Wind Design Considerations For Steel Joists and Joist Girders

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Webinar Description

This webinar will provide a comprehensive review of wind forces on steel joist and joist girder roof systems, including wind load determination, wind load combinations, and wind load application. Specification, analysis, and design to resist uplift loads will be a primary focus, but also load paths and connections for wind moment frames, collectors, and braces.

Learning Objectives

- Review of appropriate load combinations involving wind.
- How to clearly specify wind load requirements to joist manufacturer.
- Using ideal load paths for wind forces.
- Best practices for miscellaneous items such as braces, screen walls, and roofing effects on joists.

Outline

- Wind forces on the roof
  - From the building code
  - Load combinations
  - Uplift
  - Downward wind
- Wind effects on joist system
  - End anchorage
  - Bridging

Outline

- Lateral wind loads
  - Diaphragms and collectors
  - Load paths and transfer details
  - Bracing for wind forces
- Membrane roofs
- Consideration in Joist Selection

Mechanics of Wind Forces

- Bernoulli Equation

$$P_{total} = \frac{1}{2}\rho V^2 + P_{static}$$

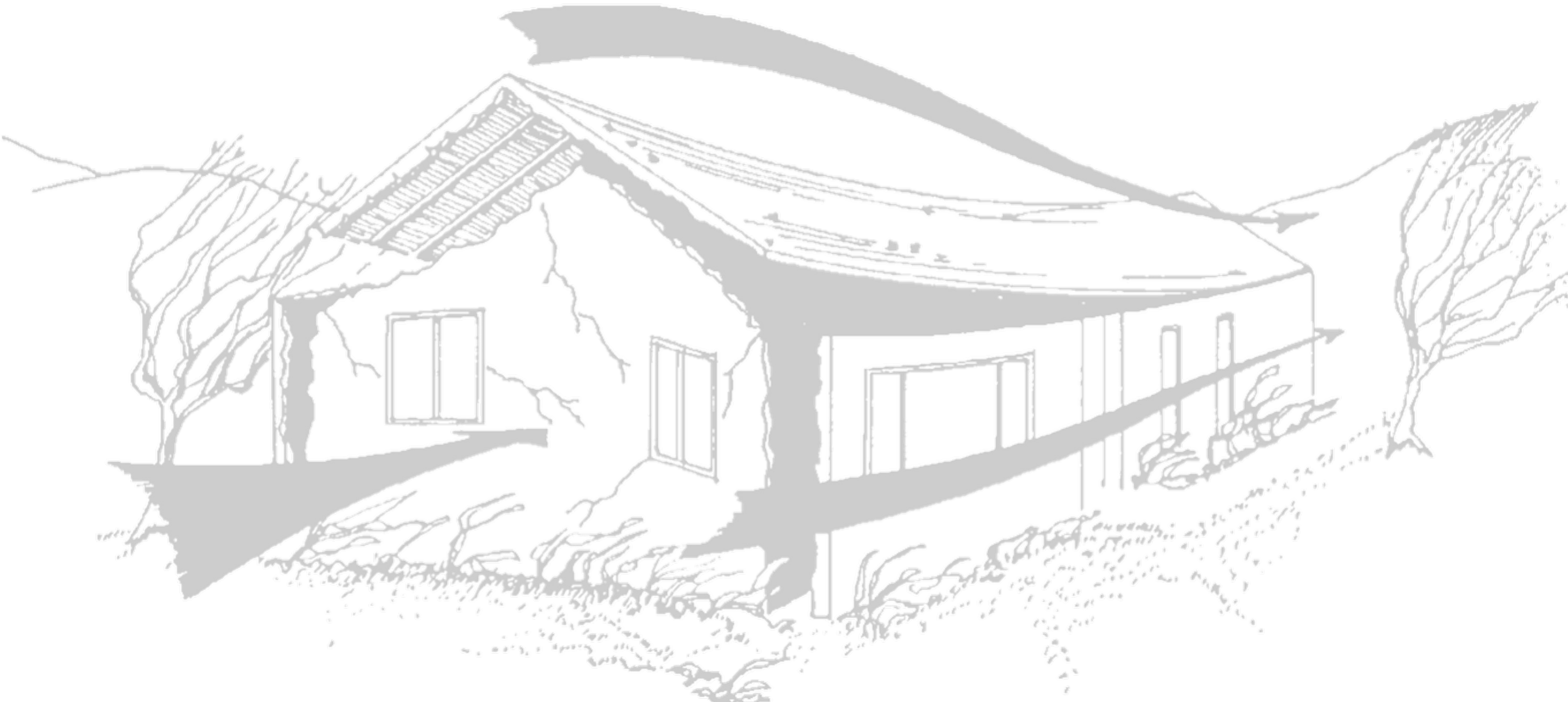
$$\Delta P = \frac{1}{2}\left[\frac{0.0765(\frac{lb}{ft^3})}{32.2\ (\frac{ft}{sec^2})}\right]\left[\frac{5280(\frac{ft}{mi})}{3600(\frac{sec}{hr})}\right]^2\left[V(\frac{mi}{hr})\right]^2$$

$$= 0.00256\, V^2\left(\frac{lbf}{ft^2}\right) = \Delta P(psf)$$

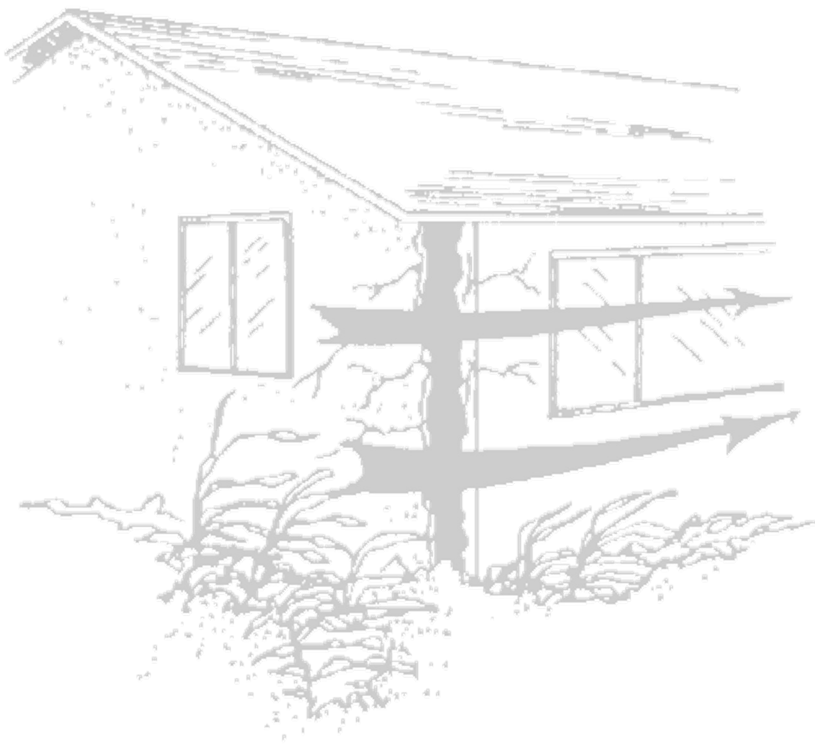
$$q_z = 0.00256\ K_z K_{zt} K_d V^2\ (\text{lb/ft}^2)$$

Nature of Wind Forces

Nature of Wind Forces



Nature of Wind Forces



Nature of Wind Forces

Wind Uplift on Joists and Deck

- Even if the system is robust, it has to stay on the building!

Standards and Codes

- Code of Standard Practice for Steel Joists and Joist Girders (effective Jan. 2020)
- Provisions from ASCE 7-16

History: 1965 Standard Building Code

SECTION 1205 — WIND LOADS

1205.1 — MINIMUM DESIGN LOADS

Buildings or other structures shall be capable of withstanding the horizontal loads shown in the following table and, applied in each zone, allowing for wind from any direction. The first height zone shall be measured above the average level of the ground adjacent to the building and the subsequent height zones shall be added progressively upward to the overall height of the building.

DESIGN WIND PRESSURE FOR VARIOUS HEIGHT ZONES OF BUILDINGS OR OTHER STRUCTURES

Height Zone Ft.	Lb./Sq. Ft. Horizontal Loads	
	For Southern Inland Regions	For Southern Coastal Region*
Less than 30	10	25
31 to 50	20	35
51 to 99	24	45
100 to 199	28	50
200 to 299	30	50
300 to 399	32	50
Over 400	40	50

*Coastal regions is that area lying within 125 miles of the coast and subject to hurricanes, tropical disturbances and occasional winds attaining exceptionally high wind velocities.
(See Appendix "D" for Hurricane Requirements.)

1205.2 — EXTERIOR WALLS

Every exterior wall shall be capable of withstanding the loads specified in the above table, acting either inward or outward.

1205.3 — ROOFS — WIND LOADS

(a) The roofs of all buildings or other structures shall be designed to withstand loads acting outward normal to the surface equal

12 - 5

to one and one-quarter (1¼) times the horizontal loads specified for the corresponding height zone in which the roof is located. The height is to be taken as the mean height of the roof structure above the average level of the ground adjacent to the building or other structure. The load is to be applied over the entire roof.

(b) Roofs with slopes greater than thirty degrees (30°) shall withstand resulting loads acting inward normal to the surface equal to those specified for the height zone in which the roof is located, the load to be applied to the windward slope only.

(c) Overhanging eaves and cornices shall be capable of withstanding upward loads equal to twice those specified.

(d) Adequate anchorage of the roof to the walls and columns and of walls and columns to the foundations shall be required in all cases.

1205.4 — CHIMNEYS

Chimneys of circular cross section shall be capable of withstanding sixty (60) per cent of the loads specified. Chimneys of square or rectangular cross section shall be capable of withstanding the full loads specified.

1205.5 — SIGNS

(a) Ordinary solid signs erected on ground level shall be capable of withstanding a load of fifteen (15) pounds per square foot. Solid signs on the roofs of buildings or other structures shall be capable of withstanding the loads specified in Section 1205.1 corresponding to the height of the center of the sign. Signs in which the open area is less than twenty-five (25) per cent of the gross area shall be considered to be solid signs and the gross area shall be used in computing the load.

(b) Open signs erected at ground level shall be capable of withstanding a pressure of thirty (30) pounds per square foot, applied to the projected area of the members. Open signs on the roofs of buildings or other structures shall be capable of withstanding twice the loads specified in Section 1205.1 corresponding to the height of the center of the sign, applied to the projected area of the members.

1205.6 — OTHER STRUCTURES

The Building Official may require evidence to support the values of the wind load used in the design of structures not specifically covered by this section.

1205.7 — SHIELDING AND UNUSUAL EXPOSURES

(a) No allowance shall be made for the shielding effect of other buildings or structures.

(b) If the building or other structure is on an ocean promontory, or in any other location considered by the Building Official to be unusually exposed, higher wind loads may be specified by the Building Official.

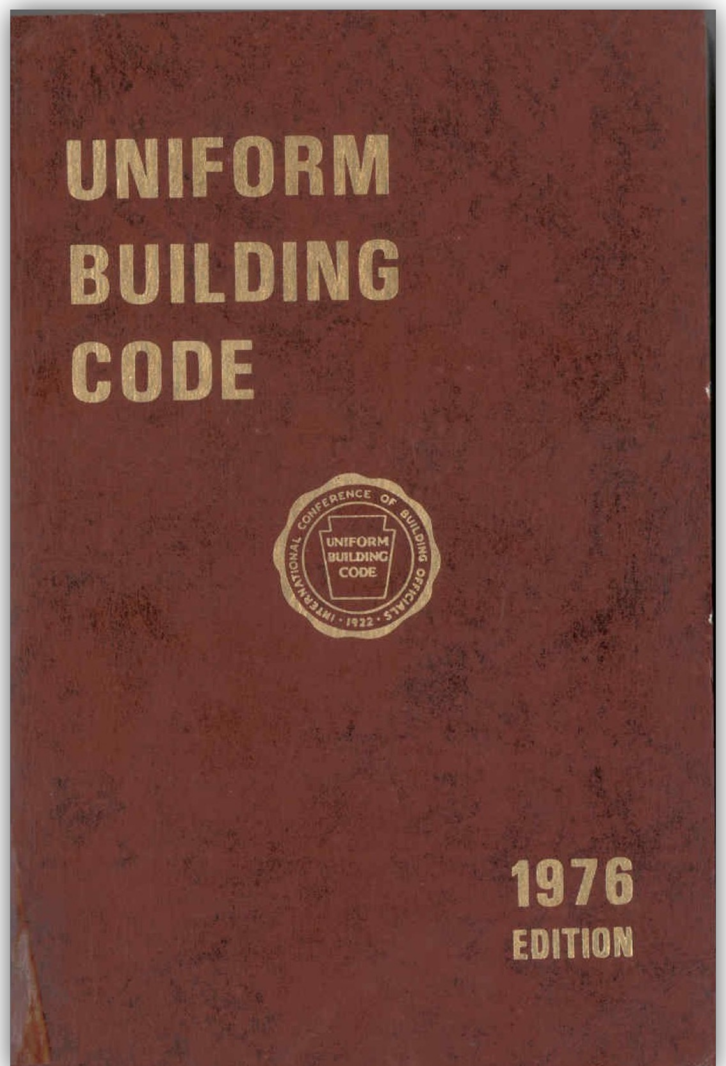
1205.8 — OVERTURNING MOMENT

The overturning moment due to the wind load shall not exceed sixty-six and two-thirds (66⅔) per cent of the moment of stability of the building or other structures due to the dead load only unless the building or other structure is anchored to its foundations so as to resist the excess overturning moment without exceeding the allowable working stresses for the materials used.

1205.9 — STRESSES DURING ERECTION

Provision shall be made for wind stresses during erection of a building or other structure.

History: 1976 Uniform Building Code



1976 EDITION 23-F, 23-G, 23-H

TABLE NO. 23-F—WIND PRESSURES FOR VARIOUS HEIGHT ZONES ABOVE GROUND[1]

HEIGHT ZONES (in feet)	WIND-PRESSURE-MAP AREAS (pounds per square foot)						
	20	25	30	35	40	45	50
Less than 30	15	20	25	25	30	35	40
30 to 49	20	25	30	35	40	45	50
50 to 99	25	30	40	45	50	55	60
100 to 499	30	40	45	55	60	70	75
500 to 1199	35	45	55	60	70	80	90
1200 and over	40	50	60	70	80	90	100

- Wind Loads
  - Over 140 pages in Provision catalog
  - 64 pages of Commentary catalog
- From two half-size pages to over 200 full-size pages
- Over 170 times the length of 40 years ago

ASCE 7-16 Wind Loads

- Many steel joist structures will qualify for the simplified methods for determining wind loads.
  - Part 2 of Chapter 28 for MWFRS
  - Part 2 of Chapter 30 for C&C

- Conditions required for use of the simplified method for C&C loads include:
  - Roof height of 60 feet or less
  - Enclosed structure
  - Regular-shaped building
  - Roof is not steeply sloped

ASCE 7-16 Wind Loads

Table 28.2-1 Steps to Determine Wind Loads on MWFRS Simple Diaphragm Low-Rise Buildings

Step 1: Determine risk category of building or other structure, see Table 1.5-1

Step 2: Determine the basic wind speed, *V*, for applicable risk category, see Fig. 26.5-1A, B or C

Step 3: Determine wind load parameters:

- Exposure category B, C or D, see Section 26.7
- Topographic factor, K_{zt}, see Section 26.8 and Fig. 26.8-1

Step 4: Enter figure to determine wind pressures for h = 30 ft (9.1 m)., p_{S30}, see Fig. 28.6-1

Step 5: Enter figure to determine adjustment for building height and exposure, λ, see Fig. 28.6-1

Step 6: Determine adjusted wind pressures, p_s, see Eq. 28.6-1

Table 30.3-1 Steps to Determine C&C Wind Loads Enclosed Low-rise Buildings (Simplified Method)

Step 1: Determine risk category, see Table 1.5-1

Step 2: Determine the basic wind speed, *V*, for applicable risk category see Figure 26.5-1A, B or C

Step 3: Determine wind load parameters:

- Exposure category B, C or D, see Section 26.7
- Topographic factor, K_{zt}, see Section 26.8 and Figure 26.8-1

Step 4: Enter figure to determine wind pressures at h = 30 ft., p_{net30}, see Fig. 30.5-1

Step 5: Enter figure to determine adjustment for building height and exposure, λ, see Fig. 30.5-1

Step 6: Determine adjusted wind pressures, p_{net}, see Eq. 30.5-1.

Determining Wind Loads for Joists

- Steel Joist Institute (SJI) Code of Standard Practice

SPECIFYING DESIGN LOADS

Neither the Steel Joist Institute nor the joist manufacturer establishes the loading requirements for which structures are designed.

The specifying professional shall provide the nominal loads and load combinations as stipulated by the applicable code under which the structure is designed and shall provide the design basis (ASD or LRFD).

The specifying professional shall calculate and provide the magnitude and location of ALL JOIST and JOIST GIRDER LOADS. This includes all special loads (drift loads, mechanical units, net uplift, axial loads, moments, structural bracing loads, or other applied loads) which are to be incorporated into the joist or Joist Girder design. For Joist Girders, reactions from supported members shall be clearly denoted as point loads on the Joist Girder. When necessary to clearly convey the information, a Load Diagram or Load Schedule shall be provided.

Determining Wind Loads for Joists

- ASCE provides formulas for design wind pressures and net design wind pressures. These are NOT the same as the NET uplift required by SJI.

$$p = q_h[(GC_{pf}) - (GC_{pi})] \ (\text{lb/ft}^2) \ (\text{N/m}^2) \quad (28.4\text{-}1)$$

$$p_{\text{net}} = \lambda K_{zt}\, p_{net30} \quad (30.5\text{-}1)$$

- ASCE net is the sum of internal and external pressures.
- SJI net, is the final resultant pressure, less appropriate dead load – result of the load combination

ASCE 7-16 Load Combinations

- 2.3 COMBINING FACTORED LOADS USING STRENGTH DESIGN
  - 2.3.2 Basic Combinations

1. $1.4D$
2. $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$
3. $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.5W)$
4. $1.2D + 1.0W + L + 0.5(L_r \text{ or } S \text{ or } R)$
5. $1.2D + 1.0E_v + E_h + L + 0.2S$
6. $0.9D + 1.0W$
7. $0.9D - \mathrm{E_v} + 1.0E_{mh}$

ASCE 7-10 Load Combinations

- 2.4 COMBINING NOMINAL LOADS ALLOWABLE STRESS DESIGN
  - 2.4.1 Basic Combinations

1. D
2. $D + L$
3. $D + (L_r \text{ or } S \text{ or } R)$
4. $D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
5. $D + (0.6W)$
6. $D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R)$
7. $0.6D + 0.6W$
8. $0.6D + 0.7E_v + 0.7E_h$
9. $D + 0.525E_v + 0.525E_h + 0.75L + 0.75S$
10. $0.6D - 0.7E_v + 0.7E_h$

Determining Wind Loads for Joists

- When wind uplift is a design consideration, it should be specified as net uplift on the steel joists and joist girders.
- The chart on the following slide is a typical components and cladding roof wind pressures provided on the contract documents.

Determining Wind Loads for Joists

ROOF SURFACES						
EFFECTIVE WIND AREA	POSITIVE PRESSURES (PSF)			NEGATIVE PRESSURES (PSF)		
	ZONE					
	1	2	3	1	2	3
10 SF	12.4	12.4	12.4	-30.4	-51.0	-76.8
20 SF	11.6	11.6	11.6	-29.6	-45.6	-63.6
50 SF	10.6	10.6	10.6	-28.6	-38.4	-46.2
100 SF	9.8	9.8	9.8	-27.8	-33.0	-33.0

Determining Wind Loads for Joists

- Roof pressure needs to be converted to net uplift, or more correctly, the result of the appropriate load combination for wind forces acting upward.
- The specifying professional knows the design dead load and if there are collateral dead loads that should not be deducted from the gross uplift.
  - Maximum Dead Load (for gravity loading)
  - Minimum Dead Load (for wind uplift)
    - $DL_{min} = DL_{max}$ - Collateral Load

Determining Wind Loads for Joists

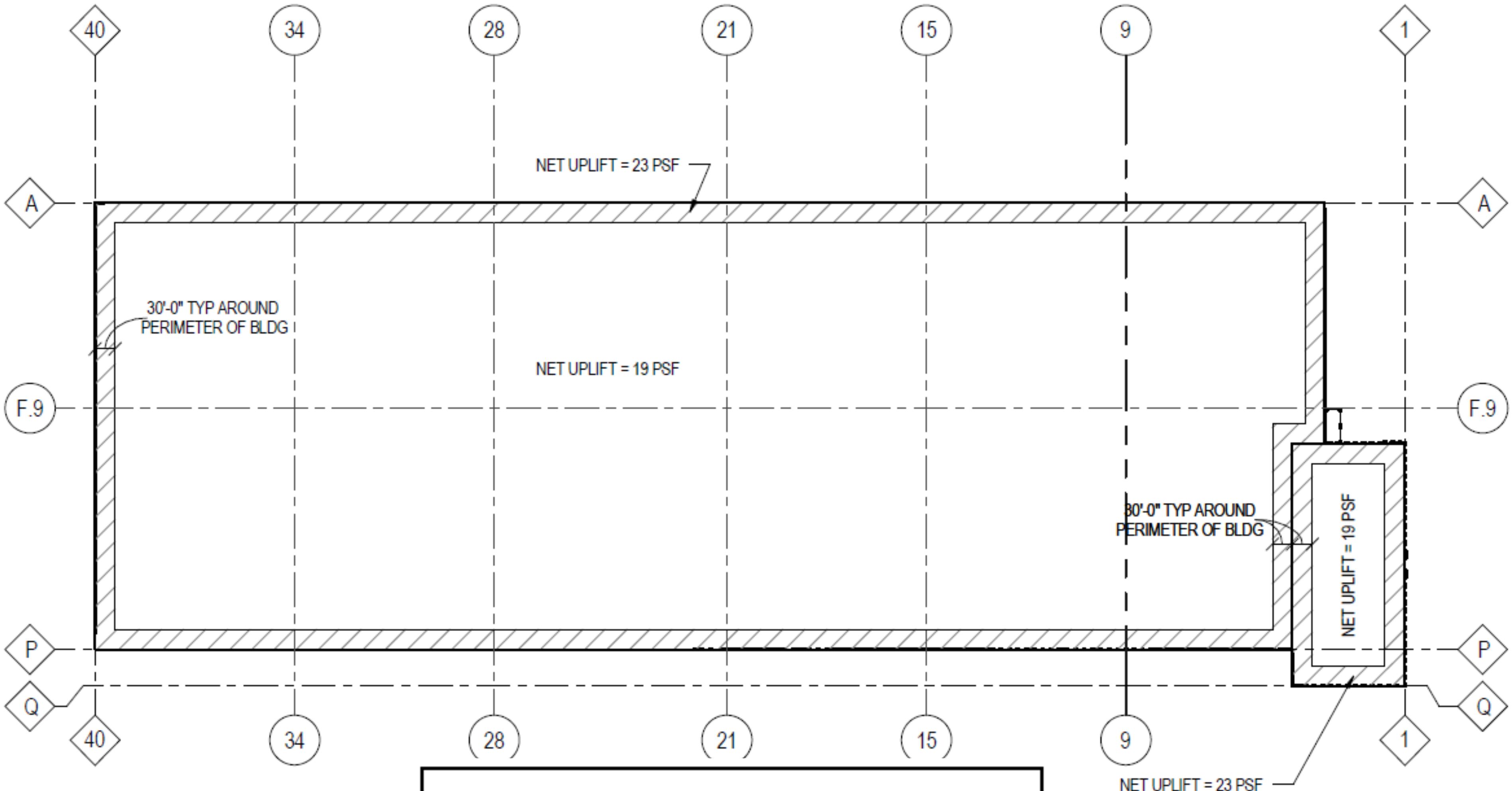
- Joists are considered components and cladding (C&C).
- Per ASCE definition of Effective Width, the width need not be less than one third the span.
- So for steel joists, a simple rule is that for all joist spans of 18 foot or greater, use the 100 square foot values, i.e. 18 x 6 = 106 > 100 $ft.^2$

Determining Wind Loads for Joists

- Joist girders can be considered part of the main wind force-resisting system (MWFRS).
  - Typically, separate MWFRS pressure values are not provided for the joist girders, and the joist designer applies the C&C net uplift forces from the joists to the joist girders.
- Joist girder tension webs must be designed to resist, in compression, 25 percent of their axial force.
- Uplift loads on a Joist Girder of less than 25 percent of the gravity loads have minimal or no effect on the girder design.

