Bridging of Open-Web Steel Joists and Joist Girders

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INTRODUCTION

Bridging is an integral component of the open-web steel joist system that braces the joists against unanticipated horizontal movement during erection, the placing of construction loads, and to permanently restrain the joist chords from out-of-plane or lateral movement when other means are not present. The purpose of this paper is to provide the Specifying Professional a clear understanding of the Steel Joist Institute's bridging requirements as given in the Standard Specifications [SJI, 2005 and 2007] In the paper, these three distinct bridging functions will be referred to as: ERECTION BRIDGING, CONSTRUCTION BRIDGING, and PERMANENT BRIDGING.

One of the most important aspects of safe erection of joist products is proper bridging. A joist may be unstable as soon as the hoisting cable is released, even without other applied construction loads. ERECTION BRIDGING is required if the joist is not stable under its own self-weight and the weight of one erector (who would be traveling to the joist midpoint to release the hoisting cable). ERECTION BRIDGING is defined in the OSHA Safety Standards as "the bolted diagonal bridging that is required to be installed prior to releasing the hoisting cables from the steel joists" (see OSHA 1926.751 **Definitions**). It should be said that not all joists require ERECTION BRIDGING when being set into position on a structure.

A second function of the joist bridging is to provide adequate lateral support for the joist to support the construction loads present while a permanent means of top chord lateral support (normally metal decking) is installed. A lateral displacement of the joist at this phase of the erection sequence may mean that a construction load caused the joist to distort, roll over, or shift from its intended position resulting in both the ironworkers and/or joists falling (see Figures 1 and 2). The installed bridging, now acting as CONSTRUCTION BRIDGING, is there to prevent any such occurrence as just described.

The final function of joist bridging is to permanently brace both the joist top and bottom chords. The bridging that has been installed will now be referred to as PERMANENT BRIDGING as it should remain as part of the structural system for the life of the structure. Where the metal decking creates a sufficient diaphragm, then the bridging does not have a permanent role at the top chord, after construction is complete. One exception would be when a standing seam roof (SSR) is attached directly to a joist top chord. The SJI has determined that this type of roofing system does not provide the required diaphragm strength, thus the PERMANENT BRIDGING is necessary for the joists to function properly [Hodge, 1986]. For the joist bottom chord, the bridging also serves a permanent role, both when the bottom chord is subject to tension as well as compression forces. Since the bottom serves to laterally brace the joist web members (when modeled as pinned ends), then the bottom chord itself must be braced laterally, even when it is in tension, in order to fulfill this role. When joists are used for roof construction, they are frequently subject to a net uplift force, creating compression in the bottom chord, where the bottom chord PERMANENT BRIDGING will provide the necessary buckling resistance.

FIGURE 1 CONSTRUCTION LOADS SET ON UNBRIDGED, UNANCHORED JOISTS

FIGURE 2 POTENTIAL CONSEQUENCE OF SETTING A BUNDLE OF DECK ON UNBRIDGED, UNANCHORED JOISTS

OSHA

Since 1984, representatives of the steel community have worked with the Department of Labor and the Occupational Safety and Health Administration (OSHA) to establish new rules for the safe erection of structural steel and as part of that rule, safe erection standards for Open Web Steel Joists. As stated in the Federal Register [OSHA, 2001],

> "By this notice the Occupational Safety and Health Administration (OSHA) revises the construction industry safety standards which regulate steel erection. The final rule enhances protections provided to workers engaged in steel erection and updates the general provisions that address steel erection. The final rule sets performance-oriented criteria, where possible, to protect employees from steel erection related hazards such as working under loads; hoisting, landing and placing decking; column stability; double connections; hoisting, landing and placing steel joists; and falls to lower levels."

The OSHA Safety Standards supplement the SJI Specifications and Table 1 summarizes the Federal Regulations that are included in 29 CFR 1926.757 - **Open web steel joists** related to the erection of joist products.

