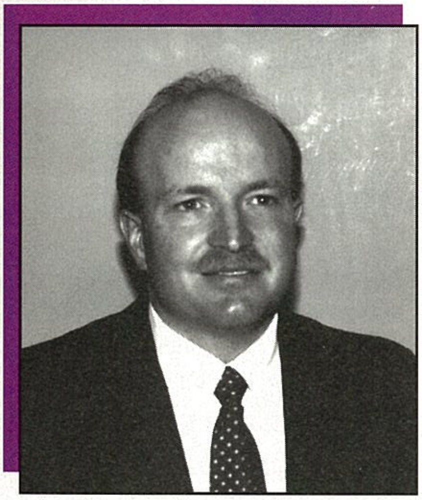
SPECIFYING STEEL JOISTS AND JOIST GIRDERS

A primer on using SJI load tables



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THE STEEL JOIST INSTITUTE IS IN ITS SEVENTH DECADE OF ESTABLISHING STEEL JOIST INDUSTRY STANDARDS and in 1994 published the 40th Edition Standard Specifications Load Tables and Weight Tables for Steel Joists and Joist Girders. Significant changes in this latest edition include the addition of KCS Joists to the K-series, revised stability criteria and the addition of the recently revised ASTM A529 steel to the materials section of all series.

The SJI standard specification consists of three distinct series: open web steel joists (K series); long span and deep long span steel joists (LH and DLH series); and joist girders.

K-series and LH/DLH series joists are defined as simply supported, uniformly loaded trusses, supporting a floor or roof deck so constructed as to brace the top chord against lateral buckling. The KCS joist is a K-series joist that is designed to support uniform plus concentrated loads or other non-uniform loads. KCS joist chords are designed for constant moment capacity at all interior panels. All webs are designed for a vertical shear equal to the specified shear capacity. Further, all webs except the end diagonal are designed for 100% stress reversal. Joist girders are designed as simply supported primary members. Loads will be applied through steel joists, and will be equal in magnitude and evenly spaced along the joist girder top chord.

K-series
- Depth: 8 in. to 30 in.
- Span: Up to 60 ft.
- Uniform Loading: 550 plf max.
- Parallel chord joists installed to a maximum slope of $^1/_2$-in. per ft.
- $2^1/_2$-in. standard bearing depth

KCS-series
- Depth: 10 in. to 30 in.
- Shear capacity: up to 9.2 kips
- Moment capacity: up to 1833 in.-kips

LH-series
- Depth: 18-in. to 48-in.
- Span: Up to 96 ft.
- Uniform Loading: up to 1,000 plf
- 5-in. standard bearing depth

DLH-series
- Depth: 52 in. to 72 in.
- Span: Up to 144 ft.
- Uniform Loading: Up to 700 plf
- 5-in. and $7^1/_2$-in. standard bearing depth

Joist Girders
- Depth: 20 in. to 72 in.
- Span: Up to 60 ft.
- 6-in. and $7^1/_2$-in. standard bearing depth

The standard load tables facilitate specifying joists through the use of standard designations and defines the joist depth, series designation, live load deflection capacity, erection stability bridging and approximate joist weight. Joist girder tables include member depth, number of joist spaces and loading at each joist location.

Design Example: Uniformly Loaded Joist And Joist Girder

For a given bay size we would select the member spans, spacing and depths based on specific loading needs and serviceability requirements.

Given: 50-ft. x 40-ft. bay with joists spaced 6-ft.-3-in. on center: roof live load equals 20 psf (non-reducible); dead load equals 15 psf (includes joist and joist girder self-weight) for a total load of 35 psf.

Step One:

Determine the number of joist spaces (N)
N = 1

Step Two:

Select joist
a. span = 40-ft.
b. TL = 6.25 ft. x 35 psf = 219 plf
c. From K-series load table select 22 K 7 (self weight of joist = 9.7 plf) from table:
TL = 231 plf
LL for L/360 = 123 plf
LL for L/240 = 123 x 1.5 = 185 plf.

