Utilizing, Specifying and Then Bridging Open Web Steel Joists

MAY 15, 2024

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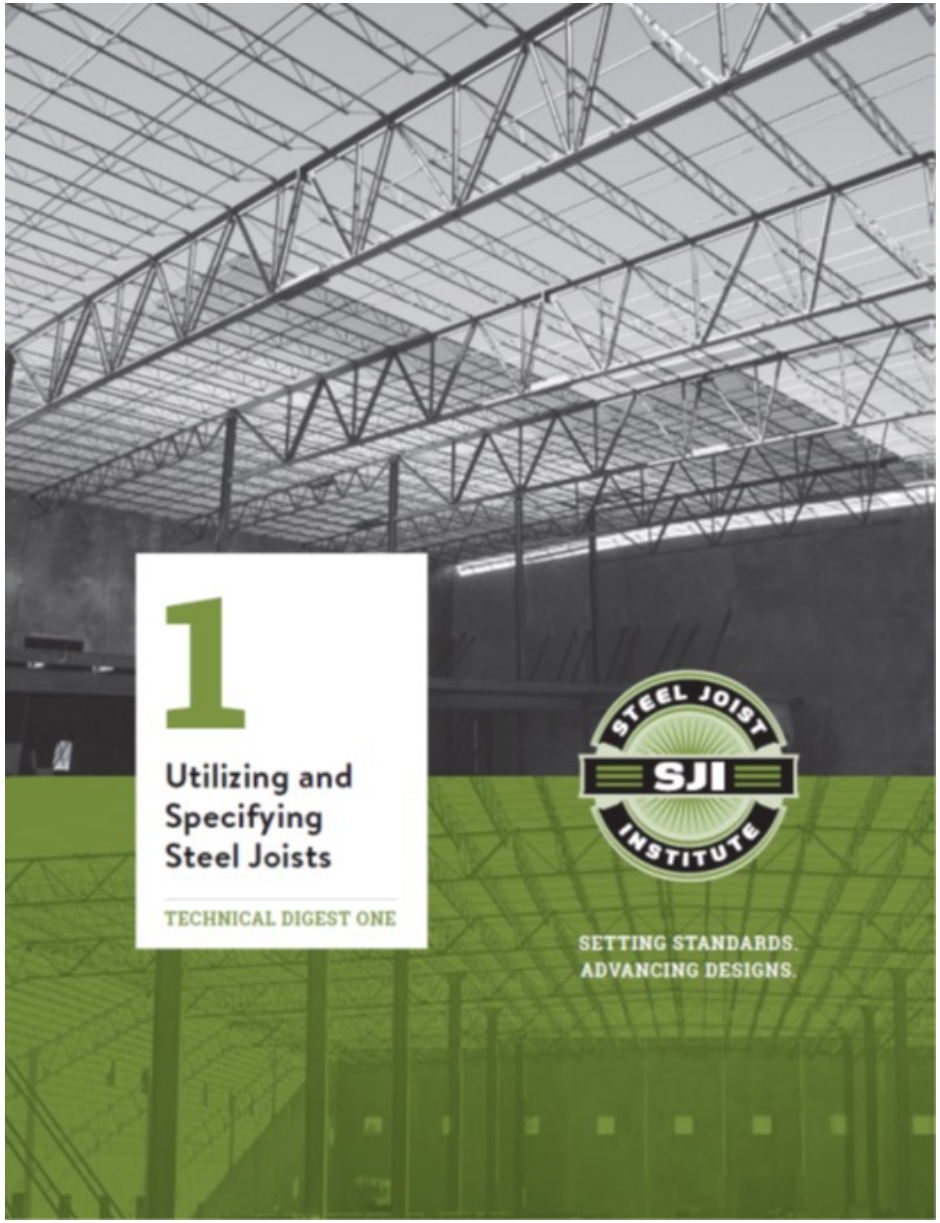
Webinar Description

The first part of the webinar will provide guidance to the specifying professional for single-story and multistory buildings using open web steel joists and joist girders, and it is based upon the recently published SJI Technical Digest 1 “Utilizing and Specifying Steel Joists.” An overview of the SJI joist types is followed by design considerations and loading types.

The second part is based upon the recently published SJI Technical Digest 2 “Bridging and Bracing of Steel Joists and Joist Girders.” This part of the webinar will focus on the bridging systems that laterally brace steel joists. After a brief discussion of the purpose and theory of bridging, the specification requirements and details for bridging will be explored.

Learning Objectives

- Learn the types of SJI open web products and the contents of Technical Digest 1.
- Understand the role of steel joists in the building design and better understand how to specify steel joists.
- Learn the purpose, theory and types of bridging.
- Understand the basics of specifying and then properly installing bridging.


1
Utilizing and Specifying Steel Joists
TECHNICAL DIGEST ONE
STEEL JOIST
SJI
INSTITUTE
SETTING STANDARDS.
ADVANCING DESIGNS.

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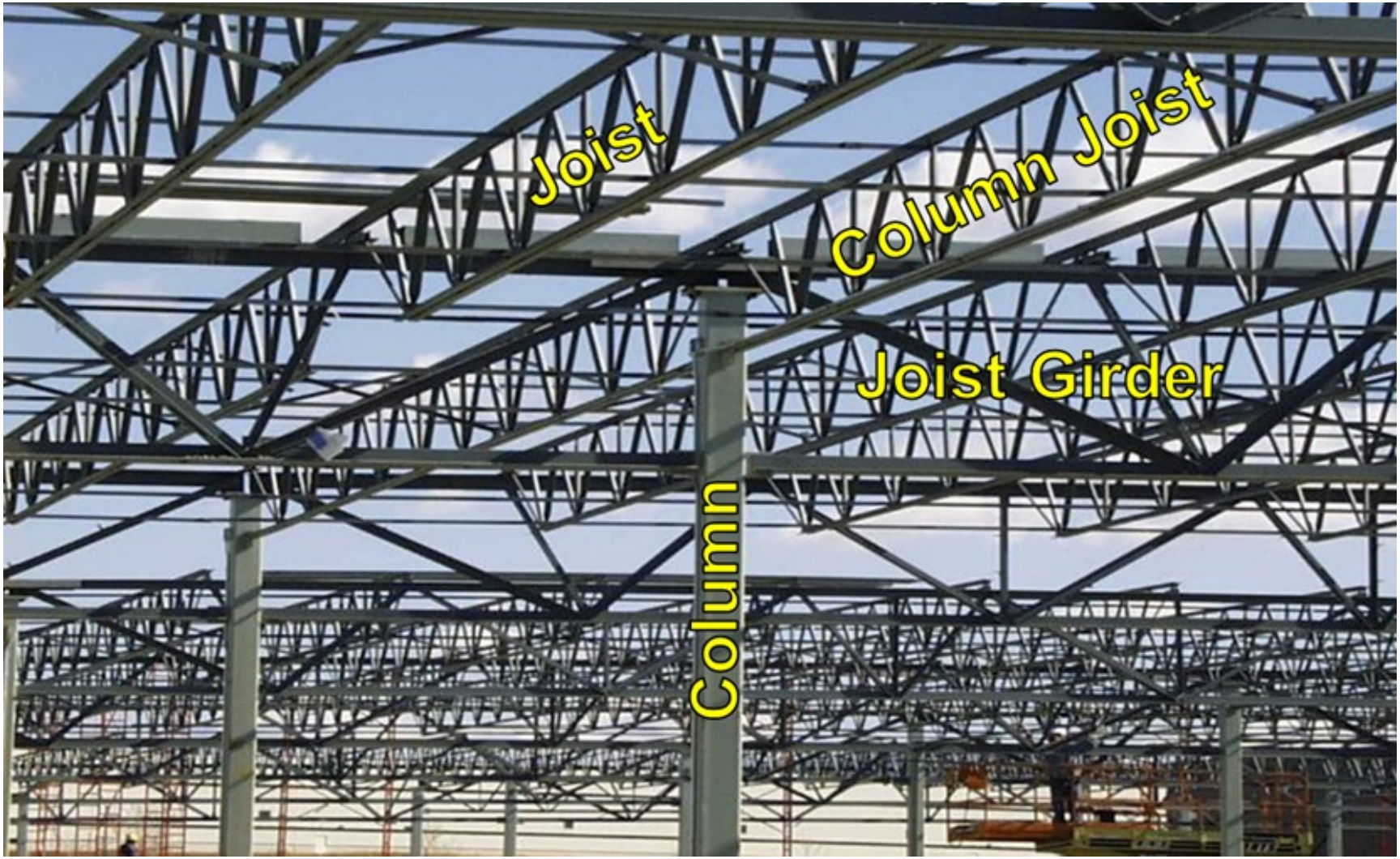
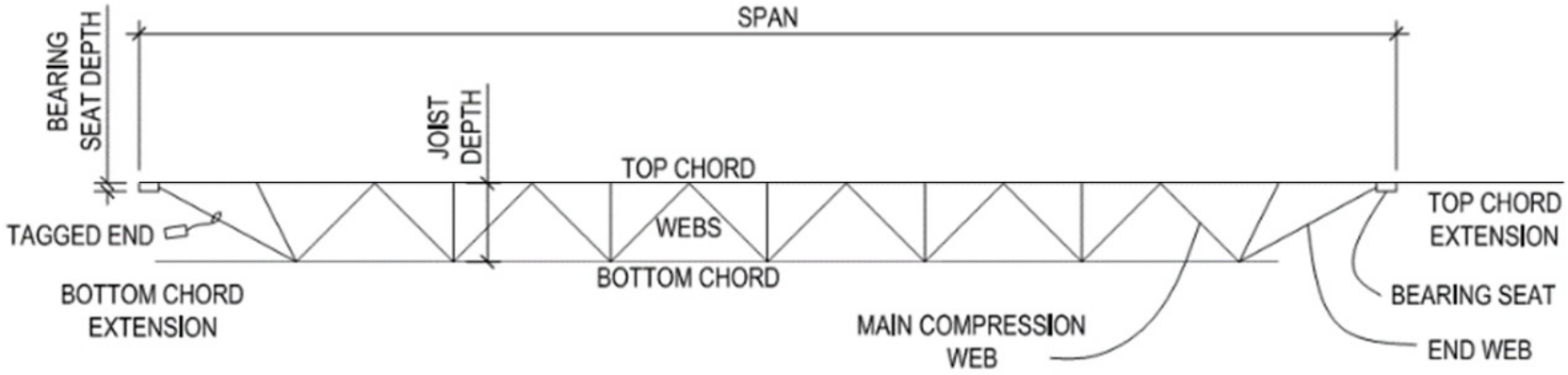
Standard and Special Joist Types



Joist Nomenclature and Member Types



Rod Webs

Crimped Angle Webs

Double Angle Webs

Standard Joist Types

- K-Series
- KCS
- LH and DLH-Series
- Load/Load Joists
- CJ-Series
- Chord Extensions (TCX) and Extended Ends
- Joist Substitutes and Outriggers
- Special Profile Joists
- Joist Girders

K-Series

- K-Series joists are designed as simple span uniformly loaded members unless specified otherwise. K-Series is the most common joist for roof construction.
- Designations: 10K1 to 30K12
- Depths: 10 to 30 in.
- Standard Seat Depth (Height): 2.5 in.
- Span Range: 10 to 60 ft.
- **ASD** Load Range: up to 550 plf
- **LRFD** Load Range: up to 825 plf

K-Series Load Tables

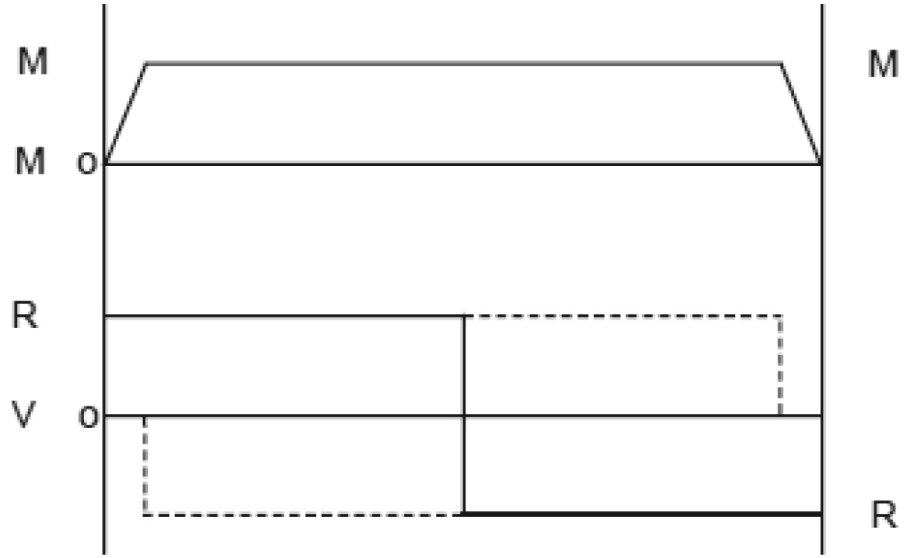
ASD

STANDARD LOAD TABLE FOR OPEN WEB STEEL JOISTS, K-SERIES
Based on a 50 ksi Maximum Yield Strength - Loads Shown In Pounds Per Linear Foot (plf)

Joist Designation	24K4	24K5	24K6	24K7	24K8	24K9	24K10	24K12	26K5	26K6	26K7	26K8	26K9	26K10	26K12
Depth (In.)	24	24	24	24	24	24	24	24	26	26	26	26	26	26	26
Approx. Wt. (lbs./ft.)	7.8	7.9	8.5	9.0	9.4	10.3	11.7	13.5	8.1	8.6	9.0	9.7	10.4	11.8	13.7
Span (ft.) ↓															
23	550	550	550	550	550	550	550	550							
	550	550	550	550	550	550	550	550							
24	520	550	550	550	550	550	550	550							
	516	544	544	544	544	544	544	544							
25	479	540	550	550	550	550	550	550	550	550	550	550	550	550	550
	456	511	520	520	520	520	520	520	550	550	550	550	550	550	550
26	442	499	543	550	550	550	550	550	542	550	550	550	550	550	550
	405	453	493	499	499	499	499	499	535	541	541	541	541	541	541
27	410	462	503	550	550	550	550	550	502	547	550	550	550	550	550
	361	404	439	479	479	479	479	479	477	519	522	522	522	522	522
28	381	429	467	521	550	550	550	550	466	508	550	550	550	550	550
	323	362	393	436	456	456	456	456	427	464	501	501	501	501	501
29	354	400	435	485	536	550	550	550	434	473	527	550	550	550	550
	290	325	354	392	429	436	436	436	384	417	463	479	479	479	479
30	331	373	406	453	500	544	550	550	405	441	492	544	550	550	550
	262	293	319	353	387	419	422	422	346	377	417	457	459	459	459
31	310	349	380	424	468	510	550	550	379	413	460	509	550	550	550
	237	266	289	320	350	379	410	410	314	341	378	413	444	444	444
32	290	327	357	397	439	478	549	549	356	387	432	477	519	549	549
	215	241	262	290	318	344	393	393	285	309	343	375	407	431	431
33	273	308	335	373	413	449	532	532	334	364	406	448	488	532	532
	196	220	239	265	289	313	368	368	259	282	312	342	370	404	404
34	257	290	315	351	388	423	502	516	315	343	382	422	459	516	516
	179	201	218	242	264	286	337	344	237	257	285	312	338	378	378
35	242	273	297	331	366	399	473	501	297	323	360	398	433	501	501
	164	184	200	221	242	262	308	324	217	236	261	286	310	356	356
36	229	258	281	313	346	377	447	487	280	305	340	376	409	486	487
	150	169	183	203	222	241	283	306	199	216	240	263	284	334	334
37	216	244	266	296	327	356	423	474	265	289	322	356	387	460	474
	138	155	169	187	205	222	260	290	183	199	221	242	262	308	315
38	205	231	252	281	310	338	401	461	251	274	305	337	367	436	461
	128	143	156	172	189	204	240	275	169	184	204	223	241	284	299
39	195	219	239	266	294	320	380	449	238	260	289	320	348	413	449
	118	132	144	159	174	189	222	261	156	170	188	206	223	262	283
40	185	208	227	253	280	304	361	438	227	247	275	304	331	393	438
	109	122	133	148	161	175	206	247	145	157	174	191	207	243	269
41	176	198	216	241	266	290	344	427	215	235	262	289	315	374	427
	101	114	124	137	150	162	191	235	134	146	162	177	192	225	256
42	168	189	206	229	253	276	327	417	205	224	249	275	300	356	417
	94	106	115	127	139	151	177	224	125	136	150	164	178	210	244

