This Technical Note updates and replaces LGSEA Technical Note 552

Summary: Cold-formed steel (CFS) joists are becoming very popular where non-combustible material and long unsupported spans are required in design. The purpose of this Technical Note is to provide a review and summary of the AISI design requirements for cold-formed steel floor joists.

Disclaimer: Designs cited herein are not intended to preclude the use of other materials, assemblies, structures or designs when these designs and materials demonstrate equivalent performance for the intended use; CFSEI documents are not intended to exclude the use and implementation of any other design or construction technique.

BEHAVIOR OF C-SECTIONS

Cold-formed steel joist members are typically C-shaped cross sections. The C-shape is singly-symmetric with the shear center eccentric from the centroid as shown in Figure 1. If the C-section is not braced and is not loaded through the shear center it will twist (Figure 1). If the C-section is discretely braced the C-shape member may also undergo lateral-torsional buckling between the brace locations when subject to major axis bending.

In addition to overall buckling, the local buckling mode may influence the behavior of the compression elements of the cross section, i.e. web, compression flange, and edge stiffener. Distortional buckling also must be considered and it occurs when the compression flange and the lip rotate about the flange web junction with the web providing some elastic restraint to rotation. A rigid floor sheathing, such as plywood, may also provide some restraint against distortional buckling.

An excellent resource for design of CFS floor systems is AISI D110, Cold-Formed Steel Framing Design Guide.

BUILDING CODE SPECIFIED DESIGN REQUIREMENTS

Cold-formed steel floor systems shall be designed in accordance with the North American Standard for Cold-Formed Steel Framing - Floor and Roof System Design (AISI S210) or solely in accordance with the requirements of the North American Specification for the Design of Cold-Formed Steel Structural Members (AISI S100).

AISI S210 permits design on the basis of either discretely braced design or on the basis of continuously braced design. However, the typical floor joist is continuously braced by sheathing attached to the compression flange. The design provisions of AISI S210 for a continuously braced design are summarized as follows.

Bending (Section B1.2.1)

For flexure alone, the yield moment (Procedure I), Section C3.1.1 of AISI S100 applies:

\[ M_y = S_c F_y \]
To achieve the yield moment, continuous bracing must be provided in accordance with Section B4 of AISI S210 which stipulates that the sheathing shall consist of a minimum of 3/8 inch wood structural sheathing that complies with DOC PS 1, DOC PS 2 or steel deck with a minimum profile depth of 9/16" and a minimum thickness of 0.0269". The sheathing or deck shall be attached with minimum No. 8 screws at a maximum 12 inches on center.

In addition to sheathing or deck attached to the compression flange, Section B4 of AISI S210 requires that for joist spans that exceed 8 feet, the tension flange shall be laterally braced at a maximum spacing of 8 feet (Figures 2 and 3). Each brace is to be designed for the following force:

\[ F_L = 1.5 \left( \frac{m}{d} \right) P \]  
(B4-1, AISI S210 sim.)

\[ P = \text{uniform joist load} \times \text{brace spacing} \]

**Figure 2: Required Brace Force**

### Shear (Section B1.2.2)

Shear alone shall be evaluated in accordance with AISI S100 Section C3.2. Section C3.2 contains provisions for both the un-punched and punched web.

### Web Crippling (Section B1.2.3)

Unless a web stiffener is used, web crippling alone shall be evaluated by using AISI S100 Section C3.4. S100 contains design provisions for both the un-punched and punched web.

### Bending and Shear (Section B1.2.4)

AISI S100 Section C3.3 is to be used to evaluate the combination of bending and shear.

### Bending and Web Crippling (Section B1.2.5)

Unless a web stiffener is used, AISI S100 Section C3.5 is to be used to evaluate the combination of bending and web crippling.

### Distortional Buckling

AISI S210 does not specifically address distortional buckling performance for floor joists. However, Section C3.1.4 of S100 stipulates the design criteria for assessing the flexural performance of a beam. CFSEI Tech Note G101-08 provides design aids as well as examples to assist with the evaluation of distortional buckling.

### Bearing Stiffeners (Section B3.1)

For bearing stiffeners other than clip angles, the design shall be in accordance with Section C3.7.1 or Section C3.7.2 of AISI S100. For clip angle bearing stiffeners the design is to be in accordance with Section B3.1.1 of AISI S210. Design guidance and examples for clip angle bearing stiffeners are given in CFSEI Technical Note F100.

### Serviceability

AISI S210 is silent regarding design for serviceability. However, AISI S100 Section A8 states that the structure shall be designed to perform its required functions during its expected life. Also, serviceability limits shall be cho-
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DESIGN OF FLOOR JOISTS

Floor joist design typically involves the determination of the maximum permissible joist span for a specified loading condition and spacing. Manufacturer’s load tables and AISI S230 Standard for Cold-Formed Steel Framing – Prescriptive Method for One and Two Family Dwellings (AISI S230) tabulates the maximum permissible span.

The following discussion summarizes the evaluation of the maximum permissible span for the various limit states.