Step Three:

Select joist girder
a. Panel point load, P = 219 plf x 40-ft. = 8.8 kips
b. Select girder depth using 50-ft. span, 8 panel and 9 kips. Refer to "Joist Girder Design Guide Weight Table." The rule of about one inch of depth for each foot of span applies in this example. Therefore, select a depth of 48-in.
c. Joist girder designation will be 48G8N8.8K. Table shows self weight of approximately 40 plf.
d. Weight of joist/joist girder is approximately:
Joist 9.7 plf/6.25-ft. = 1.55;
Girder 40 plf/40-ft. = 1.00
Total equals 2.55 psf.

Step Four:

For rectangular bay with joists and girders spanning opposite direction:
Joist (26K10) = 2.07
Girders (40G6N12K) = .94
Total equals 3.01 psf.
Use original layout

Step Five:

22 K 7 joist spanning 40-ft. requires three rows of bridging (from Section 5-Application of the SJI Specification). Standard load table indicates the center row to be bolted diagonal bridging.

The joist, joist girder and bridging designations can be adequately specified on a design drawing plan.

Design Example: Concentrated And Varying Loads

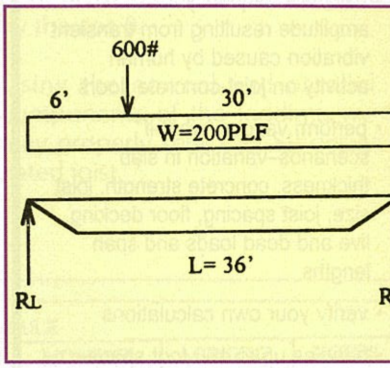
Concentrated and varying loads, such as those imposed by mechanical units and drifting snow, present a slightly more complex joist selection. However, the specifier has options to help make this process easier. The desired end result is the presentation of a standard joist selection on design drawing plans or a joist special loading diagram.

Our first option is the selection of a standard K-series or LH-series designation from the SJI load tables using a method equivalent to that used for uniform loading. Secondly, however, we can select a KCS joist from the load table. Either of these two methods also may be applied by using "double joists" if we assure the loading is transferred into each joist. Generally, these two methods will resulting a more economical selection. The third method incorporates a special loading diagram on the design drawings outlining the information to be considered in the manufacturer's designs. Though generally considered a less desirable option, under some circumstances this method may be the only realistic option when standard joist capacities are exceeded or requirements are complex.

With all three options it is prudent to consider the effect of top chord bending when loads are judged to be significant—either place loads at panel points or direct the manufacturer to design for chord bending. The addition of extra diagonal webs in the shop or field can minimize or eliminate chord bending considerations.

Selecting A Standard Joist:

Select a joist to span 36-ft. and carry a uniform load of 200 plf plus a concentrated load of 600 lbs. located 6-ft. from one end.



Step One:

Solve for reactions
R_L = 4100 lbs.
R_R = 3700 lbs.

Step Two:

Solve for the maximum moment:

zero shear is located at 3700/200 = 18.5 ft. from the right end (note location of point of zero shear; possible shear reversal is insignificant)
$M = 8.5(3700)-200(18.5)^2/2$
= 34255 ft.-lbs.

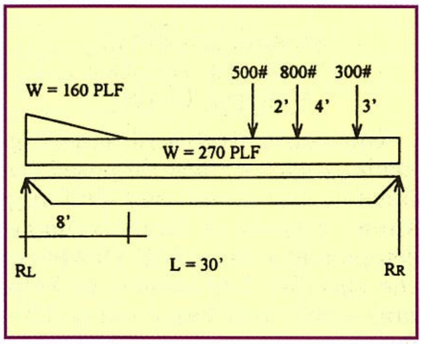
Step Three:

Solve for the end shear to completely cover the actual shear diagram:
V_{load} = 4100 - 200(6)
= 2900 lbs.
V_{end} = 18/12 x 2900
= 4350 lbs.

Step Four:
Solve for equivalent uniform loads based on the maximum moment and joist end shear:

Shear:
$W_{eq} = V_{end}/18 = 242$ plf
Moment:
$W_{eq} = 8M/L2 = 211$ plf
Therefore, choose 22K6 with
$W_{allow} = 257$ plf

Another example: *Utilizing KCS joists follow a similar procedure. Select a KSC joist to span 30-ft., carry a uniform load of 270 plf, a drift load of 160 plf to zero plf over 8-ft. at one end and a series of loads at 3-ft., 7-ft. and 9-ft. of 300 lbs., 800 lbs. and 500 lbs. respectively on the other end.*



Step One:
Solve for reactions:
RL = 5000 lbs.
RR = 5430 lbs.

