Bridging – How it Works and What to Work Around

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SJII Webinars

- Credits – 0.15 CEUs, 1.5 PDHs
- Certificates – issued within 2 weeks
Learning Objectives

• Attendees will learn the types and roles of bridging.

• The governing criteria for the bridging spacing and sizing will be reviewed.

• The connection details and options will be explored, both the specification requirements and the realities of field installation.

• A number of potential conflicts and resolutions for bridging locations will be discussed, such as working around sprinkler systems.
Bridging – How it Works and What to Work Around
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The Steel Joist Institute hosts the webinar "Bridging – How it Works and What to Work Around."

Steel joists provide excellent economy for vertical, in-plane loads. The lateral support bracing system – bridging – is a key to the performance of a steel joist. This webinar will explore steel joist bridging from two perspectives. First, the types, roles, forces, and specification criteria – “How It Works.” And second, the challenges, potential conflicts, and solutions for the bridging layout and installation – “What to Work Around.”
Bridging – How it Works and What to Work Around

- Basic
- Safety
- Theory behind Bridging
- SJI specification Requirements
- Types of Bridging
- Bridging Spacing and Sizes with Tables
- Joist Girder Bridging
- Anchorage of Bridging
- Special Usages
- Field Conditions
- How to Specify Bridging
THE 44TH EDITION
K-Series | LH-Series | DLH-Series | Joist Girders

STANDARD SPECIFICATIONS
Load Tables and Weight Tables for Steel Joists and Joist Girders

Basics

Bridging is intended to deal with the internal bracing forces which occur in the joist system and not used for forces external to the joist system.

Since Joist are very strong in the vertical plane (strong axis) but less strong in the horizontal plane (weak axis) bridging plays a key role in the overall strength of a open web joist system.

- Bridging provides lateral stability during the erection process.
- Bridging provides lateral stability when the chords are not braced during the application of loads.
  - Bottom chords during uplift
  - Top chords when Standing Seam decks are used.
  - Brace the bottom chord for webs in compression.
Safety

- Bridging and metal deck installation are critical to developing the full load carrying capacity of a steel joist.

- Install Erection Stability Bridging, where required, before attempting to support any weight on the joist.

- Make sure horizontal bridging rows are continuous and anchored at both ends.

- Limit the magnitude and placement of construction loads.
Safety – Tie Joists

- Tie joists (at column lines) are often set first, before adjacent joists.
- This is potentially dangerous where Erection Stability Bridging is required.
Safety – Tie Joists

- A Danger Tag is used at tie joists as a warning, and OSHA requires alternate methods of stabilizing the tie joist.
Theory Behind Bridging

- Joist behave like wide flange beams with compression in the top chord and tension in bottom chord.

- The result is Lateral Torsional Buckling.

- Bridging provides lateral restraint either permanently or until other means of restraint are provided.

- When deck is attached this provides the lateral restraint to the joist top chord.
Joist behaves like a beam!
Compression (top) portion buckles with tension (bottom) portion resisting...

Lateral torsional buckling
Without lateral restraint joists tend to deflect out of plane.

Bridging and end anchorage resist this deflection.
Joists have very low out-of-plane flexural and torsional stiffness!
With bridging installed the deflection is less and there is a significant increase in the load carrying capacity.
With bridging installed on the bottom chord, it (bottom chord) is kept in plane with the top chord and increases the capacity.
With full lateral restraint the top chord will buckle in plane
With bridging at the 1st bottom chord panel point, when the bottom chord and the end web is in compression there is a significant increase in capacity.
First Bottom Chord Panel Point Forces

Gravity Load

Uplift Load
Parallel Joists
Axial force diagram for one line of bridging

Axial forces in the bridging accumulate
SJI Specification Requirements

- Slenderness Limits
- Uplift Bridging
Construction Loads and Strength

- The key to joist strength, before decking is attached, is top chord slenderness about the vertical axis.

- $R_{yy}$
Slenderness Limit Variation

• Before 2010 Spec…
  – K-Series $L/R_{yy} = 145$
  – LH-Series $L/R_{yy} = 170$

• In the 2010 and 2015 Spec (44th edition)
  – K and LH series are combined and the $L/R_{yy}$ limits are the same for all joist types.
    – Variable Slenderness Limit
  – Recognize that construction stress varies with joist span (tributary area)
  – Recognize that construction stress varies with span to depth ratio
Radius of Gyration Requirement Limits

The radius of gyration of the top chord about its vertical axis shall not be less than:

$$r_y \geq \frac{\ell}{\left( 124 + 0.67 \, d_j + 28 \, \frac{d_j}{L} \right)} \text{, in.}$$  \hspace{1cm} (103.4-1a)

$$r_y \geq \frac{\ell}{\left( 124 + 0.026 \, d_j + 0.34 \, \frac{d_j}{L} \right)} \text{, mm}$$  \hspace{1cm} (103.4-1b)

or

$$r_y = \frac{\ell}{170}$$  \hspace{1cm} (103.4-2)

Where,

d\text{, is the steel joist depth, in. (mm)}

L\text{ is the design length for the joist, ft. (m)}

r\text{ is the out-of-plane radius of gyration of the top chord, in. (mm)}

\ell\text{ is the spacing in inches (millimeters) between lines of bridging as specified in Section 104.5(d).}
## Slenderness Limit Variation