Presentation of Uplift Design

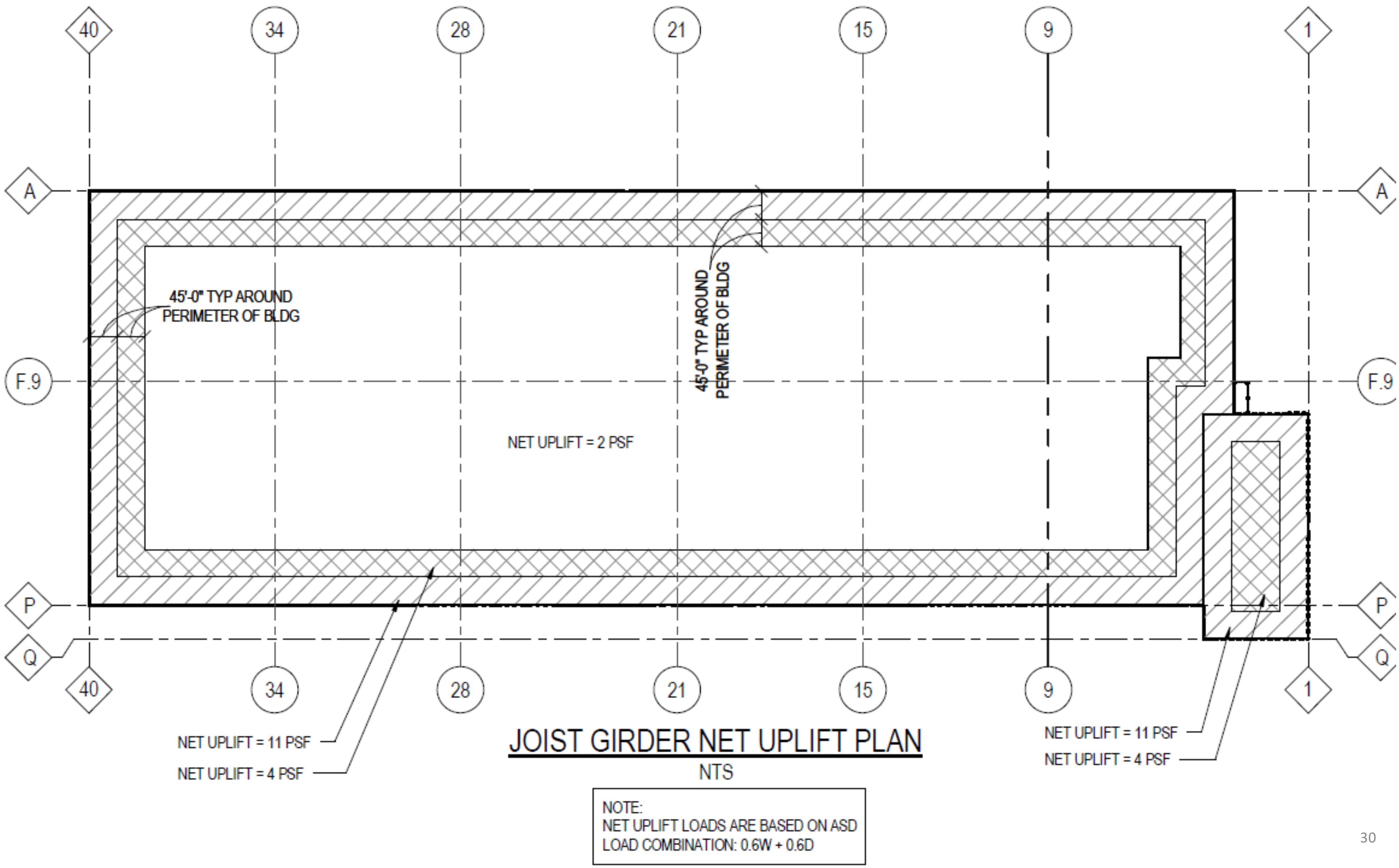
- Use a ***Net Uplift*** plan



NOTE:
NET UPLIFT LOADS ARE BASED ON
ASD LOAD COMBINATION: 0.6W + 0.6D

Presentation of Uplift Design

- Use a ***Net Uplift*** plan



Presentation of Uplift Design

- Let’s compromise

UPLIFT DIAGRAM ON JOIST & JOIST GIRDER

SCALE: NONE

NOTE:

1. LINEAR INTERPOLATION IS PERMITTED.
2. JOIST UPLIFT LOAD COMBINATION IS 0.6D + 0.6W
   DEAD LOAD = 12 PSF.

LOCATION	GROSS UPLIFT PRESSURE (ULTIMATE) (psf)			EDGE ZONE
	①	②	③	
AREA < 10 ft^2	-50.6	-84.9	-127.8	20'-0"
AREA = 50 ft^2	-47.6	-63.9	-53.8	20'-0"
AREA = 100 ft^2	-46.3	-54.9	-54.9	20'-0"

Presentation of Uplift Design

- Not enough direction

WIND PRESSURE TABLE					
	TRIBUTARY AREA (SQ. FT)				
ZONE	10	25	50	75	100+
1 POS	21	18.5	16.5	15.5	15
1 NEG	-22	-21	-20	-19.5	-19
2 NEG	-46	-41	-36	-33	-31
OVH NEG	-62	-62	-62	-62	-62

NOTES:
1. POSITIVE PRESSURE ACTS TOWARD SURFACE
2. NEGATIVE PRESSURE ACTS AWAY FROM SURFACE
3. DETERMINE WIND LOAD BY USING TRIBUTARY AREA OF INDIVIDUAL JOIST. LINEAR INTERPOLATION IS PERMITTED.
4. OVH PRESSURE IS APPLIED TO OVERHANG ONLY
5. ZONE 1 POSITIVE PRESSURE IS APPLIED OVER ENTIRE ROOF AREA

Polling Question #1

T/F: The uplift specified in the structural drawings, for joist and joist girders, should be shown as **NET** uplift.

A. True

B. False

Design Example

Chapter 30

WIND LOADS – COMPONENTS AND CLADDING (C&C)

Table 30.3-1 Steps to Determine C&C Wind Loads for Enclosed and Partially Enclosed Low-Rise Buildings

Step 1: Determine risk category; see Table 1.5-1.

Step 2: Determine the basic wind speed, V, for applicable risk category; see Figs. 26.5-1 and 26.5-2.

Step 3: Determine wind load parameters:

- Wind directionality factor, K_d; see Section 26.6 and Table 26.6-1.
- Exposure category B, C, or D; see Section 26.7.
- Topographic factor, K_{zt}; see Section 26.8 and Fig. 26.8-1.
- Ground elevation factor, K_e; Section 26.9 and Table 26.9-1
- Enclosure classification; see Section 26.12.
- Internal pressure coefficient, (GC_{pi}); see Section 26.13 and Table 26.13-1.

Step 4: Determine velocity pressure exposure coefficient, K_h; see Table 26.10-1.

Step 5: Determine velocity pressure, q_h, Eq. (26.10-1).

Step 6: Determine external pressure coefficient, (GC_p):

- Walls; see Fig. 30.3-1.
- Flat roofs, gable roofs, hip roofs; see Fig. 30.3-2.
- Stepped roofs; see Fig. 30.3-3.
- Multispan gable roofs; see Fig. 30.3-4.
- Monoslope roofs; see Fig. 30.3-5.
- Sawtooth roofs; see Fig. 30.3-6.
- Domed roofs; see Fig. 30.3-7.
- Arched roofs; see Fig. 27.3-3, Note 4.

Step 7: Calculate wind pressure, p; Eq. (30.3-1).

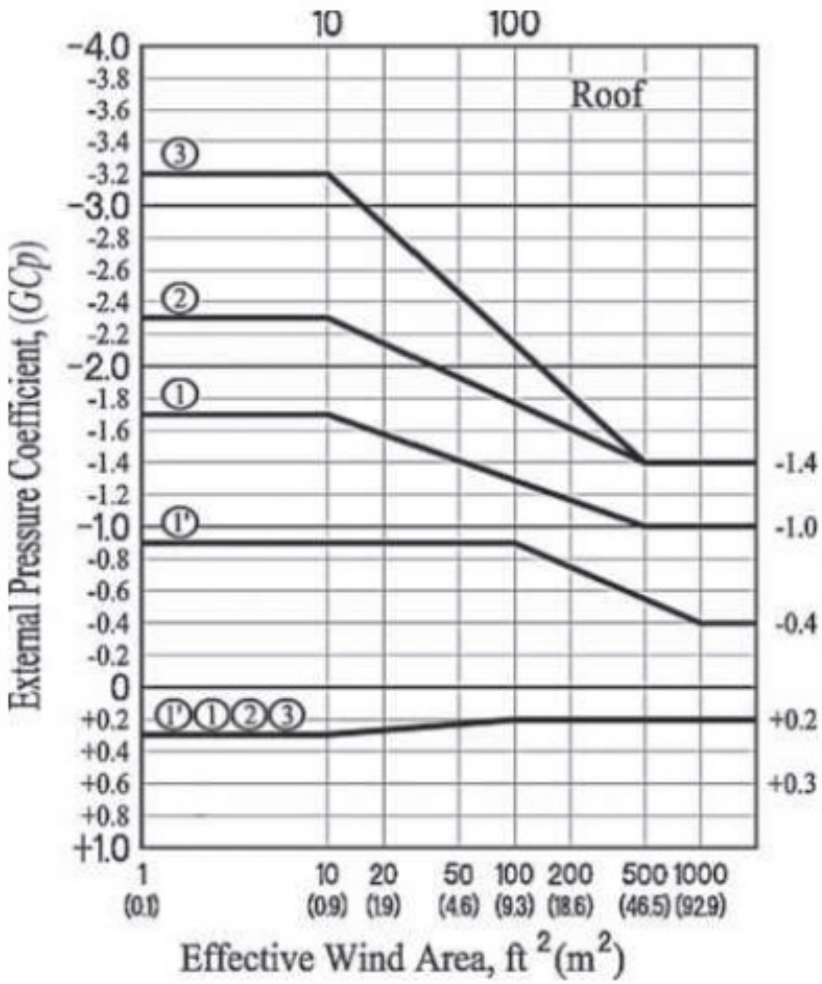
Design Example

- Rectangular building with height = 40’, and flat roof
- Risk category II
- V = 140 mph
- Exposure C
- $K_d = 0.85$; $K_{zt} = 1.0$; $K_e = 1.0$; $K_z = 1.04$
- Enclosed Building, GC_{pi} = +/- 0.18

$$q_z = 0.00256 K_z K_{zt} K_d K_e V^2 \ (\text{lb/ft}^2); \ V \text{ in mi/h} \qquad (26.10\text{-}1)$$

Design Example

- Effective Wind Area – effective width need not be less than 1/3 the span.
- Provide all relevant pressures for most economical design.
- Joists spanning over 39’ can be considered in the 500 sq. ft zone.



Design Example

- Calculate *p* for 100 sf and 500 sf effective wind areas

$$p = q_h[(GC_p) - (GC_{pi})](\text{lb/ft}^2) \qquad (30.3\text{-}1)$$

LRFD Components and Cladding Pressures (psf)		
A_e (sq. ft)	**100**	**500**
Zone 1'	-47.9	-32.4
Zone 1	-65.6	-52.3
Zone 2	-85.6	-70.1
Zone 3	-103.3	-70.1

D_{min} for net uplift = 10 psf (1.0D)

Design Example

- Joists placed at 6’-0” on center and spanning 50’
- DL = 15 psf, LL = 20 psf, WL+ = 16 PSF
- Use ASD
- Controlling load combination is (DL + 0.75LL + 0.45WL)
- Total load = 224 plf
- Uniform live load = 120 plf
- Select 30K8 (225 plf total load, W_{360} = 130 plf)
- Joist weight is approximately 450 pounds

Design Example

- 500 square foot Zone 1’
  - Net uplift = 0.6D + 0.6W = 0.6*10 + 0.6*(-32.4) = -13.5 psf

- @ 6’-0” spacing = 81 plf net uplift

  ~36% of downward loading of 225 plf

- Joist weight is approximately 470 pounds. 5% more than no uplift. Note that uplift bridging is required.

Design Example

- Let’s assume plans are not clear and the joist supplier uses the *p* = -32.4 psf as the net uplift.

- @ 6’-0” spacing = 195 plf net uplift

  Now ~87% of downward loading of 225 plf

- 30K8 with 193 plf net uplift weights about 540 pounds.

  15% heavier than 30K8 supporting required net uplift and requires an additional row of bridging.

Design Example

- Now, let's consider a scenario where only 100 sf pressures are given and the same joist completely in Zone 2
- Net uplift Zone 2 100 sf = 45.4 psf
- Net uplift Zone 2 500 sf = 36.1 psf
- @ 6'-0" spacing NU_{100} = 273 plf & NU_{500} = 217 plf
- 30K8 with 273 plf net uplift is 17% heavier than 30K8 supporting required net uplift

Positive Wind Pressure Considerations

- The total joist load for the purposes of selecting a joist designation should represent the maximum result of the load combinations, which may include a downward (positive) wind force in the controlling load case.
  - For LRFD
    - **$1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.5W)$**
    - **$1.2D + 1.0W + L + 0.5(L_r \text{ or } S \text{ or } R)$**
  - For ASD
    - **$D + (0.6W \text{ or } 0.7E)$**
    - **$D + 0.75L + 0.45W + 0.75(L_r \text{ or } S \text{ or } R)$**

Positive Wind Pressure Considerations

- Example (ASD)

Dead Load (D) = 15 psf

Live Load (L_r) = 20 psf

Positive Wind (W) = 16 psf
(110 mph, 40' height, exposure C, 100 sq. ft. eff. area)

Total Design Load = D + L_r = 35 psf

Or

D + 0.75(0.6W) + 0.75(L_r) = 37.2 psf ← Governs

Wind – Not to be Taken Lightly!

Applying Wind Uplift to Joists

- Connections are a critical part of the load path
  - Design of joist seat
  - Capacity of attachment
    - Welds
    - Bolts

Connection Design for Uplift

- Anchorage failure example

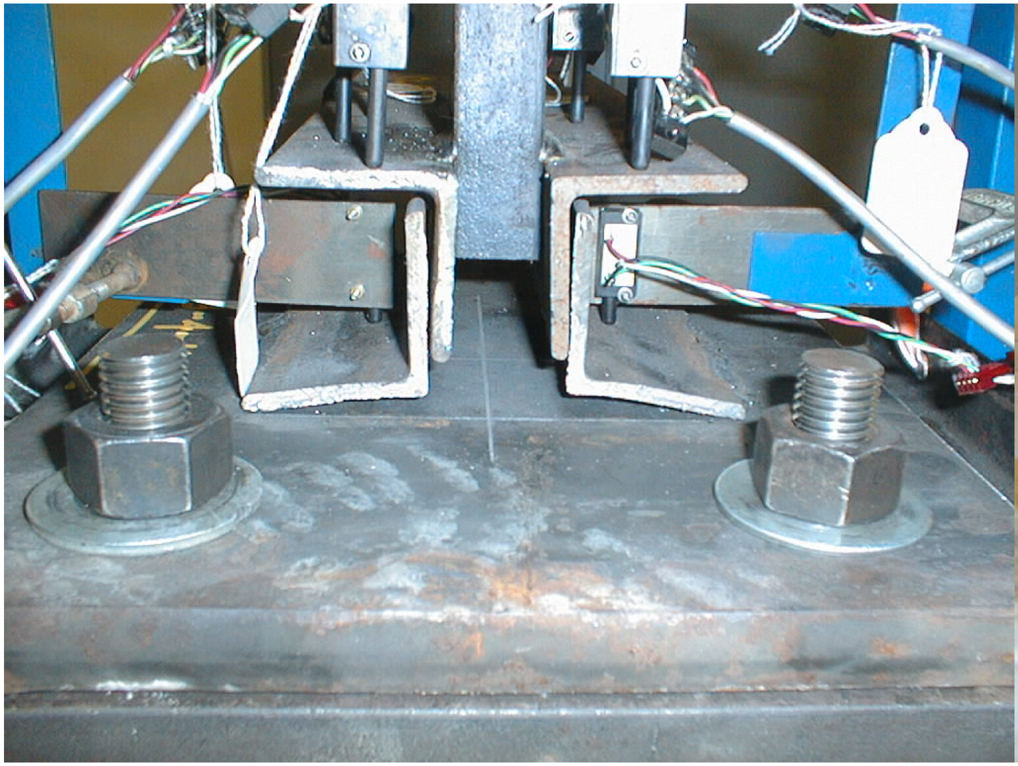
Connection Design for Uplift

- Division of Responsibility
  - SJI Specification and Code of Standard Practice
    - "The joist manufacturer will provide a seat of sufficient thickness and strength to resist the uplift end reaction resulting from the specified uplift."
    - "The adequacy of the end anchorage connection (bolted or welded) between the joist or Joist Girder bearing seat and the supporting structure is the responsibility of the **specifying professional**. The contract documents shall clearly illustrate the end anchorage connection."

Welded End Anchorage

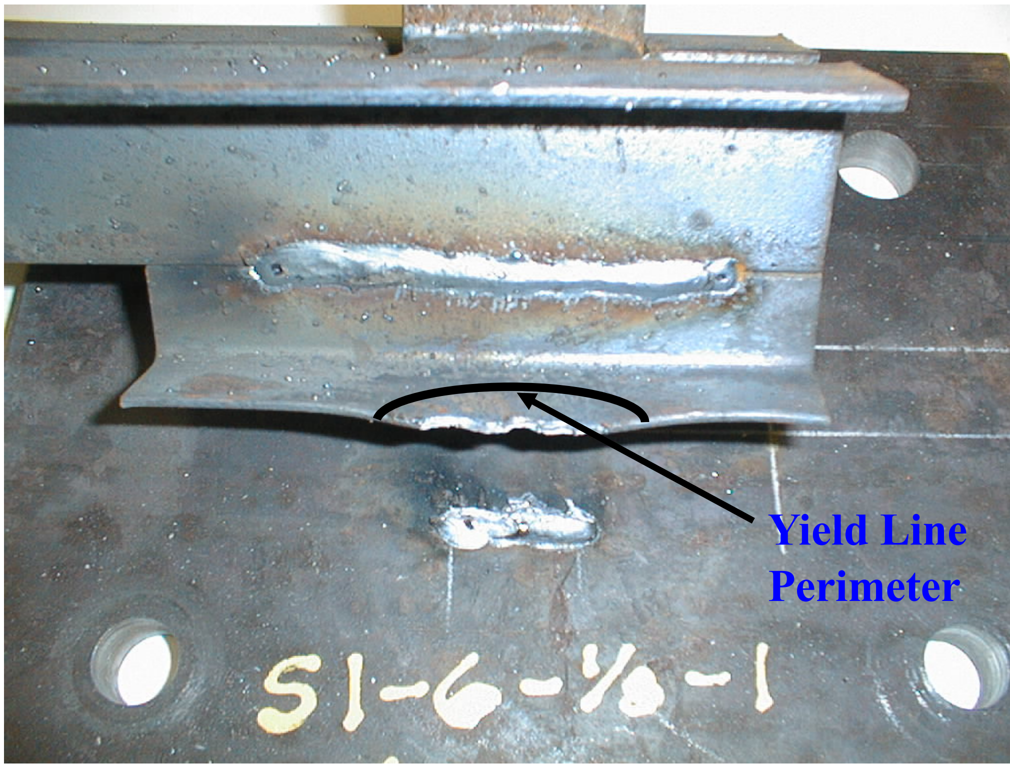
- The strength of the joist bearing seat for an uplift loading combination is a function of both the joist seat thickness and length of the end anchorage welds.
- The minimum anchorage welds from the SJI Specification may not develop the full capacity of the joist seat assembly for uplift.
- Longer end anchorage weld length aids the joist manufacturer in providing an economical design of the joist bearing seat.