Step Two:
Solve for maximum moment:
MMAX = 443 in.-kips

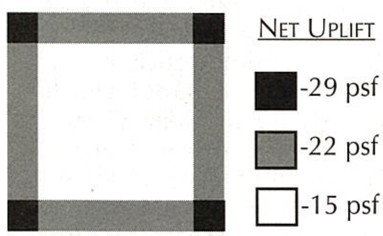
Step Three:
Select a 22KCS2
M = 488 in.-kips
R = 5900 lbs.
Bridging for section no. 6 and L = 30 ft.

Since the maximum uniform load of 430 plf does not exceed 550 plf and a standard KCS joist can be selected from the load table, a load diagram is not required.

Joist And Joist Girders Subjected To Uplift Loading

Joist and joist girders in roof systems will be subjected to net uplift loads if the code imposed wind uplift exceeds the permanent dead load. This uplift loading will affect the design of the members and the bridging. Under gravity loads, the top chord of the joist is in compression and the bottom chord is in tension. If a net uplift loading occurs, the bottom chord of the joist will be in compression. Due to this load reversal in the chords, the bridging design must always be adjusted to account for the uplift condition. Uplift also causes a stress reversal in the joist webs. This condition must be checked by the manufacturer.

SJI specifications require the joist manufacturer be informed of the net uplift occurring on the joists and joist girders. This may be accomplished with a note on the drawings such as "Design and furnish joists and bridging for a net uplift of 15 psf." Many building codes require that components and cladding be designed to resist increased wind loading at corners and edges. In this situation, the best method for informing the manufacturer of the net uplift on the joists is to provide a net uplift diagram.



As mentioned, the engineer also should specify the uplift load on the joist girders. The manufacturer will design bottom chord braces for the girder as required by the uplift load. Joist girders may be considered as primary members when determining the uplift loads. Because of this, the uplift load on joist girders would usually be less than the uplift load on joists, and therefore the engineer may elect to specify a lower net uplift load on the joist girders.

End Moment And Chord Forces In Joists

Joist End Moments

When joists are used as part of a rigid frame, the engineer must provide the joist end moments to the manufacturer. This may be accomplished through the use of notes, a joist load diagram or a schedule of joist moments. (See sample joist schedule and load diagram at right.) All should include the magnitude and direction of the moments for the various load cases considered. In addition, the specifying engineer should specify that the bottom chord braces be designed and furnished by the joist manufacturer. Unless specifically instructed otherwise, the general procedure is to design the joist as a simple span member and then to check the chords and web members for the affects of the end moments. The manufacturer will allow a one-third stress increase for all load combinations containing wind or seismic loads unless they are specifically requested not to do so.

Chord Forces

Bracing systems and moment frames may impart axial loads into joist chords. These forces should be specified to the manufacturer through notes, on a load diagram or in a schedule. Again, the engineer should specify that bottom chord braces be designed and furnished by the joist manufacturer. The manufacturer will check the affect of the chord forces and adjust the chord design accordingly.

Sloping Joists

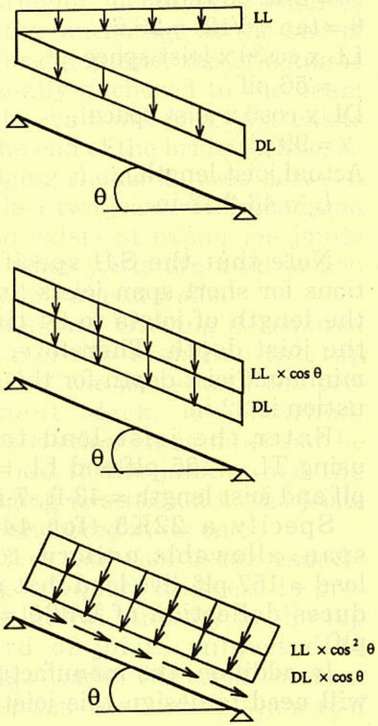
Currently, SJI specifications do not address joists that are to be used at a slope greater than $^1/_2$-in. per ft.Due to a lack of information, designers currently have no easy means for the proper selection of sloped joists. Some of the commonly encountered problems with sloped joist designation including:

- Decrease in joist moment capacity with increased joist slope.
- Overspanning of joists.
- Inconsistency in how loads are being applied to sloped joists.
- Affect of the load component parallel to the chords of the joists.