ERECTION BRIDGING

The SJI **K**-Series and **LH**- and **DLH**-Series Load Tables [SJI, 2005] show the total safe uniformly distributed loads for standard products at various spans. As the span increases for a particular joist designation, the uniformly distributed load-carrying capacity decreases. The Load Tables also indicate when the span becomes too great for a particular joist designation to be erected without ERECTION BRIDGING.

Standard **K**-Series joists that require ERECTION BRIDGING are indicated by the **RED** SHADED area in the Load Tables [SJI, 2005] and are found in the OSHA Safety Standards 1926.757 **Table A - Erection Bridging for Short Span Joists** [OSHA, 2001]. This table gives the minimum span for each shortspan joist designation (e.g. 26K8) and indicates when ERECTION BRIDGING must be installed. ERECTION BRIDGING is the bolted diagonal bridging that is required to be installed prior to releasing the hoisting cables. If Table A indicates that ERECTION BRIDGING is Not Mandatory (NM), the joists can be spaced out, attached, and then bridged in accordance with the SJI Standard Specifications for Open Web Steel Joists, **K**-Series Section 6 [SJI, 2005].

TABLE 1 SUMMARY OF FEDERAL REGULATIONS 29 CFR 1926.757 – OPEN WEB STEEL JOISTS

Description	**Applicable Section(s)**
Column or tie joists at or near columns must be bolted	[.757(a)(1) and (2)]
Increased strength of column or tie joists up to 60 foot span	[.757(a)(3)]
Column or tie joists over 60 foot span to be set in tandem and fully bridged	[.757(a)(4)]
Any supporting structure must be stabilized prior to setting joists or Joist Girders	[.757(a)(5)]
Joists must be prevented from unintentional displacement prior to installation	[.757(a)(6)]
Joists shall not be modified without the approval of the project structural engineer of record (SEOR)	[.757(a)(7)]
Unless panelized, joists in bays of 40 foot or greater span must be bolted to their supports unless constructability does not allow	[.757(a)(8)]
Joists and Joist Girders shall not be used as anchorage for fall arrest systems	[.757(a)(9)]
A bridging terminus point must be established before any erection bridging is installed	[.757(a)(10)]
Joists and Joist Girders need to be attached to the support structure	[.757(b)(1), (2) and (3) and (c)(1) and (2)]]
Only a certain number of employees are allowed on joists until bridging is installed and anchored	[.757(c)(3) and (4)]
Joists that require erection bridging are specified in Tables A and B	[.757(d)(1)]
Erection bridging requirements are defined for joist spans over 60 feet through 100 feet [.757(d)(2)] over 100 feet through 144 feet	[.757(d)(3)] and over 144 feet [.757(d)(4)]
There are additional bridging requirements for bottom chord bearing joists	[.757(d)(5)]
Bolted diagonal erection bridging must be shown on the joist placement plans	[.757(d)(6)]
Loads placed on joists shall not exceed their capacity	[.757(e)(1)]
No construction loads shall be placed on unbridged, unanchored and unattached joists	[.757(e)(2)]
Joist bridging bundles may not exceed 1000 lbs	[.757(e)(3)]
Metal decking or deck accessory bundles may not exceed 4000 lbs and may only be set on partially bridged joists under certain conditions	[.757(e)(4)]
Construction loads shall be placed within 1 foot of the bearing surface of the joist end	[.757(e)(5)]

The required bolted diagonal ERECTION BRIDGING for **K**-Series joists must be installed as the row of bridging nearest the mid-span of the joist. The ERECTION BRIDGING must also be anchored to prevent lateral movement of the joist prior to the hoisting cables being released (see Section 6). This can be accomplished by securing the bridging to a fixed object such as a wall, steel beam or other stable portion of the structure. OSHA refers to this anchorage point as a bridging terminus point.

