Snow load calculations using IBC 2003

Homework problem Fall 2000

Determine ground snow load

From snow load map

\[ ngsl := 0.025 \frac{\text{lb}}{\text{ft}^3} \]

From internet

\[ \text{elev} := 2500 \text{ft} \]

\[ p_g := ngsl \cdot \text{elev} \quad p_g = 62.5 \text{ psf} \]

Importance factor (Table 1604.5)

\[ I_s := 1.0 \]

Exposure Factor (Table 1608.3.1)

Based on site description, use Exposure B, and assume the roof is partially exposed.

\[ C_e := 1.0 \]

Thermal factor (Table 1608.3.2)

Since roof is flat and there is no attic space, assume the roof is unventilated. Residential space can be assumed to be heated. The R-value does not exceed 25.

\[ C_t := 1.0 \]

Flat roof snow load

\[ p_f := 0.7 \cdot C_e \cdot C_t \cdot I_s \cdot p_g \]

\[ p_f = 43.75 \text{ psf} \]

Rain-on-snow surcharge is ignored

Partial loading

Partial loading is not needed for simply supported steel spans.

Drift load

Drift load caused by parapet walls

Calculate density of drift. Ignore rain-on-snow while calculating drift loads.

\[ \gamma := \frac{0.13}{\text{ft}} \cdot p_g + 14 \cdot \frac{\text{lb}}{\text{ft}^3} \]

\[ \gamma = 22.125 \cdot \frac{\text{lb}}{\text{ft}^3} \]

If \( \gamma \) exceeds 30pcf, use 30pcf

\[ \gamma := \begin{cases} \gamma > 30 \cdot \frac{\text{lb}}{\text{ft}^3}, & \gamma = 30 \cdot \frac{\text{lb}}{\text{ft}^3} \end{cases} \]

\[ \gamma = 22.125 \cdot \frac{\text{lb}}{\text{ft}^3} \]
Calculate depth of base snow
\[ h_b := \frac{p_f}{\gamma} \quad h_b = 1.977 \text{ ft} \]

Input height of obstruction (in this case, the parapet wall)
\[ h := 6 \cdot \text{ft} \]

Calculate height of cornice
\[ h_c := h - h_b \quad h_c = 4.023 \text{ ft} \]

If base snow "buries" the cornice, ignore drift loads.
\[
\frac{h_c}{h_b} = 2.034 \quad \text{If } \frac{h_c}{h_b} < 0.2, \text{ ignore drift loads}
\]

**Calculate height of drifted snow on windward roofs.**

*Long direction of building (East-West)*

Windward direction
\[ l_u,\text{wind} := 80 \cdot \text{ft} \]

If \( l_u,\text{wind} < 25 \cdot \text{ft}, 25.\text{ft}, l_u,\text{wind} \)
\[ l_u,\text{wind} = 80 \text{ ft} \]

\[ h_d,\text{wind} := \frac{3}{4} \left[ \frac{0.43}{3\sqrt{h_b}} \left( \frac{1}{4\sqrt{p_g + 10 \cdot \text{psf}}} \right) \right] \cdot 1.5 \cdot -\left[ \frac{3}{4\sqrt{h_b}} \right] \]
\[ h_d,\text{wind} = 2.93 \text{ ft} \]

Leeward direction
Since there is no structure upwind of the parapet for a leeward drift, \( l_u \) is zero and there is no leeward drift.
\[ h_d,\text{EW} := h_d,\text{wind} \quad h_d,\text{EW} = 2.93 \text{ ft} \]

Since wind can come from either direction, this drift load can be applied to either the East or West wall.

*Short direction of building (North-South)*

Windward direction
\[ l_u,\text{wind} := 72 \cdot \text{ft} \]

If \( l_u,\text{wind} < 25 \cdot \text{ft}, 25.\text{ft}, l_u,\text{wind} \)
\[ l_u,\text{wind} = 72 \text{ ft} \]

\[ h_d,\text{wind} := \frac{3}{4} \left[ \frac{0.43}{3\sqrt{h_b}} \left( \frac{1}{4\sqrt{p_g + 10 \cdot \text{psf}}} \right) \right] \cdot 1.5 \cdot -\left[ \frac{3}{4\sqrt{h_b}} \right] \]
\[ h_d,\text{wind} = 2.79 \text{ ft} \]
Leeward direction
Since there is no structure upwind of the parapet for a leeward drift, \( l_u \) is zero and there is no leeward drift.
\[ h_{d,NS} := h_{d,wind} \quad h_{d,NS} = 2.79 \text{ ft} \]

Since wind can come from either direction, the windward drift load can be applied to either the North or South wall.

