

From the Foundation

Steel Joists in Floors and Ceilings

By Neal L. Peterson, RPE

This article is the last in the Foundation's series on lightweight steel framing systems.

The use of steel joists for ceiling or floor members is becoming more common as the structures being built require more non-combustible materials. The use of non-combustible materials is increasingly being required by building codes to improve the fire and life-safety characteristics of a structure.

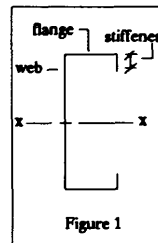
There are three primary factors that control the design of steel joists: (1) deflection, (2) bending moment and (3) web crippling. Deflection Design

One of the principal features that controls the design is the limitation placed on the amount of acceptable deflection the joist can have to minimize the impact to the finish material that the joist supports. Typically, the acceptable limit for deflection as defined by model codes is L/360 for live load only and L/240 for live load plus dead load.

Table 1: Code Deflection Limits

Code	Agency	Deflection Limits
Uniform Building Code	ICBO	L/360 Live Load L/240 Live + Dead Load
Standard Building Code	SBCCI	L/360 Live Load L/240 Live + Dead Load
National Building Code	BOCA	L/360 Design Load (live + dead load)

As an example, the acceptable live load deflection for a 20-foot single span joist is (20 ft. x 12 in./ft.)/240, or one inch. The amount of deflection that a joist member will experience under load is determined by the member's moment of inertia (I_x). The moment of inertia is a measure of how stiff the member is to resist deformation under load. The I_x does not establish the maximum structural load a member can withstand, it only limits the amount of deflection. The moment of inertia (I_x) is published in the manufacturers' technical information as either I_x or the moment of inertia around the strong axis. The strong axis and parts of a light gauge member are as shown in Fig. 1.



To calculate the safe span for a structure, the following formula can be used to determine a single span condition:

$$S_{span} = \left[\frac{188800000 \times I_x}{W \times Defl \times space} \right]^{1/3}$$

Where

- S_{span} = single span, ft.
- I_x = moment of inertia, in⁴
- W = load per square foot, psf
- Defl = allowable deflection limit (model code value)
- Space = spacing of joists, inches

As an example:

6" joist, 18 gauge, $I_x = 2.50 \text{ in.}^4$

live + dead load per sq. ft. = 50 psf
deflection limit = 240 (live + dead load)

spacing of joist = 16 inches o.c.

$$S_{span} = \left[\frac{188800000 \times 2.50 \text{ in.}^4}{50 \text{ psf} \times 240 \times 16 \text{ in. o.c.}} \right]^{1/3}$$

$$= 13.496 \text{ ft. (13'6")}$$

An additional calculation for the live load portion of the total load would also be completed to determine which deflection calculation controls the allowable span based on deflection.

Bending Moment Design

The second factor that must be addressed when using light gauge steel members is the maximum amount of bending moment the joist can withstand. The allowable bending moment is determined by the type of steel that is used in the manufacturing of the joist and the section modulus of the member. Both of these values are published in the manufacturers' technical literature as the allowable bending or compressive stress and the section modulus measured around the strong axis (S_x). These two values multiplied together determine the maximum bending moment the member can withstand. (Some manufacturers publish the maximum bending moment in their product data.) The maximum bending moment establishes the safe load carrying capacity of the member. The maximum safe single span can be determined with the following equation:

$$S_{span} = \frac{(F_b \times S_x \times 8000)^{1/2}}{W \times \text{space}}$$

Where

S_{span} = single span, ft.

F_b = allowable bending (compressive) stress, ksi

S_x = section modulus, in.³

W = load per sq. ft., psf

Space = spacing of joists, in.

As an example:

6" joist, 18 gauge

Live load per sq. ft. = 50 psf

spacing of joist = 16 in. o.c.