Standard **LH**-Series joists that require ERECTION BRIDGING are indicated by the **RED** or **BLUE** SHADED areas in the Load Tables [SJI, 2005] and are also found in the OSHA Safety Standards 1926.757 **Table B - Erection Bridging for Long Span Joists** [OSHA, 2001]. This table gives the minimum span for each longspan joist designation (e.g. 32LH06) and indicates when ERECTION BRIDGING must be installed. ERECTION BRIDGING is the bolted diagonal bridging that is required to be installed prior to releasing the hoisting cables. If Table B indicates that ERECTION BRIDGING is Not Mandatory (NM), the joists can be spaced out, attached, and then bridged in accordance with the SJI Standard Specifications for Longspan Joists, **LH**-Series Section 105. All standard **DLH**-Series joists require ERECTION BRIDGING as indicated by the **BLUE** or **GRAY** SHADED areas in the Load Tables [SJI, 2005].

The required bolted diagonal ERECTION BRIDGING for **LH**-Series joists depends on its length. Where the span of the steel joist is less than 60 feet, the bolted diagonal ERECTION BRIDGING must be installed as the row of bridging nearest the mid-span of the joist. Where the span of the steel joist is over 60 feet through 100 feet, the required bolted diagonal ERECTION BRIDGING must be installed as the two rows of bridging nearest the third points of the joist. Where the span of the steel joist is over 100 feet through 144 feet as indicated by the **GRAY** shading, all rows of bridging are considered ERECTION BRIDGING and must be completely installed. The bridging row(s) must be anchored to prevent lateral movement of the joist (see Section 105).

The shaded areas of the Load Tables were established based on the typical joist self weights and the typical minimum top and bottom chords sizes (from a survey of joist manufacturers), plus the weight of an erector, taken as 300 lbs. The equation was developed by Minkoff, using the Rayleigh-Ritz method with an assumed sinusoidal lateral and torsional deformation [Minkoff, 1975], [Galambos, 1993].

For special joist designs, the Specifying Professional cannot check the Minkoff equation without knowing the exact joist section properties. So a conservative comparison can be made to a standard joist type that would be found in the Load Tables, or the joist manufacturer can be contacted to determine the need for ERECTION BRIDGING. Since all ERECTION BRIDGING will in turn become CONSTRUCTION BRIDGING, the more severe CONSTRUCTION BRIDGING criteria are used to establish the ERECTION BRIDGING forces, sizes, and connections.

Column Joists

Joists located at or near column lines (see Figure 3) are referred to as OSHA Column Joists, tie joists, strut joists or "OC" joists. The current OSHA Safety Standards for Steel Erection, 29 CFR Part 1926 require that, where columns are not framed in at least two directions with solid structural steel members, joists at column lines shall be field bolted and the joist bottom chords must be restrained by a vertical stabilizer plate [OSHA, 2001]. The bearing seats of Column Joists will always be provided with slotted holes so that bolts can be inserted at the time of joist placement. Where constructability does not allow a steel joist to be installed directly at the column, the OSHA Safety Standards state that an alternate means of stabilizing the tie joists shall be installed on both sides near the column.

When the current OSHA Safety Standards for Steel Erection, Final Rule, became effective, it contained the following requirement for Column Joists,

> "Where steel joists at or near columns span 60 feet or less, the joist shall be designed with sufficient strength to allow one employee to release the hoisting cable without the need for erection bridging."

An "Inspection policy and procedures for OSHA's steel erection standards for construction" was subsequently issued on March 22, 2002 and following that, on July 18, 2003 an OSHA Notice "Extension of enforcement policy on column joists" was issued. The effective date of that enforcement policy was originally extended to July 18, 2004, or until a new directive was to be issued. OSHA has now extended this policy indefinitely. The policy is as follows: "for all joists at or near columns that span 60 feet or less, employers will be considered to be in compliance with 1926.757(a)(3) if they erect these joists either by: (1) installing bridging or otherwise stabilizing the joist prior to releasing the hoisting cable, or (2) releasing the cable without having a worker on the joists."

The SJI conducted extensive research to develop design methods in an effort to meet this original OSHA provision for Column Joists [Emerson, 2001] [Ziemian et al, 2004]. The research was to produce procedures for SJI member companies to use in the design of Column Joists. In attempting to develop these design procedures, it was necessary to make assumptions regarding field conditions that could affect the strength of Column Joists. After careful consideration of the wide range of variability in field conditions, the SJI member companies determined that for some joist lengths there are no existing joist designs that would provide the necessary stability (even with the vertical stabilizer plate). Therefore, OSHA not withstanding, the SJI can not recommend that employees ever be allowed on unbridged joists. SJI member companies use the DANGER TAG shown in Figure 4 to warn the erection companies that the Column Joists or tie joists will not support the weight of an employee unless the joist is properly stabilized and bridged.