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SLENDERNESS LIMIT

\[
(124 + 0.67d_j + 28\frac{d_j}{L})
\]
Bottom Chord Bridging for Uplift

- SJI Standard Specifications, K, LH, DLH Series

  “...When these forces are specified, they must be considered in the design of joists and/or bridging. A single line of bottom chord bridging must be provided near the first bottom chord panel points whenever uplift due to wind forces is a design consideration.”
Types of Bridging

• Cross Bridging
• Horizontal Bridging
• Uplift Bridging
• Erection Bridging
• Construction Bridging
• Permanent Bridging
UPLIFT BRIDGING
PLACED NEAR FIRST BOTTOM CHORD PANEL POINT AT BOTH ENDS OF JOIST WHEN NEEDED

BOLTED ERECTION STABILITY CROSS BRIDGING (EX)

HORIZONTAL BRIDGING

HORIZONTAL BRIDGING
Types of Bridging

- Cross Bridging
- Horizontal Bridging
- Uplift Bridging
Bottom Chord Bridging for Uplift

• When the joist is subject to uplift, the bridging provides lateral restraint for the bottom chord in compression.
• Generally the joist bottom chord will fail out of plane between the rows of bridging.
Bottom Chord Bridging Spacing

• Bottom Chord, 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

  – A common option is to equally space bottom chord rows between the first bottom chord panel points
Bridging Spacing for Uplift

Typical Bridging Configuration:
5 @ 8’-0”

Uplift Bridging
Erection Stability Bridging

A Common Alternative
4 Rows Equally Spaced

4 Rows Equally Spaced Between Uplift Bridging
Erection Stability Bridging

• Joists exhibit varying degrees of stability dependent upon the span, depth, member sizes, self weight and other parameters.

• Erection Bridging provides stability to the joist prior to any load (other than self weight) being placed on the joist.

• Bolted diagonal Erection Bridging which must be installed prior to releasing hoisting cables may be required.
Erection Stability Bridging
Erection Stability Bridging

\[
W = \frac{-b \pm \sqrt{b^2 - 4\cdot a \cdot c}}{2\cdot a} \text{ lbs.}; \quad \text{If } \frac{W_u}{W_{\text{actual}}} > 1.00 \text{ Erection Bridging is not required.}
\]

\[
b = P \cdot \frac{\pi^2 + 3}{12} \cdot \frac{\pi^2 + 4}{16} - \frac{\pi^4 \cdot E \cdot I_y}{2 \cdot (k \cdot L)^3} \cdot \left[ \beta_x \cdot \left( \frac{\pi^2 - 3}{24} \right) - \frac{y_o}{2} \right]
\]

\[
a = \left( \frac{\pi^2 + 3}{24} \right)^2 = 0.732
\]

\[
c = (P)^2 \left( \frac{\pi^2 + 4}{16} \right)^2 - \frac{\pi^4 \cdot E \cdot I_y}{2 \cdot (k \cdot L)^3} \cdot \left[ P \cdot \left( \beta_x \cdot \frac{\pi^2 - 4}{16} - a_e \right) + \frac{\pi^4 \cdot E \cdot C_w}{2 \cdot (k \cdot L)^3} + \frac{\pi^2 \cdot G \cdot J}{2 \cdot k \cdot L} \right]
\]

Where:

\[
P = \text{ Factored weight of erector} = 1.2 \times \text{(assumed weight of 250 lbs.)} = 300 \text{ lbs.}
\]
Erection Stability Bridging

• Bridging Lines
  – For spans up through 60 feet (18288 mm), welded horizontal bridging may be used except where the row of bridging nearest the center is required to be bolted diagonal bridging as indicated by the Red shaded area in the Load Table.

  – For spans over 60 feet (18288 mm) bolted diagonal bridging shall be used as indicated by the Blue and Gray shaded areas of the Load Table.
Shading for Erection Stability Bridging

- Red shading: one row nearest the center shall be bolted diagonal bridging and installed before release of hoisting cables.
Shading for Erection Stability Bridging

- Blue shading: all rows shall be bolted diagonal and the two rows near 1/3 points shall be installed before the release of hoisting cables
Shading for Erection Stability Bridging

- Grey shading: all rows shall be bolted diagonal bridging and installed before release of hoisting cables
Construction Bridging

- Construction Bridging – Installed after the Erection Bridging.
- Construction Bridging All rows installed prior to construction loads being placed.
- Construction Bridging - Includes uplift bridging.
Construction Stress

\[ F_{\text{construction}} = \left( \frac{\pi^2 E}{\left( \frac{0.9 \ell_{br}}{r_y} \right)^2} \right) \geq 12.2 \text{ ksi} \]

Note that this is an ultimate force

Where,

E = Modulus of Elasticity of steel = 29,000 ksi (200,000 Mpa) and \( \frac{\ell_{br}}{r_y} \) is determined from Equations 103.4-1a, 103.4-1b or 103.4-2

Construction stress develops \textit{approximately} 25% of the joist load carrying capacity.
Construction Loads