The method illustrated above (Selecting A Sloping Joist) produces several benefits in that it:

- Eliminates the need for additional loads tables
- Ensures the joist will be designated for the moment capacity for which it was specified
- Considers the actual joist

Selecting A Sloping Joist



Joists are specified by their actual length and the load normal to the joist as the values that are used in the SJI load table. The dead and live loads for a roof system are typically oriented on two different axis.

The live load is applied over the plan length and the dead load is applied over the slope length

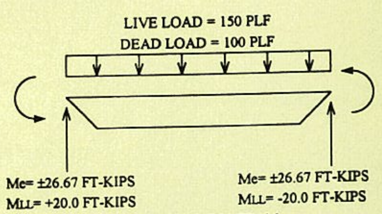
To orient both loading to the same axis, multiply the live load by the cos θ.

To determine the normal component of each, multiply again by the cos θ.

Using the normal and parallel components of the loading, we may properly select an SJI designated joist.

JOIST SCHEDULE

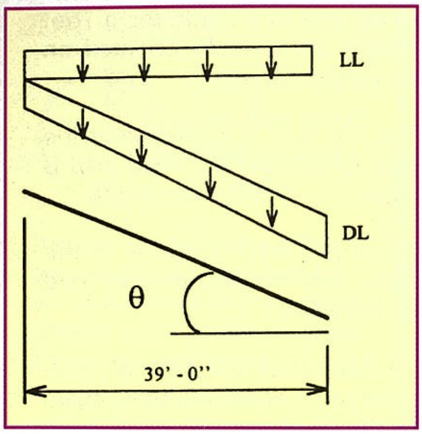
MARK	DEPTH (inches)	TOTAL LOAD (plf)	LIVE LOAD (plf)	SPAN (feet)	MOMENT LIVE LOAD (ft-kips)		MOMENT LATERAL LOAD (ft-kips)		NOTES
					+		+		
					LEFT	RIGHT	LEFT	RIGHT	



JOIST LOAD DIAGRAM

length during selection, preventing overspan conditions

- Adds the parallel component into the top chord axial force of the joists



Example:
Roof slope = 6:12
LL = 14 psf
DL = 22 psf
Plan dimension of bay,
L_p = 39-ft.
Typical joist spacing
= 5-ft. on center
$\theta = \tan^{-1}(6/12) = 26.6^{o}$
LL x $\cos^2\theta$ x joist space
= 56 plf
DL x $\cos\theta$ x joist space
= 99 plf
Actual joist length,
L_s = 43-ft.-7-in.

Note that the SJI specifications for short span joists limits the length of joists to 24 times the joist depth. Therefore, the minimum joist depth for this situation is 22-in.

Enter the joist load table using TL = 155 plf and LL = 56 plf and joist length = 43-ft.-7-in.

Specify a 22K5 (for 44-ft. span, allowable uniform total load = 157 plf, live load that produces deflection of L/360 = 76 plf).

In addition, the manufacturer will need to design this joist for the affects of the load parallel to the joist. This load would be:

$[(LL \times \cos\theta)+DL]\sin\theta$ = 77 plf

This load will be applied as an additional top chord axial force in the joist.

This selection can now be incorporated in the design drawings as in earlier examples.

Bridging Considerations

Joist bridging is required for the following reasons:

- Align the joists during erection.
- Provide stability for the joist during erection.
- Provide gravity load stability for joists with standing seam roofs.
- Provide bracing for the bottom chord for wind uplift and axial loads.
- Control the slenderness ratio of the bottom chord.
- Assist in stabilizing the web systems.

In typical situations, the size,

ROCK CHURCH, Virginia Beach, VA

36,000 ft.^{2} church

type and number of rows of bridging required depend on the length, spacing and designation of the joists in the area under consideration. The bridging requirements also are affected by wind uplift loading and the type of deck supported by the joists.