If a Column or tie joist spans more than 60 feet it needs to be set in tandem with an adjacent joist with all bridging installed unless an alternative method of erection is used that provides the same stability. This alternative method needs to have been designed by a qualified person and be included in a site-specific erection plan (see OSHA 1926.752 **Site layout, site-specific erection plan and construction sequence**). A site-specific erection plan allows the employer to develop alternative means and methods that provide employee protection equivalent to the provisions of the Federal Regulations.

FIGURE 3 COLUMN JOIST BEING CONNECTED; BOTTOM CHORD IS "KNIFED IN" BETWEEN VERTICAL STABILIZER PLATE

FIGURE 4 TYPICAL SJI MANUFACTURER'S DANGER TAG ATTACHED TO COLUMN JOIST

Joist Girders

Joist Girders are primary structural members that are normally supported by structural steel columns; however, they can also bear on steel plates on masonry or concrete supports. Joist Girders must be erected singly as shown in Figure 5. They can be underslung and rest on the top or side of the columns or be square-ended and frame into the columns.

A loose connection of the bottom chord angles to the column or other support is required during erection in order to stabilize the bottom chord laterally and to help brace it against possible overturning. These plates "knife in" between the bottom chord angles that are spaced apart (see Figure 6). A vertical stabilizer plate is required to be furnished on each column by the structural steel supplier (minimum size 3/4 x 6 x 6 in.) and must extend at least 3 in. below the bottom chord of the Joist Girder. If a stabilizer plate cannot be used because of a constructability issue, some other means of laterally stabilizing the Joist Girder must be provided. Any final connection, if required, of the Joist Girder bottom chord to the column should be in accordance with instructions from the EOR.

Since Joist Girders are erected without ERECTION BRIDGING, a minimum stiffness relative to the overall length is required, and is given in section 1003.4 (a). The radius of gyration of the Joist Girder top chord about the vertical axis, shall not be less than the Joist Girder span divided by 575.

FIGURE 5 JOIST GIRDER BEING SET ON TWO COLUMNS WITH TWO CONNECTORS

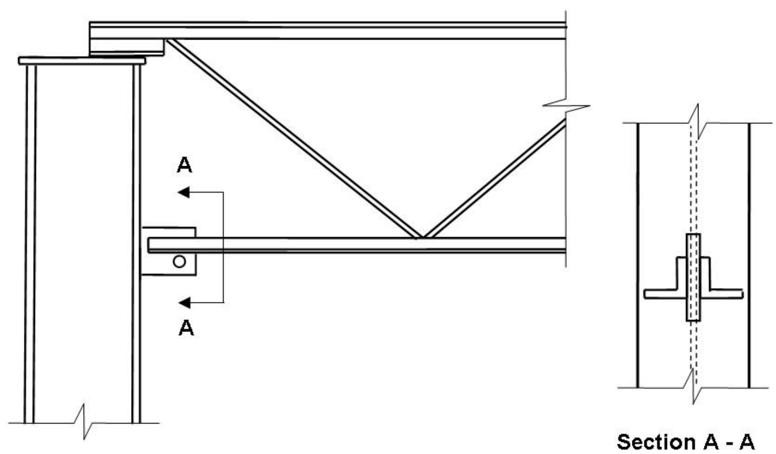

FIGURE 6 JOIST GIRDER BEARING ON STRUCTURAL STEEL COLUMN WITH VERTICAL STABILIZER PLATE

BRIDGING FOR CONSTRUCTION LOADS

After any required ERECTION BRIDGING is installed and the hoisting cables have been released, the remaining bridging rows (these would be called CONSTRUCTION BRIDGING) need to be installed before the application of additional construction loads. Under no circumstances are construction loads of any description to be placed on unbridged joists. As previously described, many joists are laterally unstable until the joists are properly bridged and the bridging and the joists are properly anchored. The joists should be completely bridged immediately after final placement and end attachment is completed in accordance with OSHA and SJI requirements.

