SELECTING and SPECIFYING Steel Joists

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An insider's guide to selecting and specifying K-series, LH, DLH-series joists and joist girders

Since the Steel Joist Institute adopted the first standard specification and first load table in 1928 and 1929, respectively, the building designer has been able to specify standard joist designations rather than design each structural component of each steel truss. The current Steel Joist Institute's Standard Specification Load Tables and Weight Tables for Steel Joists and Steel Girders contains three standard specifications for three distinct series.

K-SERIES

Open Web Steel Joists or K-series are defined as simply supported uniformly loaded trusses that can support a floor or roof deck (see Figure 1). The top chord of the joist is assumably braced against lateral buckling by the deck. The K-series is distinguished by the depth range of 8″ to 30″ with a maximum span of up to 60′ and standard seat depth of 2 1/2″. Maximum uniform load for K-series joists is 550 plf. The standard load table found in the Steel Joist Institute Specification uses standard designations which define the joist depth, a series designation, the total load capacity, live load capacity based on $L/360$ allowable deflection, erection stability bridging requirements and approximate joist weight. It also includes the K-series economy table so the lightest joist for a given load can easily be selected. The ends of K-series joists must extend at least 2 ½″ over steel supports (see Figure 2).

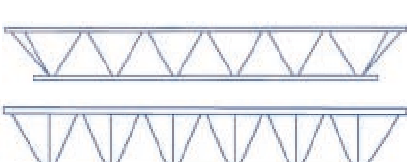

Figure 1.

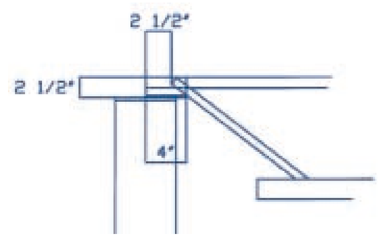

Figure 2.

The KCS joist is a K-series joist developed to allow the building designer to easily specify a standard joist to support not only uniform loads but also 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 shear capacity. In addition, all webs (except the first tension web, which remains in tension under all simple span gravity loads) will be designed for 100 % stress reversal. The building designer will calculate the maximum moment and maximum shear and select the appropriate KCS joist from the KCS joist load tables. If a KCS joist cannot be selected, or if any uniform load exceeds 550plf or any concentrated load exceeds the shear capacity of the joist, double KCS joists can be used, or an LH-series joist can be selected.

LH AND DLH JOISTS

The second series, the Long Span and Deep Long Span steel joist or the LH and DLH series, is defined as simply supported uniformly loaded trusses (see Figure 3). LH series may support a floor or a roof deck. DLH series may support a roof deck. Both series are designed assuming the top chord is braced against lateral buckling by the deck. Its depth of 18″ to 48″ distinguishes the LH series joist. It has a maximum span of 96′ and a maximum uniform loading up to 1000 plf. Its depth of 52″ to 72″ and a maximum span of 144′ distinguish the DLH series. It has a maximum loading of 700 plf.

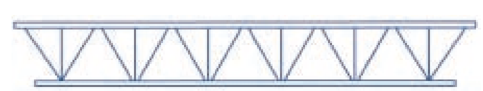

Figure 3.

The standard seat depth is 5″, although a 7 1/2″ seat depth is preferred for the larger joist designations. The ends of LH and DLH series joists must extend a distance of no less than 4″ over a steel support (see Figure 4). The standard load tables found in the Steel Joist Institute's Specification use standard designations that define the joist depth, a series designation, the total load capacity, live load capacity based on $L/360$ allowable deflection, erection

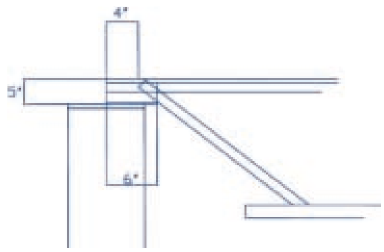

Figure 4.

stability bridging and approximate joist weight.

JOIST GIRDERS

The third series is Joist Girders designed as simply supported, primary load carrying members. Loads will be applied through steel joists and typically will be equal in magnitude and evenly spaced along the joist girder top chord. The ends of joist girders must extend a distance of no less than 6″ over a steel support. Joist girder tables found within the Steel Joist Institute's Specifications include member depth, number of joist spacings, loading at each joist location and an approximate weight of the joist girder. The Steel Joist Institute's Weight Table for Joist Girders includes approximate weights for joist girders with depths from 20″ up to 72″ and spans up to 60′. Standard seat depth is $7\frac{1}{2}$″. The ends of Joist Girder series joists must extend a distance of not less than 6″ over a steel support.

