Snow load calculations using IBC 2003

Homework problem Fall 2000

$psf := \frac{lbf}{ft^2}$ $kip := 1000 \cdot lbf$

Determine ground snow load

From snow load map

$$ngsl := 0.025 \cdot \frac{lbf}{ft^3}$$

from internet

$$elev := 2500 \cdot ft$$

$$p_g := ngsl \cdot elev \qquad p_g = 62.5 \cdot psf$$

Importance factor (Table 1604.5)

$$I_s := 1.0$$

Exposure Factor (Table1608.3.1)

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

$$p_f := 0.7 \cdot C_e \cdot C_t \cdot I_s \cdot p_g \qquad p_f = 43.75 \cdot psf$$

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.

$$\gamma := \frac{0.13}{ft} \cdot p_g + 14 \cdot \frac{lbf}{ft^3} \qquad \gamma = 22.125 \cdot \frac{lbf}{ft^3}$$

If γ exceeds 30 pcf, use 30 pcf

$$\gamma := if\left(\gamma > 30 \cdot \frac{lbf}{ft^3}, 30 \cdot \frac{lbf}{ft^3}, \gamma\right) \qquad \gamma = 22.125 \cdot \frac{lbf}{ft^3}$$

Calculate depth of base snow

$$h_b := \frac{p_f}{\gamma} \qquad h_b = 1.977\,ft$$

Input height of obstruction (in this case, the parapet wall)

$$h := 6 \cdot ft$$

Calculate height of cornice

$$h_c := h - h_b \qquad h_c = 4.023\,ft$$

If base snow "buries" the cornice, ignore drift loads.

$$\frac{h_c}{h_b} = 2.034$$

If $h_c/h_b < 0.2$, ignore drift loads

Calculate height of drifted snow on windward roofs.

Long direction of building (East-West)

Windward direction

$$l_{u.wind} := 80 \cdot ft$$

l_u must be greater than 25 ft.

$$l_{u.wind} := \text{if}\left(l_{u.wind} < 25 \cdot ft, 25.ft, l_{u.wind}\right) \qquad l_{u.wind} = 80\,ft$$

$$h_{d.wind} := \frac{3}{4} \cdot \left[\left[\frac{0.43}{\sqrt[3]{ft}} \cdot \sqrt[3]{l_{u.wind}} \cdot \left(\frac{1}{\sqrt[4]{psf}} \cdot \sqrt[4]{p_g + 10 \cdot psf}\right)\right] \cdot ft - 1.5 \cdot ft\right]$$

$$h_{d.wind} = 2.93\,ft$$

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.

$$h_{d.EW} := h_{d.wind} \qquad h_{d.EW} = 2.93\,ft$$

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

$$l_{u.wind} := 72 \cdot ft$$

l_u must be greater than 25 ft.

$$l_{u.wind} := \text{if}\left(l_{u.wind} < 25 \cdot ft, 25.ft, l_{u.wind}\right) \qquad l_{u.wind} = 72\,ft$$

$$h_{d.wind} := \frac{3}{4} \cdot \left[\left[\frac{0.43}{\sqrt[3]{ft}} \cdot \sqrt[3]{l_{u.wind}} \cdot \left(\frac{1}{\sqrt[4]{psf}} \cdot \sqrt[4]{p_g + 10 \cdot psf}\right)\right] \cdot ft - 1.5 \cdot ft\right]$$

$$h_{d.wind} = 2.79\,ft$$

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.