Construction loads are defined in the OSHA Safety Standards as “any load other than the employee(s), the joists and the bridging bundles.” These loads include the weight of metal deck bundles and individual sheets being placed, the weight of multiple Erectors placing the deck, and the equipment loads such as welding machines and leads, hand tools, bridging for adjacent bays, etc. The Standard strictly prohibits placing construction loads on unbridged joists and gives the proper procedure for landing bridging bundles on unbridged joists (see 29CFR1926.757(e)(1), (2) and (3)). It is critical that the magnitude of construction loads on any one joist be limited and it is advisable that the loads be placed as close as possible to the ends of the joist. There is an exception for the placement of a bundle of decking after the installation of at least one bridging row, but not all bridging rows, if certain stringent conditions are met. Any Erector who allows construction loads to be placed on unbridged joists is in direct violation of the Federal Regulation as well as the Steel Joist Institute's **K**-Series Specifications Section 6, and the **LH**- and **DLH**-Series Specifications, Section 105 [SJI, 2005] and may be held liable for any injuries sustained if an accident should occur.

The SJI Standard Specifications for Open Web Steel Joists, **K**-Series Section 5.4 [SJI, 2005] requires that each bridging connection resist a nominal (unfactored) horizontal force of not less than 700 pounds (Section 5.4a). The spacing of the bridging rows shall be determined by the radius of gyration of the top chord about its vertical axis and shall not be less than $\ell/145$, and to meet this criteria, the quantity of top chord bridging rows shall not be less than as shown in Table 5.4-1. The number of rows of bottom chord bridging shall not be less than the number of top chord rows (Section 5.4c); the top and bottom chord bridging rows may be spaced independently.

TABLE 5.4-1

U.S. UNITS

NUMBER OF ROWS OF TOP CHORD BRIDGING**

Refer to the K-Series Load Table and Specification Section 6 for required bolted diagonal bridging.

Distances are Joist Span lengths in feet – See "Definition of Span" preceding Load Table.

*Section Number	One Row	Two Rows	Three Rows	Four Rows	Five Rows
#1	Up thru 16	Over 16 thru 24	Over 24 thru 28		
#2	Up thru 17	Over 17 thru 25	Over 25 thru 32		
#3	Up thru 18	Over 18 thru 28	Over 28 thru 38	Over 38 thru 40	
#4	Up thru 19	Over 19 thru 28	Over 28 thru 38	Over 38 thru 48	
#5	Up thru 19	Over 19 thru 29	Over 29 thru 39	Over 39 thru 50	Over 50 thru 52
#6	Up thru 19	Over 19 thru 29	Over 29 thru 39	Over 39 thru 51	Over 51 thru 56
#7	Up thru 20	Over 20 thru 33	Over 33 thru 45	Over 45 thru 58	Over 58 thru 60
#8	Up thru 20	Over 20 thru 33	Over 33 thru 45	Over 45 thru 58	Over 58 thru 60
#9	Up thru 20	Over 20 thru 33	Over 33 thru 46	Over 46 thru 59	Over 59 thru 60
#10	Up thru 20	Over 20 thru 37	Over 37 thru 51	Over 51 thru 60	
#11	Up thru 20	Over 20 thru 38	Over 38 thru 53	Over 53 thru 60	
#12	Up thru 20	Over 20 thru 39	Over 38 thru 53	Over 53 thru 60	

*Last digit(s) of joist designation shown in Load Table

**See Section 5.11 for additional bridging required for uplift design.

The SJI Standard Specifications for Longspan Steel Joists, **LH**-Series and Deep Longspan Steel Joists, **DLH**-Series requires that each bridging connection to the joist must be able to resist a horizontal force not less than that specified in Table 104.5-1 (Section 104.5e). Where two attachment points to a joist are utilized, each attachment must be able to resist one-half of the bridging force given in the table. The spacing of the bridging rows shall be determined by the radius of gyration of the top chord about its vertical axis and shall not be less than $\ell/170$, and to meet this criteria, the maximum spacing of lines of top chord bridging shall not exceed the values in Table 104.5-1. The number of rows of bottom chord bridging shall not be less than the number of top chord rows; the top and bottom chord bridging rows may be spaced independently (Section 104.5d) [SJI, 2005].