KCS Joists

KCS Joist chords are designed for a flat positive moment envelope. The moment capacity is constant at all interior panels. All webs are designed for a vertical shear equal to the specified shear capacity and interior webs will be designed for 100% stress reversal



KCS Load Tables

ASD

STANDARD LOAD TABLE FOR KCS OPEN WEB STEEL JOISTS

Based on a 50 ksi Maximum Yield Strength

JOIST DESIGNATION	DEPTH (in.)	MOMENT CAPACITY (k-in.)	SHEAR CAPACITY* (lbs)	APPROX. WEIGHT** (lbs/ft.)	GROSS MOMENT OF INERTIA ($in.^4$)	ERECTION STABILITY BRIDGING REQ'D (ft.)	BRIDGING TABLE SECTION NUMBER
10KCS1	10	172	2000	6.0	29	NA	1
10KCS2	10	225	2500	7.5	37	NA	1
10KCS3	10	296	3000	10.0	47	NA	1
12KCS1	12	209	2400	6.0	43	NA	3
12KCS2	12	274	3000	8.0	55	NA	5
12KCS3	12	362	3500	10.0	71	NA	5
14KCS1	14	247	2900	6.5	59	NA	4
14KCS2	14	324	3400	8.0	77	NA	6
14KCS3	14	428	3900	10.0	99	NA	6
16KCS2	16	349	4000	8.5	99	NA	6
16KCS3	16	470	4800	10.5	128	NA	9
16KCS4	16	720	5300	14.5	192	NA	9
16KCS5	16	934	5800	18.0	245	NA	9
18KCS2	18	395	4700	9.0	127	35-0	6
18KCS3	18	532	5200	11.0	164	NA	9
18KCS4	18	817	5700	15.0	247	NA	10
18KCS5	18	1062	6200	18.5	316	NA	10
20KCS2	20	442	5200	9.5	159	36-0	6
20KCS3	20	595	6000	11.5	205	39-0	9
20KCS4	20	914	7900	16.5	308	NA	10
20KCS5	20	1191	8400	20.0	396	NA	10
22KCS2	22	488	5900	10.0	194	36-0	6

KCS Example

Using ASD, select a 40-foot KCS joist with a total load of 270 plf which includes a live load of 120 plf, plus a moveable 2.0 kip concentrated live load.

- The maximum required moment (based on the concentrated load at mid-span) = 888 kip-in.
- The maximum required shear (based on the concentrated load adjacent to the support) = 7,400 lbs.
- Minimum depth = (40 ft)(12 in./ft)/24 = 20 in.

KCS Load Tables

ASD

STANDARD LOAD TABLE FOR KCS OPEN WEB STEEL JOISTS

Based on a 50 ksi Maximum Yield Strength

JOIST DESIGNATION	DEPTH (in.)	MOMENT CAPACITY (k-in.)	SHEAR CAPACITY* (lbs)	APPROX. WEIGHT** (lbs/ft.)	GROSS MOMENT OF INERTIA ($in.^4$)	ERECTION STABILITY BRIDGING REQ'D (ft.)	BRIDGING TABLE SECTION NUMBER
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12KCS2	12	274	3000	8.0	55	NA	5
12KCS3	12	362	3500	10.0	71	NA	5
14KCS1	14	247	2900	6.5	59	NA	4
14KCS2	14	324	3400	8.0	77	NA	6
14KCS3	14	428	3900	10.0	99	NA	6
16KCS2	16	349	4000	8.5	99	NA	6
16KCS3	16	470	4800	10.5	128	NA	9
16KCS4	16	720	5300	14.5	192	NA	9
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20KCS4	20	914	7900	16.5	308	NA	10
20KCS5	20	1191	8400	20.0	396	NA	10
22KCS2	22	488	5900	10.0	194	36-0	6

KCS Example

Maximum live load deflection = span/240 = (40 ft)(12 in./ft) = 480 in./240 = 2.0 in.

$\Delta = \Delta$ uniform load + Δ concentrated load

$\Delta = 5wL^4/384EI + PL^3/48EI$

The effective moment of inertia of $I_{gross}/1.15$ is used for this calculation. $I = 308/1.15 = 268$ in.^{4}

$\Delta = (1728)(5)(0.120)(40^4)/[(384)(29{,}000)(268)] = 0.89 +$

$(1728)(2)(40^3)/[48)(29000)(268)] = 0.59$ in.

$\Delta = 0.89$ in. + 0.59 in. = 1.48 in. < 2.0 in. OK

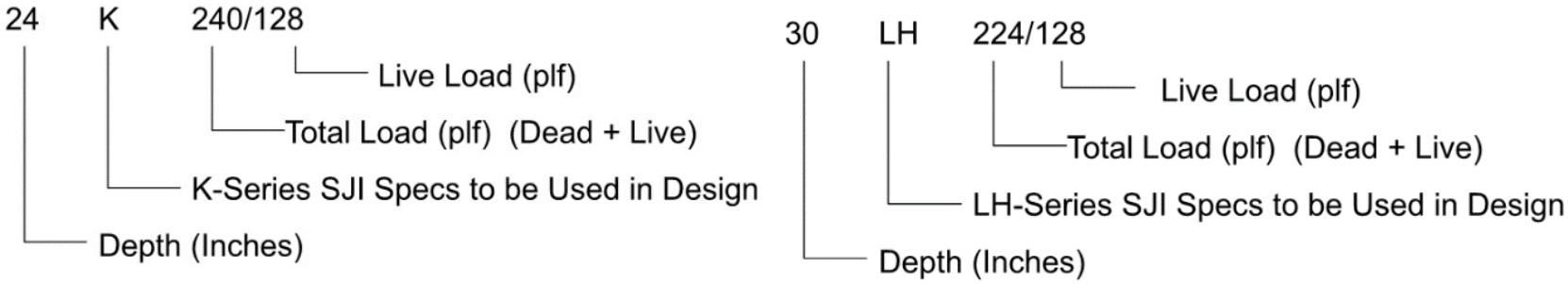
LH and DLH Joists

LH-Series joists have been standarized in depths from 18 inches through 48 inches.

- Spans up through 96 feet.
- Standarized in depths from 52 inches through 120 inches.
- Spans up through 240 feet.

The standard depth of the bearing seat at the ends of underslung LH-Series and DLH-Series joists is 5 inches for chord section numbers 17 and smaller, and 7.5 inches for chord section numbers 18 and larger.

Load/Load Joists



Uniform load-per-foot designated joists (load/load joists) are an alternative to the standard K, LH, and DLH-Series joists.

CJ-Series Joists

CJ-Series, composite joists, are another option for floor systems. The joists are connected to the concrete slab using headed steel stud anchors such that the joist and slab act together as one structural element.

The SJI catalog for CJ-joists can be ordered on the SJI Website www.steeljoist.org

CJ-Series Joists

Composite joists are specified to the joist manufacturer as shown below:

The composite steel joist designation:

30 CJ 2188 / 1168 / 420

30	CJ	2188	1168	420
Depth (in.)	Composite Joist Series	[1] Total Factored Composite Design Load (plf)	Total Factored Composite Live Load (plf)	Total Factored Composite Dead Load (plf)

[1] Total Factored Composite Design Load = Total Factored Composite Live Load + Total Factored Composite Dead Load + Total Factored Non-Composite Dead Load.

Polling Question

CJ-Series joists can be specified to the joist manufacturer as ASD or LRFD.

A. True

B. False

Top Chord Extensions (TCX and Extended Ends)

Joist Substitutes and Outriggers

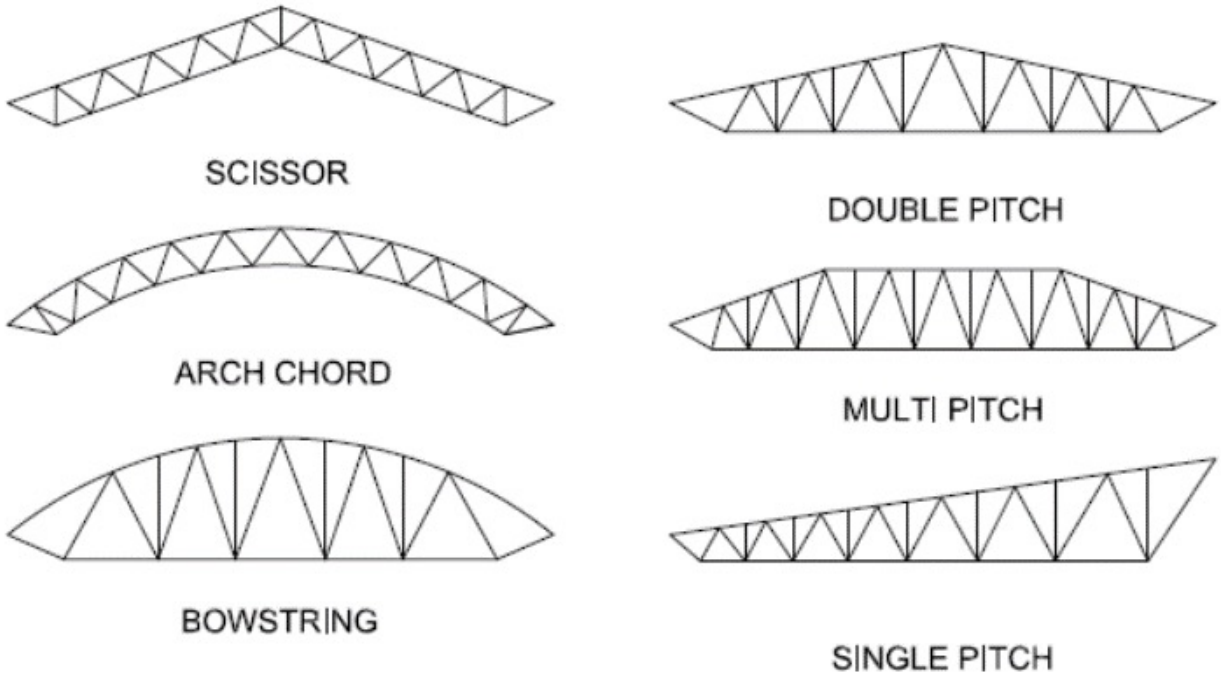
Joist substitutes are 2.5 inch deep members commonly used for uniformly loaded simple spans up to 10 feet in length.

For members less than 10 feet, joist substitutes should be used instead of open-web joists.

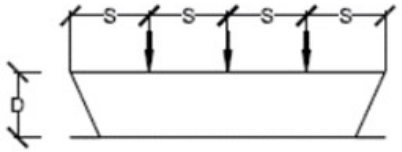
Special Profile Joists

Special profile LH joists are non-standard configurations and require special design beyond the SJI Specifications (SJI 2020a). See SJI Technical Digest 7 - Special Profile Steel Joists and Joist Girders.

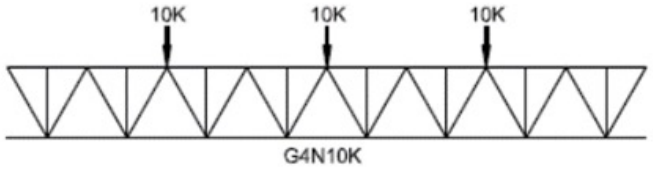
- Scissor
- Arch Chord
- Bowstring
- Double Pitch
- Multi Pitch
- Single Pitch



Joist Girders



FOR D/S < .36



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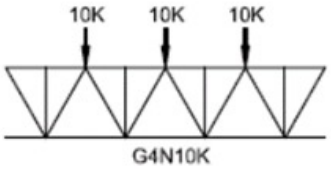

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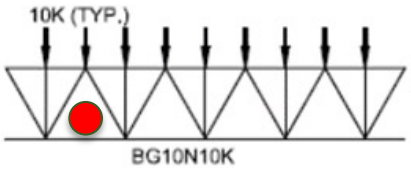

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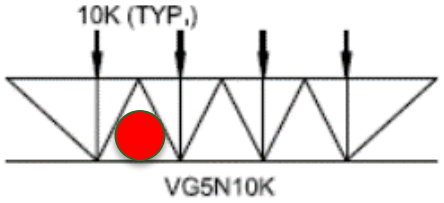


Chapter 2 Camber and Bridging

- Camber is used to counteract some or all dead load deflection. Since joists are typically cambered, it is not appropriate to specify total load deflection.
- The Steel Joist Institute Specification tabulates the approximate camber for K, LH and DLH joists and joist girders.
- Camber is solely based on length, and ranges from 1/4 inch for a 20-foot joist, to 4 1/4 inches for a 100-foot joist.
- For joists over 100 feet, the camber is span/300.

Chapter 6 Specifying Loads

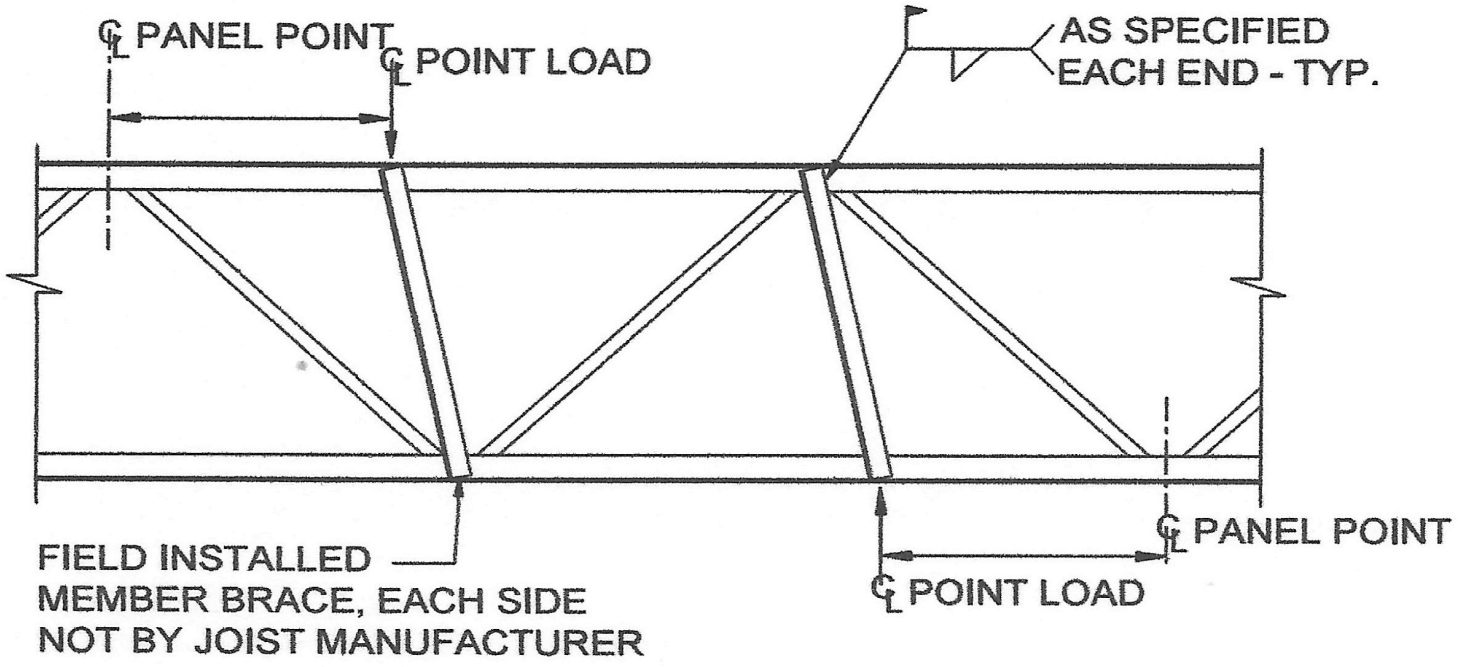
It must be understood that the joist manufacturer does **not** establish the loading requirements for the steel joists and joist girders.

The specifying professional must provide the magnitude and location of all loads for which the joists and joist girders are to be designed.

Joists with Concentrated Loads Less than or Equal to100 Pounds

For nominal concentrated loads between panel points, which have been accounted for in the specified uniform design loads, a "strut" to transfer the load to a panel point on the opposite chord shall not be required, provided the sum of the concentrated loads within a chord panel does not exceed 100 pounds and the attachments are concentric to the chord.