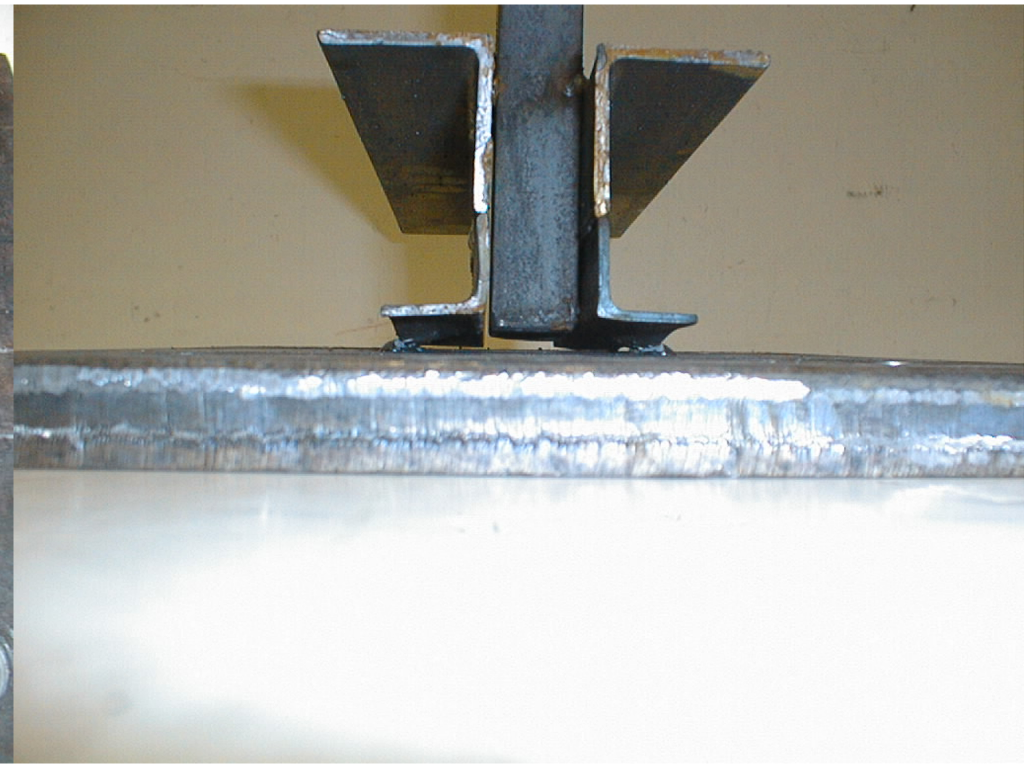
Welded Seat Testing



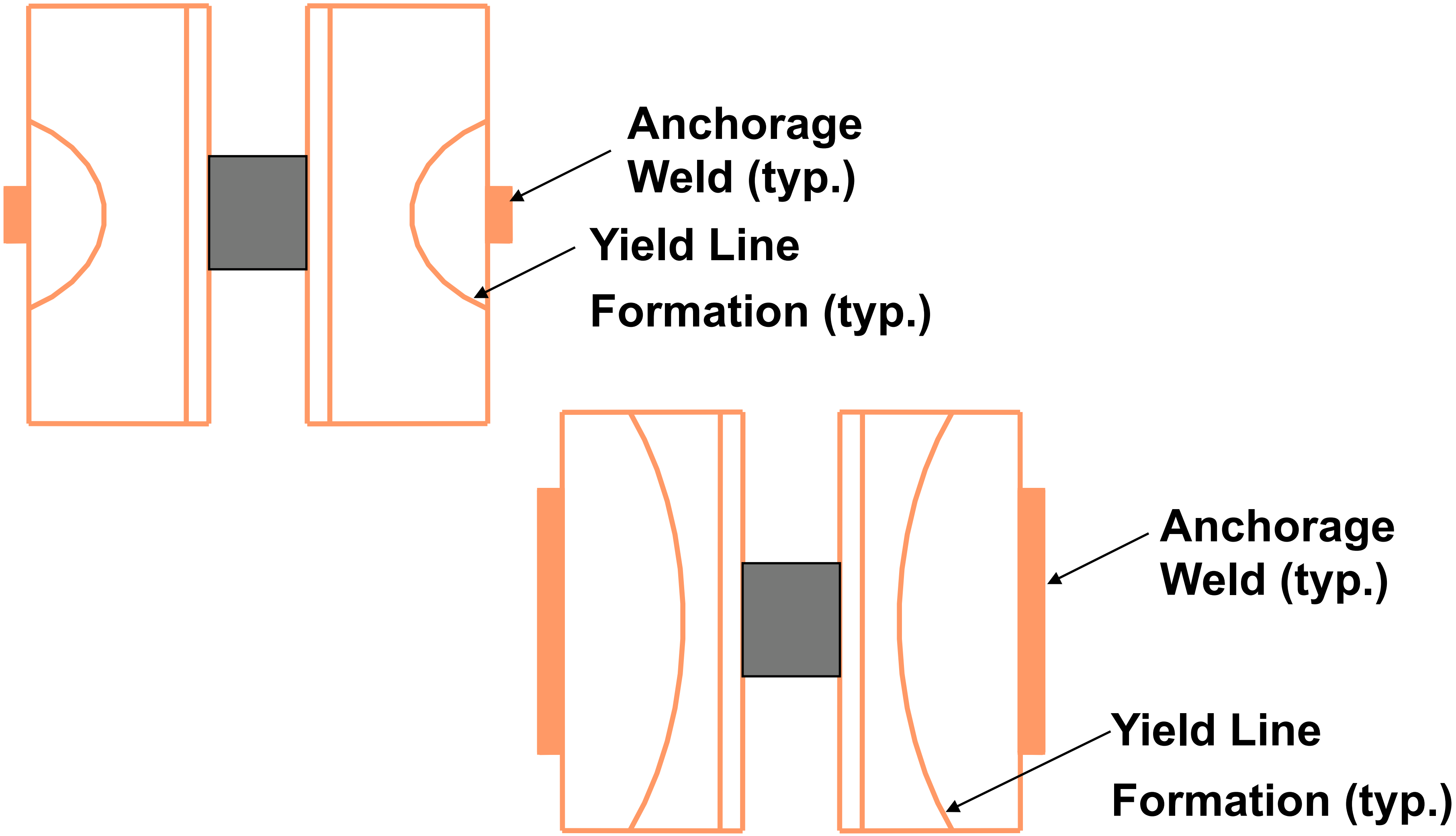
Failure Mechanism

Welded Seat Testing

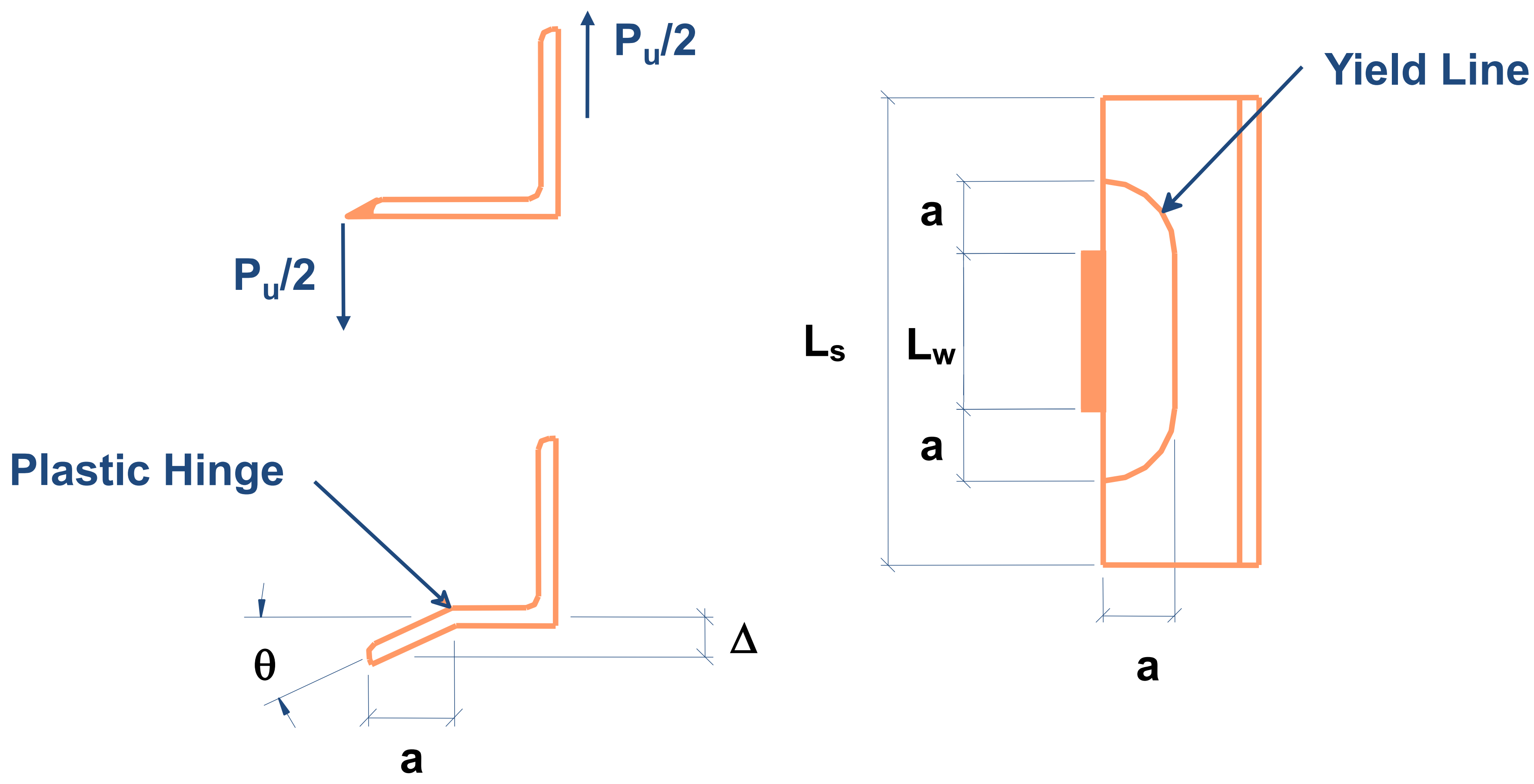




Welded Seat Yield Line



Welded Seat Yield Line



Yield Line Design Procedure

$P_n = 2\ M_p\ L_{yl}\ /\ a$

Where:

P_n	=	Nominal uplift capacity
M_p	=	Plastic moment capacity of plate per unit length
	=	$F_y\ Z$
Z	=	$t^2\ /\ 4$
L_{yl}	=	Length of yield line
a	=	$2.3\ t$
Ω	=	1.67 (AISC-ASD safety factor for bending)
P_n/Ω	=	Allowable uplift strength
ϕ	=	0.90 (AISC-LRFD resistance factor for bending)
ϕP_n	=	Design uplift strength

Minimum End Anchorage Welds

JOIST SERIES and SECTION NUMBER	MINIMUM FILLET WELD
K Series	(2) 1/8" x 2-1/2"
LH Series, 02-06	(2) 3/16" x 2-1/2"
LH/DLH Series, 07-17; JG	(2) 1/4" x 2-1/2"
DLH Series, 18-25; JG*	(2) 1/4" x 4"

* Joist Girders with a self weight greater than 50 plf.

Bolted End Anchorage

- Final welding is typical for stability (lateral support)
- Only bolts are considered anchorage for uplift
  - Type and diameter by **specifying professional**
  - Provide sufficient tensile strength for uplift reaction
  - Higher strength than minimums per SJI may be required

Bolted End Anchorage

JOIST SERIES and SECTION NUMBER	MINIMUM BOLTS
K Series	(2) 1/2" A307
LH Series, 02-06	(2) 1/2" A307
LH/DLH Series, 07-17; J G	(2) 3/4" A307
DLH Series, 18-25; JG*	(2) 3/4" A325

* Joist Girders with a self weight greater than 50 plf.

Bolted Connection Design for Uplift

- The bearing seat design is a check of prying action
  - AISC design procedure is followed
  - An uplift reaction equal to the full tensile capacity of the bolts may not be achieved with maximum practical seat thicknesses and without stiffeners.

Typical Prying Action Capacity

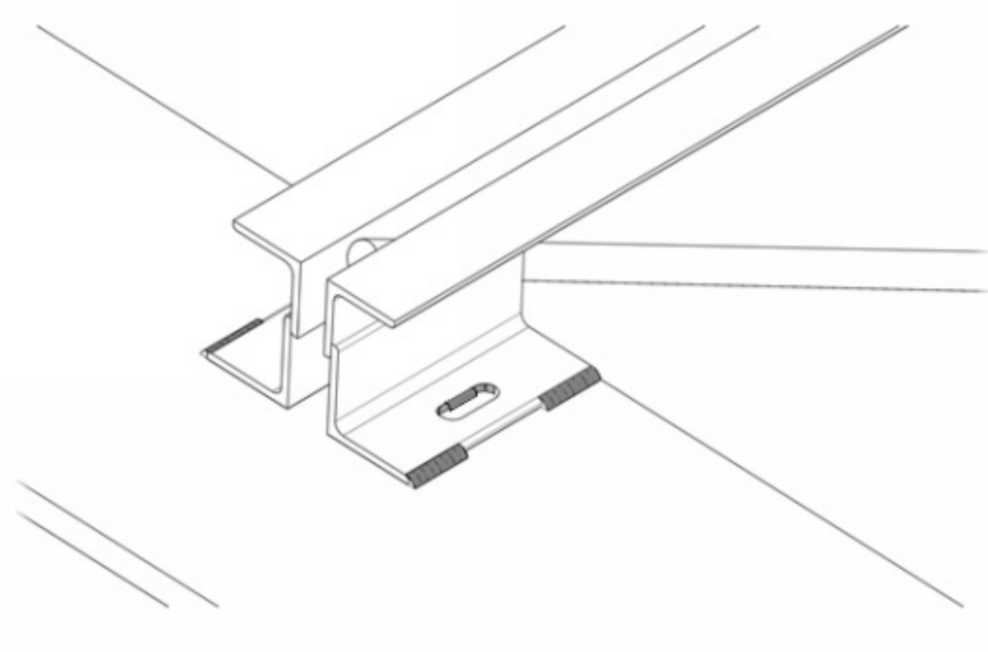
Connection Type to Supporting Member	LRFD Strength Kips	ASD Strength Kips
(2) ½" A307 bolts (1/4" thick steel)	10.5	7.0
(2) ½" A325 bolts (1/4" thick steel)	10.5	7.0
(2) ¾" A307 bolts (1/2" thick steel)	26.4	17.6
(2) ¾" A325 bolts (1/2" thick steel)	36.0	24.0
(2) 1" A325 bolts (1" thick steel)	106.0	70.7

Typical Prying Action Capacity

- Capacities on the prior slide were between 51 % and 100 % of the full tensile bolt strength, depending on the thickness of the bearing seat leg.
- A rule of thumb would be to size the bolt diameter, grade, and quantity of bolts based upon using 75 % of the full tensile strength (allowing the remaining capacity for prying action).

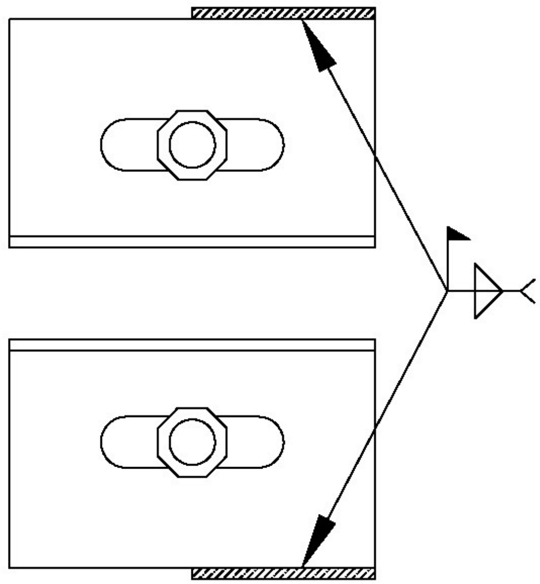
Connection Design for Uplift

- Where a joist seat has been detailed for a bolted connection, and for any reason the bolt is not utilized, the empty slot in the bearing seat leg severely diminishes uplift capacity. In such a condition, if a weld and no bolt is to be used on a slotted bearing seat, then the weld should be applied within the empty slot.

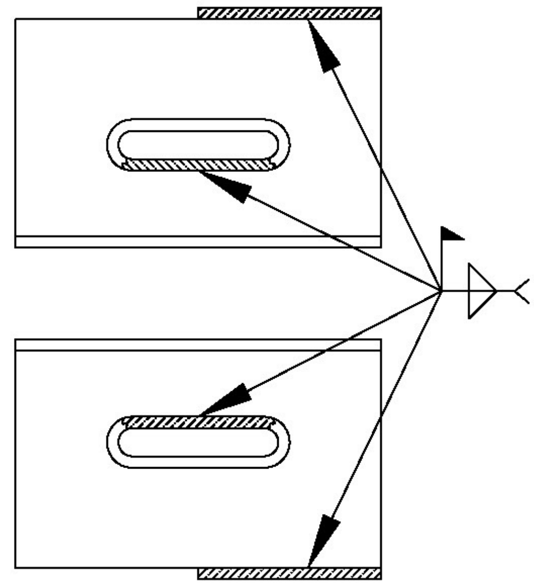


Typical Bolted Joist Connection

ERECTOR NOTE:
WHERE JOIST ARE FABRICATED TO ALLOW FOR FIELD BOLTING TO THE SUPPORTING STRUCTURE, THE BOLTED CONNECTIONS ARE FOR INITIAL ATTACHMENT ONLY, UNLESS SPECIFICALLY DIRECTED BY THE ENGINEER OF RECORD. SNUG-TIGHTENED BOLTS SHALL REMAIN IN THE BEARING SEAT SLOTS AFTER FINAL CONNECTION IS MADE VIA WELDING PER THE CONTRACT STRUCTURAL DOCUMENTS. IF A BOLTED CONNECTION IS NOT USED, OR THE BOLTS ARE REMOVED AFTER ERECTION, JOIST SEATS MUST BE WELDED ALONG THE INSIDE EDGE OF SEAT SLOTS.



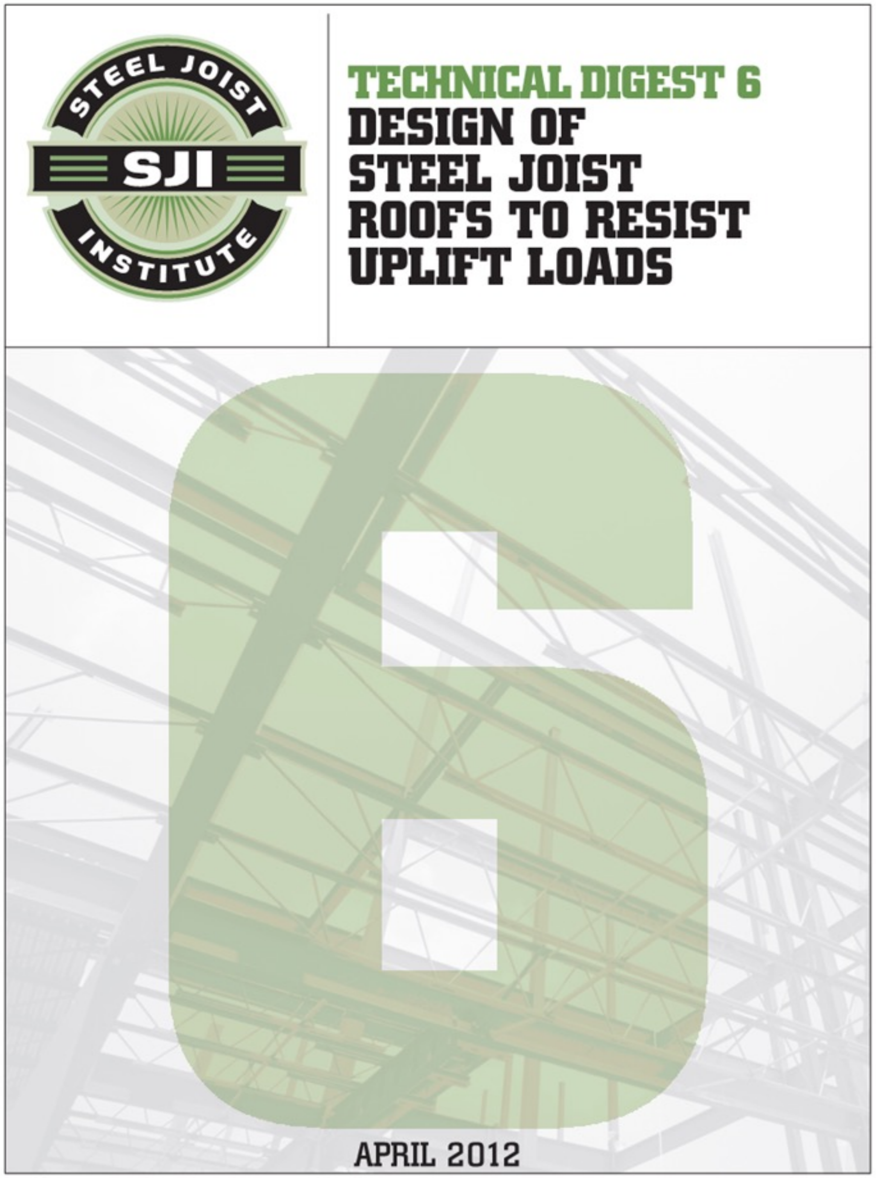
WITH BOLTS



IF BOLTS ARE REMOVED

End Anchorage

- For more on End Anchorage and joist design for uplift, refer to the Steel Joist Institute Technical Digest #6, *Design of Steel Joist Roofs to Resist Uplift Loads*



Polling Question #2

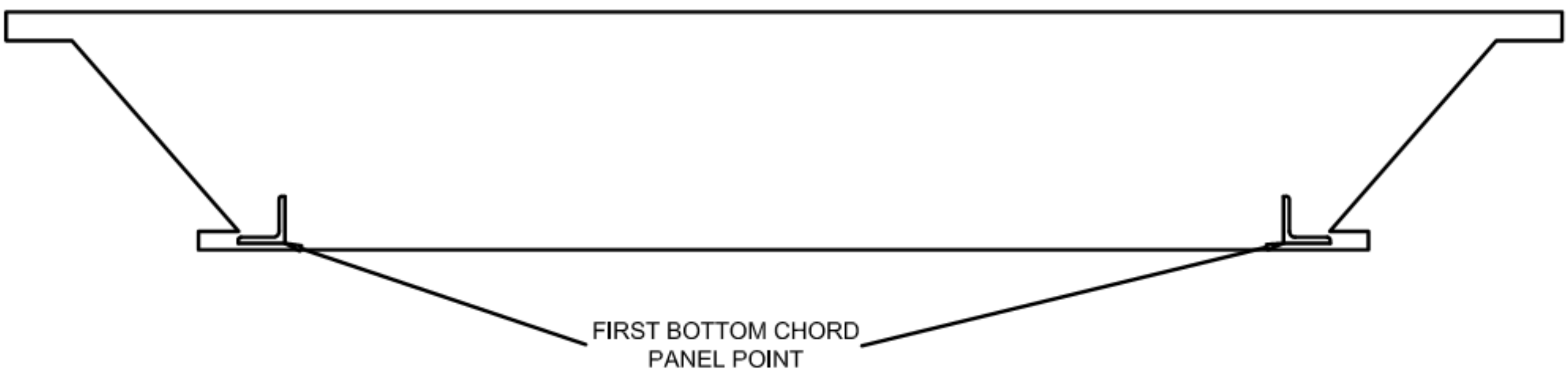
Positive wind pressure should be considered in specifying a joist designation whether standard or load/load.

A. True

B. False

Bottom Chord Bridging for Uplift

Bottom Chord Bridging for Uplift

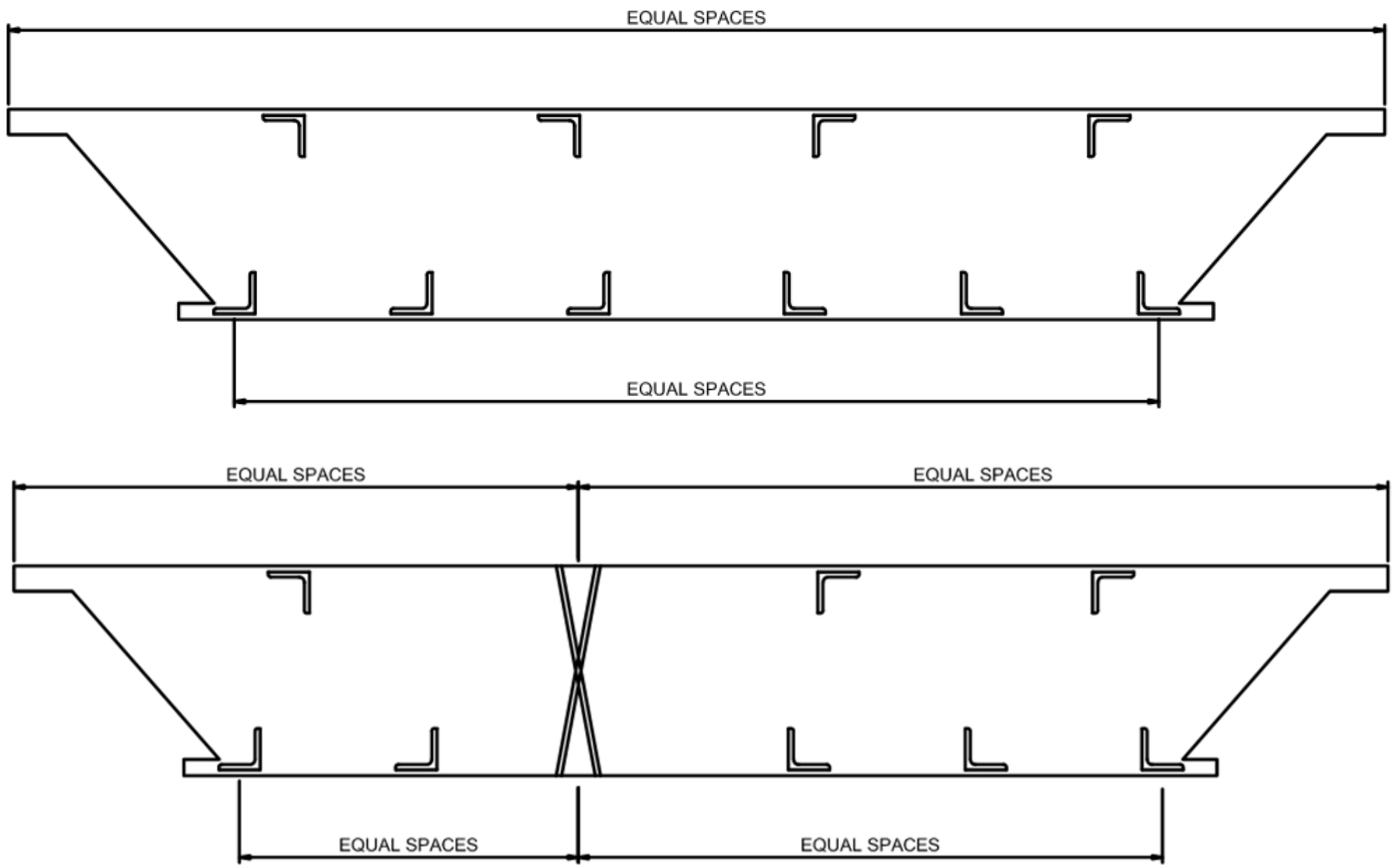


Bottom Chord Bridging for Uplift

- SJI Standard Specifications, Uplift Bridging
  - Bottom chord bridging need not align with top chord bridging
  - Total number of bottom chord rows shall not be less than the number of top chord rows
  - Can be advantageous to space rows more closely near center of span
  - Commonly equal spacing on bottom chord