TABLE 104.5-1

LH-DLH SECTION*NUMBER	MAXIMUM SPACING OF LINES OF TOP CHORD BRIDGING	NOMINAL** HORIZONTAL BRACING FORCE (lbs)	(N)
02, 03, 04	11'-0" (3352 mm)	400	(1779)
05, 06	12'-0" (3657 mm)	500	(2224)
07, 08	13'-0" (3962 mm)	650	(2891)
09, 10	14'-0" (4267 mm)	800	(3558)
11, 12	16'-0" (4876 mm)	1000	(4448)
13, 14	16'-0" (4876 mm)	1200	(5337)
15, 16	21'-0" (6400 mm)	1600	(7117)
17	21'-0" (6400 mm)	1800	(8006)
18, 19	26'-0" (7924 mm)	2000	(8896)

Number of lines of bridging is based on joist clear span dimensions.
* Last two digits of joist designation shown in load table.
** Nominal bracing force is unfactored.

The bracing force that a joist imparts to the bridging is based on three assumptions. The first is an initial out-of-straightness taken as L/920. The second is the resultant total nominal bracing force of 0.0044P. Then, since horizontal bridging rows must be continuous and each joist is braced from both sides, the total bracing force is divided by two, and rounded, to achieve 0.0025P, where P represents the chord axial force, and the third assumption relates to the construction stress in the top chord and the axial force P that it creates. For **K**-Series joists, the bridging criteria are based on a top chord axial construction ultimate stress (F_{cr}) of approximately 17 ksi. Due to the continuity of the top chord on either side of the bridging attachments, a k-factor of 0.9 is used in calculating the top chord slenderness ratio. Hence, for an ultimate Euler stress of approximately 17 ksi and a k-factor of 0.9, the permissible slenderness ratio, l/r_{yy} is set to 145 for **K**-Series as given above.

LH- and **DLH**-Series joists are similar, except that the assumed construction stress is taken as approximately 12 ksi, and the resultant slenderness limit, l/r_{yy}, is 170.

Therefore, the nominal compressive force that accumulates in a horizontal bridging row is:

$$P_{br} = 0.0025\, n\, A_t\, F_{construction}$$

where,

$F_{construction}$ is approximately 17 ksi for **K**-Series joists, and 12 ksi for **LH**- and **DLH**-Series joists, as noted above.

A_t = is the top chord area

n = the number of joists

For horizontal bridging, n is taken as eight joist spaces. This is due, in part, to the fact that the construction loads tend to be localized, rather than spread uniformly over an entire bay, and to the probability that not all joists in a bay would exhibit the maximum out-of-straightness at any given time. For horizontal bridging, the bracing force. P_{br}, must be taken in compression.

Diagonal bridging creates a load path whereby the forces are resolved at each braced joist space and do not accumulate. However, recall that the bracing force was divided by two on the presumption of continuous bridging on each side of the joist chord. Since continuity is not required of diagonal bridging rows, and to allow the diagonal bridging force to be considered only in tension, then n is taken as two for diagonal bridging.

The tables provided in the SJI Specifications for bridging sizes are based upon the force P_{br} for the typical top chord areas for a given designation. Table 2.6-1a of the SJI Code of Standard Practice gives the maximum joist spacing for certain horizontal bridging sizes based on joist chord section numbers for **K**-Series joists and using k=0.9 for the bridging design, and Table 2.6-1b provides the same for **LH**- and **DLH**-Series joists. Diagonal bridging is only subjected to tension forces, and so the bridging size is governed by a slenderness limit (between connections) of 200, rather than by strength.