Specifying Joists with Concentrated Loads Greater than 100 Pounds



Add-Loads and Bend-Check Loads

Add-Load: A single vertical concentrated load that occurs at any one panel point along the joist chord. This load is in addition to any other gravity loads specified.

Bend-Check Load: A vertical concentrated load used to design the joist chord for the additional bending stresses resulting from this load being applied at any location between the joist panel points. This load shall already be accounted for in the specified joist designation load, uniform load, or add-load, and is used only for the additional bending check in the chord.

Specifying Traveling Loads

For a traveling load with no specific location, specifying the traveling load as an add-load is often the best option. This allows the joist manufacturer to design for the worst case for both the shear and bending moment.

If the traveling load occurs between panel points, there are two common options:

1. For the construction documents specify that field installed webs be installed at the final load location.
2. Require the joist to be designed for a bend-check load equal to the traveling load. This way, the bend-check covers localized bending between panel points and the add-load covers global shear and bending on the joist.

Specifying Axial Loads

Information that the specifying professional must provide to the joist manufacturer*:*

1. Magnitude of the axial load in kips, and whether these values are ASD or LRFD.
2. If the load is due to wind or seismic.
3. If the axial load is to be resisted by the top or bottom chord of the joist.
4. Means of axial load transfer into or out of the joist or joist girder.

Axial Load Transfer

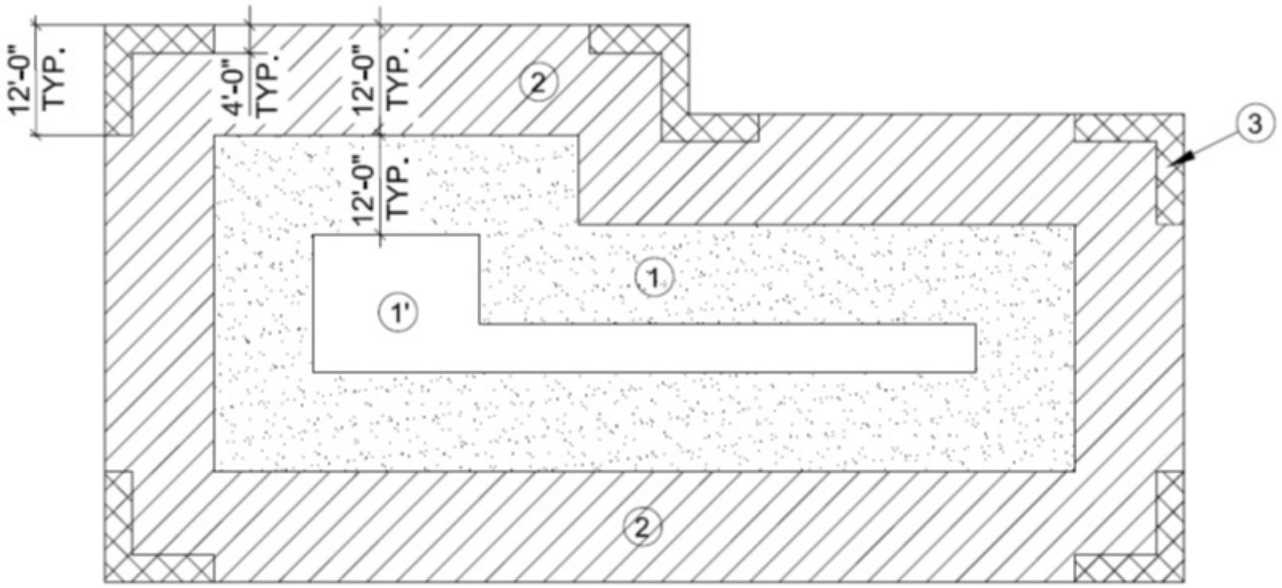
Specifying Uplift Loads

For simple loading when net uplift is specified consider a reduced dead loading to create the largest net uplift load combination.

For more complex loading or when the dead load varies greatly for use in load combinations, *gross* uplift should be specified with the minimum and maximum dead load values clearly defined.

If the uplift cannot be assigned in pounds per linear foot, a diagram can be shown for joist loading using pounds per square foot.

Specifying Uplift Loads



UPLIFT DIAGRAM

REF : 1/S001

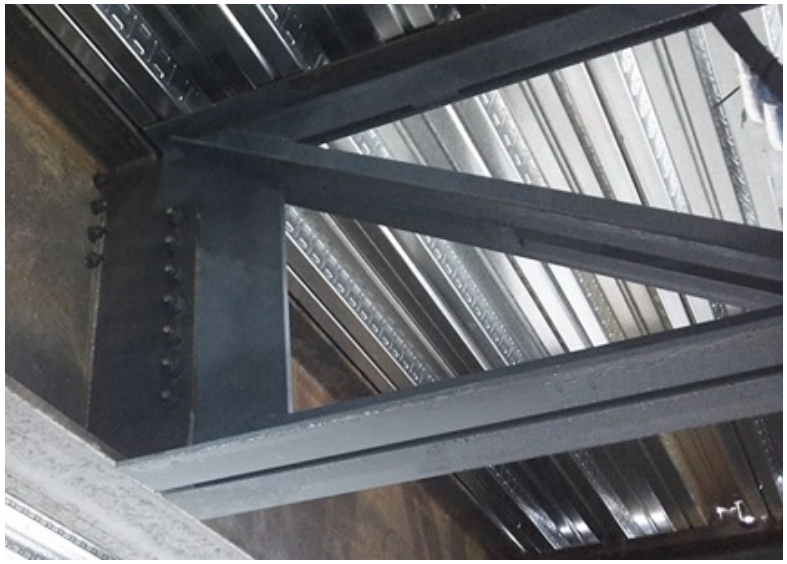
NET UPLIFT LOADING:

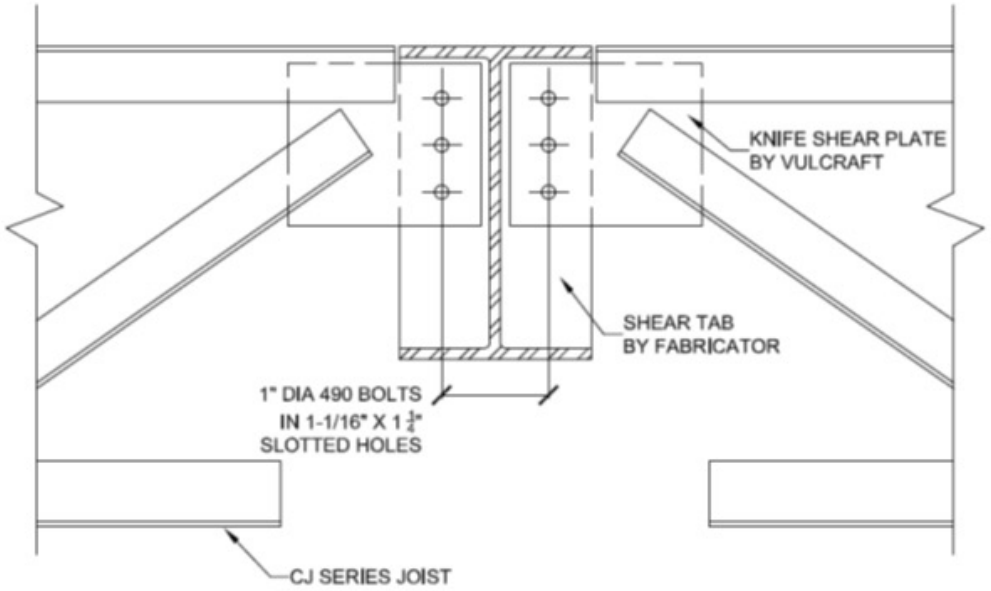
TRIBUTARY AREA	ZONE 1'	ZONE 1	ZONE 2	ZONE 3
100 SQ FT	-45.0 PSF	-82.4 PSF	-110.4 PSF	-152.4 PSF

A) WIND PRESSURES DETERMINED IN ACCORDANCE WITH ASCE 7-22
B) NET UPLIFT PRESSURES TABULATED ARE THE RESULTS OF THE LOAD COMBINATION 0.6D + 0.6W

Flush-Frame Connections

When specifying flush-frame connections, the specifying professional has several items to consider, and has several design requirements. Coordination with the joist manufacturer is encouraged. Design requirements for the specifying professional are spelled out in TD 1.

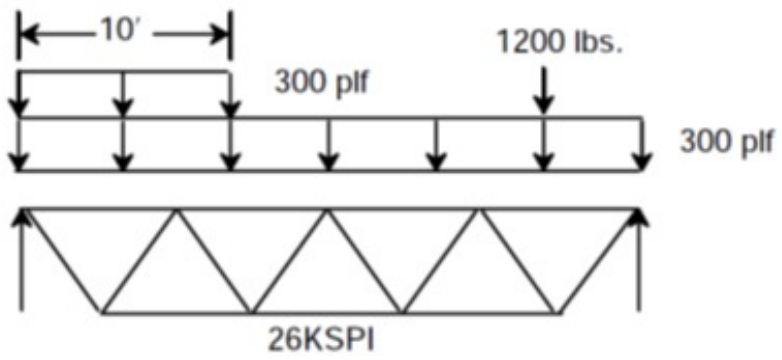


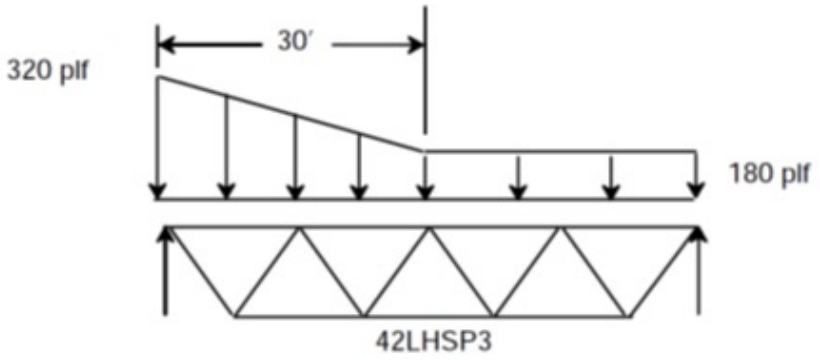


Joist and Joist Girder Diagrams

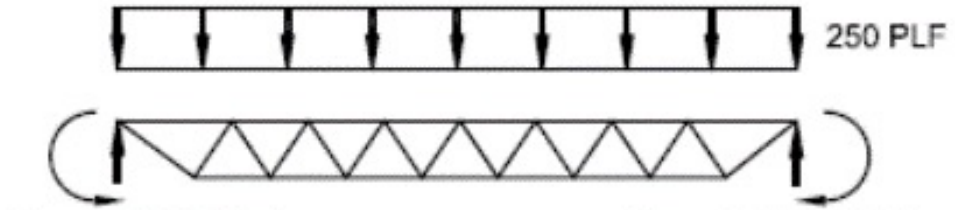
When K, LH, and DLH-Series joists and joist girders are not subjected to uniform loading, a load diagram may be the best way to convey the loading information to the joist manufacturer.

Joist and Joist Girder Diagrams





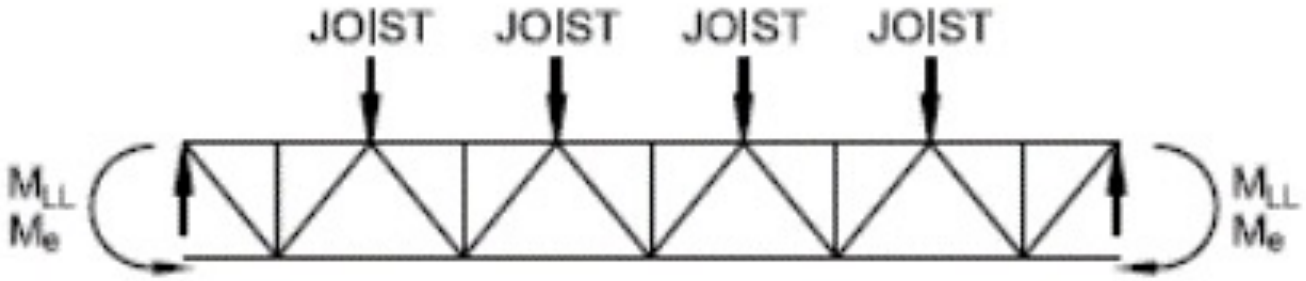
DEAD LOAD = 100 PLF
LIVE LOAD = 150 PLF



M_e = +/- 26.67 klp-ft
M_{LL} = 20.0 klp-ft

M_e = +/- 26.67 klp-ft
M_{LL} = 20.0 klp-ft

Joist and Joist Girder Diagrams



36G 5N 5.4K/2.2K
M_{LL} = 27.0 klp-ft
M_e = +/- 45.0 klp-ft

SEE PLAN FOR JOIST SPACING. WEB CONFIGURATION TO BE DETERMINED BY JOIST GIRDER MANUFACTURER.

Polling Question

Axial load transfer details are the design responsibility of the specifying professional.

A. True

B. False

Bridging for Open Web Steel Joists

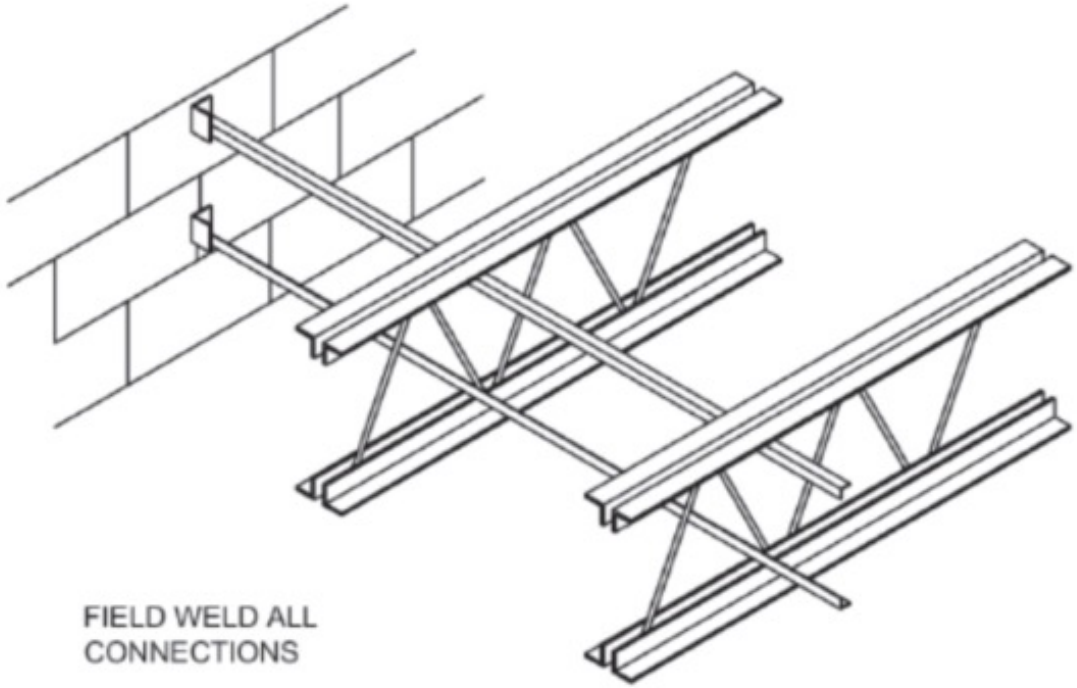
What is bridging?

Bridging is the lateral bracing members, from joist to joist, as provided by the Joist Manufacturer.

Bridging braces joists against unanticipated lateral movement during installation and during placement of construction loads and permanently restrains the joist chords from out-of-plane or lateral movement when other means are not present.