When Joist Girders support equal, uniformly spaced concentrated loads, the joist girder designation provides an adequate specification of the member. For example, the joist girder designation 60G10N12K indicates the joist girder is 60″ deep. The G indicates that it is the joist girder series, the 10N indicates the number of joist spaces, and the 12K indicates the magnitude of the concentrated load in kips. The building designer should include the self-weight of the joist girder in the panel point load. The joist manufacturer will design the joist girder using the most economical web configuration, typically where the diagonals are located under the concentrated loads (see Figure 5).

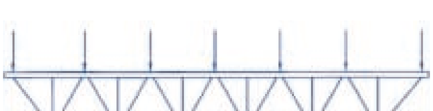
Figure 5.

As the depth to span ratios increase, it will be more economical to load both the diagonal panel points and the vertical panel points (see Figure 6). While the designation VG is not shown in the Steel Joist Institute's Specifications, joist manufacturers will recognize this designation as an indicator to locate the vertical panel points underneath the concentrated load (see Figure 7). Because the joists align with the web verticals and do not block the open panels above the bottom chord, this configuration has the largest amount of unobstructed openings to accommodate mechanical ductwork.

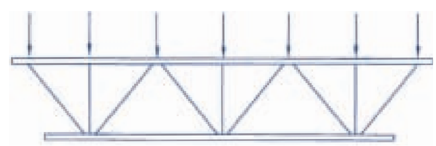
Figure 6.

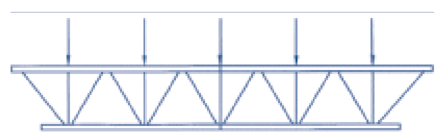
Figure 7.

BRIDGING

The final component, joist bridging, is required to:

- Align the joist during erection;
- Provide stability for the joist during erection;
- Control the slenderness ratio of the bottom chord;
- Assist in stabilizing the web systems.

The size, type and number of rows of bridging depend on the span of the joist spacing between the joist and the standard joist designation. Joist bridging may also be required to brace the bottom chord for wind uplift and axial loads. It may also provide lateral stability for the joist under gravity load with standing seam roofs.

There are two types of bridging: horizontal and diagonal. Horizontal bridging consists of continuous angles connected to the top or bottom chords (see Figure 8). Diagonal bridging consists of two angles that cross diagonally from the top chord to the bottom chord between each joist and are connected at their point of intersection (see Figure 9).

For typical situations, the number of rows of bridging required is given in tabular form in the Steel Joist Institute's Standard Specifications. These specifi-

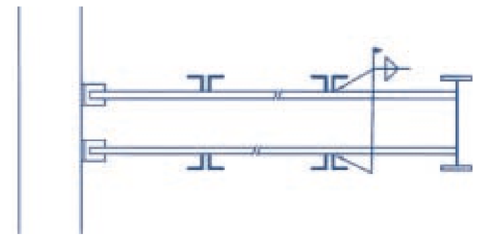
Figure 8.

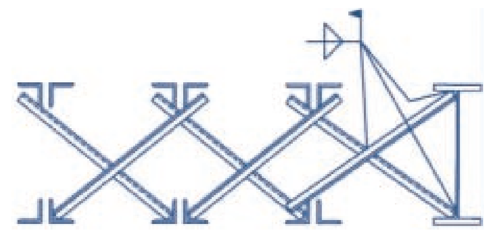
Figure 9.

cations also indicate when bolted diagonal erection stability bridging is required during construction. Bridging for all joists requires the end of each bridging load have positive anchorage. When a joist is at the end of a bridging line, such as at expansion joints or joists at end walls, x-bridging should be used between the last two joists. Standard bridging is required to laterally stabilize the joist against torsional buckling until the permanent deck is attached. Construction loads must not be applied to the joist until the bridging is attached to the joist and anchored at its ends.

Diagonal bridging between the last joist and a rigid end wall may cause the diagonal bridging to act like a vertical support and therefore will attempt to carry the joist vertical load. When the joist deflects and the end wall does not, damage may occur in the bridging, and it will no longer be effective. Substituting horizontal bridging for the diagonal bridging after erection in this last space will allow a joist near the end wall to deflect independently.