TABLE 2.6-1a

K - SERIES JOISTS MAXIMUM JOIST SPACING FOR HORIZONTAL BRIDGING							
SECTION NUMBER*	BRIDGING MATERIAL SIZE**						
	Round Rod	Equal Leg Angles					
	1/2" dia. (13 mm) r = 0.13" (3.30 mm)	**1 x 7/64 (25 x 3 mm) r = 0.20" (5.08 mm)**	**1-1/4 x 7/64 (32 x 3 mm) r = 0.25" (6.35 mm)**	**1-1/2 x 7/64 (38 x 3 mm) r = 0.30" (7.62 mm)**	**1-3/4 x 7/64 (45 x 3 mm) r = 0.35" (8.89 mm)**	**2 x 1/8 (52 x 3 mm) r = 0.40" (10.16 mm)**	**2-1/2 x 5/32 (64 x 4 mm) r = 0.50" (12.70 mm)**
	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)
1 - 9	3'- 3" (991)	5'- 0" (1524)	6'- 3" (1905)	7'- 6" (2286)	8'- 7" (2616)	10'- 0" (3048)	12'- 6" (3810)
10	3'- 0" (914)	4'- 8" (1422)	6'- 3" (1905)	7'- 6" (2286)	8'- 7" (2616)	10'- 0" (3048)	12'- 6" (3810)
11 - 12	2'- 7" (787)	4'- 0" (1219)	5'- 8" (1727)	7'- 6" (2286)	8'- 7" (2616)	10'- 0" (3048)	12'- 6" (3810)

* Refer to last digit(s) of Joist Designation

** Connection to joist must resist a nominal unfactored 700 pound force (3114 N)

Recently, the SJI has begun to investigate the difference between the assumed **K**-Series construction stress of 17 ksi verses 12 ksi for **LH**- and **DLH**-Series joists. Preliminary findings indicate that the construction stress has very little to do with the chosen joist series, but is heavily influenced by both the span and depth of a joist. For a given span length and joist spacing, the construction load will arguably be the same regardless of joist depth, while the top chord construction stress will clearly be less for a deeper joist. On this basis, equations were developed for the new SJI Standard Specifications for Composite Steel Joists, **CJ**-Series [SJI, 2007], in which $F_{construction}$ and the top chord slenderness limit varies depending on the depth and span length as follows:

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

$$\ell_{br} = \left(100 + 0.67\,d_j + 40\frac{d_j}{L}\right) r_y \text{ but not greater than, } \ell_{br} = 170\,r_y$$

It is anticipated that a similar methodology may be adopted for **K**-, **LH**-, and **DLH**-Series joists in the future. However, they would not exactly match the **CJ**-Series equations, because the **CJ**-Series allows for an ultimate top chord construction stress in excess of 17 ksi. This is due to the fact that composite joist top chords are inherently smaller than comparable non-composite top chord sizes, and the maximum span to depth ratio is greater for composite than non-composite joists.

TABLE 2.6-1b

LH - SERIES JOISTS **MAXIMUM JOIST SPACING FOR HORIZONTAL BRIDGING** SPANS OVER 60 ft. (18.3 m) REQUIRE BOLTED DIAGONAL BRIDGING						
SECTION NUMBER*	BRIDGING MATERIAL SIZE**					
	Equal Leg Angles					
	1 x 7/64 (25 x 3 mm) r = 0.20” (5.08 mm)	**1-1/4 x 7/64 (32 x 3 mm) r = 0.25” (6.35 mm)**	**1-1/2 x 7/64 (38 x 3 mm) r = 0.30” (7.62 mm)**	**1-3/4 x 7/64 (45 x 3 mm) r = 0.35” (8.89 mm)**	**2 x 1/8 (52 x 3 mm) r = 0.40” (10.16 mm)**	**2-1/2 x 5/32 (64 x 4 mm) r = 0.50” (12.70 mm)**
	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)
02, 03, 04	4’–7” (1397)	6’–3” (1905)	7’–6” (2286)	8’–9” (2667)	10’–0” (3048)	12’–4” (3759)
05 – 06	4’–1” (1245)	5’–9” (1753)	7’–6” (2286)	8’–9” (2667)	10’–0” (3048)	12’–4” (3759)
07 – 08	3’–9” (1143)	5’–1” (1549)	6’–8” (2032)	8’–6” (2590)	10’–0” (3048)	12’–4” (3759)
09 – 10		4’–6” (1372)	6’–0” (1829)	7’–8” (2337)	10’–0” (3048)	12’–4” (3759)
11 – 12		4’–1” (1245)	5’–5” (1651)	6’–10” (2083)	8’–11” (2718)	12’–4” (3759)
13 – 14		3’–9” (1143)	4’–11” (1499)	6’–3” (1905)	8’–2” (2489)	12’–4” (3759)
15 – 16			4’–3” (1295)	5’–5” (1651)	7’–1” (2159)	11’-0” (3353)
17			4’–0” (1219)	5’–1” (1549)	6’–8” (2032)	10’–5” (3175)