Bottom Chord Bridging Spacing

- Typical details used – equally space between first bottom chord panel points



Bottom Chord Bridging for Uplift

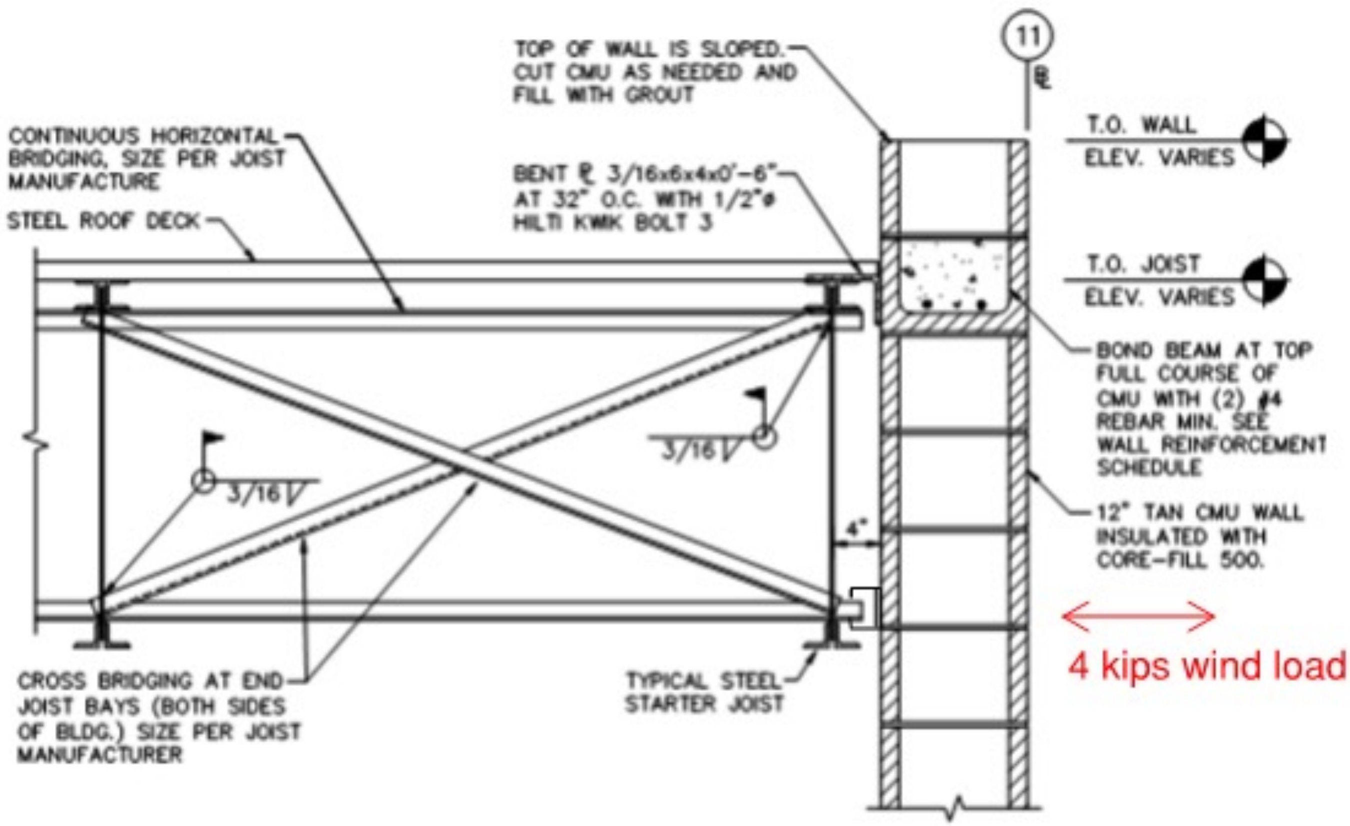
- Bridging Load Requirements
  - Bridging axial load is based on bottom chord compressive axial load
    - $P_{br} = 0.005 \, P_c$
    - Where P_c is the bottom chord compressive axial load
  - Bridging design force for number of joists, n, does not accumulate linearly
  - Randomness of initial lateral out-of-straightness

Bottom Chord Bridging for Uplift

- Bridging Load Requirements
  - The following equation can be used for the bridging force:
    - $P_{br} = 0.001\, n\, P_c + 0.004\, P_c \sqrt{n}$
    - P_c is the bottom chord compressive axial load
  - For small to moderate net uplift and reasonable number of joists, n, P_{br} at bottom chord is no larger than at top chord
  - For more severe uplift, P_{br} at bottom chord can be computed and may determine bridging size, or require a limit on the value of n.

External, Additional Forces on Bridging

- Can an additional, external wind force be transferred through the joist bridging?

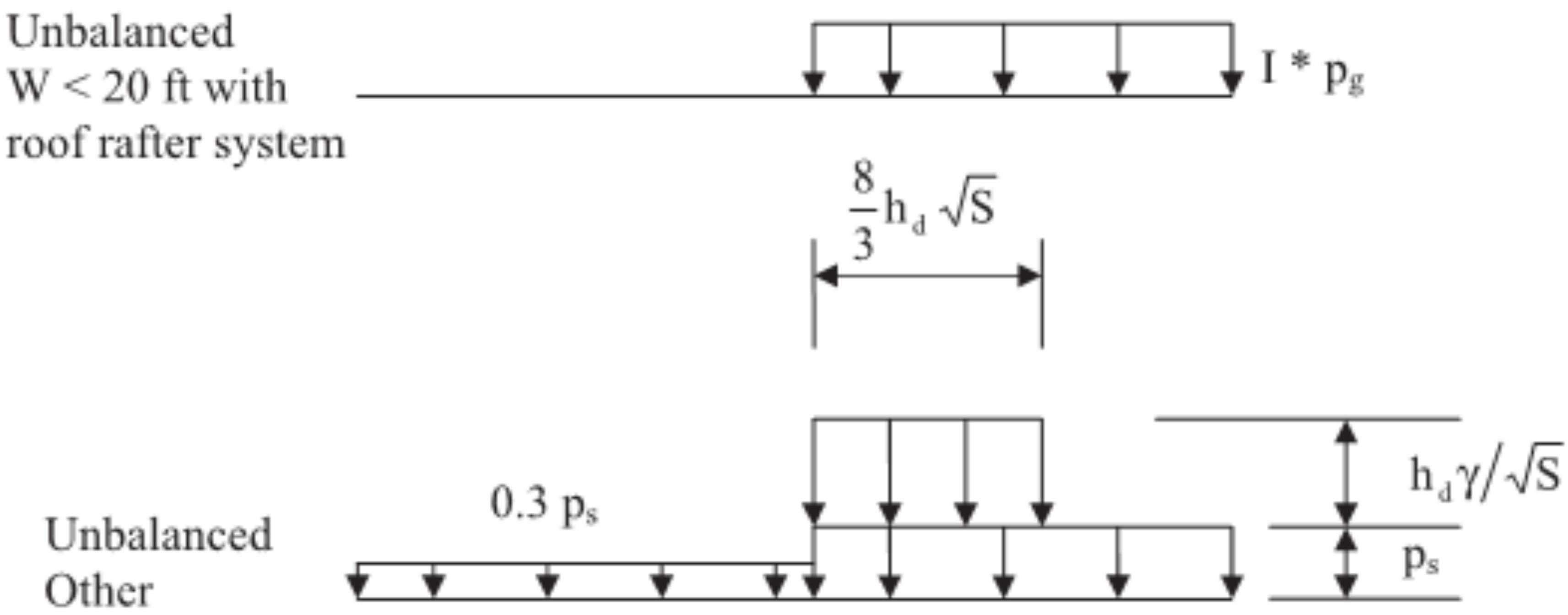


Lateral Wind Loads

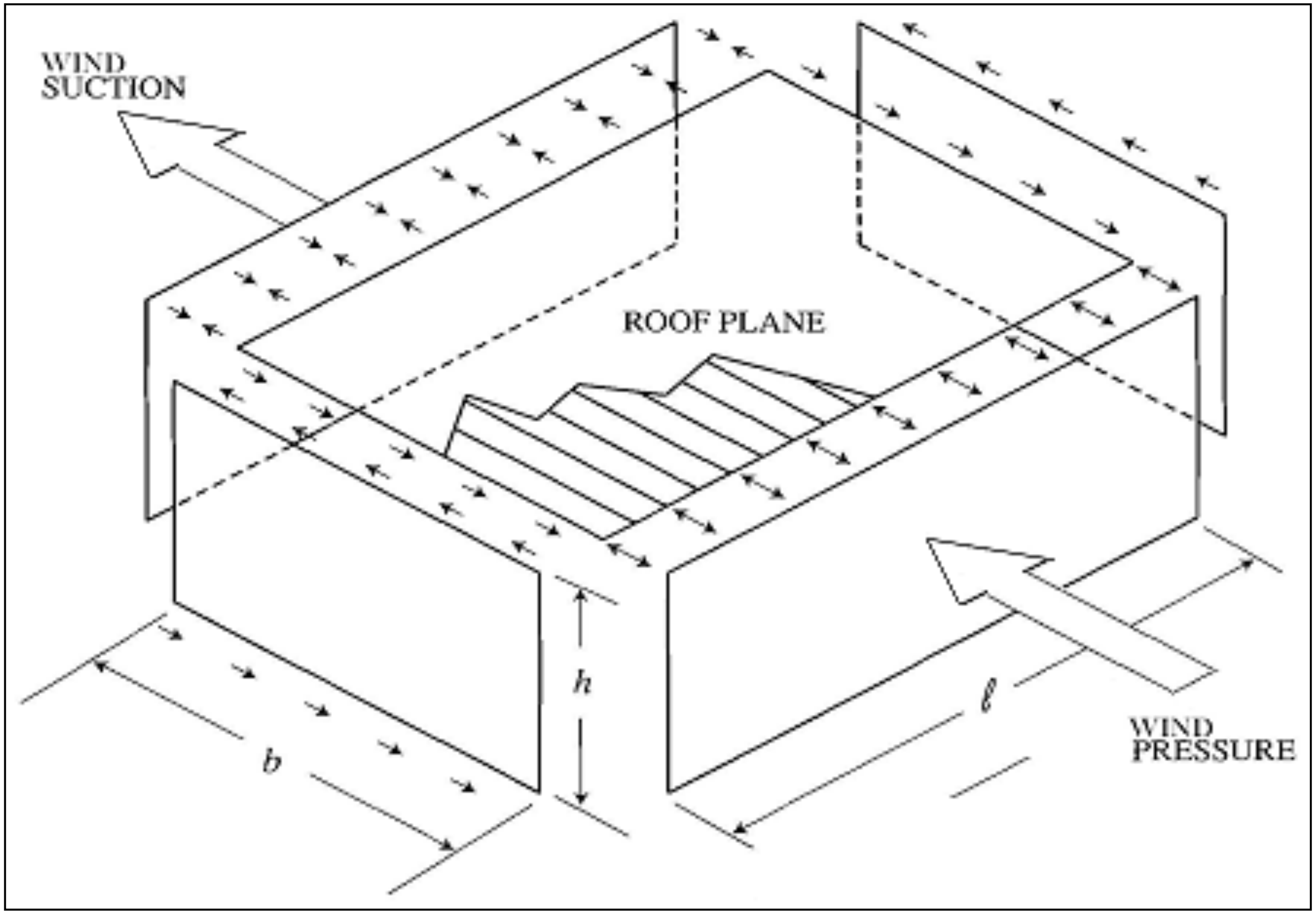
- Unbalanced Snow Loads
- Lateral Load Resisting Systems
  - Diaphragm and Shear Walls
  - Braced Frames
  - Rigid Frames
- Local Wind Bracing (Kickers)
- Roof Wind Screens

Unbalanced Roof Snow Loads

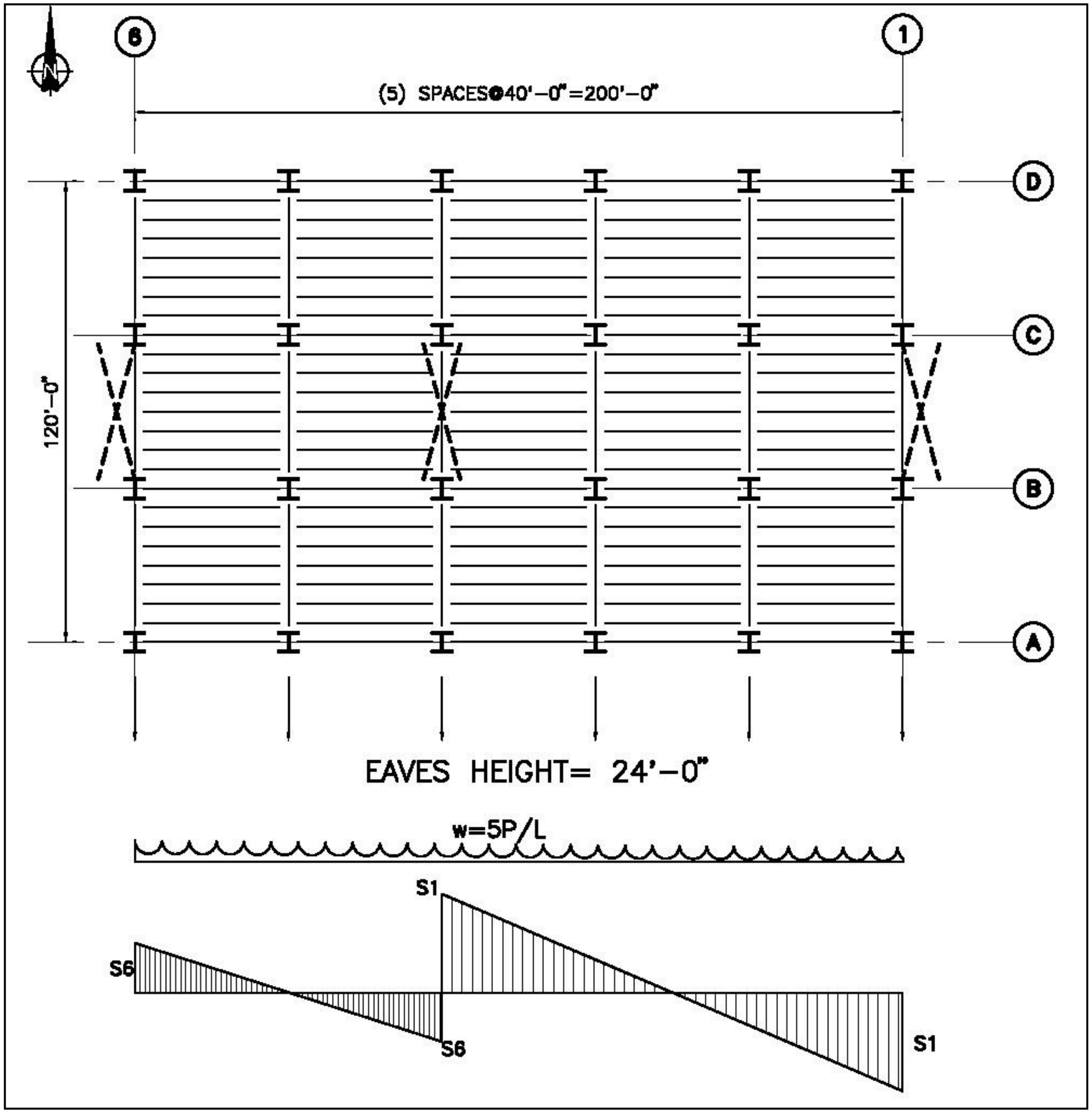
- For a pitched joist that creates the ridge line, the unbalanced snow load is not implicitly accounted for by the SJI Specifications, so a contract note to require a check is advisable.



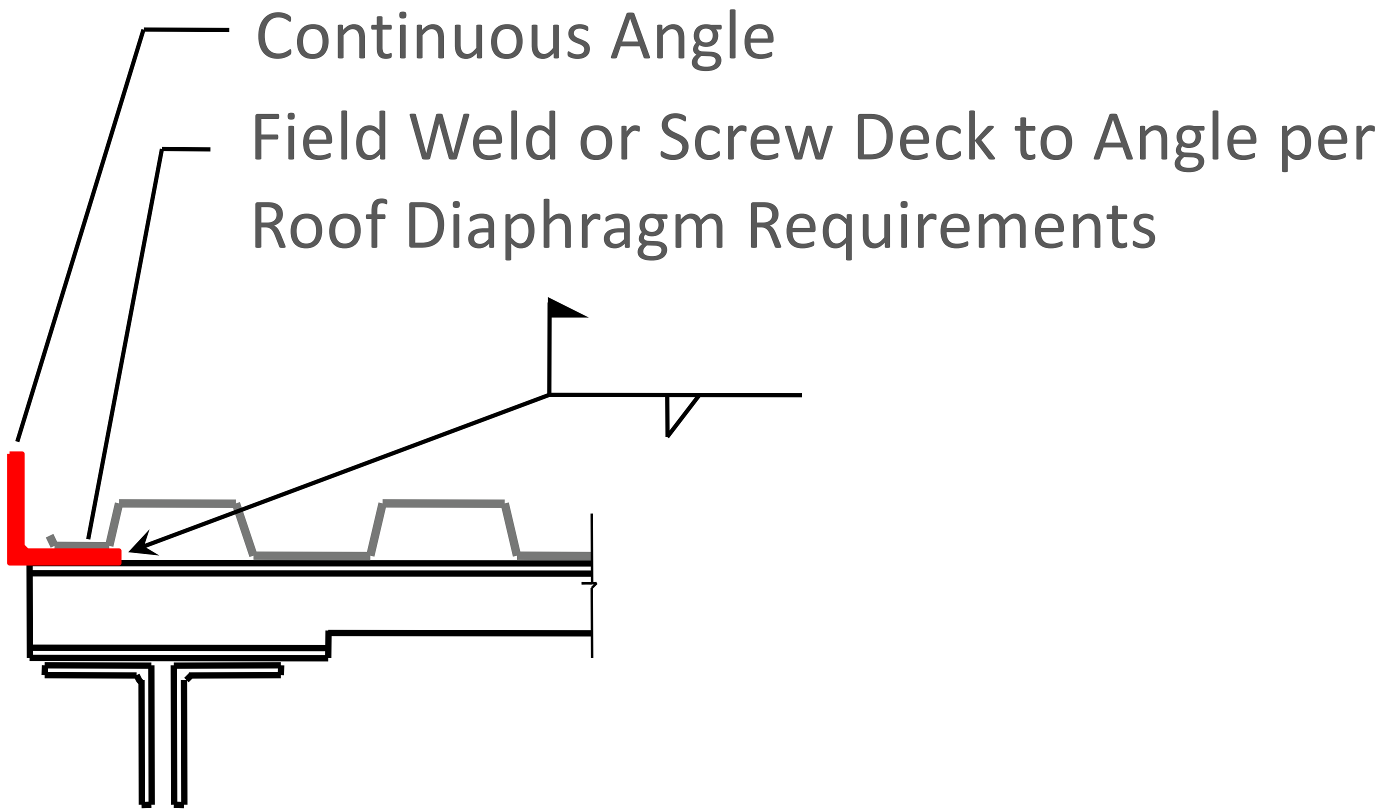
Diaphragm and Shear Walls



Diaphragm and Braced Frames

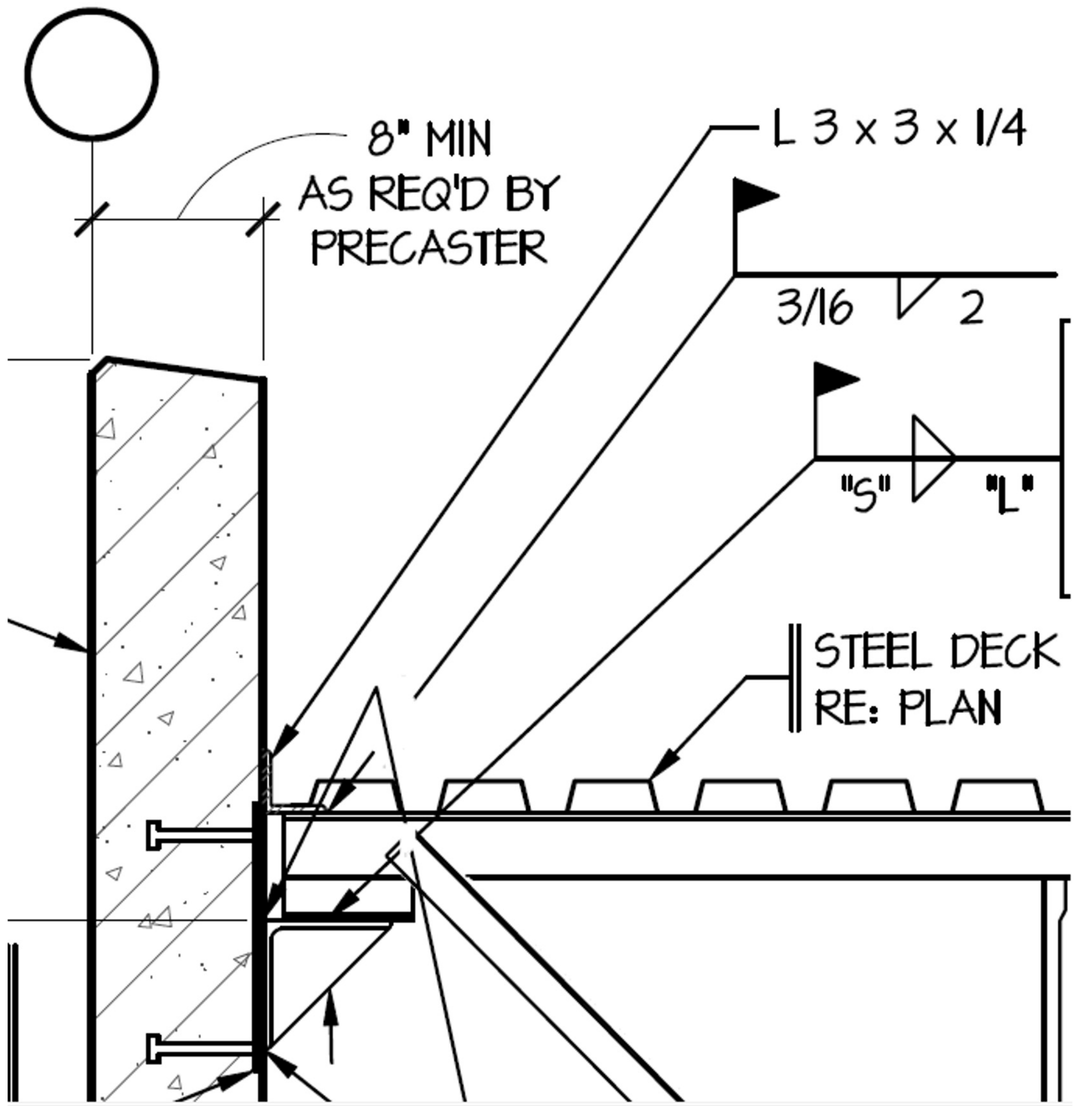


Diaphragm Boundary – Deck Support Angle



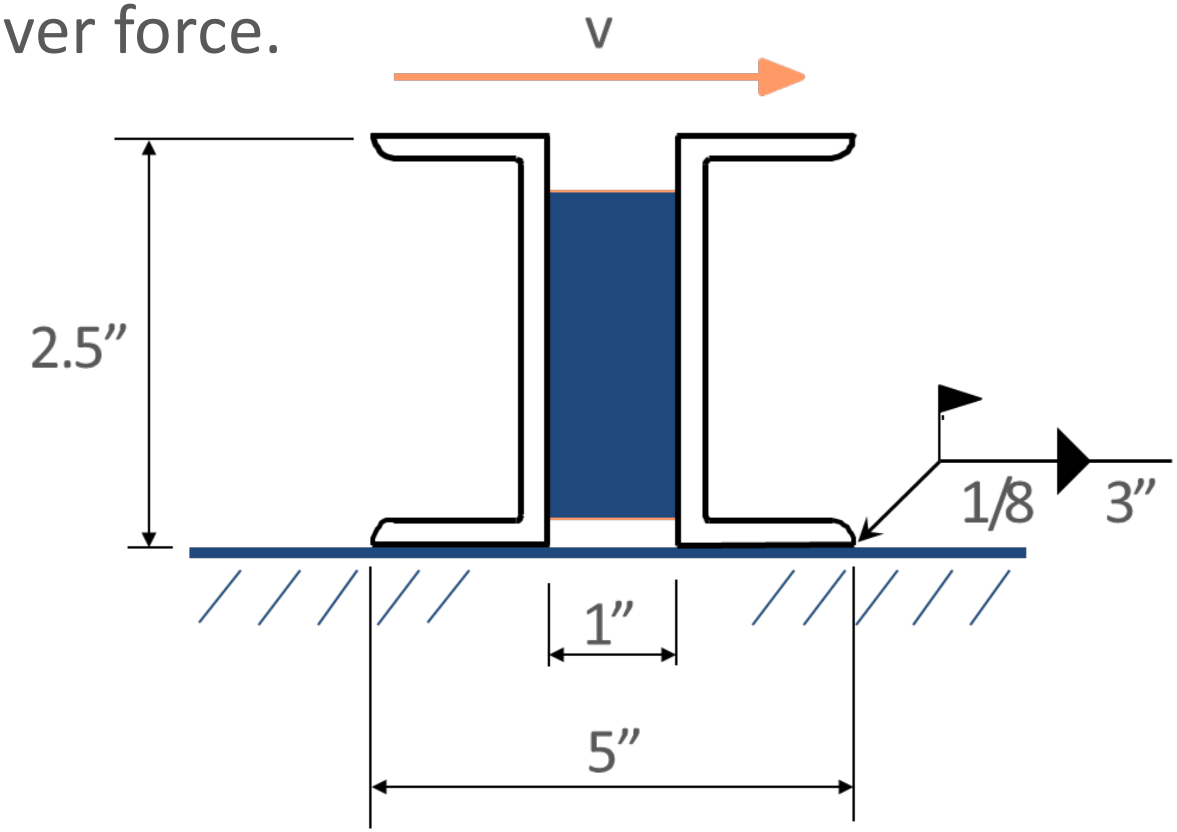
Diaphragm Boundary – Deck Support Angle

- Typical detail for joist bearing at wall
- L 3 x 3 x ¼" diaphragm chord angle attached to joist and deck but not directly attached to wall
- Diaphragm chord force is transferred to wall as a rollover force through joist seat



Joist Seat Rollover

- If there is not a direct load path from a deck edge angle or diaphragm boundary, the joist seat may be subjected to a rollover force.