Bending

The maximum joist span is a function of the span, simple or continuous, and the cross section bending strength. For a simple span joist with uniform load,

For load and resistance factor design (LRFD):

$$\phi M_n = wL^2/8 \quad L = \sqrt{8\phi M_n / w}$$

For allowable strength design (ASD):

$$M_n/\Omega = wL^2/8 \quad L = \sqrt{8M_n / \Omega w}$$
Shear

For a simple span joist with uniform load,

For LRFD:
\[ \phi V_n = \frac{wL}{2} \quad L = 2\frac{\phi V_n}{w} \]

For ASD:
\[ V_n/\Omega = \frac{wL}{2} \quad L = 2\frac{V_n}{\Omega w} \]

Web Crippling

The equations below are for a simple span joist uniformly loaded without web stiffeners. If web stiffeners are used, this design check is not required.

For LRFD:
\[ \phi R_n = \frac{wL}{2} \quad L = 2\frac{\phi R_n}{w} \]

For ASD:
\[ R_n/\Omega = \frac{wL}{2} \quad L = 2\frac{R_n}{\Omega w} \]

Deflection

Deflection is evaluated at service load therefore ASD and LRFD design checks are the same. For a simple span joist uniformly loaded,
\[ \Delta = \frac{5wL^4}{384EI_x} \]

Although L/360 is permitted by code, the deflection limit is typically L/480 for live load and L/240 for total load. If expressed as L/\delta the above equation is
\[ \frac{1}{\delta} = \frac{5wL^3}{384EI_x} \]

\[ L = \frac{1}{\delta} \left( \frac{384EI_x}{(5w\delta)} \right) \]

Figure 5: Flat strapping for tension flange bracing. Solid blocking is used at each end of strap, as well as 10’ on center along length of strap. Although top flanges may be braced with sheathing, this installation uses top strap as well.

Figure 6: detail of solid blocking—from installation shown in figure 5.
1000S162-54, $F_y = 33$ ksi joists are simple span members spaced 24” on center. The joist does not have web holes. The floor live load is 40 pounds per square foot (psf) and dead load is 10 psf. The compression flange of the joist is continuously braced by sheathing that complies with Section B4 of AISI S210.

Determine the maximum joist span and the tension flange brace requirement, $P_L$.

For LRFD:

**Deflection**

Deflection is evaluated at service load therefore ASD and LRFD design checks are the same. The service total load is 100 lb/ft = 8.33 lb/in., service live load = 80 lb/ft = 6.67 lb/in, and $I_{xx} = 9.5788$ in.$^4$ at 0.6$F_y$.

The deflection limit is $L/480$ ($\delta = 480$) for live load and $L/240$ ($\delta = 240$) for total load

$$L = \sqrt[3]{(384EI_x)/(5w\delta)}$$

For live load, $L = \sqrt[3]{(384 \times 29,500,000 \times 9.5788)/(5 \times 6.67 \times 480)} = 188.26'' = 15' - 8''$

For total load, $L = \sqrt[3]{(384 \times 29,500,000 \times 9.5788)/(5 \times 8.33 \times 240)} = 220.22'' = 18' - 4''$

**Conclusion**

The maximum joist span is the minimum span calculated for the above limit states. In this case the maximum span is governed by bending.

For ASD:

$$L = \sqrt[3]{(384EI_x)/(5w\delta)} = \sqrt[3]{(384 \times 29,500,000 \times 9.5788)/(5 \times 8.33 \times 240)} = 220.22'' = 18' - 4''$$

The joist does not have web holes. The floor live load is 40 pounds per square foot (psf) and dead load is 10 psf. The compression flange of the joist is continuously braced by sheathing that complies with Section B4 of AISI S210.

Determine the maximum joist span and the tension flange brace requirement, $P_L$.

For LRFD:

**Bending**

$$\phi M_n = 53.98 \text{ in.-kips} = 4,498 \text{ ft-lb}$$

$$L = \sqrt[3]{8 \Phi M_n / w} = \sqrt[3]{8 \times 4,498 / 152} = 15.38 = 15' - 4''$$

For ASD:

$$M_n/\Omega = 34.03 \text{ in-kips} = 2,836 \text{ ft-lb}$$

$$L = \sqrt[3]{8 M_n / w} = \sqrt[3]{8 \times 2,836/100} = 15.06 = 15' - 1''$$

**Shear**

For a simple span joist,

For LRFD:

$$\phi V_n = 2.52 \text{ kips} = 2,520 \text{ lbs}$$

$$L = 2\phi V_n/w = 2 \times 2,520 / 152 = 33.15 = 33' - 2''$$

For ASD:

$$V_n/\Omega = 1.66 \text{ kips} = 1,660 \text{ lbs}$$

$$L = 2V_n/\Omega w = 2 \times 1,660 / 100 = 33.20 = 33' - 2''$$

**Web Crippling**

Floor joists are typically required to have bearing stiffeners therefore web crippling need not be evaluated.
REFERENCES


Original author of this Technical Note:
 Nader Elhajj, P.E.
 Director, Middle East & Asia,
 FrameCAD Solutions USA Inc.

Primary author of 2011 Revision:
 Don Allen, P.E.
 CFSEI Technical Director