* Refer to last two digit(s) of Joist Designation
** Connection to joist must resist force listed in Table 104.5-1

In certain design applications that utilize bottom bearing or square-ended joists, the product is designed to bear on the bottom chord. This produces a “top heavy” condition. Therefore, their ends must be restrained laterally in accordance with the SJI Standard Specifications **K**-Series Section 5.4d or **LH**- and **DLH**-Series Section 104.5f [SJI, 2005]. This is accomplished by means of an additional row of diagonal bridging placed at or near the bearing support ends of the joists as they are being erected. Where a bottom bearing joist is extended beyond its support to form a cantilevered end, a row of diagonal bridging near the support should first be installed. In addition, the structural drawings may indicate a row of diagonal bridging in the cantilevered portion to provide lateral stability. If the joists have bottom chords extended over and connected to a column, beam, wall, or other structure, the connection should be made in accordance with the structural drawings and/or instructions from the EOR.

BRIDGING FOR PERMANENT LOADS

Top chord bridging serves a role as PERMANENT BRIDGING in the absence of a deck diaphragm, as is the case with a standing seam roof applied directly to the joist top chords. Sections 5.8(g) and 104.9(g) of the SJI Standard Specifications [SJI, 2005] for **K**-Series and

LH-, **DLH**-Series joists, respectively provide the requirements for the horizontal bridging design. The compressive force equation is,

$$P_{br} = 0.0025nP$$

This equation is similar to the equation given above for CONSTRUCTION BRIDGING, but here, n is not limited to eight, and is equal to the total number of joists between end anchors. P represents the actual top chord design force, rather than the chord area times an arbitrary construction stress.

Bottom chord bridging is always PERMANENT BRIDGING, and either limits slenderness for bottom chords in tension, or braces the bottom chord laterally for compression forces, such as those present in a net uplift loading case. Traditionally, and for simplicity in the field, the bottom chord bridging size is equal to the size as determined for the top chord.

When uplift forces are a design consideration, a row of bottom chord bridging is required near each end of shortspan joists in accordance with the SJI Standard Specifications, **K**-Series Sections 5.6 and 5.11 and longspan joists in accordance with the SJI Standard Specifications **LH**- and **DLH**-Series Sections 104.7 and 104.12 [SJI, 2005].

For a Joist Girder, the ends are laterally braced by the stabilizer plates, as discussed previously. However, additional brace points may be required along the girder span length, either to limit the slenderness ratio for bottom chords in tension, or to laterally brace the bottom chord in compression. In this case, PERMANENT BRIDGING is added in the form of bottom chord bracing (BCB) or knee bracing. This consists of separate individual pieces of material (furnished by the joist supplier) to be attached either by bolting or welding from the bottom chord of the joist to the bottom chord of the Joist Girder.

CONCLUSIONS

This paper has summarized the Steel Joist Institute and OSHA requirements for steel joist and Joist Girder bridging, and has categorized those requirements by the three functional purposes of bridging. As a complement to what is in the Specifications, some of the underlying theory, equations, and references for bridging have been provided. Future research with regard to joist bridging is likely to include a review of the construction stress levels, a unification of the **K**-Series and **LH**- and **DLH**-Series bridging requirements, and a better understanding of the accumulation of bridging forces due to net uplift.

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