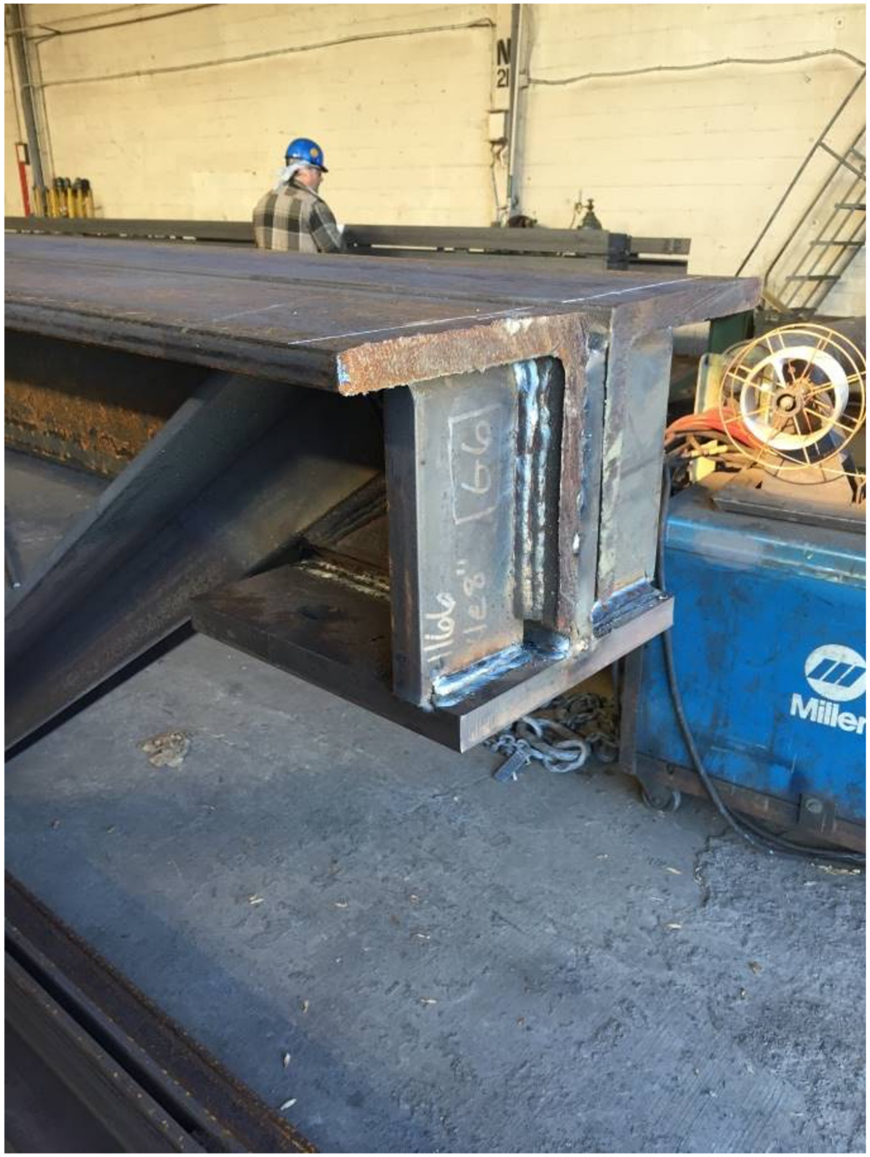


Note: Force V should be given on the structural drawings as a joist design requirement.

Diaphragm Boundary

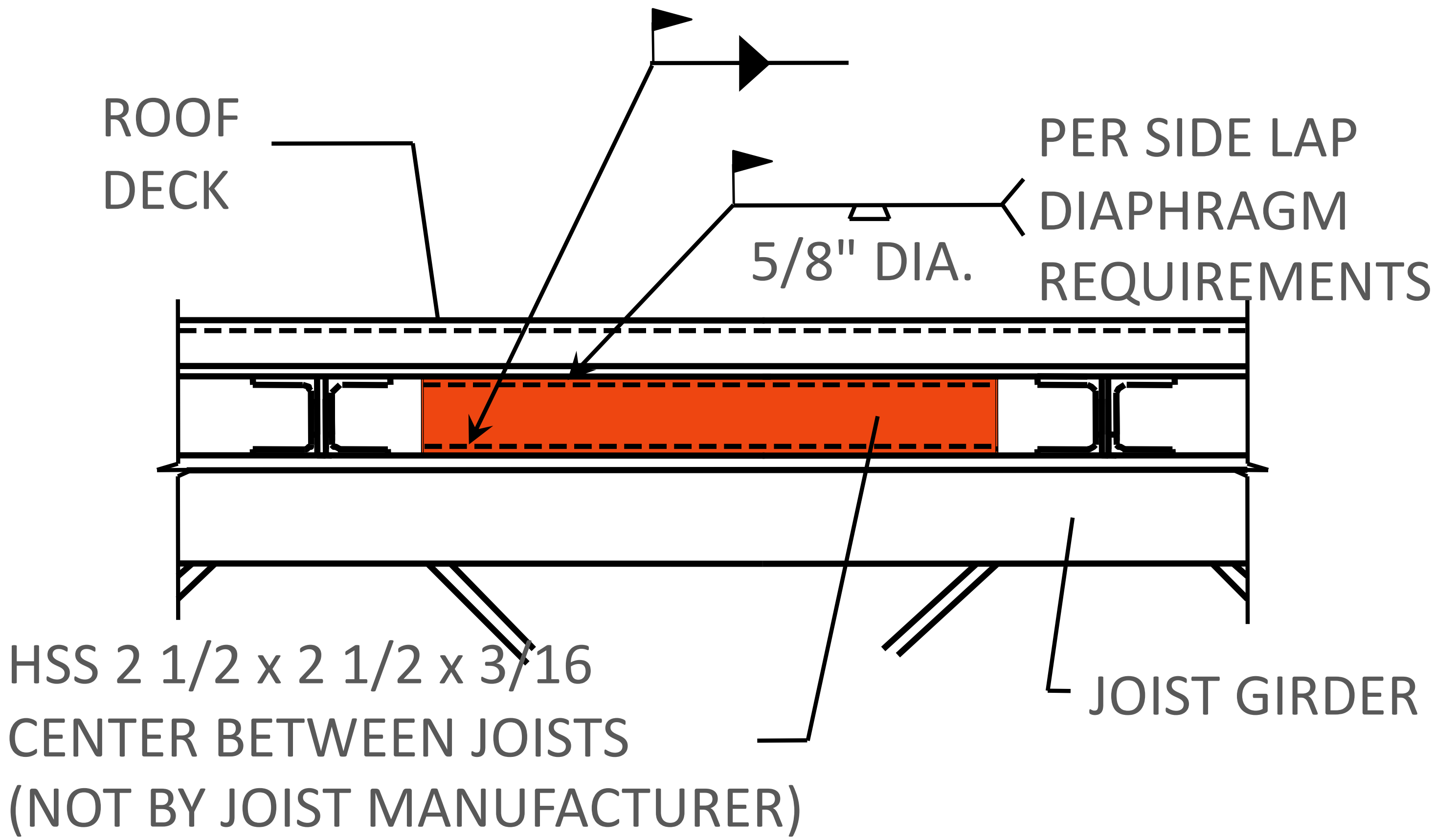
Diaphragm Boundary

- Rollover force should be noted, but 500 pounds or less will not affect the design or cost of the joist.
- Rollover forces up to 1.5 kips are handled with thicker seat angles.
- Rollover forces above 1.5 kips require seat stiffeners as shown in picture and add cost.



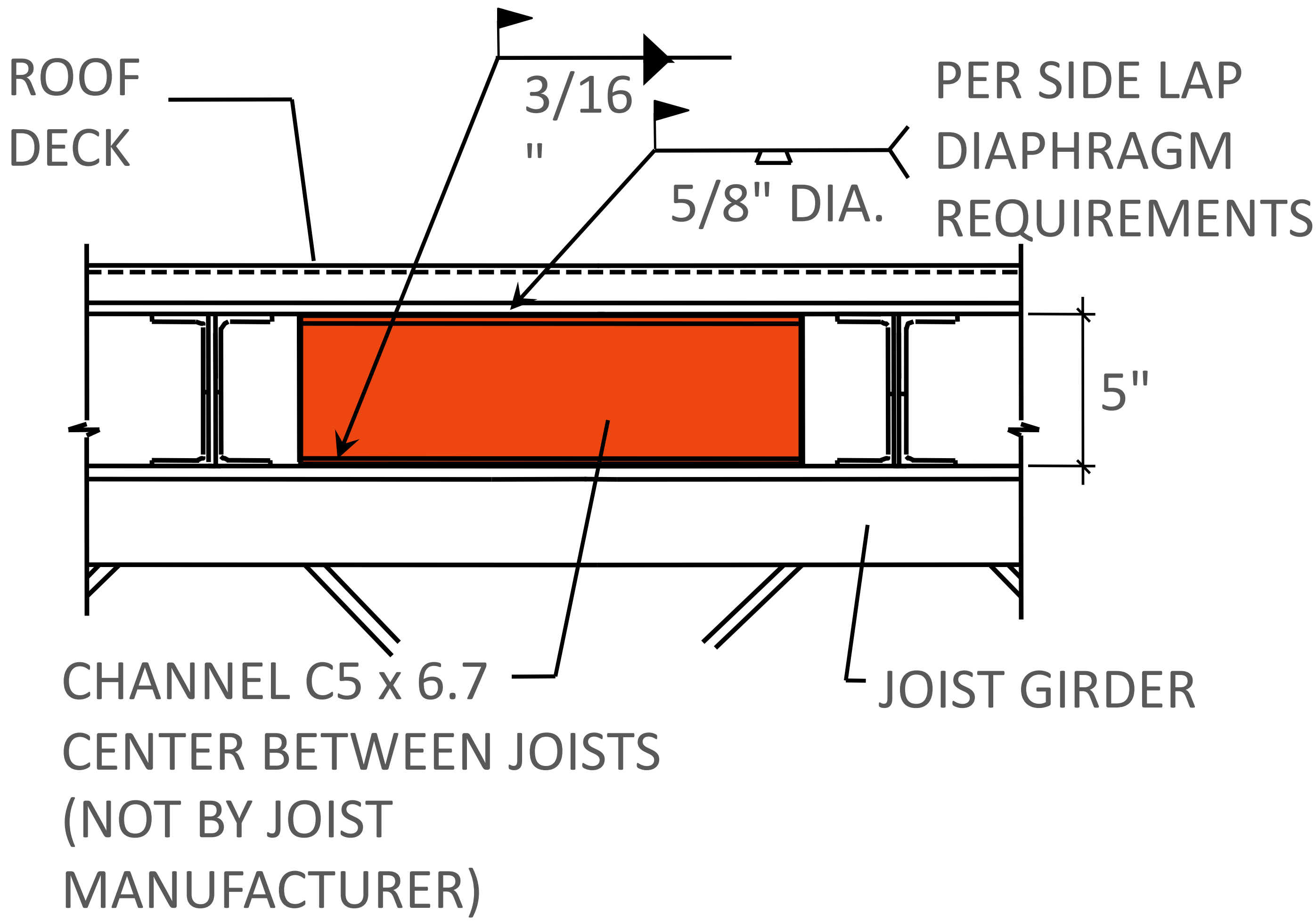
Alternate Detail to Joist Seat Rollover

- Where the diaphragm or collector chord force is large, a shear collector can be used, between the joist bearing seats. Shown here is a typical detail for K-Series.



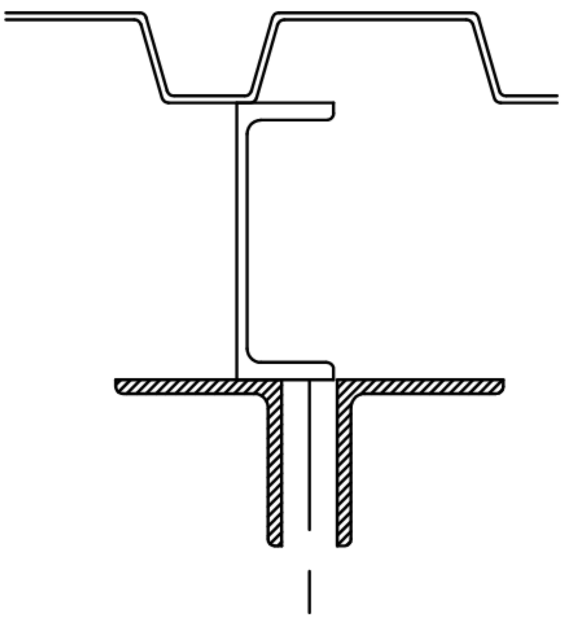
Alternate Detail to Joist Seat Rollover

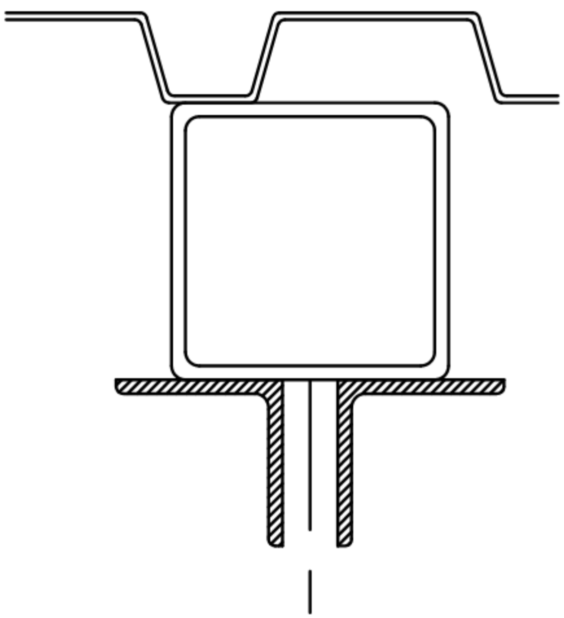
- Here is a similar detail, for use with LH/DLH-Series joists.



Alternate Detail to Joist Seat Rollover

- But maybe C5 x 6.7 is not the best choice.
- The shear collector must coincide with a low deck flute.
- 5” HSS might be a better option.

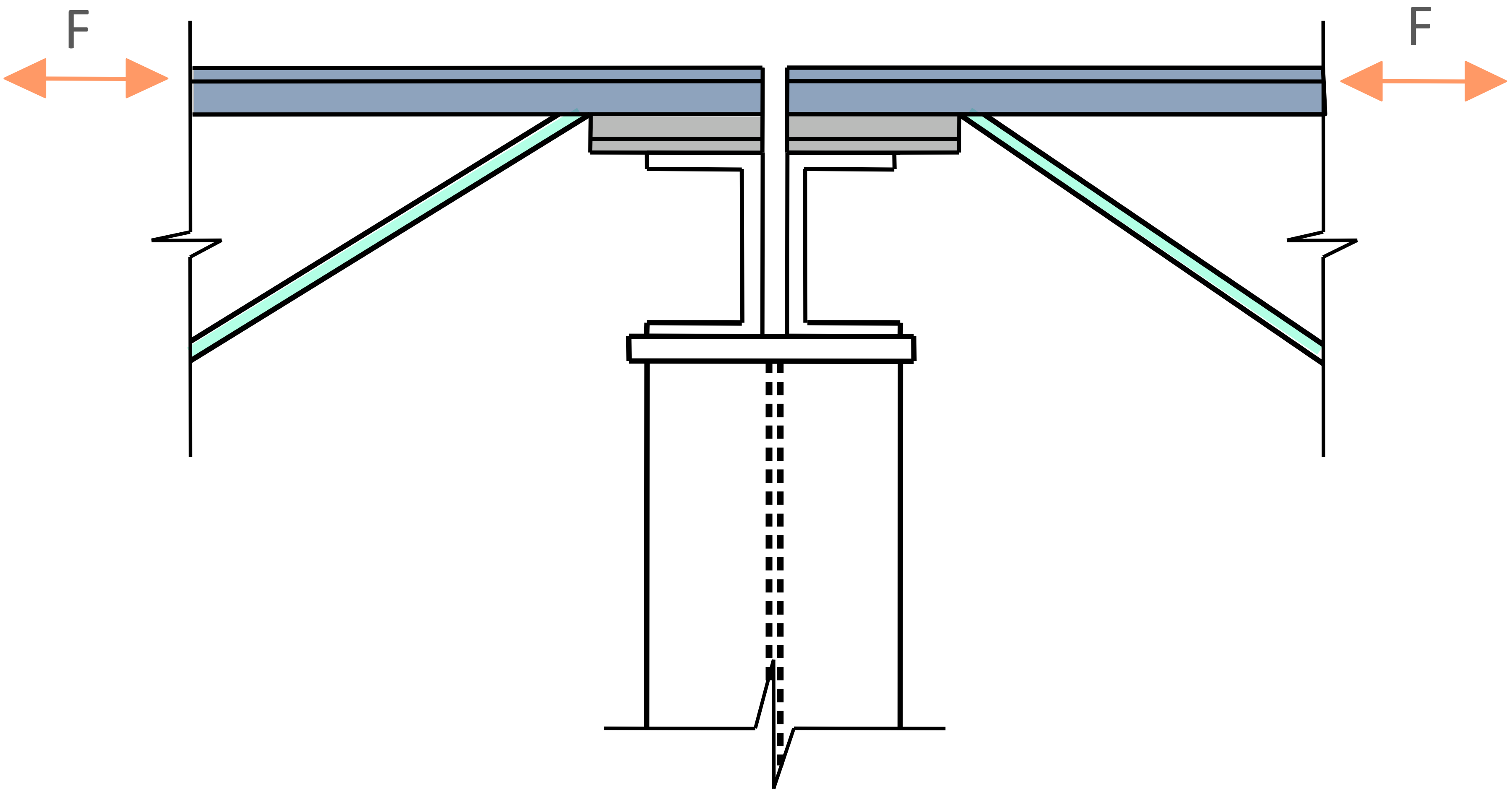




Chord Forces - Axial

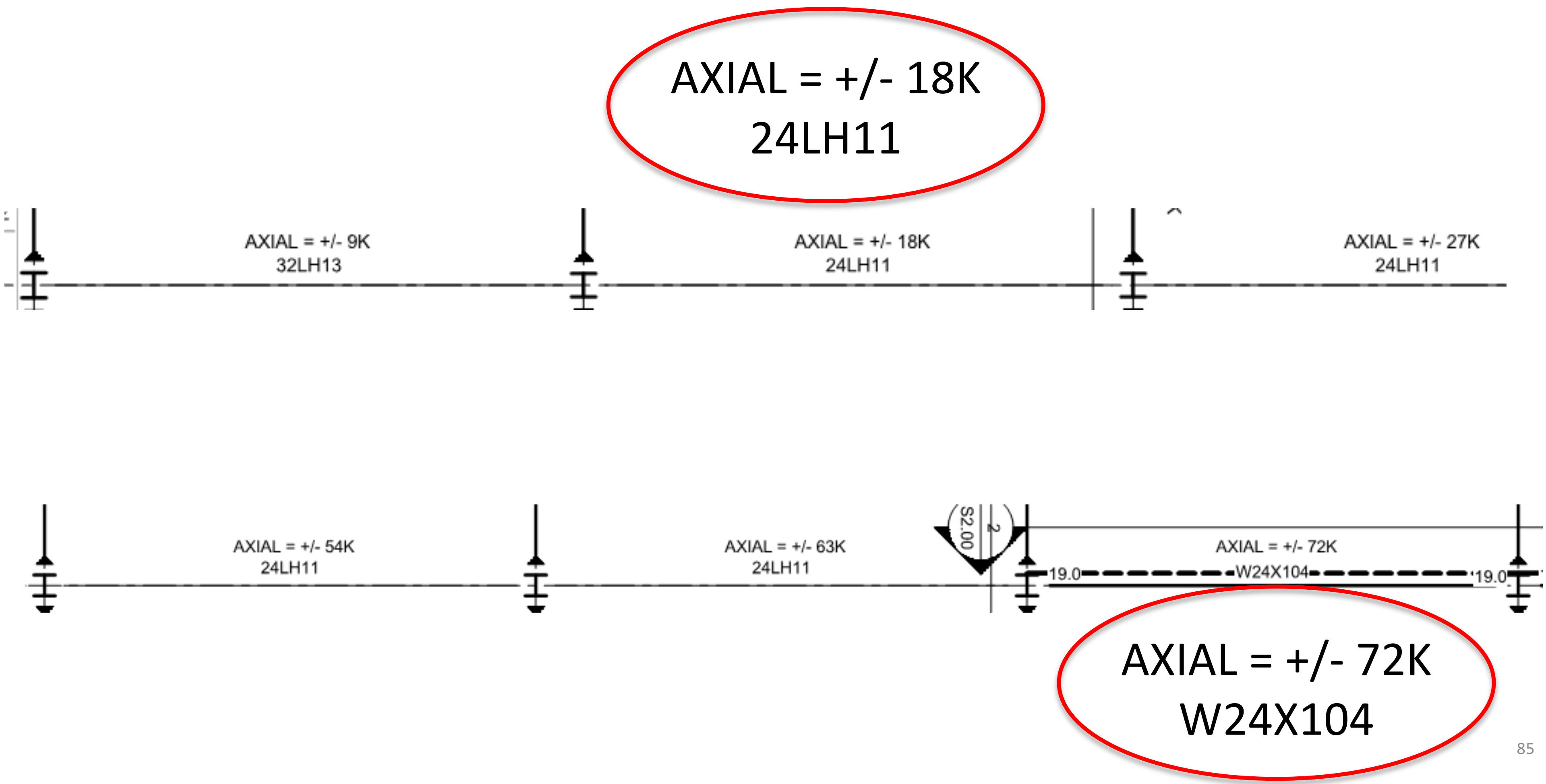
- Chord Forces are carried as additional axial loads by the top chords of joists and/or Joist Girders.
- Chord Forces may vary from one end of the chord to the other. The additional axial load for each joist and/or Joist Girder must be indicated.
- Type and magnitude of axial forces at the joist and Joist Girder end supports shall be shown on the structural drawings.
- Avoid resolving joist or Joist Girder axial forces through the bearing seat connection.

Diaphragm Chord



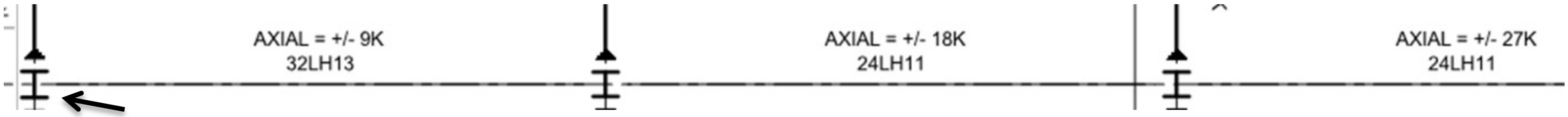
Axial Loads

- Joist or Joist Girder top chord axial loads are typically noted directly on the framing plan.