Construction Bridging
Construction Load – Deck Bundles

- Deck bundles are shown on joists with bridging installed.
- Typically, all bridging rows shall be installed before any construction loads are applied.
- OSHA allows an exception for placement of deck bundles, with certain conditions.
Construction Load – Deck Bundles

Placement of a deck bundle on joists that are not fully bridged is allowed with the following restrictions:

• The deck bundle shall be placed on a minimum of three joists.
• The joists supporting the deck bundle shall be attached to the support at both ends.
• At least one row of bridging shall be installed and anchored.
• The deck bundle weight shall not exceed 4,000 pounds.
• The edge of the deck bundle shall be placed within 1 foot from the end of the joists.
Horizontal Bridging Row at End Space

Where a bolted diagonal bridging row terminates to a wall or other vertically stiff support, bolted horizontal bridging is suggested for the end space.

This will allow for the difference in deflection between a longspan joist and the stiff support – a wall as shown in the sketch below, or a column as shown in the photo.
Permanent Bridging

- Permanent Bridging - All rows should stay installed unless a qualified professional does an evaluation and determines that some bridging can be removed.
Bridging Spacing and Size Requirements with Tables

- How many rows of bridging?
- What type of bridging?
  - Horizontal / Diagonal
  - Welded / Bolted
- What is the bridging force?
- What is the bridging size?
Using the Bridging Tables

• Bridging requirements can be either calculated or looked up in a table.

• When joists are specified as load/foot (24K350/200) the joist manufacturer will calculate the bridging requirements.

• When the joist are specified with a SJI designation (24K6) the SJI tables will be used to for the bridging requirements.

• In some cases there can be some economic advantages to calculating the bridging requirements, since the tables are always conservative.
Bridging Spacing

Quantity and Spacing
The maximum spacing of lines of bridging, $\ell_{br}$, shall be the lesser of,

$$\ell_{br} = \left( 124 + 0.67 d_j + 28 \frac{d_j}{L} \right) r_y, \text{ in.} \quad (103.4-1a)$$

$$\ell_{br} = \left( 124 + 0.026 d_j + 0.34 \frac{d_j}{L} \right) r_y, \text{ mm} \quad (103.4-1b)$$

or

$$\ell_{br} = 170 r_y \quad (103.4-2)$$

Where,
- $d_j$ is the steel joist depth, in. (mm)
- $L$ is the Joist Span length, ft. (m)
- $r_y$ is the out-of-plane radius of gyration of the top chord, in. (mm)
# Bridging Spacing Table for K and LH

American National Standard  SJ1 100 - 2015

**TABLE 5.5-1**

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</tbody>
</table>

(1) Last digit(s) of joint designation shown in Load Table.
(2) Distances are Joint Span lengths in feet – See “Definition of Span” Figure 5.2-1. Refer to the Joint Load Table and Specification Section 6 for required bolted diagonal bridging and additional stability requirements. See Section 5.12 for additional bridging required for uplift design.
KCS Joist Bridging

- The KCS Joist designation is not directly used to establish bridging requirements.
- Instead, the KCS Load Table provides an equivalent K-Series section number to use in the bridging tables.

For Bridging, 24KCS3 = 24K9
Bridging Forces

Horizontal and diagonal bridging shall be capable of resisting the nominal horizontal compressive force, \( P_{br} \) given in Equation 104.5-3.

\[
P_{br} = 0.0025 \, n \, A_t \, F_{\text{construction}} \text{, lbs (N)} \quad (104.5-3)
\]

Where,
- \( n = 8 \) for horizontal bridging
- \( n = 2 \) for diagonal bridging
- \( A_t = \text{cross-sectional area of joist top chord, in.}^2 (\text{mm}^2) \)
- \( F_{\text{construction}} = \text{assumed nominal stress in top chord to resist construction loads} \)
Horizontal Bridging Forces

- The constant, 0.0025, takes into account “two way” action, with the bridging offering support from both sides of the joist, (tension and compression).

- In addition, there is a factor of two in the constant to adjust from ultimate construction stress to nominal bridging design forces.

Horizontal bridging must be continuous. So chord bracing force is divided by two.
Diagonal Bridging Forces

• Diagonal bridging need not be continuous.

• The bridging force $P_{br}$ is the horizontal component, and the actual force in the diagonal bridging member is larger.

• $n = 2$ to account for the fact that there is not “two way” action.
Diagonal Bridging – Center Connection

- Diagonal bridging must resist compressive axial loads

The bridging design presumes a connection at the center of the “X”, so the unbraced length is taken as the distance from the chord attachment to the center intersection.