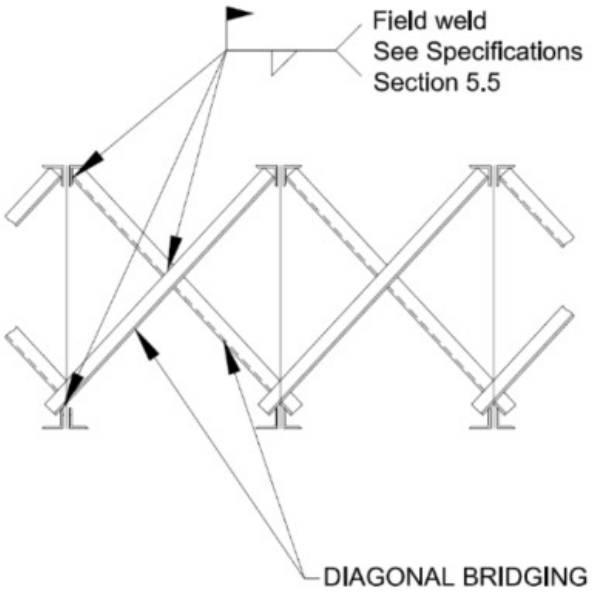
Horizontal Bridging

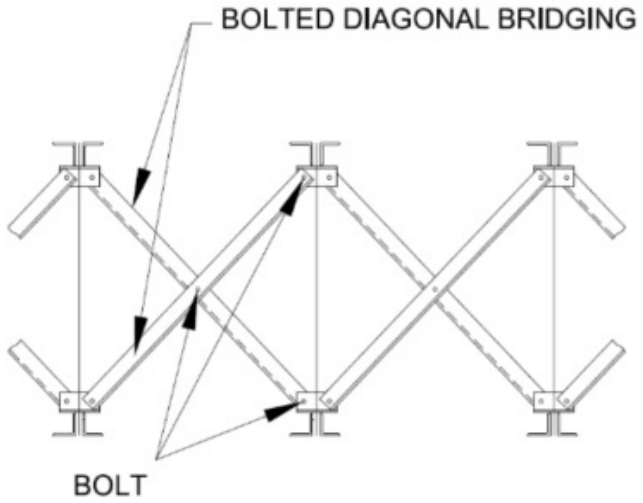
Horizontal bridging is a continuous member (typically small steel angles) installed (typically by welding) across consecutive joist top or bottom chords.



Diagonal Bridging

Diagonal bridging is a series of individual pieces to form an "X" from a top chord to adjacent bottom chord, and vice versa, in the joist space. Diagonal bridging may be bolted or welded.



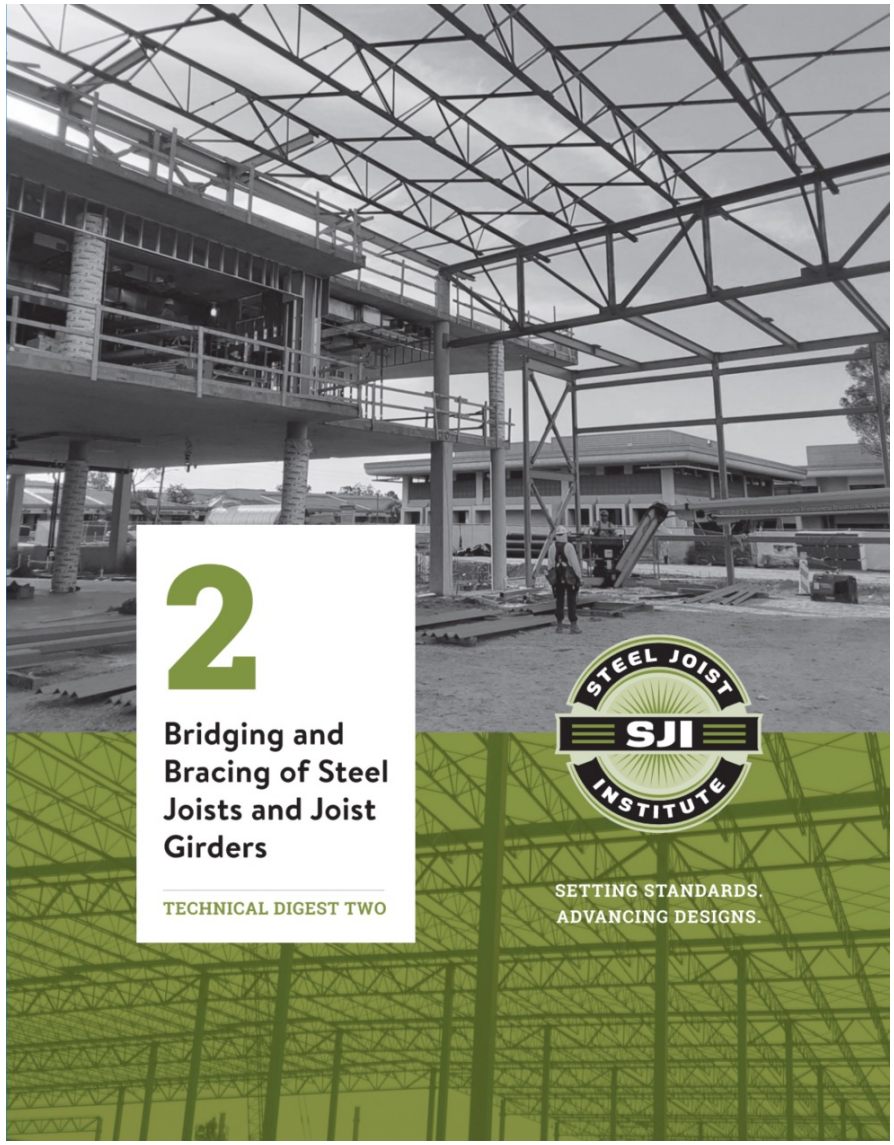


Technical Digest Two

The basis for this presentation is SJI Technical Digest 2

Bridging and Bracing of Steel Joists and Joist Girders

Published in December, 2023



Technical Digest Two

- CHAPTER 1 PURPOSE OF BRIDGING
- CHAPTER 2 BRIDGING THEORY
- CHAPTER 3 SJI SPEC REQUIREMENTS
- CHAPTER 4 RESPONSIBILITY
- CHAPTER 5 TYPICAL DETAILS
- CHAPTER 6 INSTALLATION TOPICS
- CHAPTER 7 SPECIAL PROFILES
- CHAPTER 8 RESEARCH SUMMARY
- CHAPTER 9 EXAMPLES
- CHAPTER 10 REFERENCES

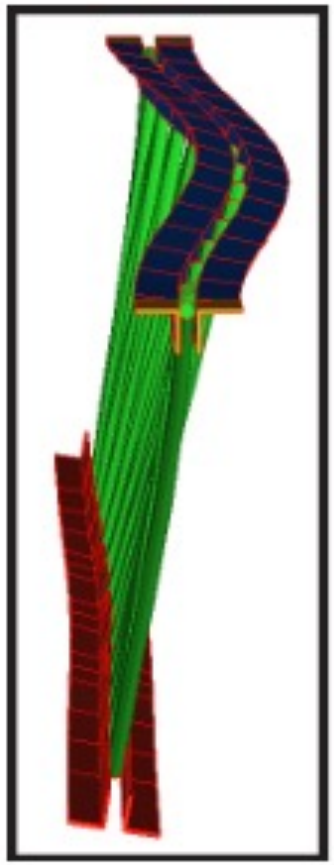
Outline

- Bridging Roles
- Bridging Theory
- Four Questions to Size and Place the Bridging
- Special Cases and Conditions

Bridging Roles - Erection

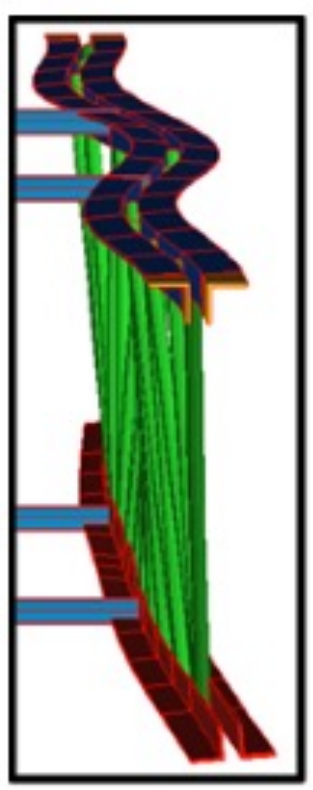
The immediate concerns with setting a joist within the structure are:

- The ability of the joist to support its own self weight while unbraced.
- The ability to support an erector, who may "walk" the joist to release the hoisting cable.
- The ability of the joist to support the worker, tools, and materials while installing bridging rows.

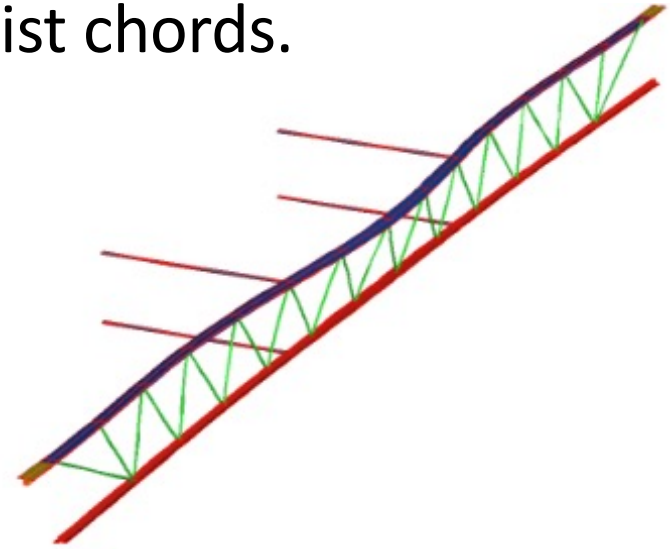


Bridging Roles - Erection

Simple analogies are that a joist without bridging is like an unbraced beam, and under load is subject to possible lateral movement and twisting movement.



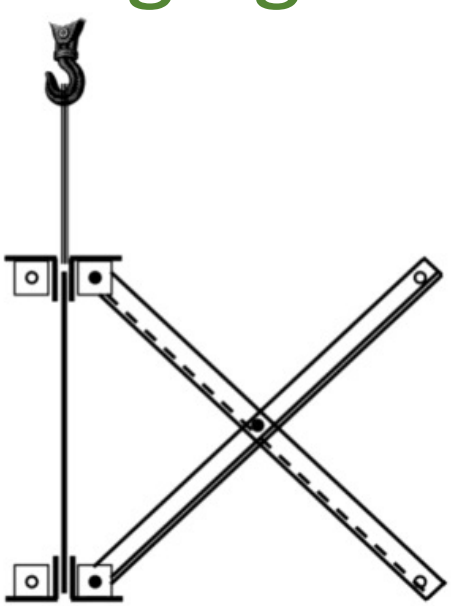
And the joist top and bottom chords are like columns. The figures model the effect of bridging to brace the joist chords.

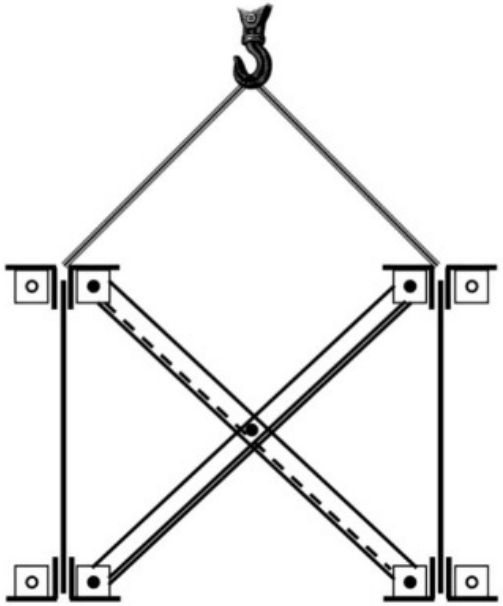


Bridging Roles - Erection

The SJI has done extensive research to determine where a joist may be unstable under only its own self weight and the weight of one erector. In those cases, bolted diagonal bridging is specified.

Bridging Roles - Erection





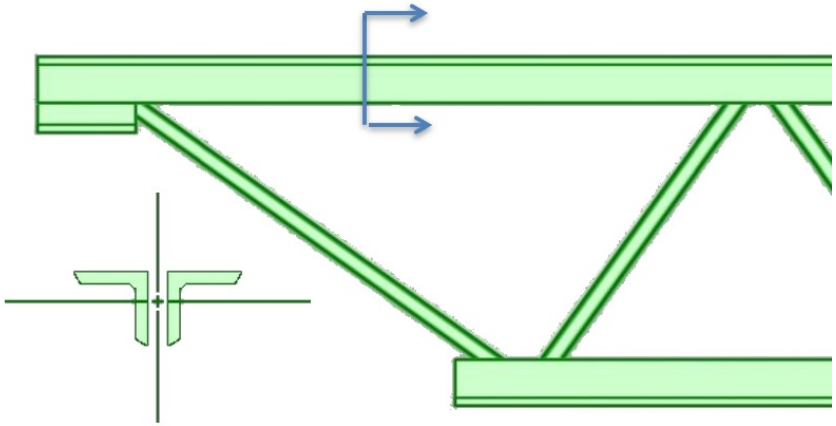
Bolted diagonal bridging allows for a bridging pair to be installed and cantilevered off the joist being hoisted, with the worker receiving the other end of the bridging pieces on an already stabilized joist or another element of the structure.

Alternately, diagonal bolted bridging can be used to join a pair of joists for hoisting, such that they will provide initial stability to each other.

Bridging Roles - Construction

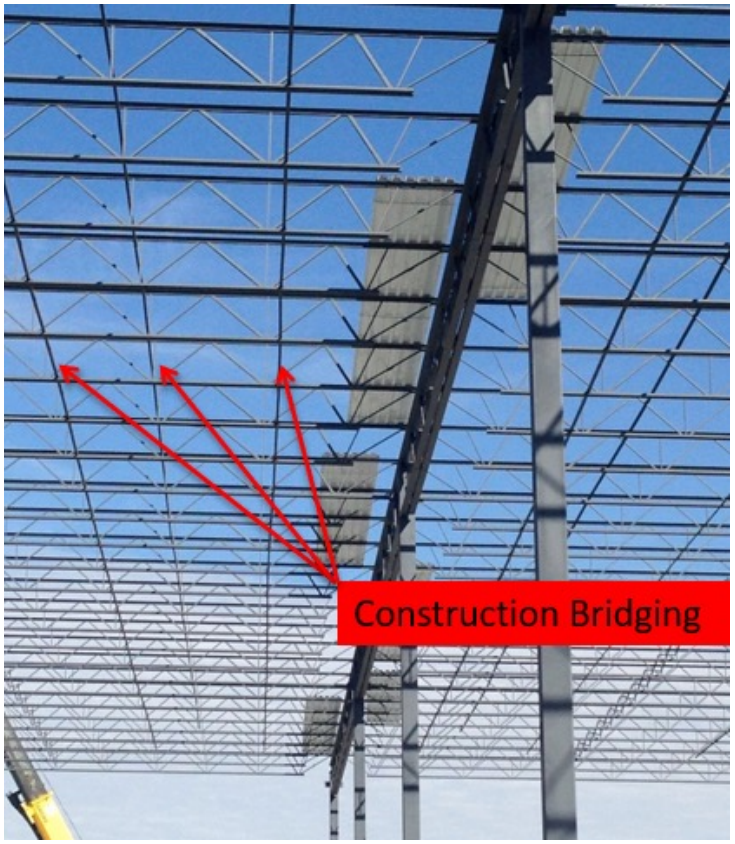
After initial stability has been achieved with the installation of erection bridging and the hoisting cables have been removed, the complete bridging system installation must create capacity for the construction loads: additional workers, tools, equipment, limited construction materials, and the metal deck.

SJI establishes the permitted axial top chord stress due to construction loads, and bridging must be spaced so as to provide sufficient strength based on the joist top chord slenderness between bridging rows, as a function of Ryy of the top chord.



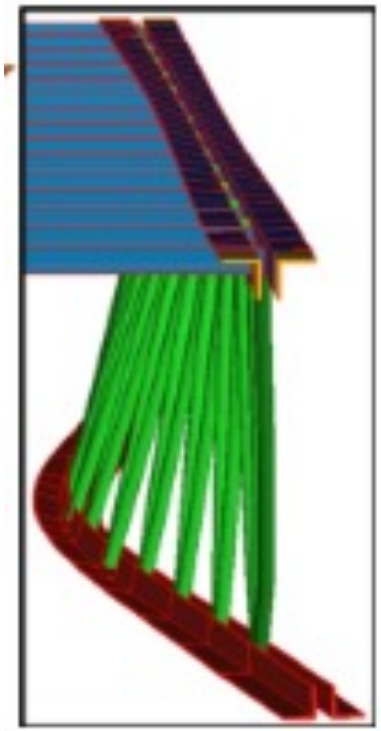
Bridging Roles - Construction

The primary construction load is typically the metal deck bundles. OSHA allows the placement of deck bundles before complete bridging installation if a series of strict conditions are met.