**Calculate drift load surcharge**

\begin{align*}
\text{Long direction of building} & \quad \text{Short direction of building} \\
\text{Long direction of building} & \quad \text{Short direction of building} \\
\text{Long direction of building} & \quad \text{Short direction of building} \\
\end{align*}

\[ p_{d,EW} := h_{d,EW} \cdot \gamma \quad p_{d,NS} := h_{d,NS} \cdot \gamma \]
\[ p_{d,EW} = 64.824 \cdot \text{psf} \quad p_{d,NS} = 61.727 \cdot \text{psf} \]

But drift load is ignored if base snow "buries" the cornice
\[ \begin{cases} 
& p_{d,EW} := \begin{cases} h_c \\
h_b 
\end{cases} \left( \begin{array}{c} < 0.2, 0 \cdot \text{psf} \end{array} \right) 
& p_{d,NS} := \begin{cases} h_c \\
h_b 
\end{cases} \left( \begin{array}{c} < 0.2, 0 \cdot \text{psf} \end{array} \right) 
\end{cases} \]
\[ p_{d,EW} = 64.824 \cdot \text{psf} \quad p_{d,NS} = 61.727 \cdot \text{psf} \]

Calculate width of drift

\begin{align*}
\text{Long direction of building} & \quad \text{Short direction of building} \\
\text{If } h_d \text{ doesn't bury cornice} & \quad \text{If } h_d \text{ doesn't bury cornice} \\
\text{If } h_d \text{ buries cornice} & \quad \text{If } h_d \text{ buries cornice} \\
\end{align*}

\[ w_{1,EW} := 4 \cdot h_{d,EW} \quad w_{1,NS} := 4 \cdot h_{d,NS} \]
\[ w_{1,EW} = 11.72 \text{ ft} \quad w_{1,NS} = 11.16 \text{ ft} \]

\[ w_{2,EW} := 4 \cdot \frac{h_{d,EW}^2}{h_c} \quad w_{2,NS} := 4 \cdot \frac{h_{d,NS}^2}{h_c} \]
\[ w_{2,EW} = 8.536 \text{ ft} \quad w_{2,NS} = 7.74 \text{ ft} \]

Determine which case applies
\[ w_{EW} := \begin{cases} h_{d,EW} > h_c, w_{2,EW}, w_{1,EW} \end{cases} \quad w_{NS} := \begin{cases} h_{d,NS} > h_c, w_{2,NS}, w_{1,NS} \end{cases} \]
\[ w_{EW} = 11.72 \text{ ft} \quad w_{NS} = 11.16 \text{ ft} \]

If width of drift exceeds the width of the lower roof, truncate the drift at the far edge. (In this case, it doesn't).

**Design loads**

Joists spanning between B & C, with no drift load. I.e., joists except those adjacent to the parapet wall

Tributary width for joists
\[ t_j := 4 \cdot \text{ft} \]
Base snow load

\[ w_{jf} := t_j \cdot p_f \quad w_{jf} = 175 \cdot \frac{\text{lbf}}{\text{ft}} \]

**Joists spanning between A & B and between C & D**

Maximum drift snow load

\[ w_{jd} := t_j \cdot p_{d,NS} \quad w_{jd} = 246.91 \cdot \frac{\text{lbf}}{\text{ft}} \]

Total snow load at parapet end of joist

\[ w_{jt} := w_{jd} + w_{jf} \quad w_{jt} = 421.91 \cdot \frac{\text{lbf}}{\text{ft}} \]

Tapering down to \( w_{jf} = 175 \cdot \frac{\text{lbf}}{\text{ft}} \) at a distance \( w_{NS} = 11.16 \text{ ft} \) from the parapet

This snow load also applies to NS girders on grid lines 2 through 4

**Joists adjacent to east and west parapet walls**

Tributary width is the same

The base snow load is the same as the previous case

\[ w_{jf} = 175 \cdot \frac{\text{lbf}}{\text{ft}} \]

Assume a trapezoidal load due to drift. Use similar triangles to determine drift load at the center of the tributary width.

\[ \frac{p_{dj}}{p_{d,EW}} = \frac{w_{EW} - t_j}{w_{EW}} \]