Axial Loads – Boundary Conditions

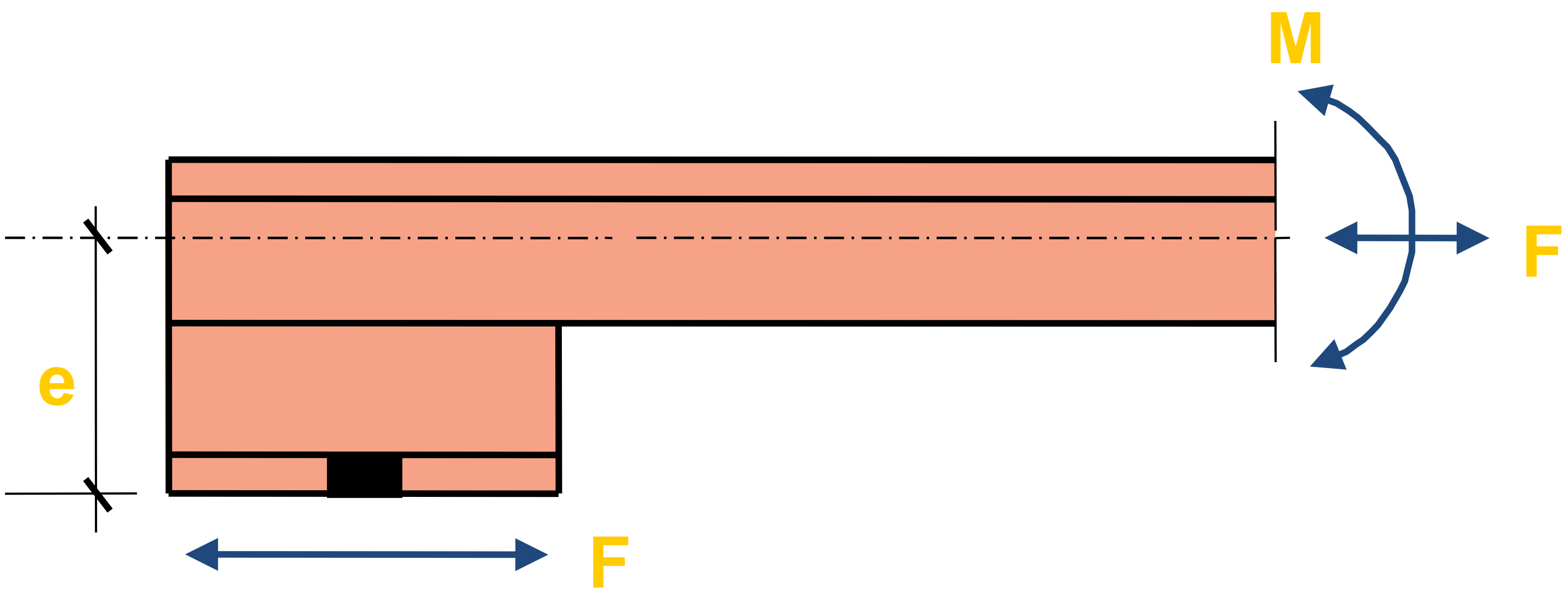
- For axial collector loads, to avoid unnecessary transfer design or an RFI from the Joist Manufacturer, it is helpful to show the magnitude of the axial load at the building perimeter.



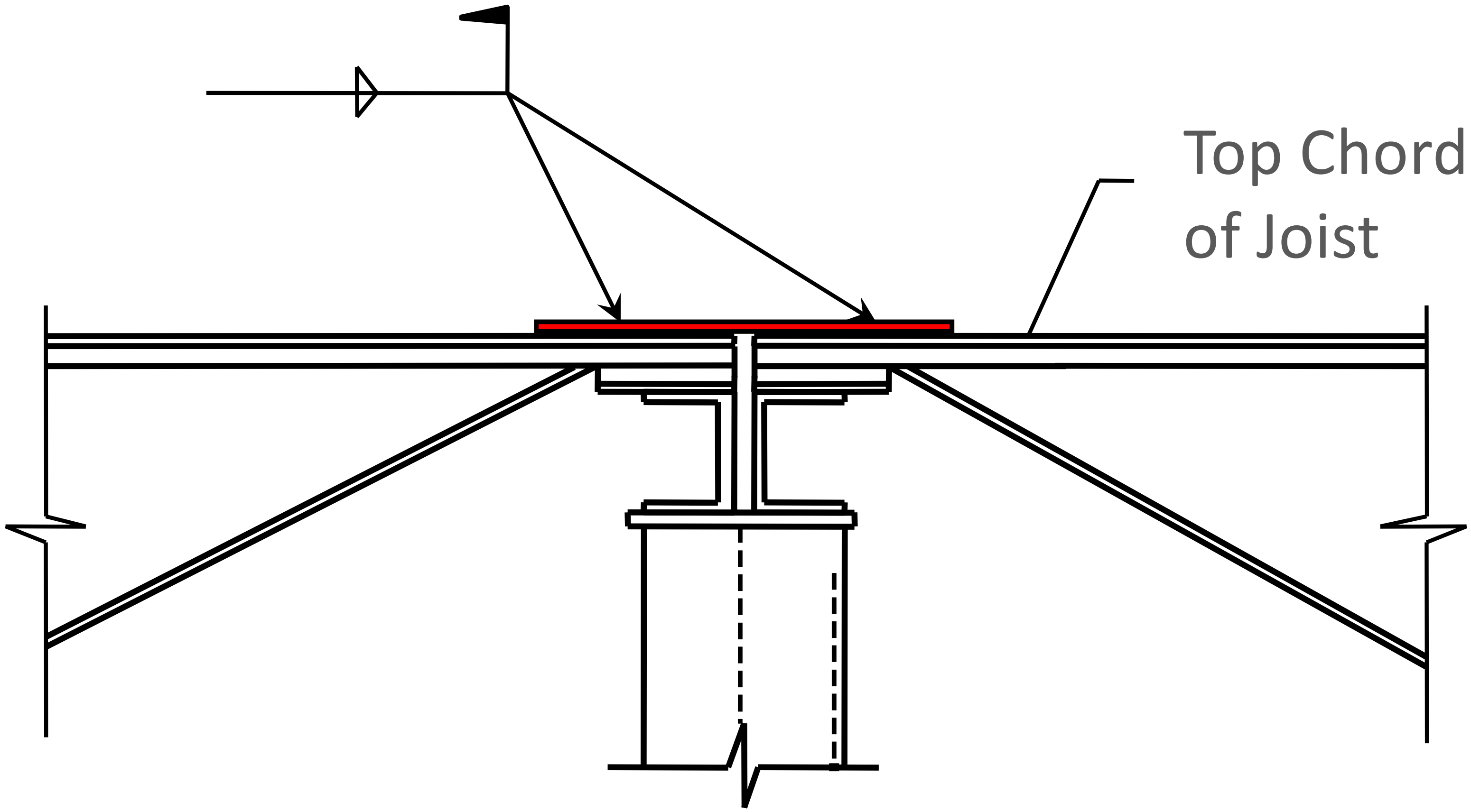
AXIAL = 0 kips
(The axial load accumulates from this end)

Wind Axial Load Transfer

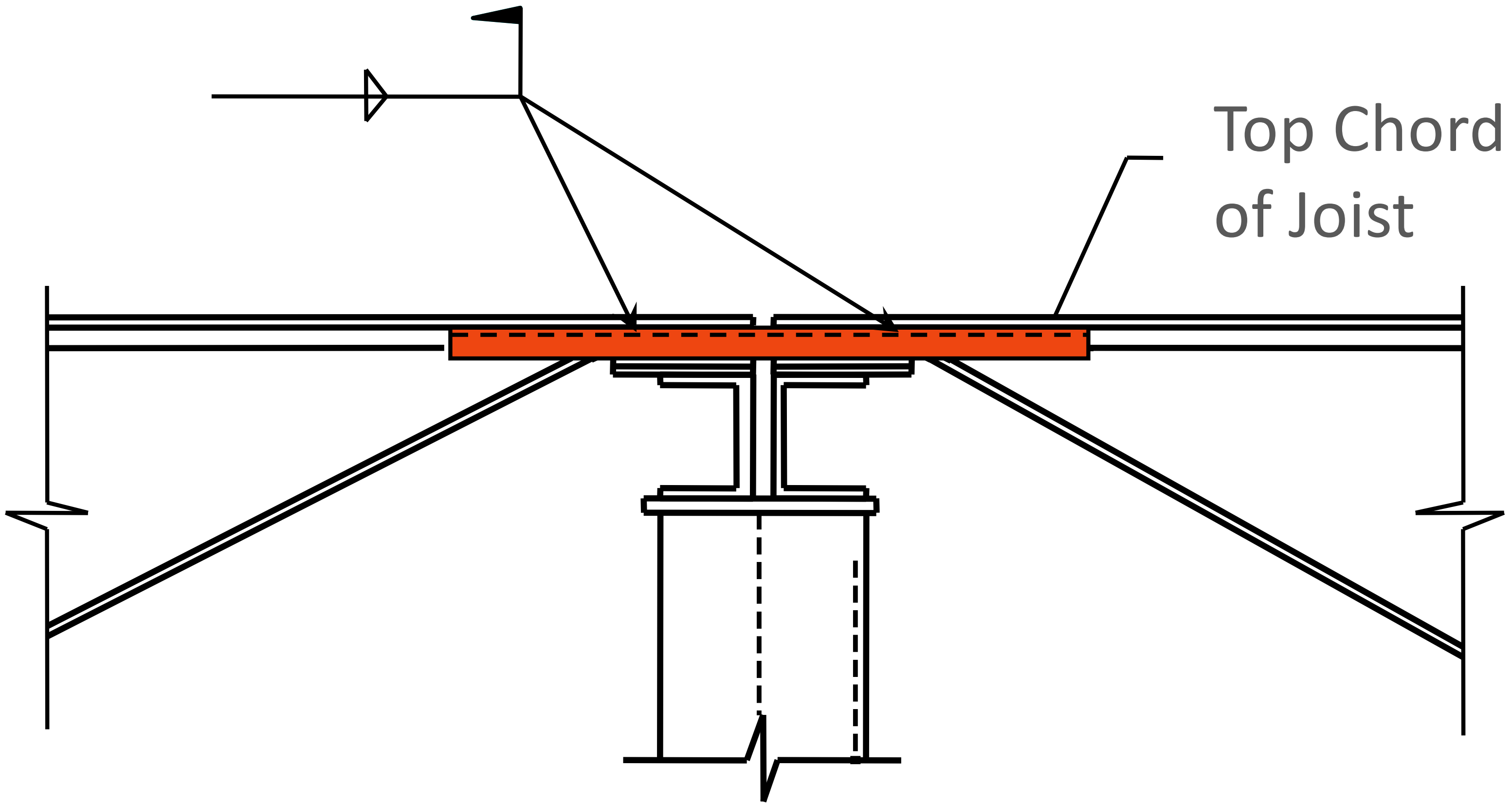
- All top chord axial loads and end moments should be transmitted directly via tie plates or tie angles. The eccentricity of horizontal forces transferred through the bearing seats is then avoided.



Joist Tie Plate

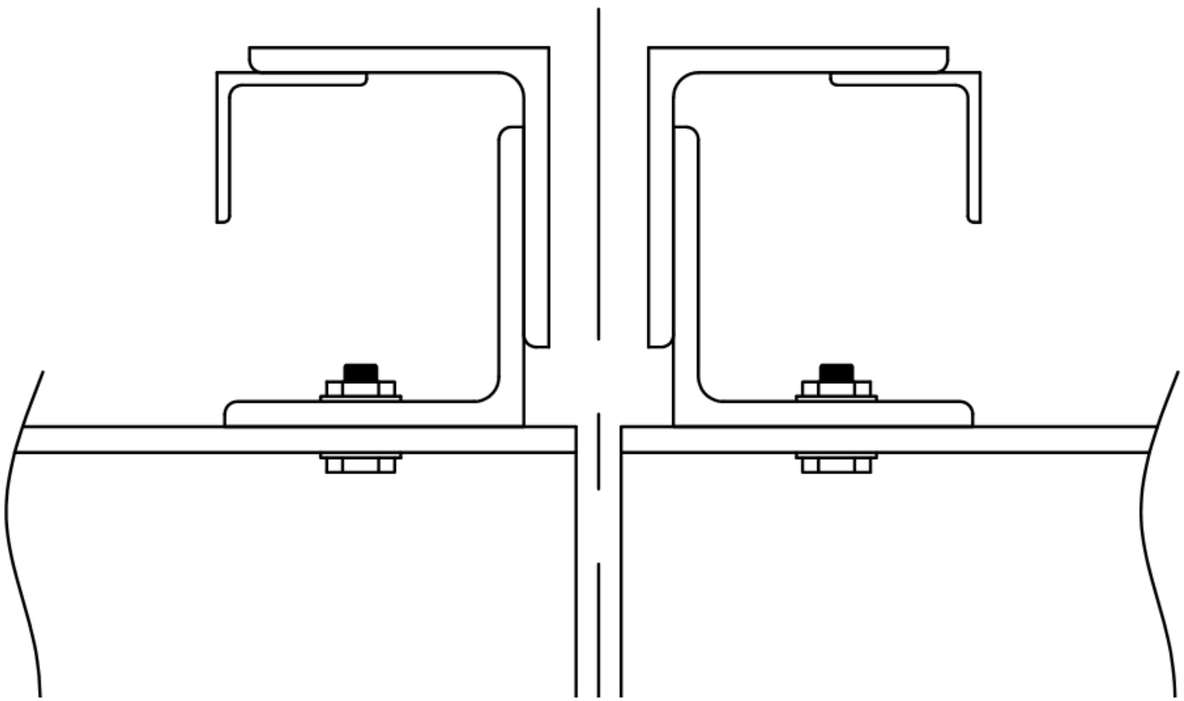


Joist Tie Angles



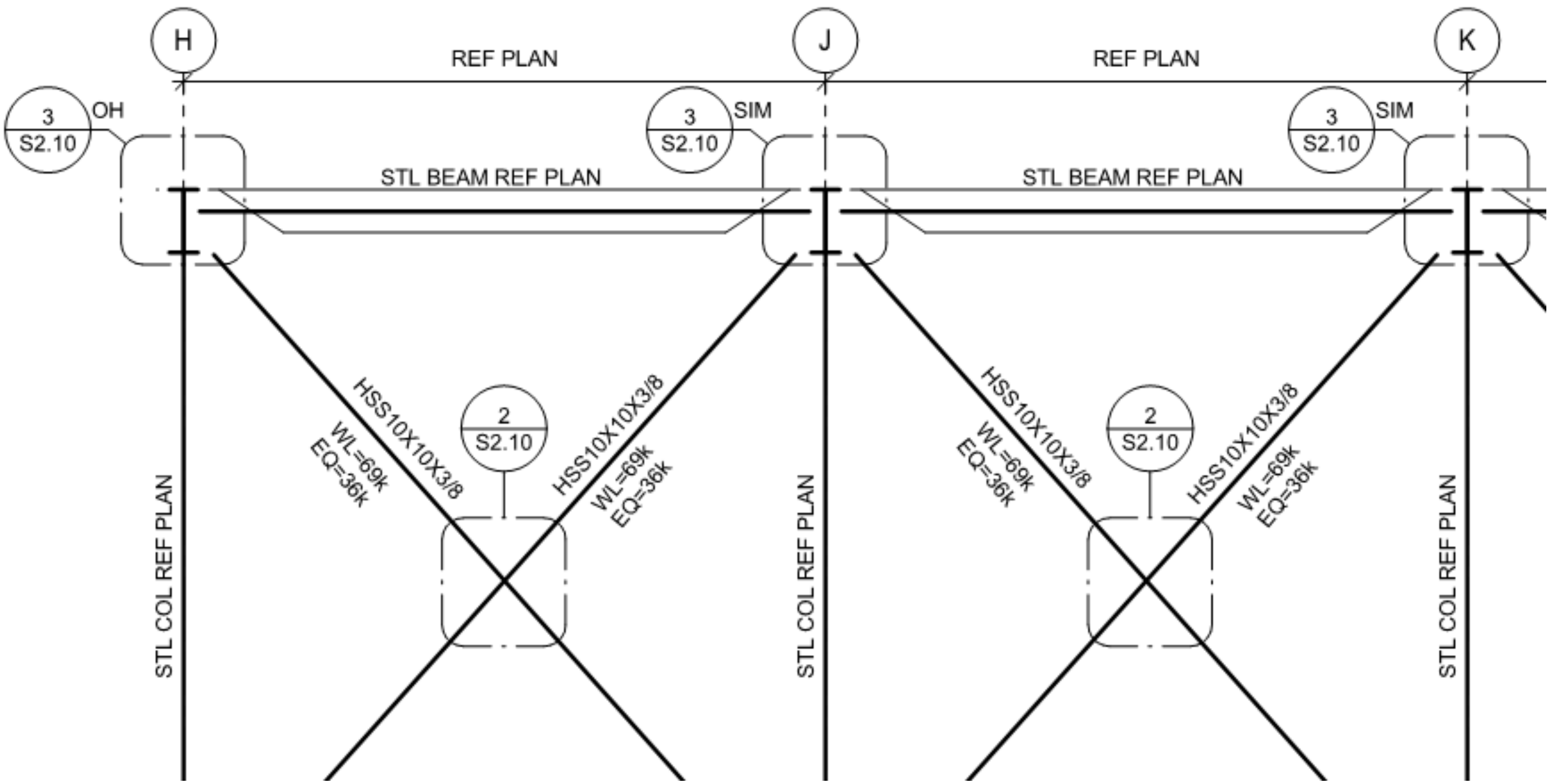
Joist Tie Angles

- Note the orientation of the tie angles, to avoid the joist end webs, in the event they are outside that chord angles rather than in the chord gap. This also allows for a down-hand field weld.



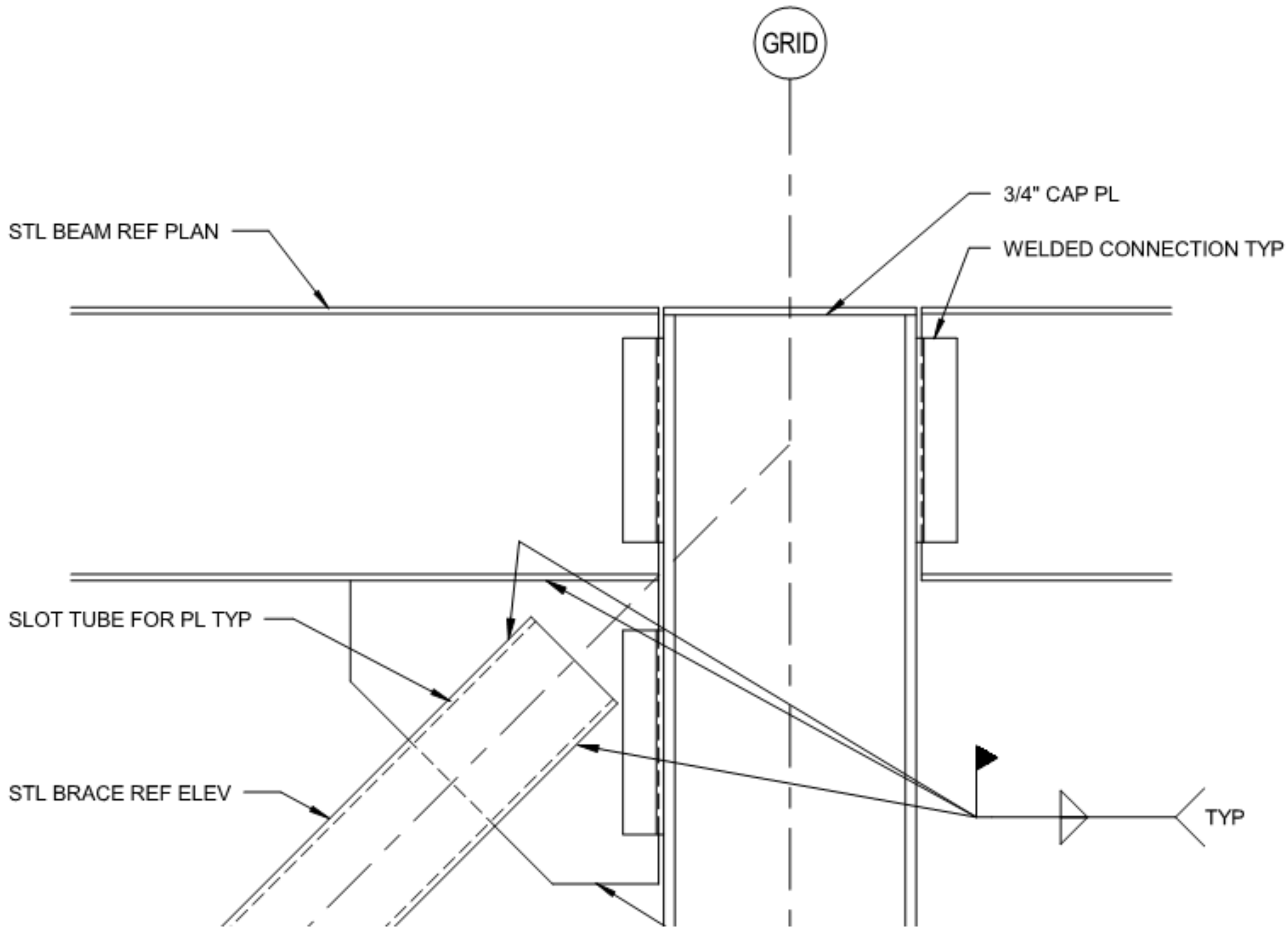
X Braced Frame

- If a joist is used in the X braced frame bay, the axial load will travel through the webs and bottom chord, in addition to the top chord.

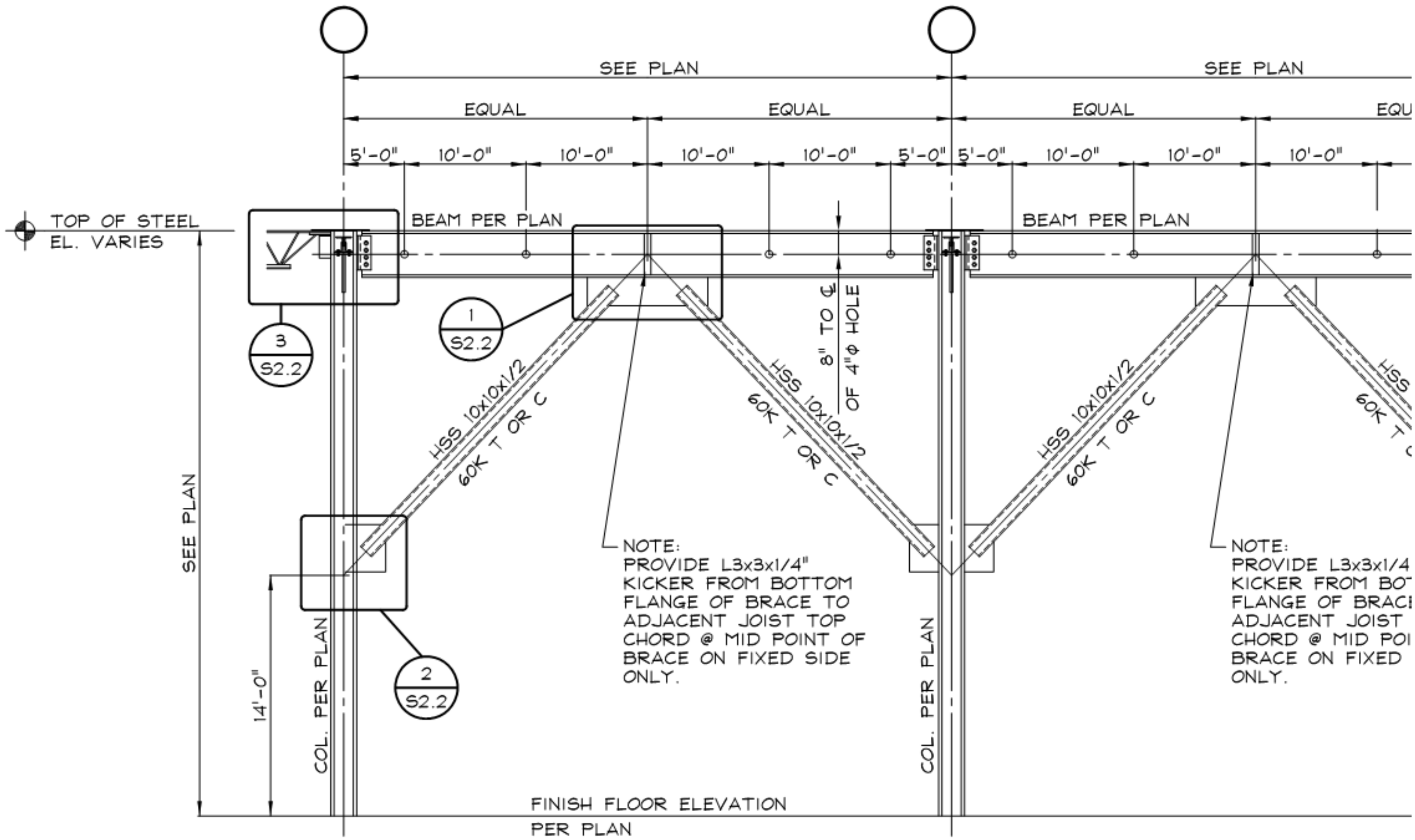


X Braced Frame

- Attention is required for the collector joist to braced frame bay transfer connection.