The two types of bridging are horizontal and diagonal. Horizontal bridging consists of continuous rods or angles connected to the top and bottom chords. Diagonal bridging consists of pairs of angles that cross diagonally from the top chord to the bottom chord in the space between each joist. For typical situations, the required number of rows of bridging is given in tabular form in the SJI standard specifications. These specifications also indicate when diagonal bridging and erection stability bridging are required during construction. The size type and number rows of bridging can be illustrated on the drawings or, alternatively, a notation on the drawings can be used to specify the bridging requirements.

Bridging for all joists requires positive anchorage at the end of the bridging line, the bridging is normally anchored to the beam or the wall. When a joist exists at the end of the bridging line, X-bridging should be used between the last two joists. This condition often exists at expansion joints and when joists are used in lieu of beams at end walls.

Standard bridging is required to laterally stabilize the top chord of the joists until the permanent deck is attached. Construction loads must not be applied to the joists until the bridging is attached to the joists and anchored at its ends.

Floor and roof decks usually have adequate stiffness to provide lateral stability to the top chord of joists subjected to design loads. The most common exception is standing seam roof systems. The engineer should assume that the standing seam roof has no diaphragm capability, and specify that sufficient bridging be provided to laterally brace the joists under design loads. The standing seam roof may be able to stabilize the top chord of the joists, but this should be substantiated with test data. If the roof does not have sufficient diaphragm stiffness to brace the top chord, the bridging design (size and spacing) must be adjusted to provide sufficient lateral bracing.

Wind loading on joists will affect the design of the bridging. Under net uplift, the bridging is required to provide lateral stability to the bottom (compression) chord of the joists. The SJI specifications requires the bridging design to account for the uplift forces. The specifications require joists subjected to uplift have a line of bridging near each of the first bottom chord panel points.

Depending on the actual amount of uplift, additional bridging may be required.

Serviceability

The two most common serviceability concerns are deflection and camber.

The SJI load tables provide deflection information for K, LH and DLH-series joists as a uniform load that will cause an approximate L/360 deflection. This can be directly proportioned for more or less stringent criteria. When a special deflection requirement is desired it should be specifically noted on the design drawings. Examples when this may be necessary are perimeter steel joist loaded with building cladding and interior joists carrying folding partition walls. In both cases, it is common for greater deflection limitations to be required, which can be defined by deflection ratios or actual deflection dimensions.

The SJI specification tabulates the camber for K, LH and DLH-series, though camber is optional with the manufacturer for K-series joists. If camber is required on K joists, it should be specified. A problem that can occur with LH and DLH joists is these may have a significant amount of camber. The problem arises in connecting the deck materials to the end walls of buildings if the camber is not recognized. For example, if the deck is to be connected to a shear wall at the end of the building and a joist is placed next to the end wall, then allowance must be made for the camber in the edge joists in order to connect the deck to the wall system. If proper details are not provided, the deck may not be able to be connected and field adjustments may be required. In those cases where the edge joist is eliminated from the end wall, the deck can often be pushed down flat on an end wall support unless the camber is such that the bending in the deck would be so severe as to buckle the deck. If special camber is required, it must be indicated on the design drawings.

Framing Considerations

One common framing consideration and frequently asked question is, which direction to span joists in rectangular bays. For floor systems, it is almost always more economical to span the joists in the long direction of framing. Since the joists sit on top of the girder, they can be made deeper than the joist girder without infringing upon the clear height requirements. The deeper joists allow larger penetrations through their web openings.

For roof framing, varies based on design requirements and layout. Some manufacturers provide information on various layouts to aid the designer. A more definite recommendation is provided for joist spacing. Wider spacing will almost always be preferred for floors and roofs. Maximizing the roof deck and floor slab design results in fewer pieces to erect, equating to a more economical solution.

The SJI specifications provide for a maximum span-to-depth ratio for all series equal to 24. The optimum joist girder depth in inches is approximately equal to the span of the girder in feet. The designer should generally follow this rule of thumb; however, for expensive wall systems a 1-ft. savings in height of structure may prove more economical as compared to the extra cost of shallower joist girders.

Joist depth should be selected based on the economy table found in the SJI specifications. The designer should examine bridging requirements for the selected joists. It may be that by selecting a slightly heavier joist, a line of bridging can be eliminated, thus resulting in a substantial decrease in the total cost of erected steel. If possible for joists spanning less than 40-ft., selections should be made so that X-bridging is not required.