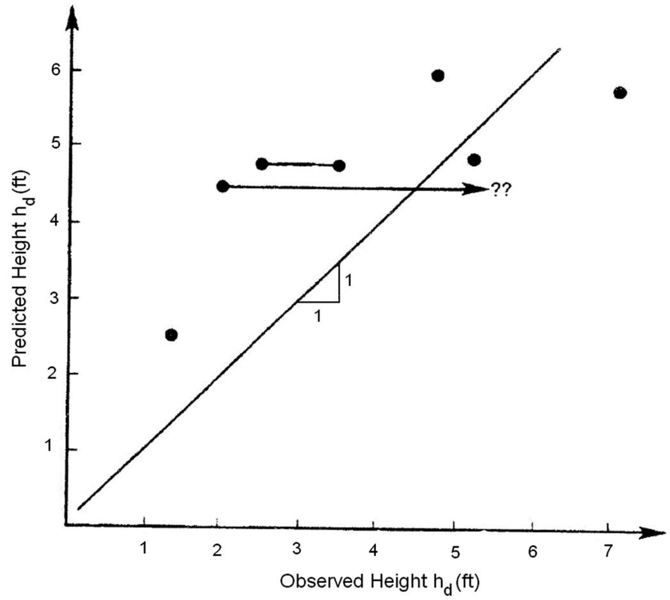
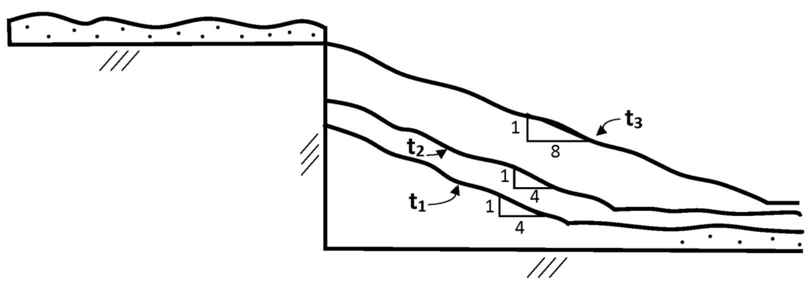


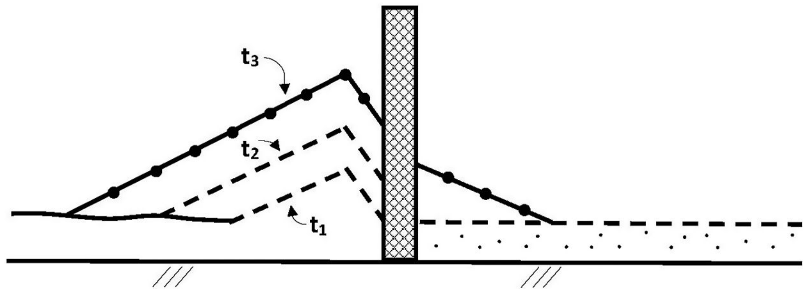
Fig. G8-3. **Leeward drift growth with time**



and has a rise-to-run of 1:8. Until the drift slope is 1:8, the trapping efficiency is presumably about 50%. After the streamlined shape is obtained (rise-to-run ~1:8), the trapping efficiency nominally drops to zero. Recent field measurements from Norway (Potac 2014) suggest a windward growth pattern as sketched in **Fig. G8-4**. At times t_1 and t_2, there is a quadrilateral shape upwind of the solid wall, but no accumulation downwind of the wall. At time t_3, there is either a quadrilateral or triangular drift upwind of the wall, plus a drift-like accumulation downwind of the wall. The lack of accumulation behind the wall at times t_1 and t_2 suggests that the windward trapping efficiency is then 100%. Sometime between t_2 and t_3, the upwind snow drift serves as a snow ramp that enables saltating snow particles to jump over the wall. When snow particles begin to jump over the wall, the windward trapping efficiency drops below 100% and the leeward trapping efficiency increases to something above 0%.

As with drifts on lower roofs as discussed in Chapter 7 of this guide, the sloped roof snow load in Eq. 7.4-1 is the balanced load below the roof projection drift load. The sloped roof snow load, p_s, is $0.7C_eC_tI_sC_sp_g$, where p_g is the 50-year

Fig. G8-4. **Growth with time of windward and leeward drifts at a solid wall**



mean recurrence interval ground snow load. Minimum roof snow loading and rain-on-snow surcharge loads do not influence this balanced load. In addition, if the crosswind length of the roof projection is small (i.e., the plan dimension perpendicular to the direction of wind under consideration is less than 15 ft), the drift load does not need to be considered for that wind direction. Drifts will form at such roof projections, but the crosswind plan dimension of the drift and the total drift load (in lb) is relatively small and can be neglected without affecting the overall integrity of the structural system.

For the common situation where a new or heavier RTU is being placed atop an existing roof, it is often desirable to raise the RTU well above the roof surface to prevent drift formation. Section 7.8 provides guidance. Specifically, the roof projection drift may be neglected if the clear distance between the top surface of the balanced snow below and the bottom of the projection (including horizontal supports) above is at least 2 ft. The author is not aware of any roof structural-performance problems related to either the 15 ft width or 2 ft bottom gap provisions.

Example 8-1. Parapet Wall Drift

Problem

Determine the design snow drift loads for the roof structure shown in **Fig. G8-5**. The site is in a suburban area (Surface Roughness 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 the 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 Surface Roughness Category B, and the roof is partially exposed (due to the presence of the conifers and the parapet wall); therefore, $C_e = 1.0$ from Table 7.3-1. From Tables 7.3-2 and 1.5-2, $C_t = I_s = 1.0$. For a roof slope of 1/4 on 12, $C_s = 1.0$ irrespective of the roof's