The center connection can be made by welding or bolting.
Alignment of Bridging Rows

• Note that in this example, the diagonal bridging rows are aligned with the end wall wind columns.
• It should not be presumed that this would automatically happen, just from a framing plan depiction.
• There are many constraints for making the bolted bridging connection that may not allow the exact alignment with and end wall element.
• If this a specific design intent, the contract drawings shall note this requirement.
# Bridging Forces

## Table 5.5-2

**Bridging Nominal Horizontal Unfactored Compressive Force**

<table>
<thead>
<tr>
<th>Joist Section Number</th>
<th>Lbs.</th>
<th>(N)</th>
<th>In.</th>
<th>Lbs.</th>
<th>(N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1-8</td>
<td>340</td>
<td>(1512)</td>
<td></td>
<td>85</td>
<td>(378)</td>
</tr>
<tr>
<td>K9-10, LH02-03</td>
<td>450</td>
<td>(2002)</td>
<td></td>
<td>113</td>
<td>(503)</td>
</tr>
<tr>
<td>K11-12, LH04-05</td>
<td>560</td>
<td>(2491)</td>
<td></td>
<td>140</td>
<td>(623)</td>
</tr>
<tr>
<td>LH06-08</td>
<td>750</td>
<td>(3336)</td>
<td></td>
<td>188</td>
<td>(836)</td>
</tr>
<tr>
<td>LH09</td>
<td>850</td>
<td>(3781)</td>
<td></td>
<td>213</td>
<td>(945)</td>
</tr>
<tr>
<td>LH/DLH10</td>
<td>900</td>
<td>(4003)</td>
<td></td>
<td>225</td>
<td>(1001)</td>
</tr>
<tr>
<td>LH/DLH11</td>
<td>950</td>
<td>(4226)</td>
<td></td>
<td>238</td>
<td>(1056)</td>
</tr>
<tr>
<td>LH/DLH12</td>
<td>1100</td>
<td>(4893)</td>
<td></td>
<td>275</td>
<td>(1223)</td>
</tr>
<tr>
<td>LH/DLH13</td>
<td>1200</td>
<td>(5338)</td>
<td></td>
<td>300</td>
<td>(1334)</td>
</tr>
<tr>
<td>LH/DLH14</td>
<td>1300</td>
<td>(5783)</td>
<td></td>
<td>325</td>
<td>(1446)</td>
</tr>
<tr>
<td>LH/DLH15</td>
<td>1450</td>
<td>(6450)</td>
<td></td>
<td>363</td>
<td>(1612)</td>
</tr>
<tr>
<td>LH/DLH16-17</td>
<td>1850</td>
<td>(8229)</td>
<td></td>
<td>463</td>
<td>(2057)</td>
</tr>
<tr>
<td>DLH18-20</td>
<td>2350</td>
<td>(10453)</td>
<td></td>
<td>585</td>
<td>(2602)</td>
</tr>
<tr>
<td>DLH21-22</td>
<td>3150</td>
<td>(14012)</td>
<td></td>
<td>790</td>
<td>(3514)</td>
</tr>
<tr>
<td>DLH23-24</td>
<td>4130</td>
<td>(18371)</td>
<td></td>
<td>1035</td>
<td>(4604)</td>
</tr>
<tr>
<td>DLH25</td>
<td>4770</td>
<td>(21218)</td>
<td></td>
<td>1195</td>
<td>(5316)</td>
</tr>
</tbody>
</table>

*(1) Last digit(s) of joist designation shown in Load Table.
(2) Or other connection type designed for the required force.*
Bridging Size

• **Horizontal** bridging shall consist of continuous horizontal steel members. The ratio of unbraced length to least radius of gyration, $\ell/r$, of the bridging member shall not exceed 300, where $\ell$ is the distance in inches (millimeters) between attachments and $r$ is the least radius of gyration of the bridging member.

• **Diagonal** bridging shall consist of cross-bracing with a $\ell/r$ ratio of not more than 200, where $\ell$ is the distance in inches (millimeters) between connections and $r$ is the least radius of gyration of the bracing member. Where cross-bracing members are connected at their point of intersection, the $\ell$ distance shall be taken as the distance in inches (millimeters) between connections at the point of intersection of the bracing members and the connections to the chord of the joists.
Bridging Size

• Horizontal bridging must be designed for the bridging force, in compression.

• For smaller designations and joist spaces, the slenderness limit will control, rather than compressive strength.

• At larger designations and wider joist spaces, the compressive strength will control, rather than the slenderness limit.

• Diagonal bridging must resist an axial compressive force based on the horizontal bridging force component. However, the slenderness limit of 200 will typically provide sufficient strength.
## Horizontal Bridging Size