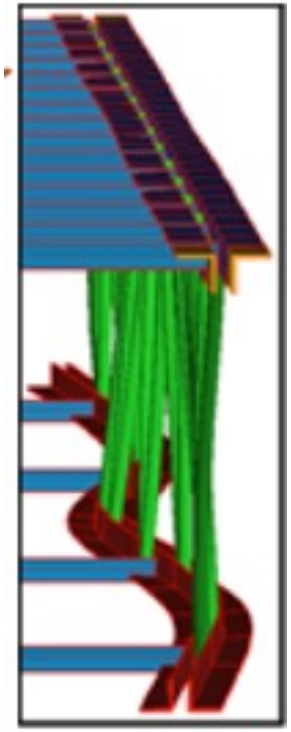
Bridging Roles - Permanent

Metal deck will permanently provide lateral support for the joist top chord, and the top chord bridging has completed it's role.



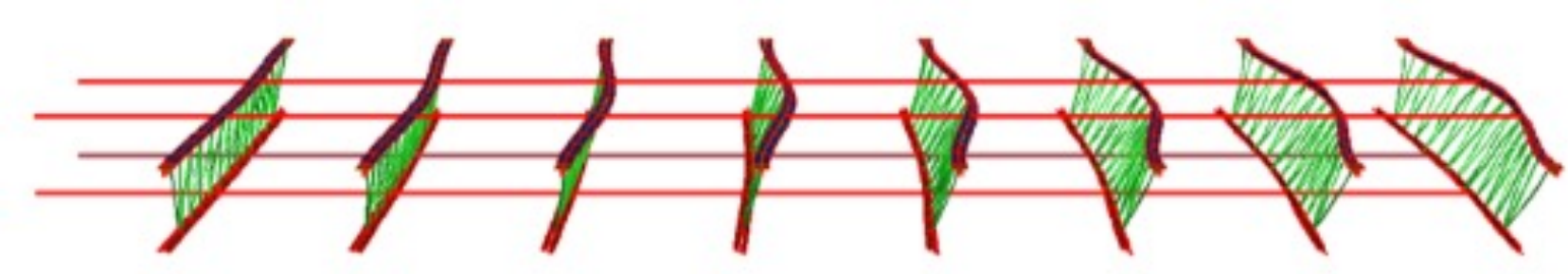
However, in the absence of metal deck or other top chord lateral support, the bridging will need to permanently brace the top chord, with a likely increase in both the number of rows and bridging size.

For wind net uplift or any other compressive axial load in the joist bottom chord, the bridging provides permanent lateral support, and may control the bottom chord size.

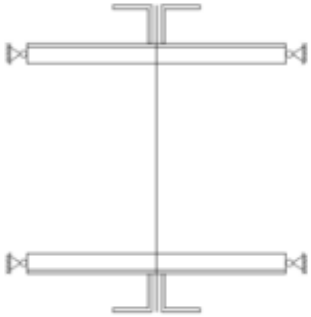


Bridging Theory

Horizontal bridging will accumulate across multiple joist chords and spaces. Termination, to anchor or to provide a load path to resolve the bridging forces, is critical.



Horizontal bridging is a “two way” system, assuming forces accumulating in both directions and requiring anchorage at each end of the bridging line.



Bracing Forces

The governing equation for bridging forces during construction is:

$$P_{br} = 0.0025\ n\ A_t\ F_{construction}\ ,\ \text{lbs}\ (N)$$

Where,

n = 8 for horizontal bridging

n = 2 for diagonal bridging

A_t = cross-sectional area of joist top chord, in.^{2} (mm^2)

$F_{construction}$ = assumed nominal stress in top chord to resist construction loads

Table 5.5-2 SJI Specification

BRIDGING NOMINAL HORIZONTAL UNFACTORED COMPRESSIVE FORCE					
JOIST SECTION NUMBER[1]	HORIZONTAL BRIDGING P_{br} (n=8)		REQUIRED BRIDGING CONNECTION WELD[2]	DIAGONAL BRIDGING P_{br} (n=2)	
	Lbs.	(N)	In.	Lbs.	(N)
K1-8	340	(1512)	1/8" x 1" (3mm x 25mm)	85	(378)
K9-10, LH02-03	450	(2002)		113	(503)
K11-12, LH04-05	560	(2491)		140	(623)
LH06-08	750	(3336)		188	(836)
LH09	850	(3781)		213	(945)
LH/DLH10	900	(4003)		225	(1001)
LH/DLH11	950	(4226)		238	(1056)
LH/DLH12	1100	(4893)		275	(1223)
LH/DLH13	1200	(5338)		300	(1334)
LH/DLH14	1300	(5783)		325	(1446)
LH/DLH15	1450	(6450)		363	(1612)
LH/DLH16-17	1850	(8229)	1/8" x 1 ¼" (3mm x 38mm)	463	(2057)
LH/DLH18-20	2350	(10453)		585	(2602)
LH/DLH21-22	3150	(14012)	1/8" x 2" (3mm x 51mm)	790	(3514)
LH/DLH23-24	4130	(18371)	1/8" x 3" (3mm x 76mm)	1035	(4604)
LH/DLH25	4770	(21218)		1195	(5316)

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

Bracing Forces

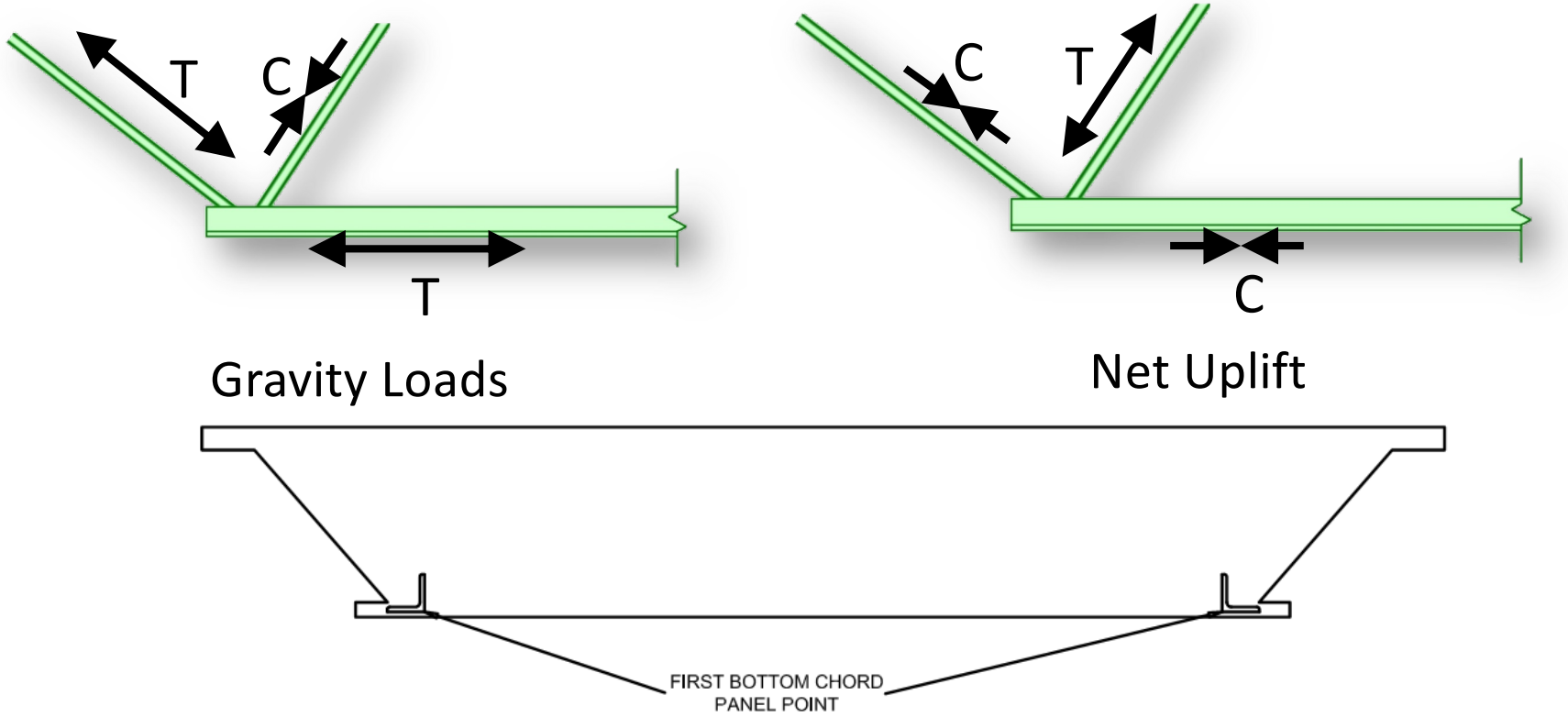
Where bridging is subject to forces as a permanent role, the accumulation of forces in horizontal bridging needs to be considered. The forces do not need to be modeled as accumulating linearly, due to the randomness of initial out-of-straightness. An equation such as this can be used to consider the force accumulation:

$$0.001\ n\ P_c + 0.004\ P_c \sqrt{n}$$

The SJI SPEC provides specific equations for the design of top chord bridging where there is not a metal deck for lateral support, just as a standing seam roofing system applied directly to the joist to chord.

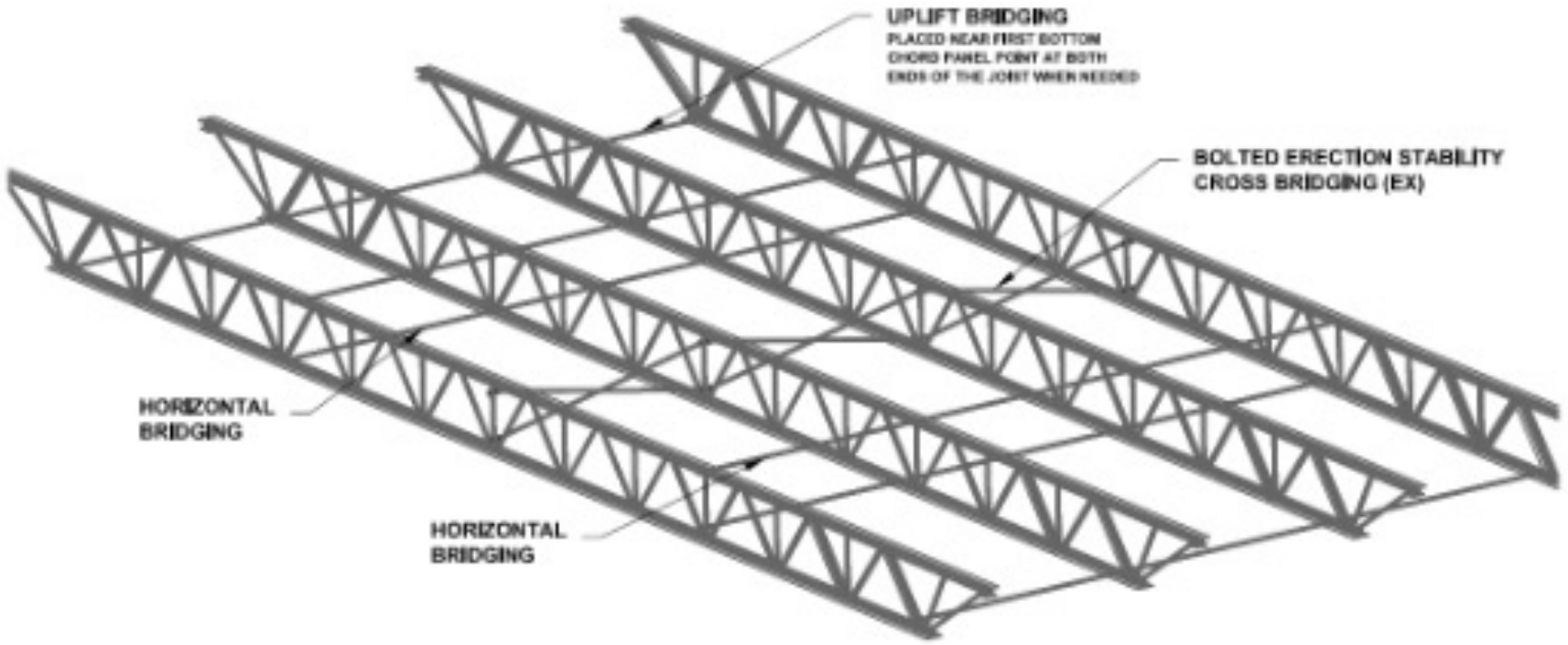
Uplift Bridging Rows

SJI Standard Specifications require bridging at the first bottom chord panel points, since two of the three intersecting primary members are in compression under uplift loading.



Bridging Placement

Here is a typical joist bay, with several types of bridging.



Four Questions to Determine the Bridging

To establish the exact bridging requirements for a particular bay of joists, there are four questions to be answered:

- How many bridging rows are needed?
- What type of bridging is needed (horizontal or diagonal)?
- What is the required bridging angle size?
- When does the bridging need to be installed?

Number of Bridging Rows

The required number of bridging rows is tabulated based upon the joist chord section number in the joist designation.

TABLE 5.5-1

U.S. CUSTOMARY UNITS

Section Number[1]	Joist Depth	NUMBER OF ROWS OF TOP CHORD BRIDGING[2] 1 Row	2 Rows	3 Rows	4 Rows	5 Rows	6 Rows	7 Rows	8 Rows	9 Rows
K1	All	17	>17 to 26	>26 to 28						
K2	All	21	>21 to 30	>30 to 32						
K3	All	18	>18 to 26	>26 to 40						
K4	All	20	>20 to 30	>30 to 41	>41 to 48					
K5	12K to 24K	20	>20 to 30	>30 to 42	>42 to 48					
	26K	28	>28 to 41	> 41 to 52						
K6	14K to 24K	20	>20 to 31	>31 to 42	>42 to 48					
	26K & 28K	28	>28 to 41	>41 to 54	>54 to 56					

Number of Bridging Rows

For designations of the “load/load” type, such as 24K250/125, the bridging rows are usually determined by finding a close equivalent in the Load Tables. Alternately, the determination can be made by checking the equations in the SJI SPEC.

Note that for KCS joists, the bridging determination is not from the designation, but rather from a chart of equivalent K-Series chord section numbers.

STANDARD LOAD TABLE FOR KCS OPEN WEB STEEL JOISTS

Based on a 50 ksi Maximum Yield Strength

JOIST DESIGNATION	DEPTH (in.)	MOMENT CAPACITY (k-in.)	SHEAR CAPACITY* (lbs)	APPROX. WEIGHT** (lbs/ft.)	GROSS MOMENT OF INERTIA ($in.^4$)	ERECTION STABILITY BRIDGING REQ'D (ft.)	BRIDGING TABLE SECTION NUMBER
28KCS5	28	1704	9200	20.5	808	53-0	12

Horizontal or Diagonal Bridging?

Where diagonal bridging is required as Erection Stability bridging for erection, or simply as a requirement for the joist span, substitution of horizontal bridging is not allowed.

On the other hand, diagonal bridging may be substituted for horizontal bridging. This could be for an entire bridging row, based upon preference. Or diagonal bridging may be added to individual joist spaces in horizontal bridging lines to create termination (a load path to resolve accumulated forces.)

Horizontal or Diagonal Bridging?

A complex equation is used to check unbridged joist capacity for joist self weight and the weight of one erector.