Joists and joist girders in roof systems will be subject to net uplift loads when the wind suction forces on the roof exceed the permanent dead load. Uplift loads could affect the design of the joists' components as well as the bridging. Under gravity loads, the top chord of the joist is in compression, and the bottom chord is in tension. Under a net uplift loading, the bottom chord of the joist will be in compression. Due to this load reversal, the bridging design may need to be adjusted to properly brace the bottom chord.

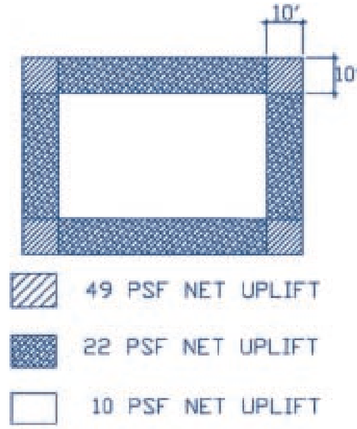

Figure 10.

The Steel Joist Institute's Specifications also requires joists subject to a net uplift to have a line of bridging near each of the first bottom chord panel points. Depending on the actual magnitude of the net uplift, additional bridging may also be required. Uplift also causes a stress reversal in the joist webs, and the manufacturer will be required to design them accordingly. Steel Joist Specifications require the net uplift on joist and joist girders be specified to the joist manufacturer. A note on the drawings, such as "Design joist and bridging for net uplift of 20 psf," can be utilized. When the building requires increased wind loadings at the corners and edges, a diagram showing the net uplift may be the best method for providing the joist manufacturer with the required loading information (see Figure 10). Joist girders should be considered primary members when determining uplift loads, and therefore the building designer may elect to specify a lower net uplift on the joist girders. The manufacturer will design the bottom chord and the bottom chord braces for the girder as required by the net uplift loadings.

The design of steel joists assumes the floor and roof decks have adequate stiffness to provide lateral stability to the top chord of the joist. A standing seam roof should be assumed to not have adequate diaphragm capacity, and bridging should be provided to laterally brace the joists under gravity loads. The top chord, the bridging size and spacing must be adjusted to provide sufficient lateral bracing. Top chord horizontal bridging must be designed for a compressive axial force of $0.0025nP$ where n is the number of joists between joist anchors, and P is the joist's top chord design force. The greater the quantity of joists between rigid bridging supports, the greater the forces due to the additive secondary forces developed at the joist locations. The magnitude of these bridging forces can be managed by the addition of rigid bridging supports such as diagonal bridging and/or horizontal trusses constructed using the joists' top chords.

END MOMENTS

When joists are used as part of a rigid frame or moment frame or other bracing system, axial loads or end moments may be induced into the joist or joist girders. A load diagram (Figure 11) or a schedule of loads may be used to inform the joist manufacturer of the magnitude and the direction of the moments and forces and the required load combinations that should be considered for each load (Figure 12). The joist manufacturer will check the affect of the moment and chord forces and adjust the design of the chords and the quantity and spacing of the bottom chord braces accordingly. Suitable connections will also be required for the transfer of these moments and chord forces from the bracing system or columns into the joists. If no other load path is provided, the top chord must also be designed to accommodate the axial force and bending moment developed due to the force coming in through the bottom of the joist seat (see Figure 13). A better force path would be created if a top plate (Figure 14), tie angles or knife plates (Figure 15) were added to connect either the adjacent joist or the adjacent column if applicable. When the deck is used in the bracing system as a diaphragm, then the load must be transferred from the deck into the beam or joist girder. The lateral stiffness of the joist seat may not be adequate to transfer this force. When this occurs, a tube steel or a C channel section can be used to transfer the lateral load from the deck to the supporting member (see Figure 16). In a hybrid roof system (Figure 17), a wood deck supported by a wood subpurlin system, and a steel joist with a wood nailer is used as a diaphragm in the lateral bracing system. Nails provide the shear connection to the subpurlins and wood nailer. Wood screws transfer the shear from the wood nailer to the top chord of the steel joist. Again, a top plate or knife plate should be used to transfer the developed axial load to the adjacent joist or column.

SPRINKLER LOADS

The building designer can account for loads from small ducts, cable trays and sprinkler systems by including a uniform collateral load of a sufficient magnitude to cover all these loads. Then a joist can be selected to resist this collateral load in addition to all the other uniform loads. Although the loads are delivered to the joists at distinct locations, this method has proved to be reasonable and economical. The building designer should specify that pipe hanger loads are to be located at joist panel points so that local bending will not be induced in the joist chords. Large ducts and sprinkler mains should be considered as concentrated loads, and the magnitude and location should be specified on the design documents.