### TABLE 2.7-1

**MAXIMUM JOIST SPACING FOR HORIZONTAL BRIDGING**

<table>
<thead>
<tr>
<th>JOIST SECTION NUMBER(^1)</th>
<th>Nominal Unfactored Force Per lbs (N)</th>
<th>1 x 7/64 (25 x 3 mm)</th>
<th>1-1/4 x 7/64 (32 x 3 mm)</th>
<th>1-1/2 x 7/64 (38 x 3 mm)</th>
<th>1-3/4 x 7/64 (45 x 3 mm)</th>
<th>2 x 1/8 (52 x 3 mm)</th>
<th>2-1/2 x 5/32 (64 x 4 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1 – 8</td>
<td>340 (1512)</td>
<td>5’-0” (1524)</td>
<td>6’-3” (1905)</td>
<td>7’-6” (2286)</td>
<td>8’-9” (2667)</td>
<td>10’-0” (3048)</td>
<td>12’-6” (3810)</td>
</tr>
<tr>
<td>K9-10, LH02-03</td>
<td>450 (2002)</td>
<td>4'-4” (1321)</td>
<td>6’-1” (1854)</td>
<td>7’-6” (2286)</td>
<td>8’-9” (2667)</td>
<td>10’-0” (3048)</td>
<td>12’-6” (3810)</td>
</tr>
<tr>
<td>K11-12, LH04-05</td>
<td>560 (2491)</td>
<td>3’-11” (1194)</td>
<td>5’-6” (1676)</td>
<td>7’-4” (2235)</td>
<td>8’-9” (2667)</td>
<td>10’-0” (3048)</td>
<td>12’-6” (3810)</td>
</tr>
<tr>
<td>LH06-08</td>
<td>750 (3336)</td>
<td>4’-9” (1448)</td>
<td>6’-3” (1905)</td>
<td>7’-11” (2413)</td>
<td>10’-0” (3048)</td>
<td>12’-6” (3810)</td>
<td></td>
</tr>
<tr>
<td>LH09</td>
<td>850 (3781)</td>
<td>4’-5” (1346)</td>
<td>5’-10” (1778)</td>
<td>7’-5” (2261)</td>
<td>9’-9” (2972)</td>
<td>12’-6” (3810)</td>
<td></td>
</tr>
<tr>
<td>LH/DLH10</td>
<td>900 (4003)</td>
<td>4’-4” (1321)</td>
<td>5’-8” (1727)</td>
<td>7’-3” (2210)</td>
<td>9’-5” (2870)</td>
<td>12’-6” (3810)</td>
<td></td>
</tr>
<tr>
<td>LH/DLH11</td>
<td>950 (4226)</td>
<td>4’-2” (1270)</td>
<td>5’-7” (1702)</td>
<td>7’-0” (2134)</td>
<td>9’-2” (2794)</td>
<td>12’-6” (3810)</td>
<td></td>
</tr>
<tr>
<td>LH/DLH12</td>
<td>1100 (4893)</td>
<td>3’-11” (1194)</td>
<td>5’-2” (1575)</td>
<td>6’-8” (2032)</td>
<td>8’-6” (2591)</td>
<td>12-6” (3810)</td>
<td></td>
</tr>
<tr>
<td>LH/DLH13</td>
<td>1200 (5338)</td>
<td>3’-9” (1143)</td>
<td>4’-1’1” (1499)</td>
<td>6’-3” (1905)</td>
<td>8’-2” (2489)</td>
<td>12’-6” (3810)</td>
<td></td>
</tr>
<tr>
<td>LH/DLH14</td>
<td>1300 (5783)</td>
<td>4’-9” (1448)</td>
<td>6’-0” (1829)</td>
<td>7’-10” (2388)</td>
<td>12’-4” (3759)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LH/DLH15</td>
<td>1450 (6450)</td>
<td>4’-6” (1372)</td>
<td>5’-8” (1727)</td>
<td>7’-5” (2261)</td>
<td>11-8” (3556)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LH/DLH16–17</td>
<td>1850 (8229)</td>
<td>4’-0” (1219)</td>
<td>5’-0” (1524)</td>
<td>6-7’ (2007)</td>
<td>10-4” (3150)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DLH18–20</td>
<td>2350 (10453)</td>
<td>3’-7” (1067)</td>
<td>4’-4’ (1321)</td>
<td>5’-10” (1778)</td>
<td>9’-1” (2769)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DLH21–22</td>
<td>3150 (14012)</td>
<td>3’-10” (1168)</td>
<td>5’-0” (1524)</td>
<td>7’-11” (2413)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DLH23–24</td>
<td>4130 (18371)</td>
<td>3’-4” (1016)</td>
<td>4’-5’ (1346)</td>
<td>6’-11” (2108)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DLH25</td>
<td>4770 (21218)</td>
<td></td>
<td>4’-1” (1245)</td>
<td>6’-5” (1956)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{1}\) Refer to last two digit(s) of Joist Designation

\(^{2}\) Connection to joist shall resist force listed in the Steel Joist Institute Standard Specifications Table 5.5-2
## TABLE 2.7-3

**K, LH, and DLH SERIES JOISTS**

**MAXIMUM JOIST SPACING FOR DIAGONAL BRIDGING**

<table>
<thead>
<tr>
<th>BRIDGING ANGLE SIZE – (EQUAL LEG ANGLE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JOIST DEPTH</td>
</tr>
<tr>
<td>in. (mm)</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>12” (305)</td>
</tr>
<tr>
<td>16” (406)</td>
</tr>
<tr>
<td>18” (457)</td>
</tr>
<tr>
<td>20” (508)</td>
</tr>
<tr>
<td>22” (559)</td>
</tr>
<tr>
<td>24” (610)</td>
</tr>
<tr>
<td>26” (660)</td>
</tr>
<tr>
<td>28” (711)</td>
</tr>
<tr>
<td>30” (762)</td>
</tr>
<tr>
<td>32” (813)</td>
</tr>
<tr>
<td>36” (914)</td>
</tr>
<tr>
<td>40” (1016)</td>
</tr>
<tr>
<td>44” (1118)</td>
</tr>
<tr>
<td>48” (1219)</td>
</tr>
<tr>
<td>52” (1321)</td>
</tr>
<tr>
<td>56” (1422)</td>
</tr>
<tr>
<td>60” (1524)</td>
</tr>
<tr>
<td>64” (1625)</td>
</tr>
<tr>
<td>68” (1727)</td>
</tr>
<tr>
<td>72” (1829)</td>
</tr>
<tr>
<td>76” (2032)</td>
</tr>
<tr>
<td>80” (2235)</td>
</tr>
<tr>
<td>84” (2438)</td>
</tr>
<tr>
<td>88” (2642)</td>
</tr>
<tr>
<td>92” (2845)</td>
</tr>
<tr>
<td>96” (3048)</td>
</tr>
</tbody>
</table>