Solving for \( p_{dj} \):

\[ p_{dj} := \frac{w_{EW} - t_j}{w_{EW}} \cdot p_{d,EW} \quad p_{dj} = 42.699 \cdot \frac{\text{lbf}}{\text{ft}^2} \]

Drift snow load on first interior joist

\[ w_{jd} := t_j \left( p_{dj} \right) \quad w_{jd} = 170.794 \cdot \frac{\text{lbf}}{\text{ft}} \]

Total snow load on first interior joist

\[ w_t := w_{jf} + w_{jd} \quad w_t = 345.794 \cdot \frac{\text{lbf}}{\text{ft}} \]

Because the load is trapezoidal, it is eccentric to the centerline of the joist and causes a small amount of torsion. This will be discussed in your design courses.
**North - South girders supporting the parapet walls along girder lines 1 and 5**

Tributary width

\[ t_{g15} := \frac{t_j}{2} \quad t_{g15} = 2 \text{ ft} \]

Max drift load at parapet wall

\[ p_{d,EW} = 64.824 \frac{\text{lbf}}{\text{ft}^2} \]

Drift load at inside edge of tributary width

\[ p_{dj2} := \frac{p_{d} + p_{d,EW}}{2} \]

Drift load

\[ w_{dg15} := \frac{1}{2}(p_{d,EW} + p_{dj2}) \cdot t_{g15} \quad w_{dg15} = 118.585 \frac{\text{lbf}}{\text{ft}} \]

Base snow load

\[ w_{f\text{g}15} := p_f \cdot t_{g15} \quad w_{f\text{g}15} = 87.5 \frac{\text{lbf}}{\text{ft}} \]

**Total snow load on N-S girders along girder lines 1 & 5**

\[ w_{tg15} := w_{dg15} + w_{f\text{g}15} \quad w_{tg15} = 206.085 \frac{\text{lbf}}{\text{ft}} \]

The East-West girders carry the joists.

Reaction of joist on perimeter E-W girder - grid lines A & D.

\[ \Sigma M_B = 0 \]

Length of North-South girders and joists

\[ L_{NS} := 24 \text{ ft} \]

\[ w_{jf} \cdot L_{NS} \frac{L_{NS}}{2} + \frac{1}{2} w_{NS} \cdot w_{jd} \left( L_{NS} \frac{1}{3} w_{NS} \right) - R_A \cdot L_{NS} = 0 \]

Solve for reaction on girder line A

\[ R_A := \frac{1}{6} \frac{3 \cdot w_{jf} \cdot L_{NS}^2 + 3 \cdot w_{NS} \cdot w_{jd} \cdot L_{NS} - w_{NS}^2 \cdot w_{jd}}{L_{NS}} \]

\[ R_A = 2.905 \text{ kip} \]
Girders on line A & D between grid lines 2 & 4 carry four of these girders as points loads equally spaced at 4-ft intervals

Reaction of joists between lines A & B on girder lines B

\[ \Sigma F_y = 0 \]
\[ R_A + R_B - w_{jf} \cdot L_{NS} - \frac{1}{2} w_{NS} \cdot w_{jd} = 0 \]

Solve for reaction on girder line B

\[ R_B := -R_A + w_{jf} \cdot L_{NS} + \frac{1}{2} w_{NS} \cdot w_{jd} \quad R_B = 2.248 \text{kip} \]

Reaction of joists between lines C & B on girder line B

\[ R_{B2} := \frac{w_{jf} \cdot L_{NS}}{2} \quad R_{B2} = 2.1 \text{kip} \]

Girders on line B between grid lines 2 & 4 are interior girders and carry joists between line A & B and between lines B & C. Therefore they carry four point loads of magnitude

\[ R_{Bsum} := R_B + R_{B2} \quad R_{Bsum} = 4.348 \text{kip} \]

The reactions are equally spaced at 4-ft intervals

The E-W girders between grid lines 1 & 2 and between 4 & 5 have slightly higher joist loads since the drift load is continuous on the joist just inside parapet wall.

Reactions due to joists just inside the parapet wall.

\[ R_{j,par} := \frac{w_t \cdot L_{NS}}{2} \quad R_{j,par} = 4.15 \text{kip} \]

For girder lines A & D, the joist nearest the parapet wall will impose this reaction as a point load on the girder.

Girders on lines B & C are interior girders and support two of these joist which causes a point load on the girder of

\[ 2 \cdot R_{j,par} = 8.299 \text{kip} \quad \text{on the joists just inside the parapet wall.} \]