ROOF TOP UNITS

It is common practice for mechanical units to be placed on the roofs of buildings. Rooftop units can vary in weight from 100 lbs. to more than 25,000 lbs. They can cover an area of a couple of sq. ft. to hundreds of sq. ft. The building designer's decision on how best to provide capacity for these rooftop units will depend on the size, quantity, required location and area of the units. The building designer may designate zones on the roof where the units may be placed and specify KCS

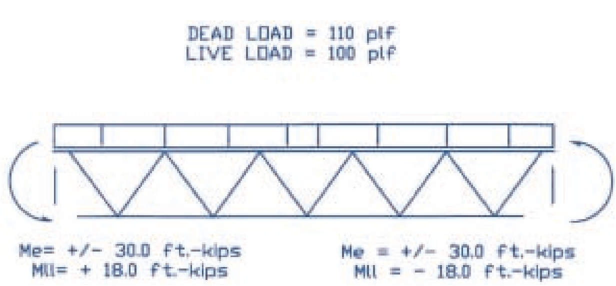

Figure 11.

joists to provide the additional capacity required to support these units. These zones should be located to provide the maximum area while affecting the fewest number of joists and joist girders. Locating the zones near columns will minimize the amount of flexural resistance required in the system and still allow a flexible system in which to locate the roof top units. The unit's reaction to the top chord of the joist must be transferred to a panel point to avoid localized bending in the top chord of the joist. If the location of the unit can be controlled, the reactions should be located over panel points. If this is not possible, a special web member must be added in the field to support this concentrated load.

When the magnitude and location of a concentrated load can be accurately specified, the joist manufacturer has the option of designing the top chord for localized bending or adding an additional web member in their shop (see Figure 18).

Three options are available to the building designer for specifying joists to support uniform loads plus concentrated or other non-uniform loads. The first option would be to select a standard K-series or LH-series designation using an equivalent uniform loading method. This method should not be used for large loadings that cause the location of zero shear to be outside the center 2% of the span due to possible stress reversal in the joists webs. The second option would be to calculate maximum moment and shear and select a KCS joist. A double joist can be specified with both of these options as long as the load is transferred equally to each joist. The third option is to include a load diagram on the contract drawings for the joist manufacturer. None of the three options consider the effects of load bending in the top chord, and therefore a method must be provided to transfer the load to a panel point.

JOISTS SPAN DIRECTION AND JOIST SPACING

For floor systems, it is usually more economical to span the joists in the long direction. Since the joists sit on top of the joist girder, they can be made deeper than the joist girder by the amount of the seat depth without infringing on the clear height requirements. Wide joist spacings provide a very economical floor system. The widest spacing for a given deck profile and slab thickness should be used. Erection costs are typically less, and the floor will usually have better vibration characteristics. Deeper joists also allow larger penetrations through their webs. While wider spacing would also be preferred for roofs, the most economical framing will vary based on design requirements and layout, as well as interaction with other building expenses such as the wall systems. The optimum joist girder depth in inches is approximately equal to the span of the girder in feet. Joist depth should be selected based on the economy table found in the Steel Joist Institute's Specification. The designer should also look at the bridging requirements for the selected joists. It may be more economical to pick a slightly heavier joist if a line of bridging can be eliminated, particularly if the heavier joist eliminates the need for any diagonal bridging.

DEFLECTION

The Steel Joist Institute load tables provide deflection information as a uniform load that will produce an $L/360$ deflection, for K, LH or DLH joists. Other deflection criteria can be directly proportioned to determine the allowable capacity to produce this deflection.

MARK	SIZE	MOMENT LIVE LOAD ft. -kips		MOMENT WIND LOAD ft. -kips		CHORD FORCES kips		NOTES
		LEFT	RIGHT	LEFT	RIGHT	TOP	BOTTOM	

Figure 12.

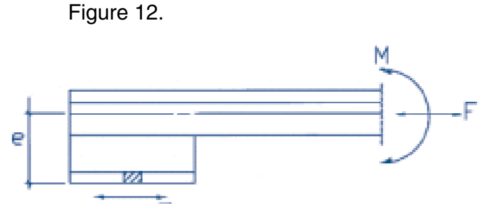

Figure 13.

Figure 14.