**INTERPOLATION BELOW THE MINIMUM VALUES SHOWN IS NOT ALLOWED.**

SEE TABLE 2.7-4 FOR MINIMUM JOIST SPACE FOR DIAGONAL ONLY BRIDGING.
Horizontal and Cross Bridging Used Together

- As the ratio of joist depth to joist space increases, bridging at the slenderness limit may no longer provide adequate strength.

- The use of horizontal bridging, in addition to diagonal, changes the diagonal bridging to tension only.

- This is required where the joist spacing is less than 70% of the joist depth and the span is more than 60’
# Bridging Size

## Table 2.7-4

<table>
<thead>
<tr>
<th>JOIST DEPTH (in. (mm))</th>
<th>MINIMUM JOIST SPACE FOR DIAGONAL ONLY BRIDGING (0.70 x DEPTH)*</th>
<th>HORIZONTAL AND DIAGONAL MINIMUM ANGLE SIZE REQUIRED FOR JOIST SPACING &lt; (0.70 x DEPTH) AND JOIST SPANS &gt; 60'-0&quot; (18.3 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>52&quot; (1321)</td>
<td>3'- 0&quot; (914)</td>
<td>1&quot; x 1&quot; x 7/64&quot; (25 x 3)</td>
</tr>
<tr>
<td>56&quot; (1422)</td>
<td>3'- 3&quot; (990)</td>
<td>1&quot; x 1&quot; x 7/64&quot; (25 x 3)</td>
</tr>
<tr>
<td>60&quot; (1524)</td>
<td>3'- 6&quot; (1066)</td>
<td>1&quot; x 1&quot; x 7/64&quot; (25 x 3)</td>
</tr>
<tr>
<td>64&quot; (1626)</td>
<td>3'- 8&quot; (1117)</td>
<td>1 1/4&quot; x 1 1/4&quot; x 7/64&quot; (32 x 3)</td>
</tr>
<tr>
<td>68&quot; (1727)</td>
<td>3'-11&quot; (1193)</td>
<td>1 1/4&quot; x 1 1/4&quot; x 7/64&quot; (32 x 3)</td>
</tr>
<tr>
<td>72&quot; (1829)</td>
<td>4'- 2&quot; (1270)</td>
<td>1 1/4&quot; x 1 1/4&quot; x 7/64&quot; (32 x 3)</td>
</tr>
<tr>
<td>80&quot; (2032)</td>
<td>4'- 8&quot; (1422)</td>
<td>1 1/4&quot; x 1 1/4&quot; x 7/64&quot; (32 x 3)</td>
</tr>
<tr>
<td>88&quot; (2235)</td>
<td>5'- 1&quot; (1549)</td>
<td>1 1/2&quot; x 1 1/2&quot; x 7/64&quot; (38 x 3)</td>
</tr>
<tr>
<td>96&quot; (2438)</td>
<td>5'- 7&quot; (1702)</td>
<td>1 1/2&quot; x 1 1/2&quot; x 7/64&quot; (38 x 3)</td>
</tr>
<tr>
<td>104&quot; (2642)</td>
<td>6'- 0&quot; (1829)</td>
<td>1 3/4&quot; x 1 3/4&quot; x 7/64&quot; (44 x 3)</td>
</tr>
<tr>
<td>112&quot; (2845)</td>
<td>6'- 6&quot; (1981)</td>
<td>1 3/4&quot; x 1 3/4&quot; x 7/64&quot; (44 x 3)</td>
</tr>
<tr>
<td>120&quot; (3048)</td>
<td>7'- 0&quot; (2134)</td>
<td>2&quot; x 2&quot; x 1/8&quot; (51 x 3)</td>
</tr>
</tbody>
</table>

*NOTE: WHEN THE JOIST SPACING IS LESS THAN 0.70 x JOIST DEPTH, BOLTED HORIZONTAL BRIDGING SHALL BE USED IN ADDITION TO DIAGONAL BRIDGING.*
Bottom Chord Bridging for Uplift

- SJI Standard Specifications require bridging at the first bottom chord panel point, since two of the three intersecting primary members are in compression under uplift loading.
Bottom Chord Bridging Spacing

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

- Bridging Load Requirements
  - Axial load based on bottom chord compressive axial load
    - $P_{br} = 0.005 \ P_c$
  - Where $P_c$ is the bottom chord compressive axial load
Uplift Bridging Forces