$F_b = 19.8$ ksi

$S_x = .80$ in.³

$$S_{span} = \frac{(19.8 \text{ ksi} \times .80 \text{ in.}^3 \times 8000)^{1/2}}{(50 \text{ psf} \times 16 \text{ in. o.c.})}$$

$$= 12.586 \text{ ft (12'7")}$$

Based on the same member being used for both examples, the maximum allowable span is controlled by bending. Both the deflection and the bending moment must be checked as it is not possible to determine which calculation will control the design.

Web Crippling

The third principal factor that must be analyzed is the effect the supported load has on the web. For a single span load condition, the critical location is at each end of the joist. The web shear normally will not control the design of the joist unless members have a large web height to metal thickness ratio.

The American Iron and Steel Institute's *Specification for the Design of Cold Formed Steel Members* requires that for a clear height of web (h) to thickness (t) ratio greater than 200, web stiffeners must be installed. The web stiffeners would be installed at bearing points when the reaction at the bearing point exceeds the allowable web crippling as published in the manufacturer's literature.

A typical web stiffener can be a rim joist track that the joist member nests into, a piece of track or stud installed perpendicular to the joist, a joist member installed back to back, or an angle nested between the flanges of the joist. The various web stiffeners are shown in Figure 2.

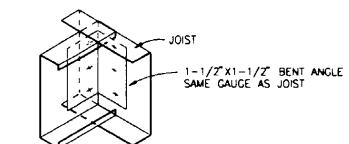
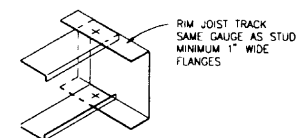
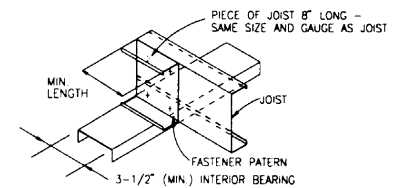
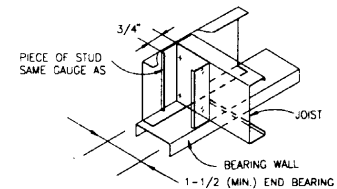
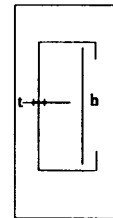


Figure 2

Selection of the web stiffener will depend on the end conditions plus the amount of load transfer that the web stiffener must take. The web stiffener reduces the possibility of web crippling (buckling) under a concentrated end reaction. The failure of the web on a single span condition with a uniform load applied to the joist will occur at the end bearing point of the joist. The allowable end reaction for both an unstiffened web and a stiffened web condition (web stiffener installed) is available in most manufacturers' product information. If the information is not available, your manufacturer's representative should be contacted for this information.

To calculate the allowable span the joist member can bridge, based on the end reaction, the following formula can be used:

$$S_{span} = \frac{P_{allow} \times 24}{W \times Space}$$

Where

S_{span} = single span, ft.

P_{allow} = allowable end reaction for specific bearing length stiffened or unstiffened, lbs.

W = load per sq. ft., psf

$Space$ = spacing of joist, in.

As an example:

6" joist, 18 gauge unstiffened

P_{allow} = 290 lbs.

live load per sq. ft. = 50 psf

spacing of joist = 16 in. o.c.

bearing length = 1 in.

$$S_{span} = \frac{290 \times 24}{50 \times 16} = 8.7 \text{ ft. (8'8")}$$

6" joist, 18 gauge w/web stiffener

P_{allow} = 640 lbs.

$$S_{span} = \frac{640 \times 24}{50 \times 16} = 19.2 \text{ ft. (19'2")}$$

For the above examples the allowable span would be 8'8" (web crippling controls the design) if web stiffeners are not installed, and would be

12' 7" (bending stress controls the design) if web stiffeners are installed on each end of the joist.



About the Author:

Neal L. Peterson is president and general manager of Devco Engineering, a firm he has been with for the past 13 years. He has been involved with municipal engineering projects, having served as both a consultant and city engineer for several municipalities in the mid-Willamette Valley area. He also taught at Oregon State University. He received a B.S. and M.S. in civil and structural engineering from Oregon State University.