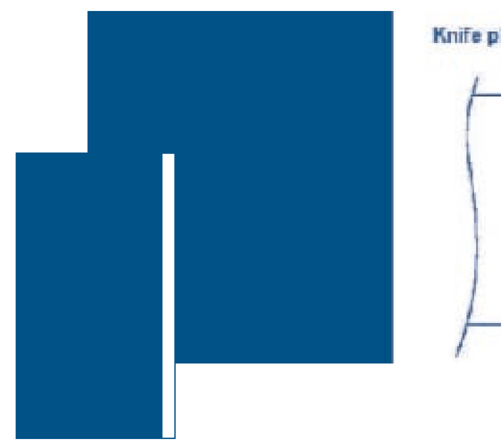

Figure 15.

Figure 16.

Figure 17.

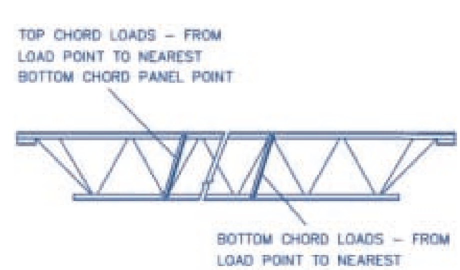

Figure 18.

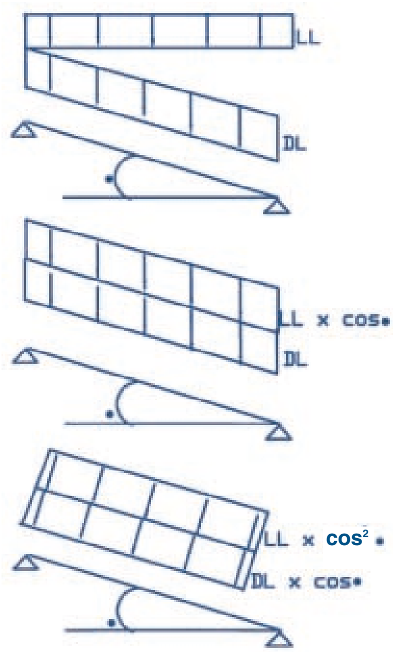

Figure 19.

CAMBER

The Steel Joist Institute's Specification designates that camber be supplied for the LH and DLH series. Camber is optional with the manufacturer for K-series, so if camber is needed on K-series joists, it should be specified. Long LH and DLH series joists will have a significant amount of camber and can cause problems in connecting the deck to the end walls if the camber has not been considered in this connection. If a joist is placed next to an end wall, and the deck is to be connected to the shear wall, then some allowance must be made either in the camber or in the location of the end wall supports so the deck will attach to the wall system. If the edge joist is eliminated and the camber is not so large as to cause the deck to buckle, the deck can often be forced into contact with the end wall support so that the connection can be made. If special camber is required to make this connection, it must be indicated on the drawings.

SLOPING JOISTS

The span of a parallel chord sloped joist is the length along the slope. Minimum depth, load carrying capacity and bridging requirements are determined using this sloped definition of span. The load capacities from the Steel Joist Institute's Standard Load Tables will be the component normal to the joist. The building designer should specify the load component, parallel to the joist (see Figure 19).

Sloping Joist Example

Roof Slope = 6:12

Dead Load (*DL*) = 20 psf

Snow Load (*SL*) = 30 psf

Plan dimension of Bay *L* = 40′-0″

Joist spacing = 4′-0″ o.c.

$\theta = \tan^{-1}(6/12) = 26.6°$

$SL \times \cos^2\theta \times$ joist space
= (30 psf)($\cos^2$26.60°)(4′-0″ o.c.) = 96 plf

$DL \times \cos\theta \times$ joist space
= (20 psf)(cos 26.60) (4′-0″ o.c.) = 72 plf

Total load (normal component) = 168 plf

Parallel load component
= $[(SL \times \cos\theta) + D] \times \sin\theta \times$ joist space
= $[(30 \times \cos 26.6°)+20] \times \sin 26.6°$ x 4′
= 84 plf

Select joist from Economy Table:
RL 168 plf/LL 96 plf

24K6 at 45′-0″ + Total load = 179/Live load (L/360) = 93 OK

Add note on drawings: Design sloping joists for parallel load component of 84 plf.

Wesley B. Myers, P.E., has worked for 15 years in steel and steel joist design and is a member of the Engineering Practice Committee of the Steel Joist Institute. A professional engineer licensed in seven states, he is currently the vice president of engineering of SMI Joist and the general manager of SMI Joist-Nevada. Visit the Steel Joist Institute's web site at:
www.steeljoist.org