- Bridging Load Requirements
  - Randomness of initial lateral out-of-straightness
  - Bridging design force for number of joists, n, does not accumulate linearly
  - The following equation can be used

\[ 0.001 \, n \, P_c + 0.004 \, P_c \, \sqrt{n} \]

where \( P_c \) is the bottom chord compressive axial load
Uplift Bridging Forces

• Bridging Load Requirements

  \[ 0.001 n P_c + 0.004 P_c \sqrt{n} \]

  – For small to moderate net uplift and reasonable number of joists, \( n, P_c \) at bottom chord is no larger than at top chord

  – For more severe uplift, \( P_c \) at bottom chord can be computed and may determine bridging size, or require a limit on the value of \( n \)

  – As \( n \) increases, tributary roof area could be based on MWFRS rather than components and cladding
CJ-Series Bridging

- CJ-Series joists follow the same bridging rules and criteria, except that the slenderness limit equation is different.

\[
\left(100 + 0.67d_j + 40 \frac{d_j}{L}\right)
\]

- This is due to the typically smaller top chord on a CJ-Series joist as compared to a non-composite joist.

- Also, the maximum span to depth ratio for a CJ-Series joists is 30, as compared to a limit of 24 for a non-composite joist.
Joist Girder Bridging or Lack There Of

- Joist girders are erected without Erection Bridging.
- Ends of the bottom chord must be strutted and the top chord must have $R_{yy}$ not less than Span/575.
- Attachment of joists provides stability for construction loads.
- For the bottom chord, permanent bridging is provided as shown below, called Knee Braces, Girder Braces or Uplift Braces.

![Diagram of joist girder bridging](image-url)
Anchorage of Bridging

• All rows of bridging must be either anchored or terminated.

• Anchorage should occur to the supporting structure.

• Termination shall occur between joists.
Anchorage of Bridging Responsibilities

• From the SJI Code of Standard Practice: The specifying professional is responsible for bridging termination connections. The contract documents shall clearly illustrate these termination connections.

• Typical details are normally adequate for welded connections to steel, unless the joists are very large.

• Connections to masonry or concrete require attention for anchorage.

• Stiffness of steel members parallel to joists should be considered, and diagonal bridging can be an alternate terminus.
Anchorage of Bridging

- Typical anchorage details:
Anchorage of Bridging

- Typical termination details:
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.
Special Usages

- Standing Seam Roof
- ESFR
- Bottom Chord Bearing Joists
- Special Shapes
- Bridging Discontinuity
- Skewed walls
- Bridging Discontinuity
- Distance of uplift bridging from the first bottom chord panel point
- Nominal thickness of bridging
- Bridging connections - Tack welding of bridging
- Galvanized bridging must be bolted not welded.
- External, Additional Forces on Bridging
Standing Seam Roofs

5.8 FLOOR AND ROOF DECKS

(g) Joist With Standing Seam Roofing or Laterally Unbraced Top Chords

...Sufficient stability must be provided to brace the joists laterally under the full design load, in accordance with Section 5.8(e). ... In any case where the attachment requirement of Section 5.8(e) is not achieved, out-of-plane strength shall be achieved by adjusting the bridging spacing and/or increasing the compression chord area and the y-axis radius of gyration. The effective slenderness ratio in the y-direction equals 0.94 L/r_y; where L is the bridging spacing in inches (millimeters).
Standing Seam Roofs

5.8 FLOOR AND ROOF DECKS

(g) Joist With Standing Seam Roofing

Horizontal bridging members attached to the compression chords and their anchorages must be designed for a compressive axial force of $0.001nP + 0.004P\sqrt{n} \geq 0.0025nP$, where $n$ is the number of joists between end anchors and $P$ is the chord design force in kips (Newtons). The attachment force between the horizontal bridging member and the compression chord is 0.01P.
Sprinkler Systems and Bridging

• For warehouses with rack storage systems and high piled storage systems, Early Suppression Fast Response (ESFR) sprinkler systems are common.

• National Fire Protection Association (NFPA) 13: Standard for the Installation of Sprinkler Systems the design and installation of ESFR systems.

• The ESFR sprinkler head elevations are normally set within the joist depth, less then 1 foot from the bottom of the metal roof deck.

• In addition to rigid rules about the placement and spacing of the ESFR heads, obstructions below an ESFR head must be limited.
ESFR Systems

• The specific requirement from NFPA which influences bridging row locations states:
  Additional sprinklers are not required where the obstruction is 2 in. or less in width and is located a minimum of 2 ft. below the elevation of the sprinkler deflector or is positioned a minimum of 1 ft. horizontally from the sprinkler.
• For joist bridging, the 1 ft. horizontal dimension normally governs.
• It is a “clear” dimension, not “center to center.”
• The erector must install horizontal bridging rows at the dimensions shown on the Joist Placement Plans when an ESFR system is being used, and an extra inch or two of tolerance may be provided.
• Excessive and unnecessary clearance requirements of say 1’-6” arbitrarily stated on the contract drawings make the joist and bridging cumbersome and possibly more costly.
ESFR Clearance

- In this BIM model, the ESFR sprinkler heads and their clearance requirements are represented by the purple cylinders.