Minkoff Equation

$$W = \frac{-b \pm \sqrt{b^2 - 4 \cdot a \cdot c}}{2 \cdot a} \text{ lbs., If, } \frac{w_u}{w_{actual}} > 1.00 \text{ Erection Bridging is not required}$$

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

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

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

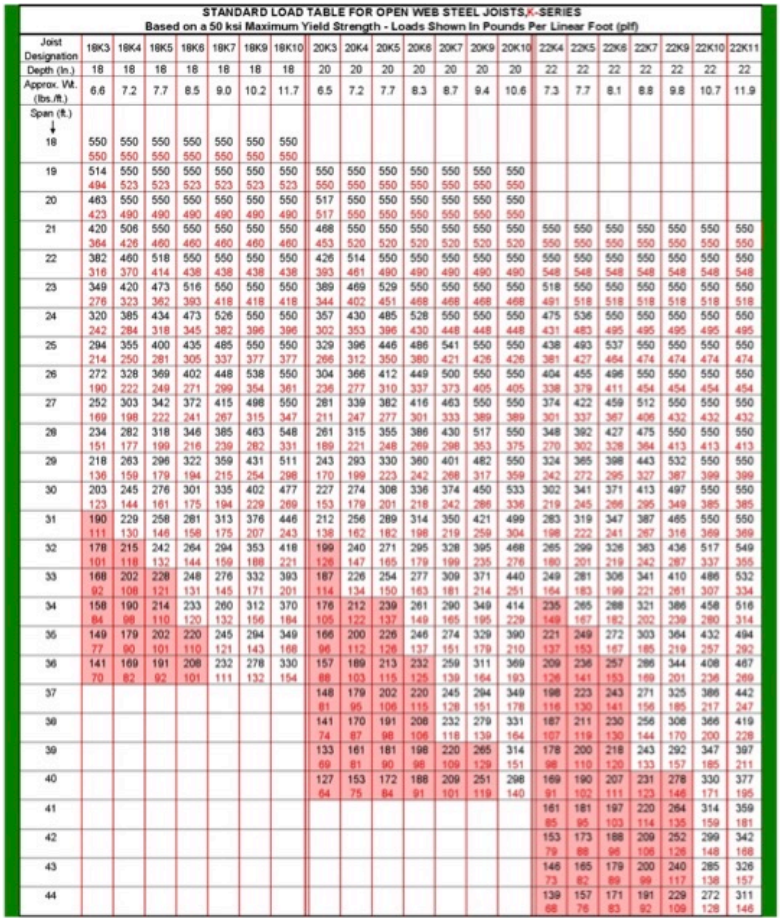
Horizontal or Diagonal Bridging?

As governed by the Minkoff equation and conservative assumptions about the joist properties, for spans up through 60 feet, 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 bolted diagonal bridging shall be used as indicated by the Blue and Gray shaded areas of the Load Table.

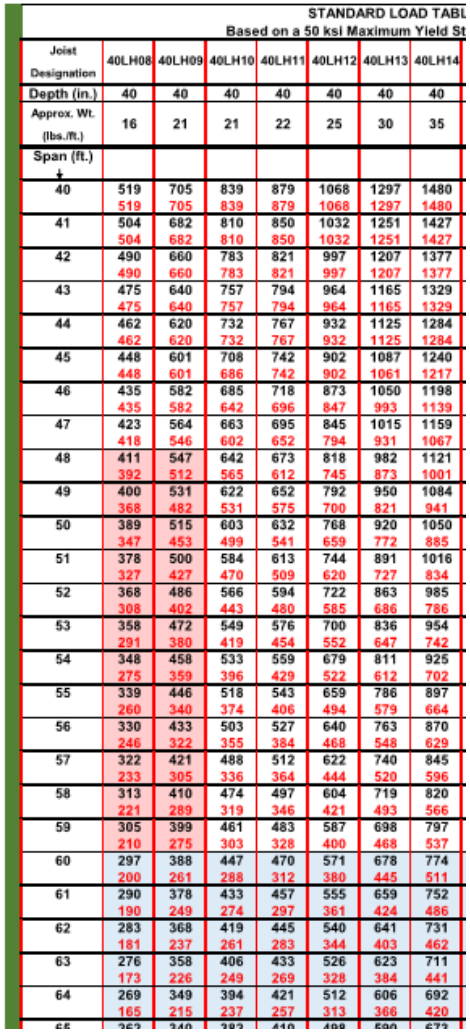
Horizontal or Diagonal Bridging?

Examples of Load Table shading:



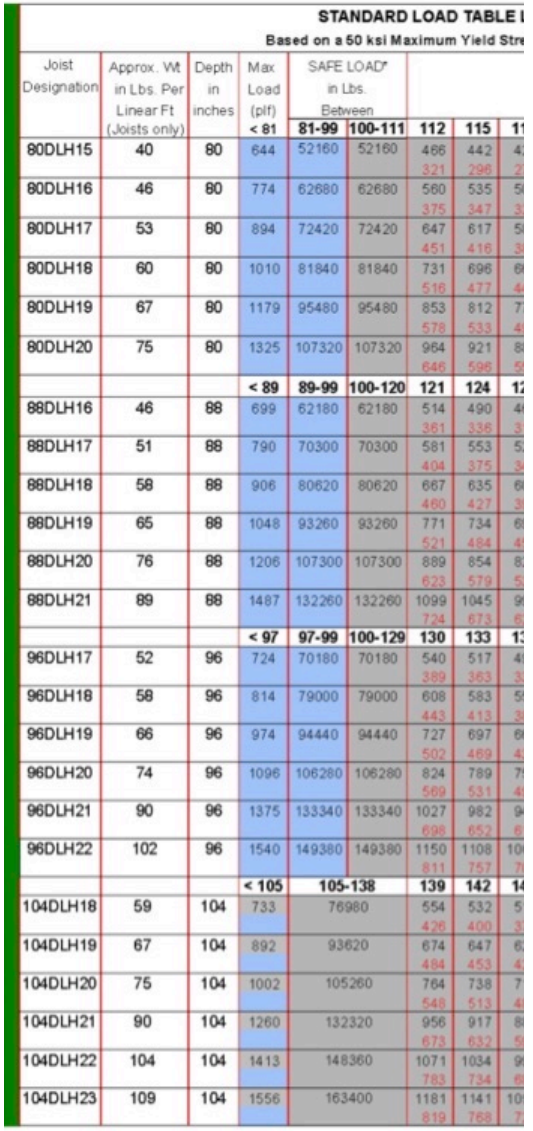
STANDARD LOAD TABLE FOR OPEN WEB STEEL JOISTS, K-SERIES
Based on a 50 ksi Maximum Yield Strength - Loads Shown In Pounds Per Linear Foot (plf)

Joist Designation	18K3	18K4	18K5	18K6	18K7	18K9	18K10	20K3	20K4	20K5	20K6	20K7	20K9	20K10	22K4	22K5	22K6	22K7	22K9	22K10	22K11
Depth (in.)	18	18	18	18	18	18	18	20	20	20	20	20	20	20	22	22	22	22	22	22	22
Approx. Wt. (lbs./ft.)	6.6	7.2	7.7	8.5	9.0	10.2	11.7	6.5	7.2	7.7	8.3	8.7	9.4	10.6	7.3	7.7	8.1	8.8	9.8	10.7	11.9
Span (ft.) ↓																					
18	550	550	550	550	550	550	550														
	550	550	550	550	550	550	550														
19	514	550	550	550	550	550	550	550	550	550	550	550	550	550							
	494	523	523	523	523	523	523	550	550	550	550	550	550	550							
20	463	550	550	550	550	550	550	517	550	550	550	550	550	550							
	423	490	490	490	490	490	490	517	550	550	550	550	550	550							
21	420	506	550	550	550	550	550	468	550	550	550	550	550	550	550	550	550	550	550	550	550
	364	426	460	460	460	460	460	453	520	520	520	520	520	520	550	550	550	550	550	550	550
22	382	460	518	550	550	550	550	426	514	550	550	550	550	550	550	550	550	550	550	550	550
	316	370	414	438	438	438	438	393	461	490	490	490	490	490	548	548	548	548	548	548	548
23	349	420	473	516	550	550	550	389	469	529	550	550	550	550	518	550	550	550	550	550	550
	276	323	362	393	418	418	418	344	402	451	468	468	468	468	491	518	518	518	518	518	518
24	320	385	434	473	526	550	550	357	430	485	528	550	550	550	475	536	550	550	550	550	550
	242	284	318	345	382	396	396	302	353	396	430	448	448	448	431	483	495	495	495	495	495
25	294	355	400	435	485	550	550	329	396	446	486	541	550	550	438	493	537	550	550	550	550
	214	250	281	305	337	377	377	266	312	350	380	421	426	426	381	427	464	474	474	474	474
26	272	328	369	402	448	538	550	304	366	412	449	500	550	550	404	455	496	550	550	550	550
	190	222	248	271	299	354	361	236	277	310	337	373	405	405	338	379	411	454	454	454	454
27	252	303	342	372	415	498	550	281	339	382	416	463	550	550	374	422	459	512	550	550	550
	169	198	222	241	267	315	347	211	247	277	301	333	389	389	301	337	367	406	432	432	432
28	234	282	318	346	385	463	548	261	315	355	386	430	517	550	348	392	427	475	550	550	550
	151	177	199	216	239	282	331	189	221	248	269	298	353	375	270	302	328	364	413	413	413
29	218	263	296	322	359	431	511	243	293	330	360	401	482	550	324	365	398	443	532	550	550
	136	159	179	194	215	254	298	170	199	223	242	268	317	359	242	272	295	327	387	399	399
30	203	245	276	301	335	402	477	227	274	308	336	374	450	533	302	341	371	413	497	550	550
	123	144	161	175	194	229	269	153	179	201	218	242	286	336	219	245	266	295	349	385	385
31	190	229	258	281	313	376	446	212	256	289	314	350	421	499	283	319	347	387	465	550	550
	111	130	146	158	175	207	243	138	162	182	198	219	259	304	198	222	241	267	316	369	369
32	178	215	242	264	294	353	418	199	240	271	295	328	395	468	265	299	326	363	436	517	549
	101	118	132	144	159	188	221	126	147	165	179	199	235	276	180	201	219	242	287	337	355
33	168	202	228	248	276	332	393	187	226	254	277	309	371	440	249	281	306	341	410	486	532
	92	108	121	131	145	171	201	114	134	150	163	181	214	251	164	183	199	221	261	307	334
34	158	190	214	233	260	312	370	176	212	239	261	290	349	414	235	265	288	321	386	458	516
	84	98	110	120	132	156	184	105	122	137	149	165	195	229	149	167	182	202	239	280	314
35	149	179	202	220	245	294	349	166	200	226	246	274	329	390	221	249	272	303	364	432	494
	77	90	101	110	121	143	168	96	112	126	137	151	179	210	137	153	167	185	219	257	292
36	141	169	191	208	232	278	330	157	189	213	232	259	311	369	209	236	257	286	344	408	467
	70	82	92	101	111	132	154	88	103	115	125	139	164	193	126	141	153	169	201	236	269
37								148	179	202	220	245	294	349	198	223	243	271	325	386	442
								81	95	106	115	128	151	178	116	130	141	156	185	217	247
38								141	170	191	208	232	279	331	187	211	230	256	308	366	419
								74	87	98	106	118	139	164	107	119	130	144	170	200	228
39								133	161	181	198	220	265	314	178	200	218	243	292	347	397
								69	81	90	98	109	129	151	98	110	120	133	157	185	211
40								127	153	172	188	209	251	298	169	190	207	231	278	330	377
								64	75	84	91	101	119	140	91	102	111	123	146	171	195
41															161	181	197	220	264	314	359
															85	95	103	114	135	159	181
42															153	173	188	209	252	299	342
															79	88	96	106	126	148	168
43															146	165	179	200	240	285	326
															73	82	89	99	117	138	157
44															139	157	171	191	229	272	311
															68	76	83	92	109	128	146



STANDARD LOAD TABL
Based on a 50 ksi Maximum Yield St

Joist Designation	40LH08	40LH09	40LH10	40LH11	40LH12	40LH13	40LH14
Depth (in.)	40	40	40	40	40	40	40
Approx. Wt. (lbs./ft.)	16	21	21	22	25	30	35
Span (ft.) ↓							
40	519	705	839	879	1068	1297	1480
	519	705	839	879	1068	1297	1480
41	504	682	810	850	1032	1251	1427
	504	682	810	850	1032	1251	1427
42	490	660	783	821	997	1207	1377
	490	660	783	821	997	1207	1377
43	475	640	757	794	964	1165	1329
	475	640	757	794	964	1165	1329
44	462	620	732	767	932	1125	1284
	462	620	732	767	932	1125	1284
45	448	601	708	742	902	1087	1240
	448	601	686	742	902	1061	1217
46	435	582	685	718	873	1050	1198
	435	582	642	696	847	993	1139
47	423	564	663	695	845	1015	1159
	418	546	602	652	794	931	1067
48	411	547	642	673	818	982	1121
	392	512	565	612	745	873	1001
49	400	531	622	652	792	950	1084
	368	482	531	575	700	821	941
50	389	515	603	632	768	920	1050
	347	453	499	541	659	772	885
51	378	500	584	613	744	891	1016
	327	427	470	509	620	727	834
52	368	486	566	594	722	863	985
	308	402	443	480	585	686	786
53	358	472	549	576	700	836	954
	291	380	419	454	552	647	742
54	348	458	533	559	679	811	925
	275	359	396	429	522	612	702
55	339	446	518	543	659	786	897
	260	340	374	406	494	579	664
56	330	433	503	527	640	763	870
	246	322	355	384	468	548	629
57	322	421	488	512	622	740	845
	233	305	336	364	444	520	596
58	313	410	474	497	604	719	820
	221	289	319	346	421	493	566
59	305	399	461	483	587	698	797
	210	275	303	328	400	468	537
60	297	388	447	470	571	678	774
	200	261	288	312	380	445	511
61	290	378	433	457	555	659	752
	190	249	274	297	361	424	486
62	283	368	419	445	540	641	731
	181	237	261	283	344	403	462
63	276	358	406	433	526	623	711
	173	226	249	269	328	384	441
64	269	349	394	421	512	606	692
	165	215	237	257	313	366	420



STANDARD LOAD TABLE
Based on a 50 ksi Maximum Yield Stre

Joist Designation	Approx. Wt in Lbs. Per Linear Ft (Joists only)	Depth in inches	Max Load (plf)	SAFE LOAD* in Lbs. Between				
			< 81	81-99	100-111	112	115	11
80DLH15	40	80	644	52160	52160	486	442	4
						321	296	2
80DLH16	46	80	774	62680	62680	560	535	5
						375	347	3
80DLH17	53	80	894	72420	72420	647	617	5
						451	416	3
80DLH18	60	80	1010	81840	81840	731	696	6
						516	477	4
80DLH19	67	80	1179	95480	95480	853	812	7
						578	533	4
80DLH20	75	80	1325	107320	107320	964	921	8
						646	596	5
			< 89	89-99	100-120	121	124	12
88DLH16	46	88	699	62180	62180	514	490	4
						361	336	3
88DLH17	51	88	790	70300	70300	581	553	5
						404	375	3
88DLH18	58	88	906	80620	80620	667	635	6
						460	427	3
88DLH19	65	88	1048	93260	93260	771	734	6
						521	484	4
88DLH20	76	88	1206	107300	107300	889	854	8
						623	579	5
88DLH21	89	88	1487	132260	132260	1099	1045	9
						724	673	6
			< 97	97-99	100-129	130	133	13
96DLH17	52	96	724	70180	70180	540	517	4
						389	363	3
96DLH18	58	96	814	79000	79000	608	583	5
						443	413	3
96DLH19	66	96	974	94440	94440	727	697	6
						502	469	4
96DLH20	74	96	1096	106280	106280	824	789	7
						569	531	4
96DLH21	90	96	1375	133340	133340	1027	982	9
						698	652	6
96DLH22	102	96	1540	149380	149380	1150	1108	10
						811	757	7
			< 105	105-138		139	142	14
104DLH18	59	104	733	76980		554	532	5
						426	400	3
104DLH19	67	104	892	93620		674	647	6
						484	453	4
104DLH20	75	104	1002	105260		764	738	7
						548	513	4
104DLH21	90	104	1260	132320		956	917	8
						673	632	5
104DLH22	104	104	1413	148360		1071	1034	9
						783	734	6
104DLH23	109	104	1556	163400		1181	1141	10
						819	768	7

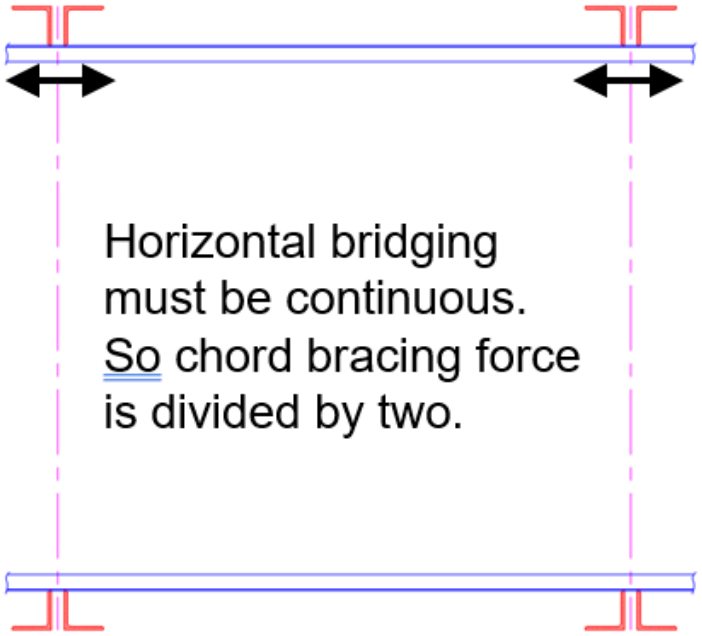
Bridging Angle Size

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

Diagonal bridging shall consist of cross-bracing with a ℓ/r ratio of not more than **200**, where ℓ is the distance in inches 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 ℓ distance shall be taken as the distance in inches between connections at the point of intersection of the bracing members and the connections to the chord of the joists.