$h_{d.NS} := h_{d.wind}$ $\qquad$ $h_{d.NS} = 2.79\,ft$

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

Long direction of building

$p_{d.EW} := h_{d.EW} \cdot \gamma$

$p_{d.EW} = 64.824 \cdot psf$

Short direction of building

$p_{d.NS} := h_{d.NS} \cdot \gamma$

$p_{d.NS} = 61.727 \cdot psf$

But drift load is ignored if base snow "buries" the cornice

$p_{d.EW} := if\left(\frac{h_c}{h_b} < 0.2, 0 \cdot psf, p_{d.EW}\right)$

$p_{d.EW} = 64.824 \cdot psf$

$p_{d.NS} := if\left(\frac{h_c}{h_b} < 0.2, 0 \cdot psf, p_{d.NS}\right)$

$p_{d.NS} = 61.727 \cdot psf$

Calculate width of drift

Long direction of building

Short direction of building

If h_d doesn't bury cornice

$w_{1.EW} := 4 \cdot h_{d.EW}$

$w_{1.EW} = 11.72\,ft$

$w_{1.NS} := 4 \cdot h_{d.NS}$

$w_{1.NS} = 11.16\,ft$

If h_d buries cornice

$w_{2.EW} := 4 \cdot \frac{h_{d.EW}^2}{h_c}$

$w_{2.EW} = 8.536\,ft$

$w_{2.NS} := 4 \cdot \frac{h_{d.NS}^2}{h_c}$

$w_{2.NS} = 7.74\,ft$

Determine which case applies

$w_{EW} := if\left(h_{d.EW} > h_c, w_{2.EW}, w_{1.EW}\right)$

$w_{EW} = 11.72\,ft$

$w_{NS} := if\left(h_{d.NS} > h_c, w_{2.NS}, w_{1.NS}\right)$

$w_{NS} = 11.16\,ft$

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

$t_j := 4 \cdot ft$

Base snow load

$w_{jf} := t_j \cdot p_f$ $\qquad$ $w_{jf} = 175 \cdot \frac{lbf}{ft}$

Joists spanning between A & B and between C & D

Maximum drift snow load

$w_{jd} := t_j \cdot p_{d.NS}$ $\qquad$ $w_{jd} = 246.91 \cdot \frac{lbf}{ft}$

Total snow load at parapet end of joist

$w_{jt} := w_{jd} + w_{jf}$ $\qquad$ $w_{jt} = 421.91 \cdot \frac{lbf}{ft}$

Tapering down to $w_{jf} = 175 \cdot \frac{lbf}{ft}$ at a distance $w_{NS} = 11.16\,ft$ 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

$w_{jf} = 175 \cdot \frac{lbf}{ft}$

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}.

$p_{dj} := \frac{w_{EW} - t_j}{w_{EW}} \cdot p_{d.EW}$ $\qquad$ $p_{dj} = 42.699 \cdot \frac{lbf}{ft^2}$

Drift snow load on first interior joist

$w_{jd} := t_j \cdot (p_{dj})$ $\qquad$ $w_{jd} = 170.794 \cdot \frac{lbf}{ft}$

Total snow load on first interior joist

$w_t := w_{jf} + w_{jd}$ $\qquad$ $w_t = 345.794 \cdot \frac{lbf}{ft}$

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

$t_{g15} := \frac{t_j}{2}$ $\qquad t_{g15} = 2\,ft$

Max drift load at parapet wall

$p_{d.EW} = 64.824 \cdot \frac{lbf}{ft^2}$

Drift load at inside edge of tributary width

$p_{dj2} := \frac{p_{dj} + p_{d.EW}}{2}$

Drift load

$w_{dg15} := \frac{1}{2} \cdot \left(p_{d.EW} + p_{dj2}\right) \cdot t_{g15}$ $\qquad w_{dg15} = 118.585 \cdot \frac{lbf}{ft}$

Base snow load

$w_{fg15} := p_f \cdot t_{g15}$ $\qquad w_{fg15} = 87.5 \cdot \frac{lbf}{ft}$

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

$w_{tg15} := w_{dg15} + w_{fg15}$ $\qquad w_{tg15} = 206.085 \cdot \frac{lbf}{ft}$

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

$L_{NS} := 24 \cdot ft$

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

Solve for reaction on girder line A

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

$R_A = 2.905 \cdot kip$

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

$\Sigma F_y = 0$

$$R_A + R_B - w_{jf} \cdot L_{NS} - \frac{1}{2} \cdot w_{NS} \cdot w_{jd} = 0$$

Solve for reaction on grider line B

$$R_B := -R_A + w_{jf} \cdot L_{NS} + \frac{1}{2} \cdot w_{NS} \cdot w_{jd} \qquad R_B = 2.248 \cdot kip$$

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

$$R_{B2} := \frac{w_{jf} \cdot L_{NS}}{2} \qquad R_{B2} = 2.1 \cdot kip$$

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

$$R_{Bsum} := R_B + R_{B2} \qquad R_{Bsum} = 4.348 \cdot kip$$

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.

$$R_{j.par} := \frac{w_t \cdot L_{NS}}{2} \qquad R_{j.par} = 4.15 \cdot kip$$

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

$2 \cdot R_{j.par} = 8.299 \cdot kip$ on the joists just inside the parapet wall.