Braced Frame and Collector Joist

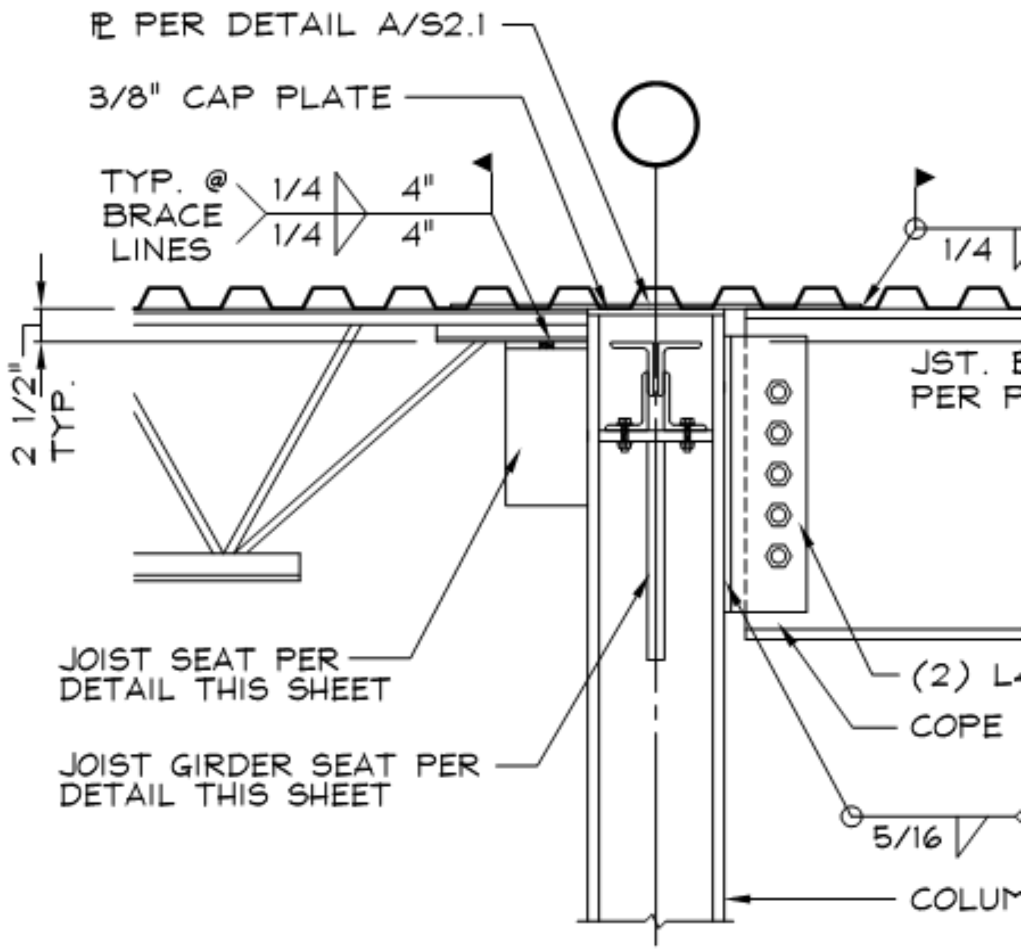


TYPICAL BRACE ELEVATION

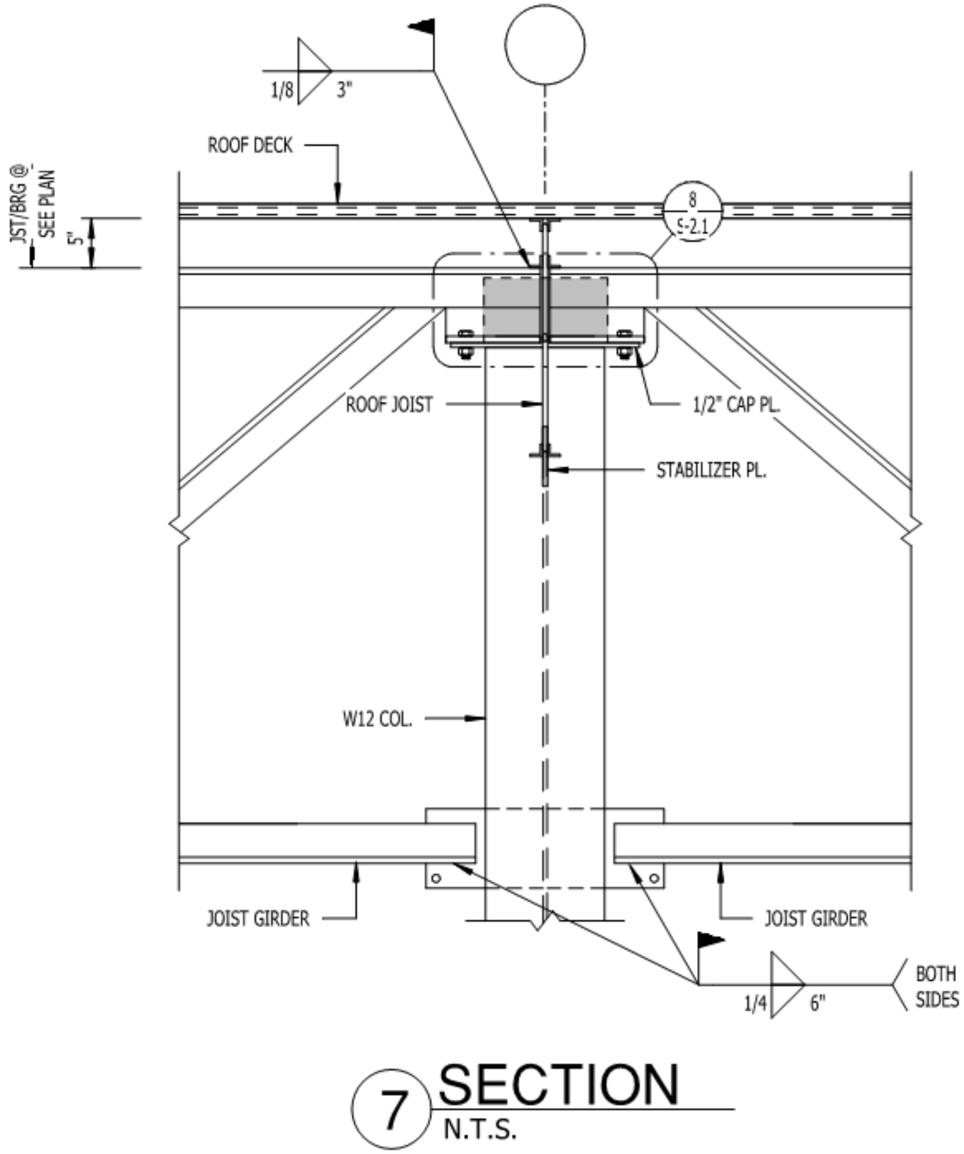
SCALE: NONE

Braced Frame and Collector Joist

- This is a good, complete detail.



Rigid Frames – End Moments



Steel Joist Institute Tools

Virtual Joists

The virtual joists table provides the approximate section properties for virtual joists for use by the structural engineer of record (SER) in preparing the building structural models.

DOWNLOAD TOOL

Joist Girder Moment Connection Design Tools

These design tools assist the SER, the connection designer and the steel fabricator with the complex task of designing appropriate connections between Joist Girders and columns. The tools can be utilized for wide flange and HSS columns.

DOWNLOAD TOOL

Virtual Joist Girders

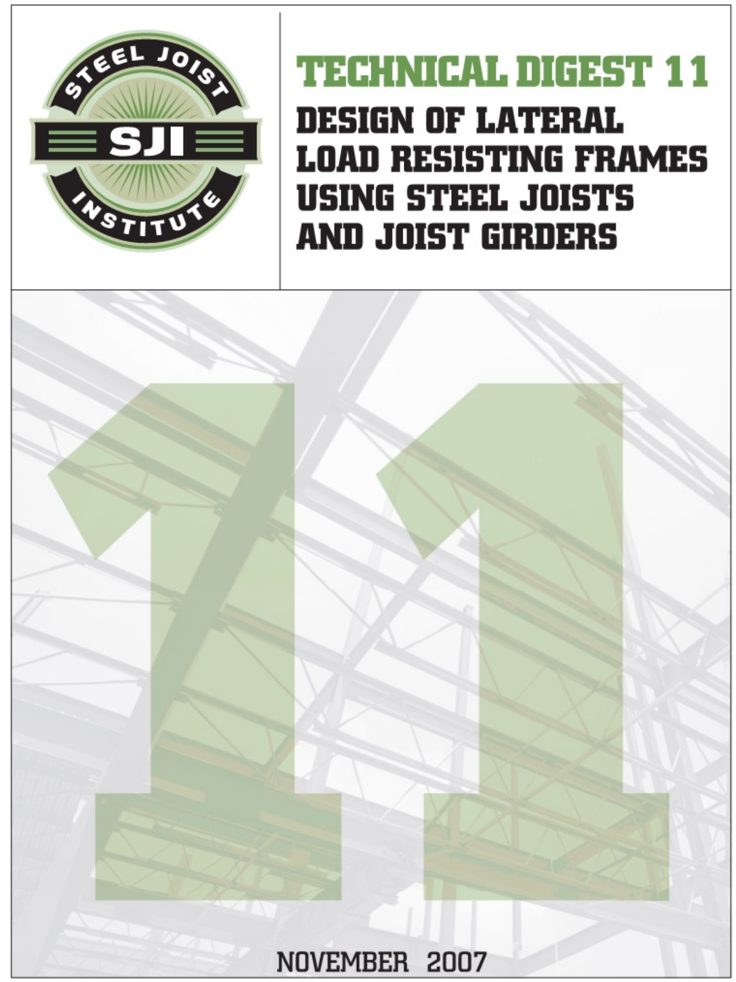
The virtual joist girder table provides the approximate section properties for virtual joists girders for use by the structural engineer of record (SER) in preparing the building structural models.

DOWNLOAD TOOL

www.steeljoist.org

Lateral Load Resisting Frames

- An additional resource is the Steel Joist Institute Technical Digest #11, *Design of Lateral Load Resisting Frames Using Steel Joists and Joist Girders*



Polling Question #3

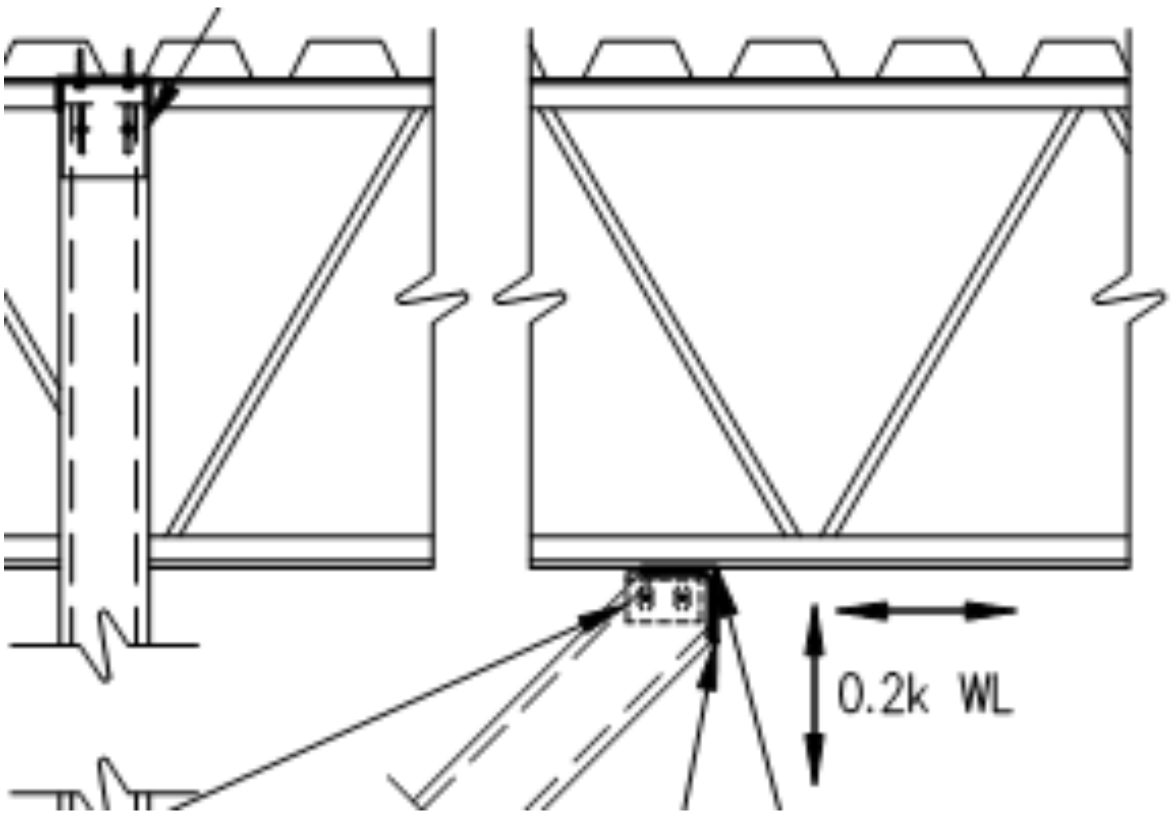
T/F: Joist seats are the best method to transfer axial loads.

A. True

B. False

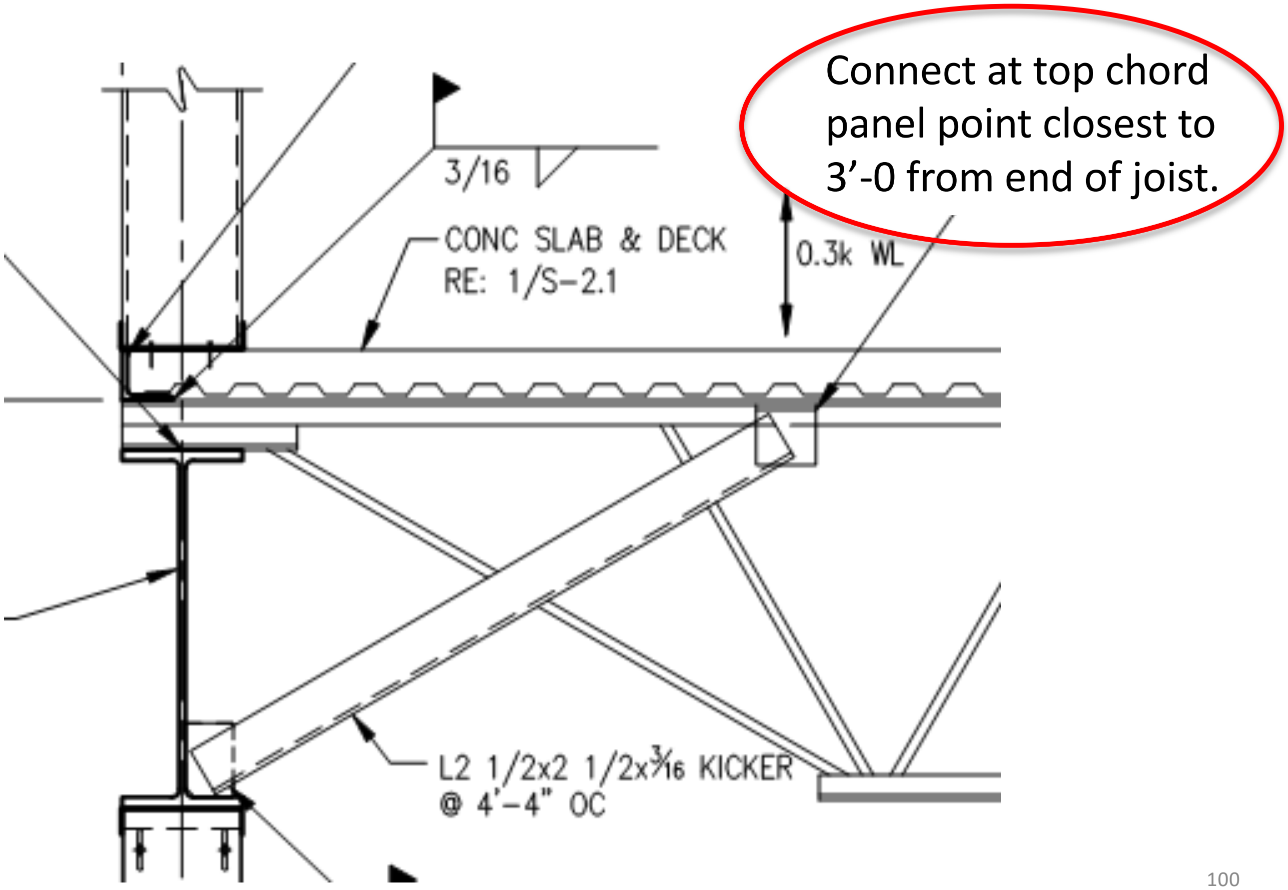
Wind Bracing Kickers

- Specifying Professional to provide horizontal and vertical components of wind bracing forces being transmitted to joists.



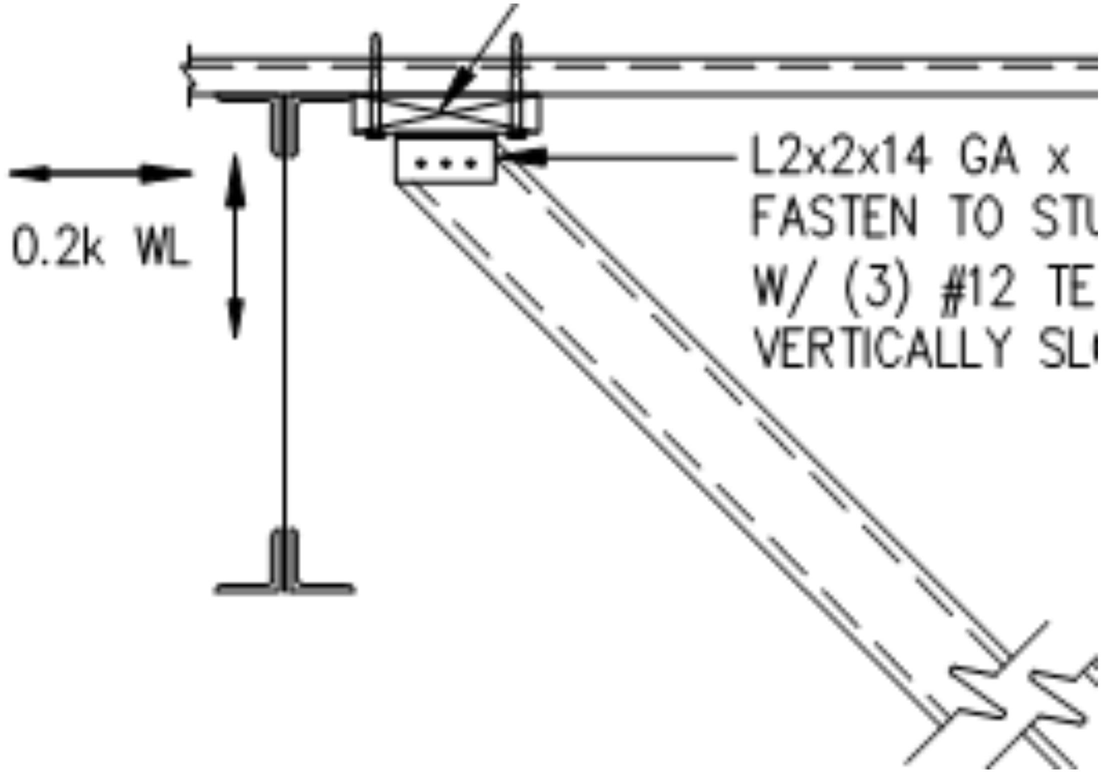
Wind Bracing Kickers

- This example does not include a horizontal component, but with ASD, assumptions can be made about an added axial wind load controlling the joist top chord design.
- It would be helpful to have guidance as to the location of the load.



Wind Bracing Kickers

- The lateral horizontal force will be assumed to transfer in to the deck diaphragm and the joist will not be designed for a lateral, out-of-plane load.



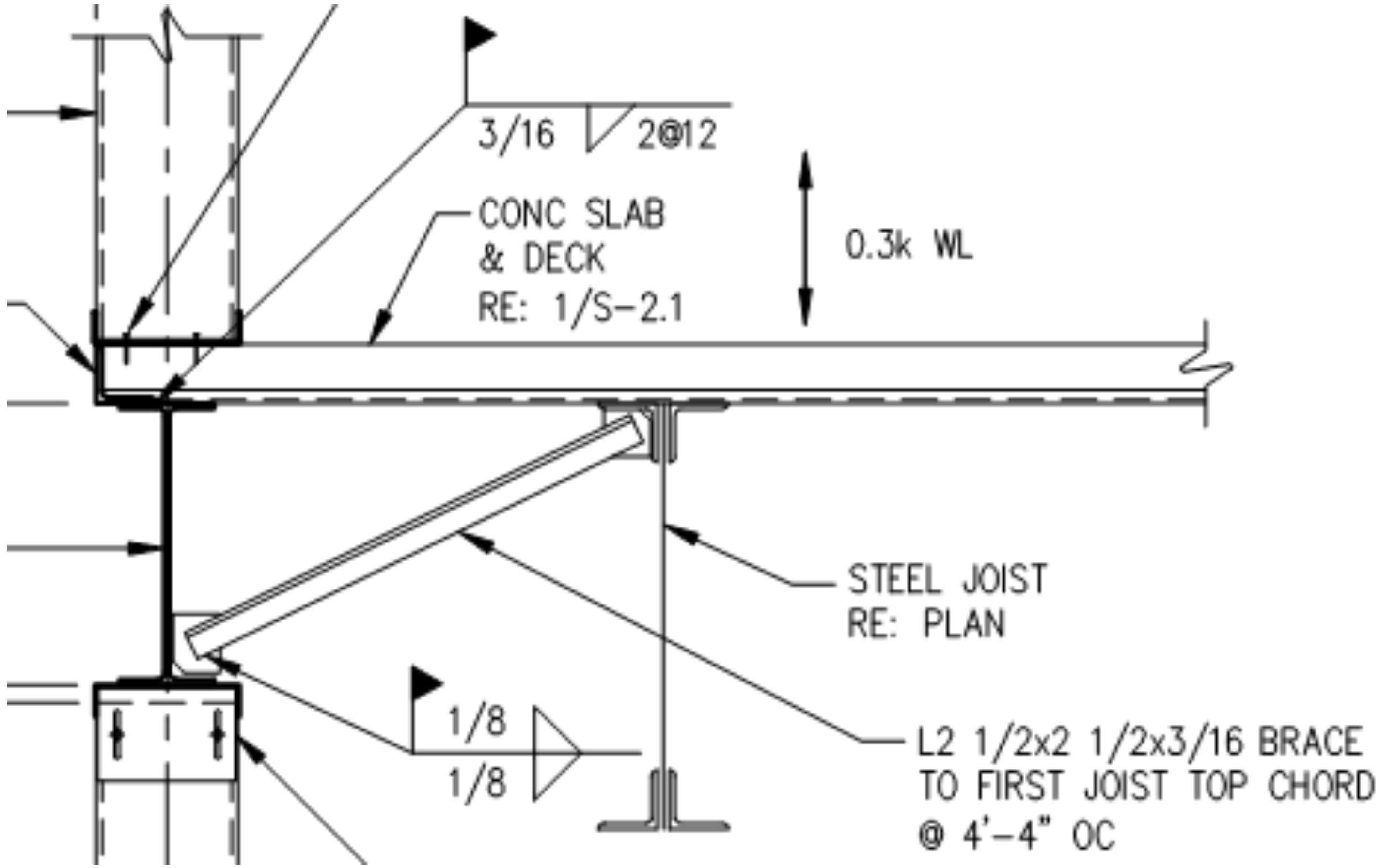
Out-of-Plane Loads

- SJI Specification
  - "Joist Girders, K-Series, LH-Series, and DLH-Series shall be open web, in-plane load-carrying steel members utilizing hot-rolled or cold-formed steel, including cold-formed steel whose yield strength has been attained by cold-working"

- Any out-of-plane loads should be resolved into the deck via structural bracing or similar and not through the joist

Wind Bracing Kickers

- This is an example of an end wall condition, with a series of wind brace loads along the joist span.