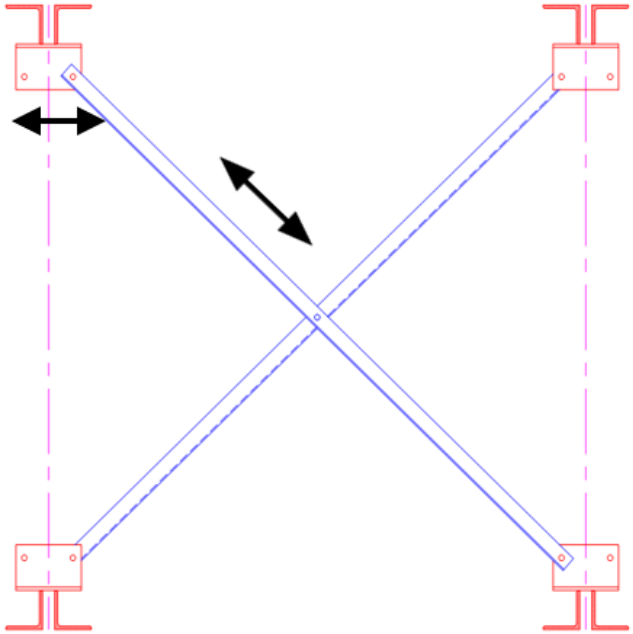
Bridging Forces

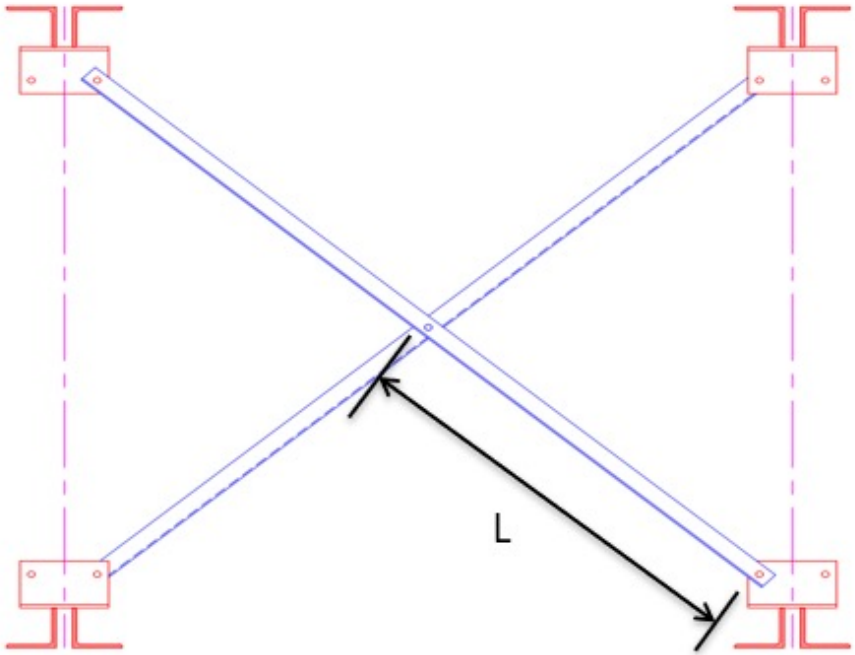
Horizontal bridging must have continuity and termination at each end of each bridging line. The bracing force as required at each joist top chord is resisted in compression on one side of the joist chord, and tension on the other side. The compression force and the spacing between the joists will govern the horizontal bridging angle size.



Bridging Forces

The chord bracing force is the horizontal component of the diagonal bridging axial force. The design length is based upon connection of the diagonal bridging pieces at their intersection.





Bridging Angle Size

On the basis of the compressive strength and slenderness limits, SJI tables provide the maximum joist spacing for combinations of joist chord section number and bridging angle size.

TABLE 2.7-1

MAXIMUM JOIST SPACING FOR HORIZONTAL BRIDGING
SPANS OVER 60 ft. (18.3 m) REQUIRE BOLTED DIAGONAL BRIDGING

JOIST SECTION NUMBER[1]	Nominal Unfactored Force P_{tr} lbs (N)	BRIDGING MATERIAL SIZE[2] 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)
K1 – 8	340 (1512)	5'-0" (1524)	6'–3" (1905)	7'–6" (2286)	8'-9" (2667)	10'–0" (3048)	12'–6" (3810)
K9-10, LH02-03	450 (2002)	4'-4" (1321)	6'-1" (1854)	7'–6" (2286)	8'–9" (2667)	10'–0" (3048)	12'–6" (3810)
K11-12, LH04-05	560 (2491)	3'–11"(1194)	5'–6" (1676)	7'–4" (2235)	8'–9" (2667)	10'–0" (3048)	12'–6" (3810)
LH06-08	750 (3336)		4'–9" (1448)	6'–3" (1905)	7'–11" (2413)	10'–0" (3048)	12'–6" (3810)
LH09	850 (3781)		4'–5" (1346)	5'–10" (1778)	7'–5" (2261)	9'–9" (2972)	12'–6" (3810)

Bridging Angle Size

SJI tables provide limits on joist spacing, based upon both the strength and slenderness limits, for combinations of joist depths and angle sizes.

Note that the joist chord section number is not a factor in the diagonal bridging size tables. And for pitched joists, the maximum depth shall be used with these tables.

TABLE 2.7-3

K, LH, and DLH SERIES JOISTS
MAXIMUM JOIST SPACING FOR DIAGONAL BRIDGING[1]

JOIST DEPTH	BRIDGING ANGLE SIZE – (EQUAL LEG ANGLE)[2]							
	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 (50 x 3 mm) r = 0.40" (10.16 mm)	2 ½ x 5/32 (64x 4 mm) r=0.50" (12.70 mm)	3 x 3/16 (76 x 5 mm) r = 0.60" (15.24 mm)	3 ½ x 1/4 (89 x 6 mm) r = 0.70" (17.78 mm)
in. (mm)	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)	ft.-in. (mm)
12" (305)	6'-7" (2007)	8'-3" (2514)	9'-11"(3022)	11'-7" (3530)	13'-3"(4038)	16'-7"(5055)	19'-11"(6070)	23'-3"(7086)
14" (356)	6'-6" (1981)	8'-3" (2514)	9'-11"(3022)	11'-7" (3530)	13'-3"(4038)	16'-7"(5055)	19'-11"(6070)	23'-3"(7086)
16" (406)	6'-6" (1981)	8'-2" (2489)	9'-10"(2997)	11'-7" (3530)	13'-3"(4038)	16'-7"(5055)	19'-11"(6070)	23'-3"(7086)
18" (457)	6'-6" (1981)	8'-2" (2489)	9'-10"(2997)	11'-6" (3505)	13'-3"(4038)	16'-7"(5055)	19'-11"(6070)	23'-3"(7086)
20" (508)	6'-5" (1955)	8'-2" (2489)	9'-10"(2997)	11'-6" (3505)	13'-2"(4013)	16'-7"(5055)	19'-11"(6070)	23'-3"(7086)
22" (559)	6'-4" (1930)	8'-1" (2463)	9'-10"(2997)	11'-6" (3505)	13'-2"(4013)	16'-6"(5029)	19'-11"(6070)	23'-3"(7086)
24" (610)	6'-4" (1930)	8'-1" (2463)	9'-9" (2971)	11'-5" (3479)	13'-2"(4013)	16'-6"(5029)	19'-10"(6045)	23'-3"(7086)
26" (660)	6'-3" (1905)	8'-0" (2438)	9'-9" (2971)	11'-5" (3479)	13'-1"(3987)	16'-6"(5029)	19'-10"(6045)	23'-2"(7061)
28" (711)	6'-3" (1905)	8'-0" (2438)	9'-8" (2946)	11'-5" (3479)	13'-1"(3987)	16'-6"(5029)	19'-10"(6045)	23'-2"(7061)
30" (762)	6'-2" (1879)	7'-11 (2413)	9'-8" (2946)	11'-4" (3454)	13'-1"(3987)	16'-5"(5004)	19'-10"(6045)	23'-2"(7061)
32" (813)	6'-1" (1854)	7'-10"(2387)	9'-7" (2921)	11'-4" (3454)	13'-0" (3962)	16'-5"(5004)	19'-9"(6020)	23'-2"(7061)

When to Install Bridging

- Red shading: one row nearest the center shall be bolted diagonal bridging and installed before release of hoisting cables.
- 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.
- Grey shading: all rows shall be bolted diagonal bridging and installed before release of hoisting cables.

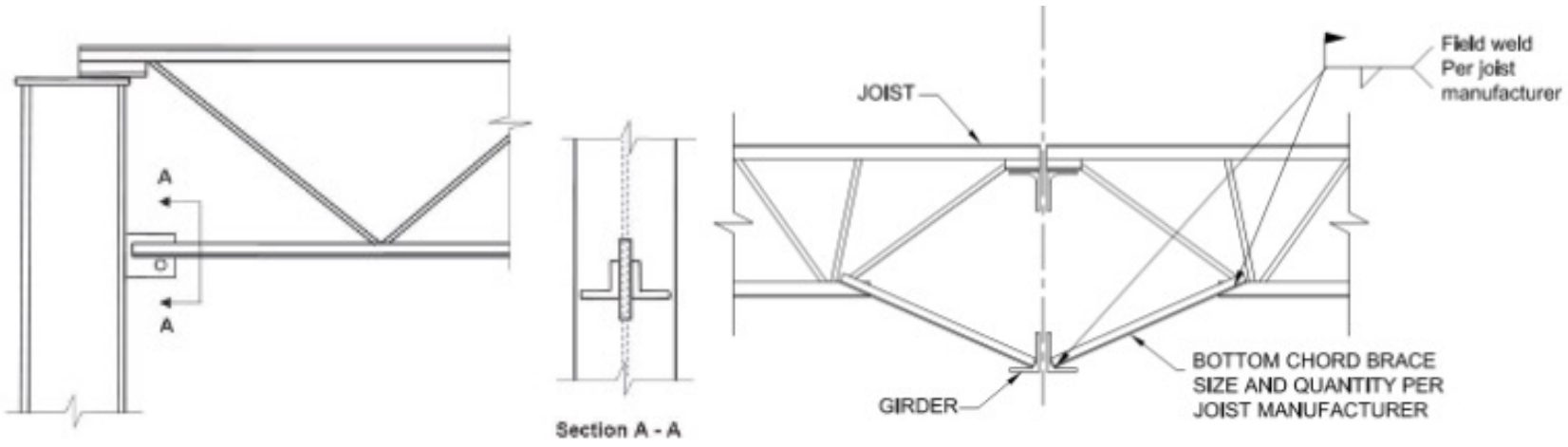
These rows of bolted diagonal bridging, to be installed before the release of hoisting cables, are specifically identified on the joist placement, with a notation such as: **ES**

“Bridging” for Joist Girders

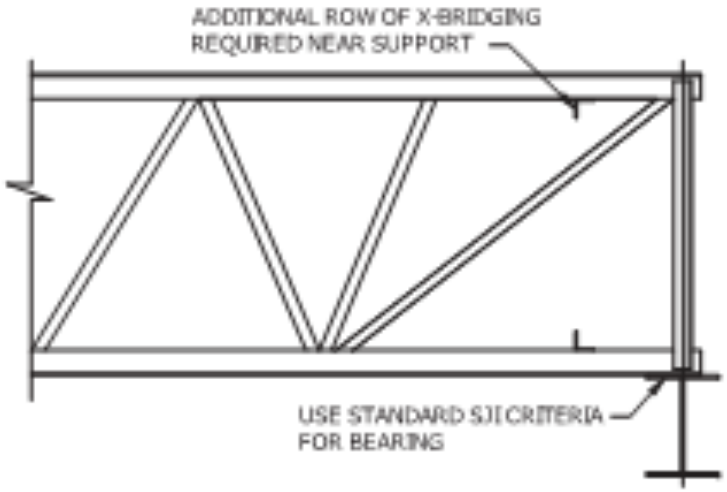
Joist girder top chords need to meet a slenderness limit for the entire span, and joist girders are not erected with bridging. They have limited exposure to construction loads until joists are placed, and then joists provide top chord lateral support.

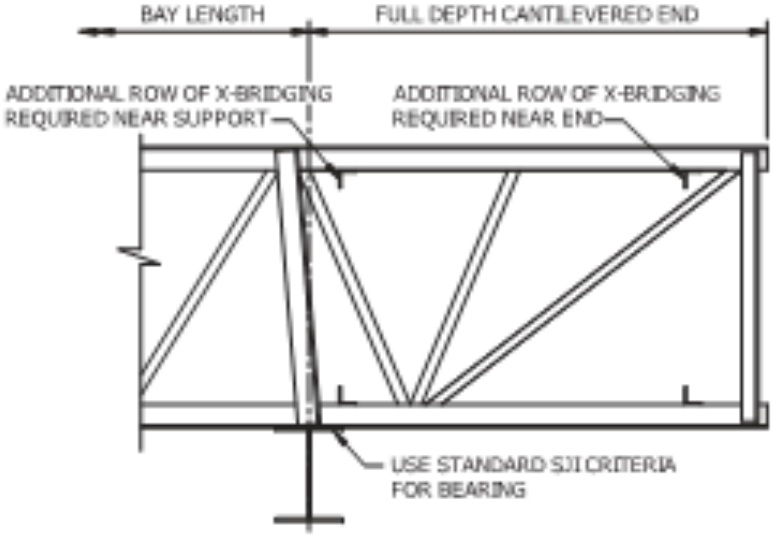
“Bridging” for Joist Girders

Permanent bridging for joist girder bottom chords is provided first by extending the bottom chords to stabilizer plates on the columns. Then, as required, bottom chord braces (also called uplift braces or knee braces) are provided at certain joist locations, as additional bracing points. If for any reason the bottom chord is not extended to stabilizer plates, then additional bottom chord braces are required at those ends.



Bottom Bearing Joists

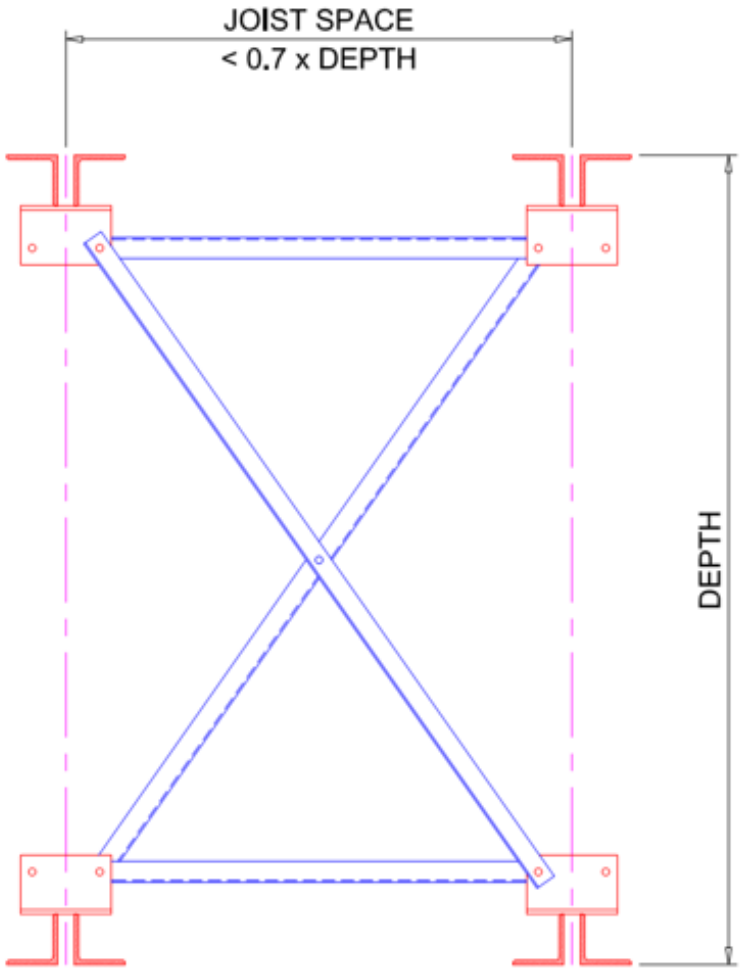




Bottom bearing (square end) joists require diagonal bridging near the support. Cantilevered bottom bearing joists require diagonal bridging near the support and at the end of the cantilever, and then possibly additional horizontal or diagonal rows within the cantilever.