- Bridging rows are routed so as to avoid any clashes with the ESFR cylinders.
Bottom Bearing Joists

- Whenever joists are bottom chord bearing, diagonal cross bridging must be installed from joist to joist at or near the bearing location to provide additional lateral erection stability.
Special Shape Joists

- Special shape joists (bowstring, scissors, gables, barrels) can be “top heavy”
When the joist center of gravity is above the supports, it is recommended that all rows be diagonal bridging.

The erector must also take special care to maintain stability, both as the joist is initially set and as construction loads are applied.
Bridging Anchorage to Skewed Walls
Bridging Discontinuity

Horizontal bridging row without termination
Bridging Discontinuity

- Horizontal bridging must be continuous.

- Where horizontal bridging is interrupted, terminate with diagonal bridging in the joist space on each side.
Distance of Uplift Bridging From the First Bottom Chord Panel Point
# Welded Bridging Connections

## Table 5.5

<table>
<thead>
<tr>
<th>JOIST SECTION NUMBER&lt;sup&gt;1&lt;/sup&gt;</th>
<th>HORIZONTAL BRIDGING ( P_{br} (n=8) )</th>
<th>REQUIRED BRIDGING CONNECTION WELD&lt;sup&gt;2&lt;/sup&gt;</th>
<th>DIAGONAL BRIDGING ( P_{br} (n=2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lbs.</td>
<td>(N)</td>
<td>Lbs.</td>
</tr>
<tr>
<td>K1-8</td>
<td>340</td>
<td>(1512)</td>
<td>85</td>
</tr>
<tr>
<td>K9-10, LH02-03</td>
<td>450</td>
<td>(2002)</td>
<td>113</td>
</tr>
<tr>
<td>K11-12, LH04-05</td>
<td>560</td>
<td>(2491)</td>
<td>140</td>
</tr>
<tr>
<td>LH06-08</td>
<td>750</td>
<td>(3336)</td>
<td>188</td>
</tr>
<tr>
<td>LH09</td>
<td>850</td>
<td>(3781)</td>
<td>213</td>
</tr>
<tr>
<td>LH/DLH10</td>
<td>900</td>
<td>(4003)</td>
<td>225</td>
</tr>
<tr>
<td>LH/DLH11</td>
<td>950</td>
<td>(4226)</td>
<td>238</td>
</tr>
<tr>
<td>LH/DLH12</td>
<td>1100</td>
<td>(4893)</td>
<td>275</td>
</tr>
<tr>
<td>LH/DLH13</td>
<td>1200</td>
<td>(5338)</td>
<td>300</td>
</tr>
<tr>
<td>LH/DLH14</td>
<td>1300</td>
<td>(5783)</td>
<td>325</td>
</tr>
<tr>
<td>LH/DLH15</td>
<td>1450</td>
<td>(6450)</td>
<td>363</td>
</tr>
<tr>
<td>LH/DLH16-17</td>
<td>1850</td>
<td>(8229)</td>
<td>463</td>
</tr>
<tr>
<td>DLH18-20</td>
<td>2350</td>
<td>(10453)</td>
<td>585</td>
</tr>
<tr>
<td>DLH21-22</td>
<td>3150</td>
<td>(14012)</td>
<td>790</td>
</tr>
<tr>
<td>DLH23-24</td>
<td>4130</td>
<td>(18371)</td>
<td>1035</td>
</tr>
<tr>
<td>DLH25</td>
<td>4770</td>
<td>(21218)</td>
<td>1195</td>
</tr>
</tbody>
</table>

<sup>1</sup> Last digit(s) of joist designation shown in Load Table.

<sup>2</sup> Or other connection type designed for the required force.

*1/8" x 1" (3mm x 25mm)*

*1/8" x 1 ½" (3mm x 38mm)*

*1/8" x 2" (3mm x 51mm)*

*1/8" x 3" (3mm x 76mm)*
Welded Bridging Connections

- In some cases the thickness of the bridging is not 0.125”, it could be less.
- 1/8” fillet welds can be placed on thinner material.
- Never use 4 tack welds on the toes of the bottom chords.
Galvanized Joist

- All bridging on galvanized joists must be bolted *not* welded
External, Additional Forces on Bridging

- Can an additional, external wind force be transferred through the joist bridging?
External, Additional Forces on Bridging

• Diagonal X bridging would be needed in multiple joist spaces to transfer force from the bottom chord level up to the deck diaphragm.

• Care must be taken to not exceed the bridging connection capacity, and welding in additional to bolting may be required.

• The deck weld attachments also must not be exceeded.

• A separate structural brace may be more advisable.
Field Conditions

- Field conditions can vary from what was designed.
Field Conditions

- Bridging is bracing – do not hang any loads from bridging.
Field Conditions

- Bridging is bracing – don’t brace to a brace!
Field Connections

Rough looking welds

Burn through hole
How to Specify Bridging

• Should the contract drawings show the bridging lines on the framing plans or simply require bridging as required per the Steel Joist Institute Specifications?

• The joist manufacturer can assume the responsibility for proper application of the SJI Specs while preparing the framing plans.
What is Coming?

• SJI will update and publish Technical Digest #2, on the topic of Bridging
• It will include what you have seen in this presentation and much, much more!
THANK YOU