Wind Bracing Kickers

- Where wind forces “kicker” to joist and create vertical component loads, reference IBC for deflection criteria

f

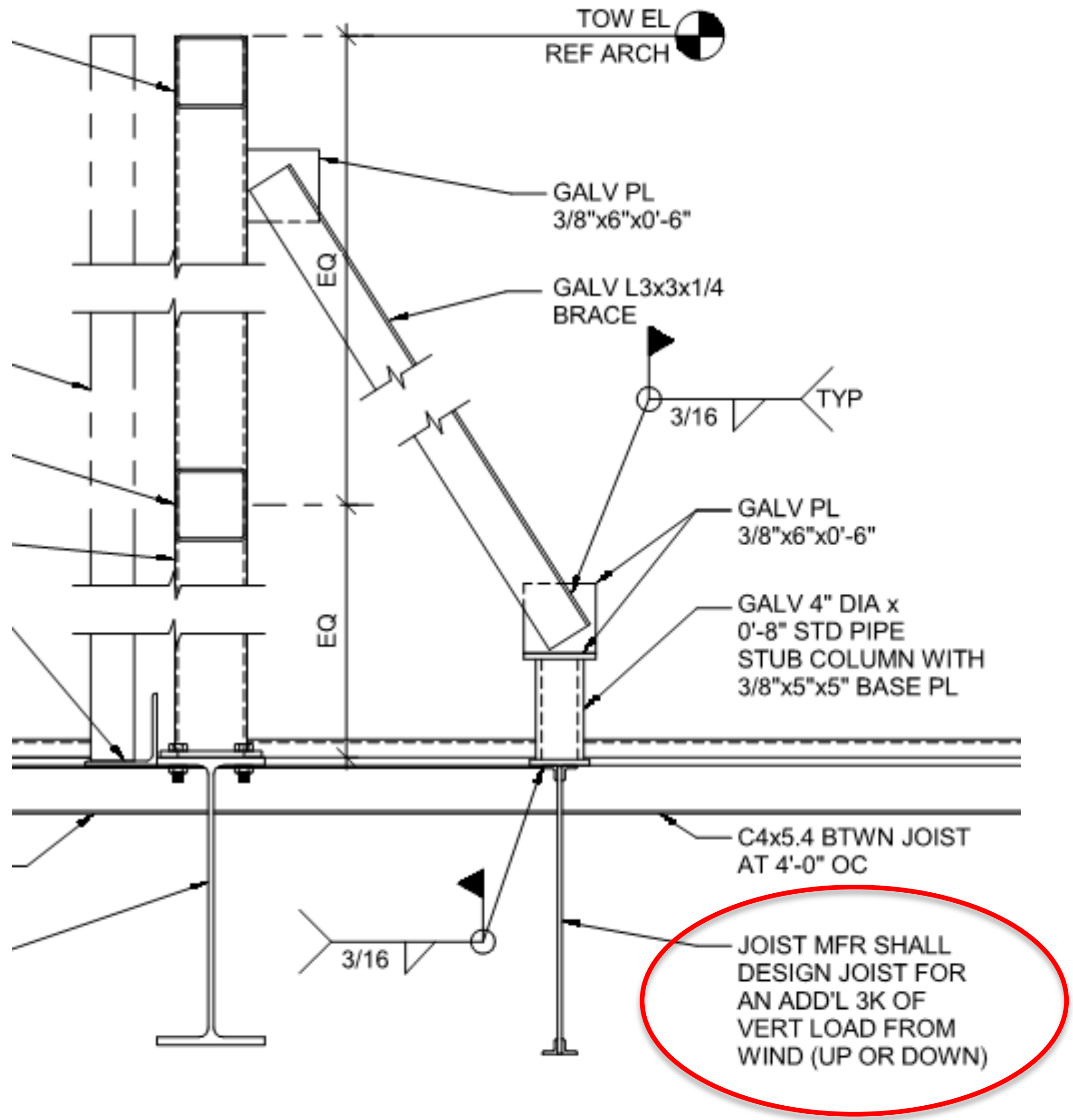
TABLE 1604.3
DEFLECTION LIMITS[a, b, c, h, i]

CONSTRUCTION	*L*	*S* or *W*[f]

f. The wind load is permitted to be taken as 0.42 times the “component and cladding” loads for the purpose of determining deflection limits herein.

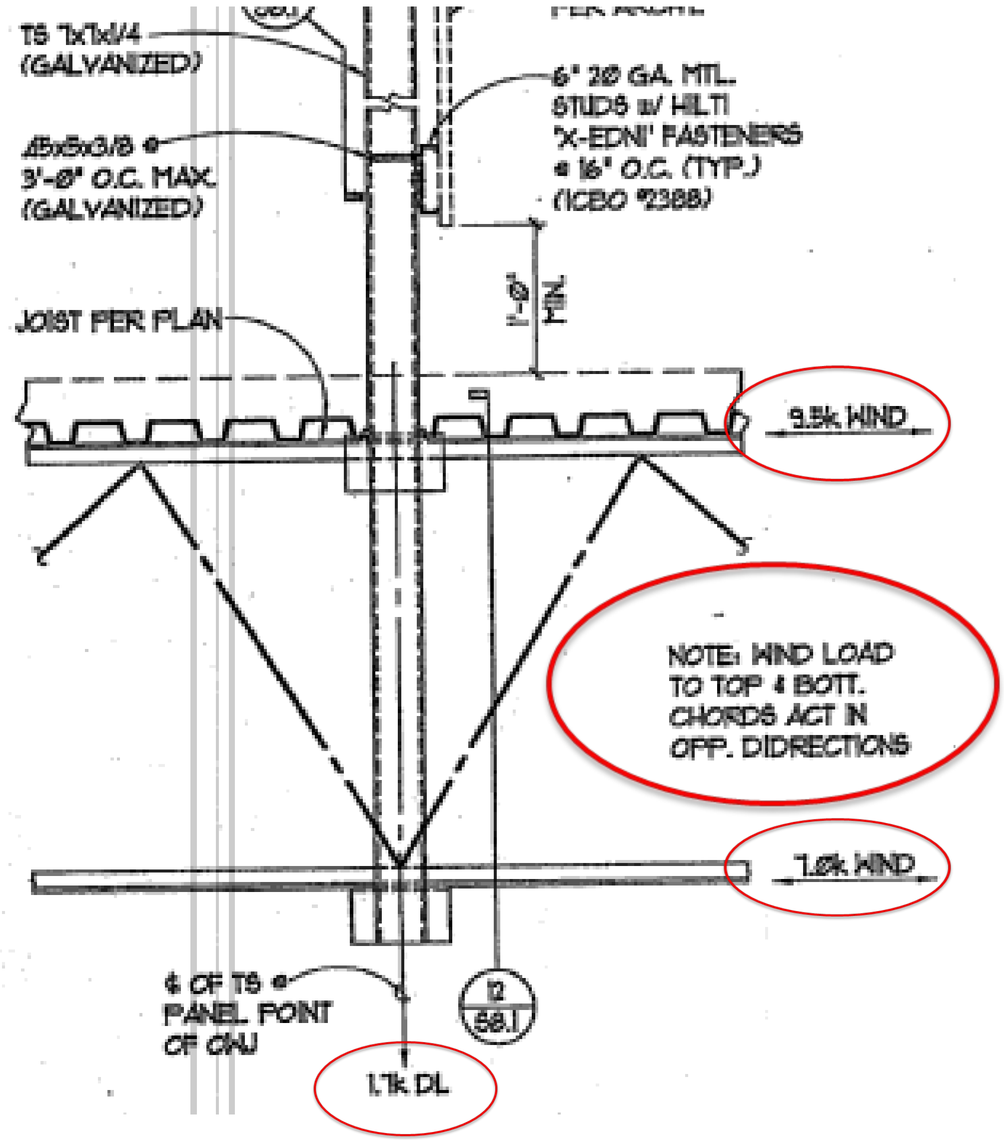
Roof Screens

- Wind creates an overturning moment from roof screens.
- A bracing member can be used to resolve the overturning effect, creating vertical wind loads on the roof joists.

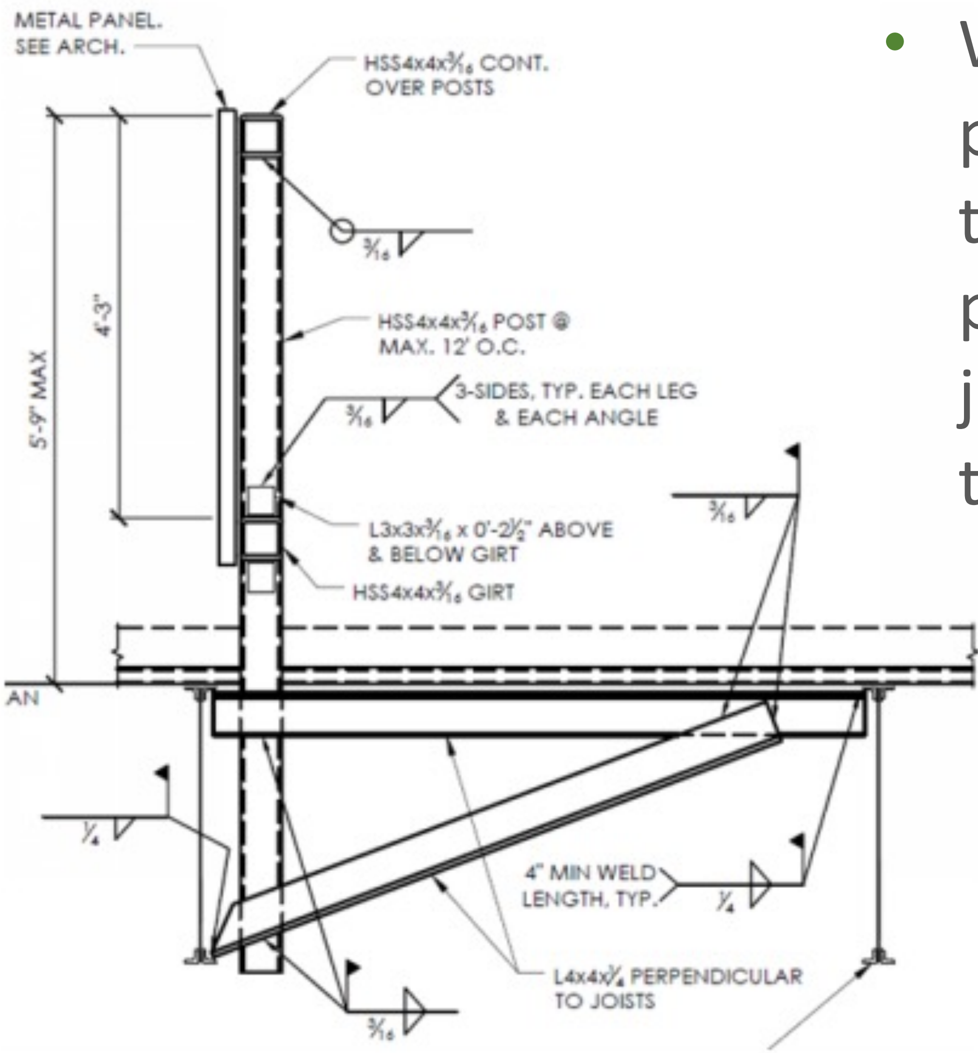


Roof Screens – Perpendicular to Joist

- Where the wind screen post is not braced, and the screen is perpendicular to the joists, it is best to extend the post and attach to both the top and bottom chord, resolving the overturning moment into a couple.



Roof Screens – Parallel to Joist

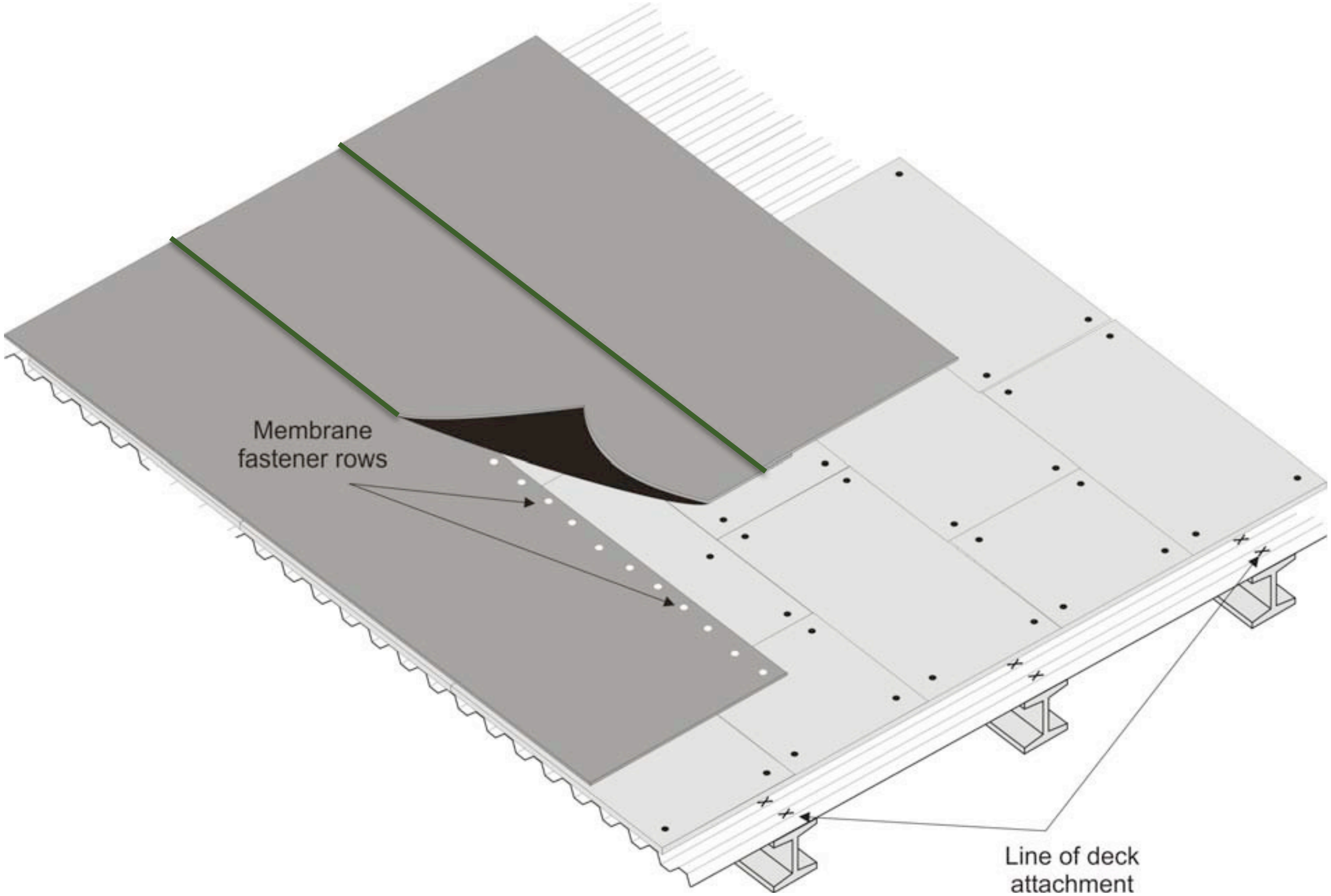


- Where the wind screen post is not braced above the roof, and the screen is parallel to the joists, the joists cannot take a torsional load.
  - It is best to extend the post and attach to both the top and bottom chord, resolving the overturning moment with bracing members below the roof.

Mechanically Fastened Membrane Roofs

- Single-ply membrane roofing is the most common system above steel joists.
- The single-ply membrane may be fully adhered.
- Alternately, and increasingly, a seam-fastened, mechanically-attached method of installation is being utilized.
- Since 2000, the width of the membrane rolls has been increasing dramatically.

Mechanically Fastened Membrane Roofs



From the National Research Council of Canada

Mechanically Fastened Membrane Roofs

- With this installation method, the single-ply membrane sheet is mechanically-attached along its outer edges into the roof deck, which results in a larger tributary uplift load per fastener and fasteners being placed in linear, non-uniform loading configurations of the roof deck and underlying supporting structure
- The directionality of the seams relative to joist and deck span direction is usually not known or controlled.

Mechanically Fastened Membrane Roofs

From the National Research Council of Canada

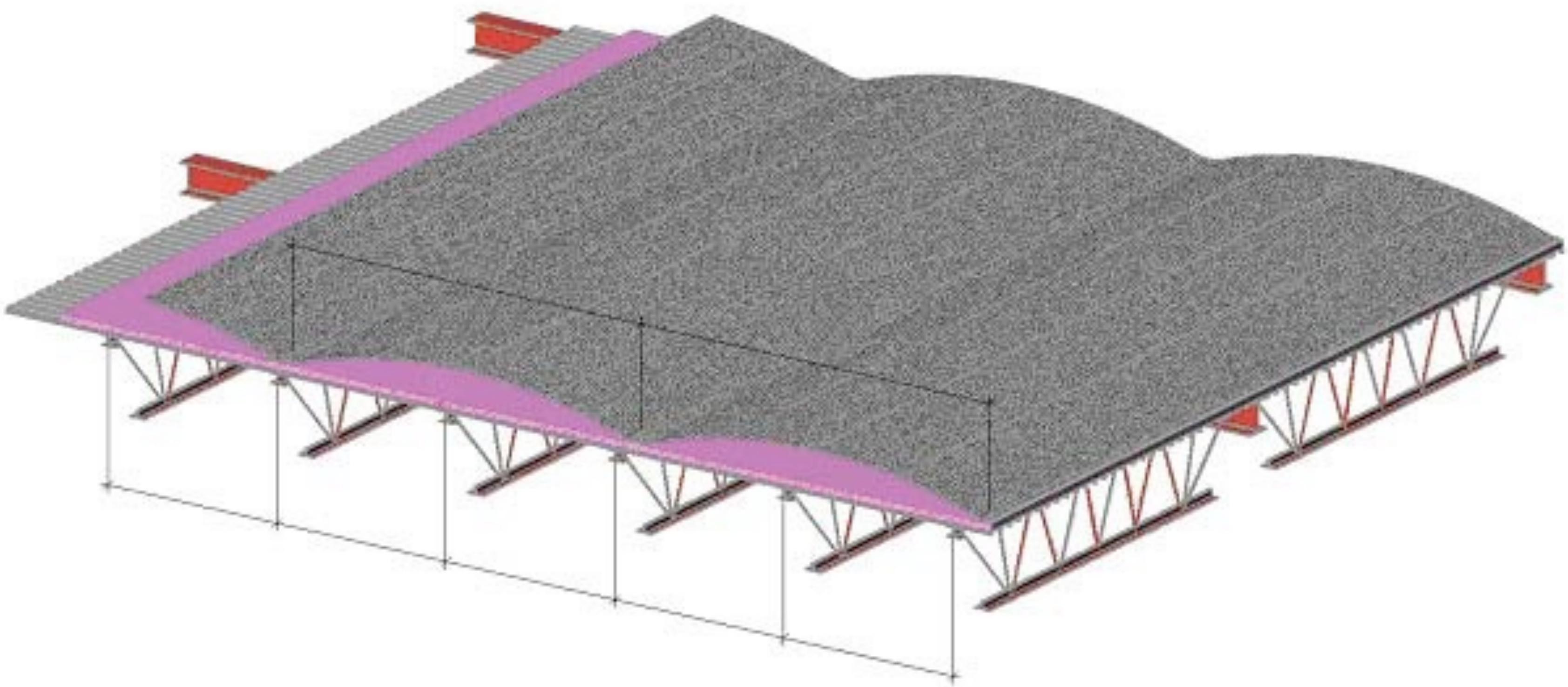
- Wind tunnel test

Mechanically Fastened Membrane Roofs

From the National Research Council of Canada

- Wind tunnel test

Deck and Joist Loading



- The tributary width that creates the "line loading" can easily become twice the actual joist tributary width.

Joist Design for Membrane Roof

- Typically, the roofing membrane is not considered in structural contract documents.
- The roofing membrane specification can be vague, with references like “attach per manufacturer recommendations”.
- A design for uniform loads may not be adequate where in fact the uplift will be applied as linear loads.
- FM Global Data Sheet 1-29 now provides separate tables for deck spans when the distance between roof cover fasteners is more than one-half the deck span.
- A fully adhered roof membrane may be the best option from a structural perspective.

Polling Question # 4

Should wind loads be presented as ASD or LRFD values?

A. ASD

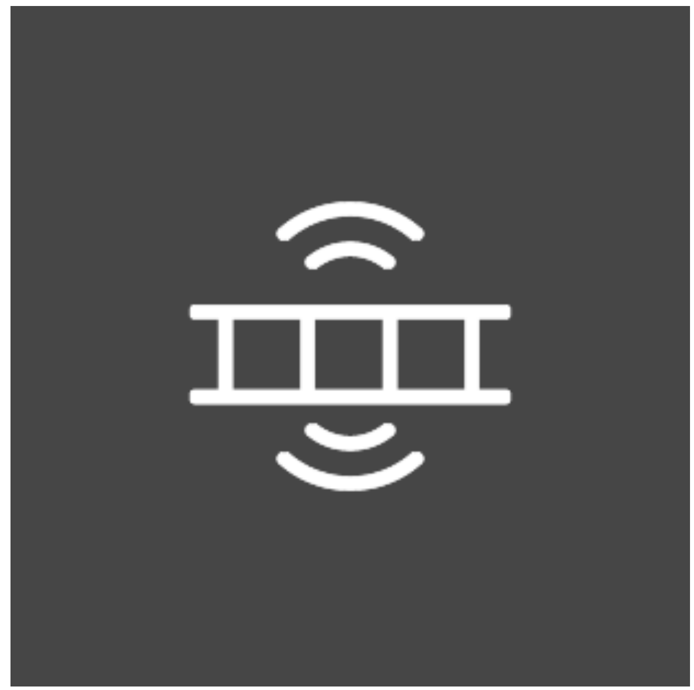
B. LRFD

C. Either provided loads are clearly notated as ASD or LRFD

SJI Design Tools

Free downloads:

- Joist Girder Analysis Tool
- Joist and Joist Girder Reinforcement Tool
- Historical Load Tables
- Roof Bay Analysis Tool
- Floor Bay Analysis Tool
- Joist Girder Moment Connection Design Tools
- Virtual Joists
- Virtual Joist Girders
- Floor Vibration



SJI Publications

Technical Digests

- #3 Structural Design of Steel Joist Roofs to Resist Ponding Loads
- #5 Vibration of Steel Joist – Concrete Floors
- #6 Design of Steel Joist Roofs to Resist Uplift Loads
- #7 Special Profile Steel Joists and Joist Girders
- #8 Welding of Open Web Steel Joists and Joist Girders
- #9 Handling and Erection of Steel Joists and Joist Girders
- #10 Design of Fire-Resistive Assemblies with Steel Joists
- #11 Design of Lateral Load Resisting Frames Using Steel Joists and Joist Girders
- #12 Evaluation and Modification of Open Web Steel Joists and Joist Girders
- #13 Specification and Design of Composite Steel Joists

Catalogs

- 45th Edition Standard Specifications Load Tables and Weight Tables for Steel Joists and Joist Girders - *Free download*
- Second Edition CJ-Series Composite Steel Joists – *Free download*
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