Diagonal Plus Horizontal Bridging

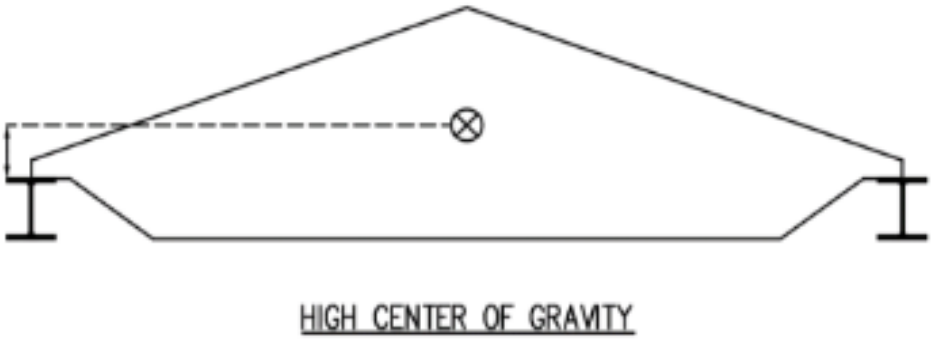
When the angle between the required horizontal bracing force and diagonal bridging members becomes too severe (spacing less than 70% of depth) horizontal bridging members are also required. This converts the bridging forces to tension only, rather than tension or compression, and limits the size of the bridging angles.

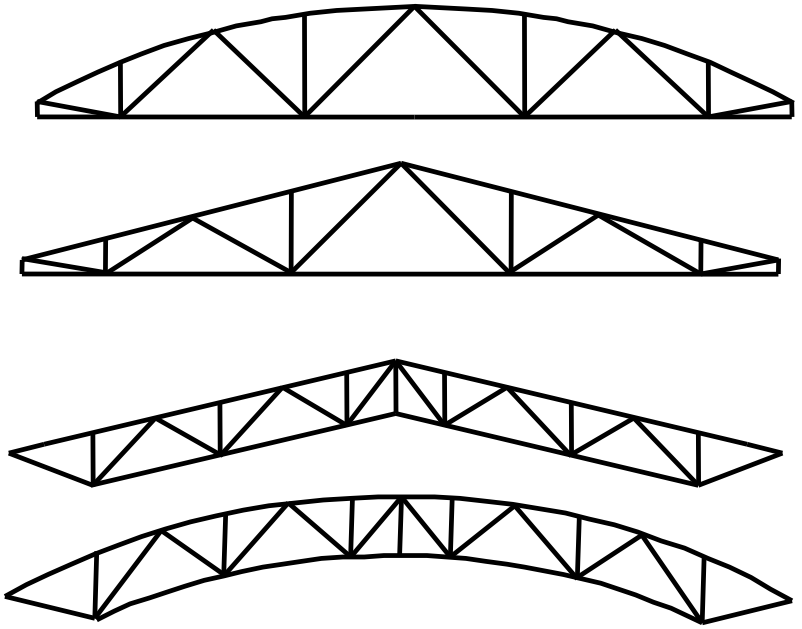


Special Profile Joists

Special profile joists require special attention for both the bridging and the erection method. Where the joist profile is “top heavy” and causes the center of gravity to be above the support, the use of diagonal bridging for all rows is likely.

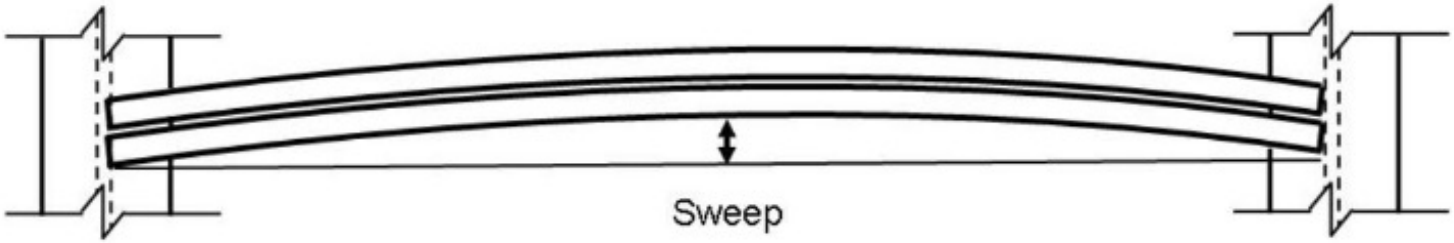
Horizontal bridging may be required along with the diagonal bridging.





Proper Installation

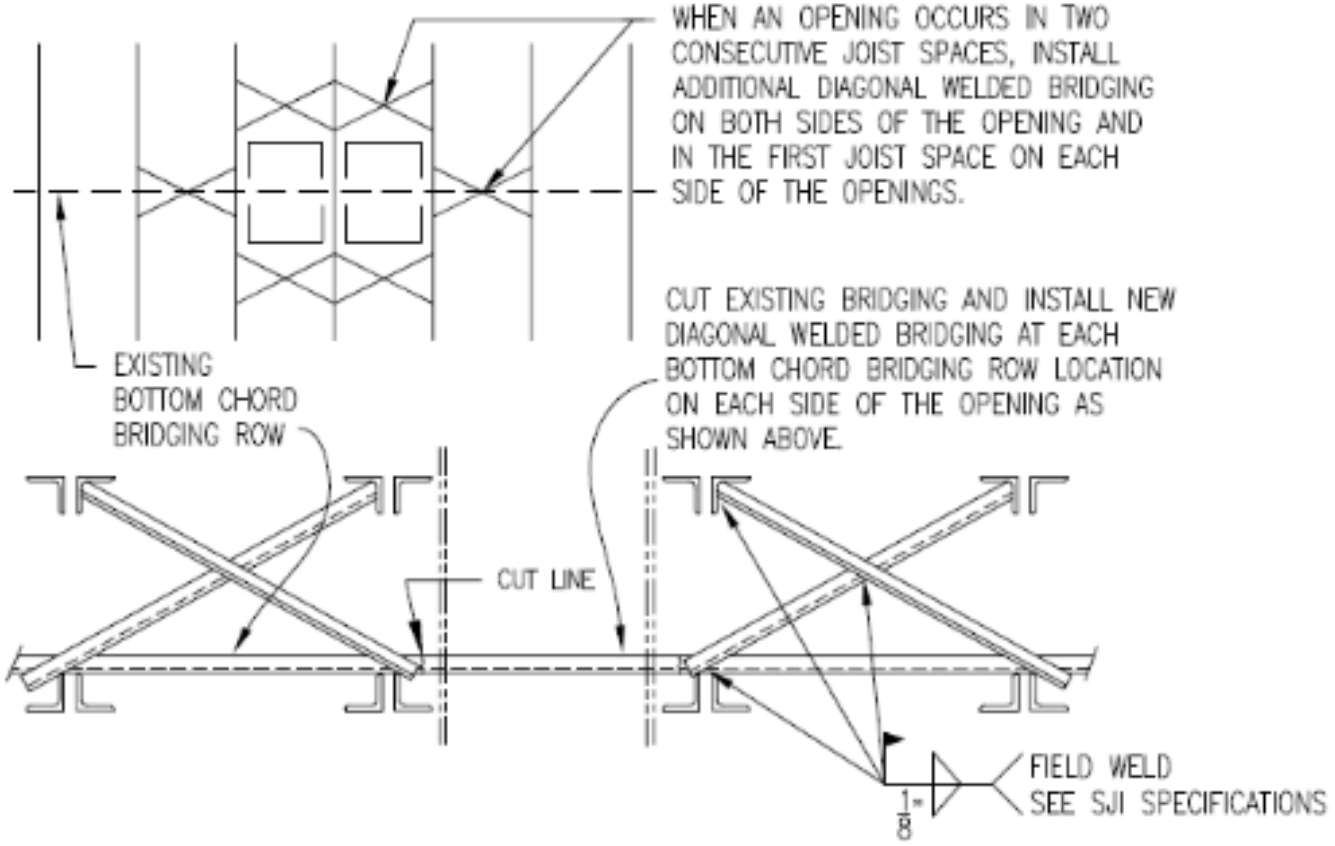
- Proper installation requires that the erector pull the joist in straight alignment, to eliminate lateral sweep, as the bridging rows are installed.



- Horizontal bridging rows must be anchored or terminated at BOTH ends. This is accomplished with anchorage to another structural element, or with the addition of diagonal bridging. Termination is required at the end of each bay and also at expansion joints or any other interruption to the bridging lines, and may also be required intermittently by the joist manufacturer, on the placement plans.

Horizontal Bridging Discontinuity

Here is a typical detail for field modifications to the bridging system where mechanical penetrations interrupt the bridging lines.



Responsibility

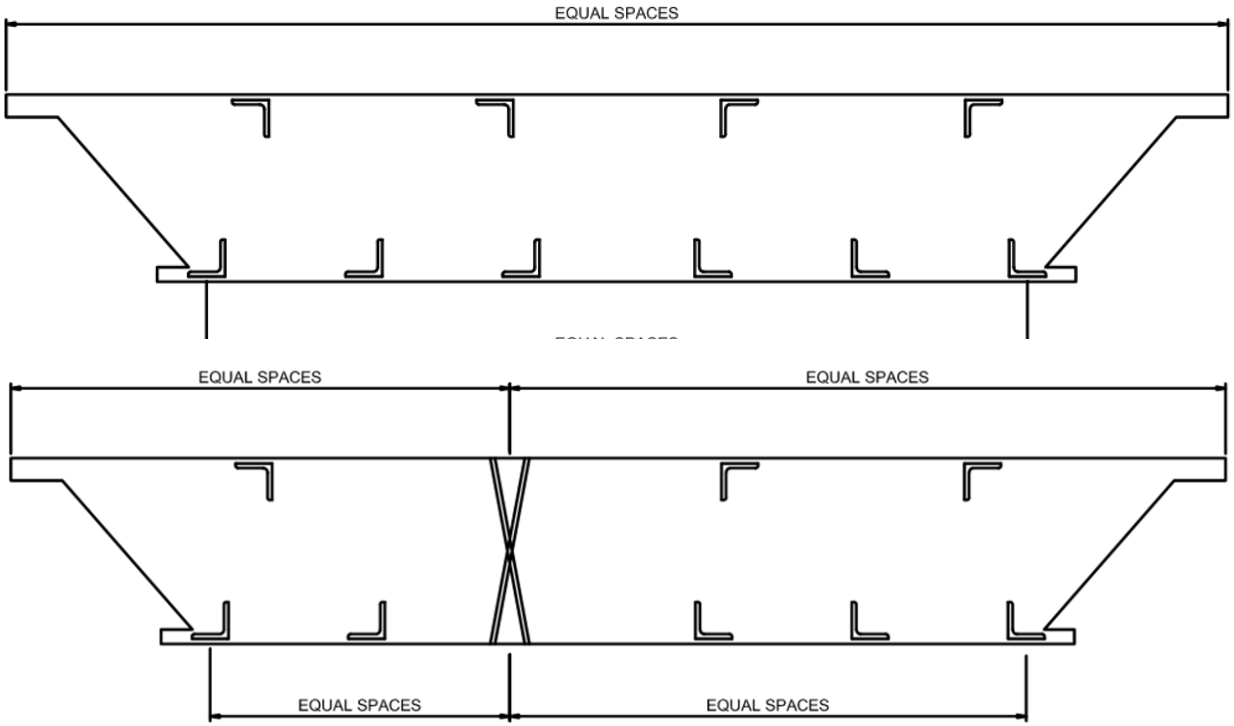
Wall anchorage of bridging rows, such as expansion bolts, is the design responsibility of the Engineer of Record.

Extra external forces should not be imposed on standard SJI bridging. The Engineer of Record shall design and specify the bracing members when other lateral forces are present.

Contract drawings do not need to show the bridging lines, and a simple note to follow the SJI requirements will suffice. This avoids RFI's for clarification if what is shown on the contract drawings does not exactly match SJI requirements.

Bridging Alignment

While the top and bottom chord horizontal bridging rows are often aligned, they are not required to be. For efficiency for uplift design, the bottom chord rows maybe be spaced in arrangements such as those shown below.



ESFR Bridging Clearance

Early Suppression Fast Response (ESFR) sprinklers systems, which are prevalent in rack storage warehouses, have specific requirements to keep sprinkler heads free of any interference, including joist bridging.

These systems require specific bridging locations, which are dimensioned on the joist placement plans and which must be followed by the erector.

Polling Question

True or False:

Bridging angles sizes are determined solely on the basis of the slenderness ratio limits.

Polling Question

True or False:

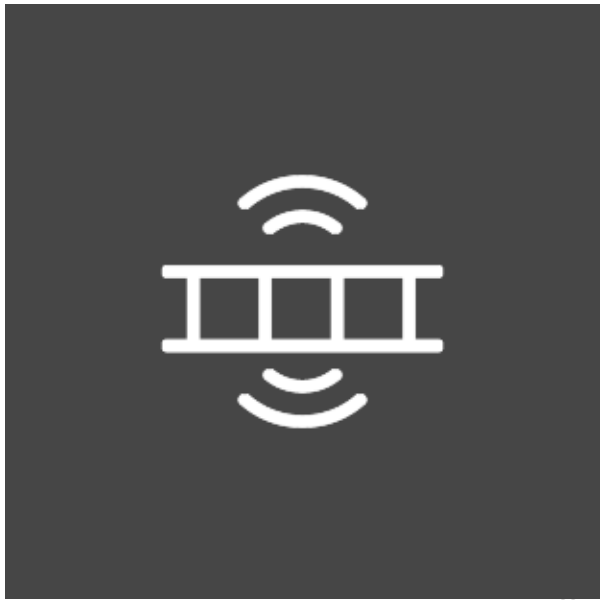
Bridging angles sizes are determined solely on the basis of the slenderness ratio limits.

Answer: FALSE

The bridging angle sizes are a function of both strength and slenderness limits, although the slenderness limits often control.

SJI Design Tools

- Free downloads
  - Steel Joist Uplift Analysis Tool
  - Joist Girder Analysis Tool
  - Joist and Joist Girder Reinforcement Tool
  - Historical Load Tables
  - Roof Bay Analysis Tool w/ Ponding Analysis
  - Floor Bay Analysis Tool w/ Vibration Analysis
  - Joist Girder Moment Connection Design Tools
  - Virtual Joists
  - Virtual Joist Girders
- Floor Vibration Analysis



SJI Publications

Technical Digests

- #1 Utilizing and Specifying Steel Joists
- #2 Bridging and Bracing of Steel Joists and Joist Girders
- #4 Guidance for Building Design Using Steel Joists
- #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
- Design Guide 40 Rain Loads and Ponding

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
- 95 Years of Open Web Steel Joist Construction

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- Earn PDHs with the 2024 webinars:
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- Floor Systems
- Uplift
- Special Profiles
- Ponding
- Bridging
- Vibration
- Roofs
- CJ-Series Composite Steel Joists
- Building Retrofit
- Welding
- Connections
- Design Tools
- Fire
- Ethics
- Joists 101

Q&A SESSION

Thank You for Attending

MAY 15, 2024

Presented by:
James M. Fisher
Tim Holtermann – CSC (Canam Steel Corp.)