Polling Question

• New requirement to earn PDH credits

• Two questions will be asked during the duration of today’s presentation

• The question will appear within the polling section of your GoToWebinar Control Panel to respond
Disclaimer

The information presented herein is designed to be used by licensed professional engineers and architects who are competent to make a professional assessment of its accuracy, suitability and applicability. The information presented herein has been developed by the Steel Joist Institute and is produced in accordance with recognized engineering principles. The SJI and its committees have made a concerted effort to present accurate, reliable, and useful information on the design of steel joists and Joist Girders. The presentation of the material contained herein is not intended as a representation or warranty on the part of the Steel Joist Institute. Any person making use of this information does so at one’s own risk and assumes all liability arising from such use.
Webinar Description

Composite steel construction has been recognized for a number of years as one of the most economical systems for constructing building floors. This webinar will focus on information contained within SJI’s “2nd Edition, Standard Specifications for CJ-Series Composite Steel Joists, Weight Tables and Bridging Tables, Code of Standard Practice”, while outlining potential benefits for utilizing SJI’s CJ-Series composite joists, discuss installation of welded shear studs, discuss typical cambering and placement of concrete, and describe recent projects where CJ-Series composite joists have been utilized.

Additionally, to facilitate the efficient design and preliminary cost studies, this webinar will demonstrate new technology, developed by RISA that allows engineers to utilize RISAFloor in order to quickly determine the required CJ-Series joist size, quantity of welded shear studs, and resulting total CJ-Series joist and bridging weights for your specific project.
Learning Objectives

• Understand the potential benefits of using SJI’s CJ-Series composite joists.

• Evaluate the computational aspects of composite steel joist behavior per SJI’s new 2nd Edition CJ-Series Specifications.

• Review guidelines for installing welded shear studs onto the chords of CJ-Series joists and serviceability considerations.

• Examine projects highlighting the recent use of SJI’s CJ-Series composite joists.

• Learn how RISAFloor can assist in determining the optimal CJ-Series joist size and assist in determining the total required CJ-Series joist weight and shear stud quantity for your specific project.
SJI CJ-Series Composite Steel Joists
SJI CJ-Series Composite Steel Joists
Introduction to CJ-Series Composite Steel Joists

- System utilizes open-web steel joists.

- Members are simply-supported and are generally not considered part of the lateral load-resisting system.

- Concrete slab is attached to the joist top chord, acting as the compression chord element.

- Horizontal shear transfer is achieved by field-welding shear studs through the metal deck to the joist top chord and thus providing direct bearing of embedments within the concrete slab.
Advantages of CJ-Series Composite Steel Joists

• Mechanical ducts and piping (MEP) can be run through the open webs of the CJ-Series joists instead of running beneath the joist bottom chord.

• Reductions in overall floor to floor height of the structure.

HVAC Ducts and Plumbing thru CJ-Series Open Web System
Advantages of CJ-Series Composite Steel Joists

- Specially designed panel configurations and web openings can be provided to accommodate MEP.

Rectangular Vierendeel Opening at Joist Mid-Span
Advantages of CJ-Series Composite Steel Joists

• Maximum span-to-depth ratio of 30 permits the use of shallower joists for any given span.

• Efficient composite design makes it possible to span greater distances.

• Increased rental value of floor spaces.
Advantages of CJ-Series Composite Steel Joists

• Composite steel joists are more efficient allowing a reduction in the joist weight for any given joist depth. For a 50 foot span, weight savings of 30 - 50% vs composite wide flange beams.

• Live load deflections are significantly reduced.

• Efficient erection of the CJ-Series joist system.

• Wide joist spacing of 6 – 10 feet reduces number of joists to be erected and fireproofed.
Advantages of CJ-Series Composite Steel Joists

• Less variations in camber as the joists are fabricated in carefully controlled rigging tables.

• Results in more level finished floors with reduced concrete surface grinding required.

• Faster steel delivery as no mill order scheduling required. CJ-Series joists are fabricated utilizing readily available hot-rolled angles.

• No need to coordinate web opening penetrations which are never known until the end of the project. Simply run pipes, electrical, small HVAC thru the joist open webs.
CJ-Series Joist Seat Types

In 2020, Over 90% of all fabricated CJ-Series joists have been fabricated with flush framed top chord bolted seats.
Designation for CJ-Series Composite Steel Joists

30 CJ 2188 / 1168 / 420

<table>
<thead>
<tr>
<th>30</th>
<th>CJ</th>
<th>2188</th>
<th>1168</th>
<th>420</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth (in.) Steel Joist</td>
<td>Composite Joist Series</td>
<td>¹Total Factored Composite Design Load (plf)</td>
<td>Total Factored Composite Live Load (plf)</td>
<td>Total Factored Composite Dead Load (plf)</td>
</tr>
</tbody>
</table>

• ¹Total Factored Composite Design Load = Total Factored Composite Live Load + Total Factored Composite Dead Load + Total Factored Noncomposite Dead Load.
• See the “SJI Composite Joist Floor Design Parameter Checklist” for form to assist organizing loading information.
• See also SJI CJ COSP-2015, Section 6.6.1, Design Input required for Composite Steel Joists.
Composite Steel Joist Design

- **Top chord** designed for compressive forces from non-composite dead load plus construction live load followed by a total composite load case check.

- **Bottom chord** designed for tension forces from composite dead and live loads.

- **Webs** designed to carry total vertical shear.

- **Shear connectors** applied to fully develop the bottom chord yield strength.

- **Concrete slab** analyzed using the transformed area concept.

- **Deflection** under composite loads analyzed using composite moment of inertia.
Virginia Polytechnic Institute and State University, Blacksburg, VA
111 Composite Steel Joists
David Samuelson

121 Influence of Bolt-Line Eccentricity on
WT Tension Member Capacity
Karl E. Barth, James G. Orbison and Peter A. Bartels

127 The Effect of Bedding Layer on the Strength of Shear
Connection in Full-Depth Precast Deck
Jong-Hee Kim, Chang-Su Shim, Shigeyuki Matsui and Sung-Pil Chang

136 Ultimate Strength Prying Models
for Bolted T-stub Connections
James A. Swanson

148 Dynamic Amplitude Prediction for Ballroom Floors
Linda M. Hanagan

154 P-V-M Interaction Curves for Seismic Design of
Steel Column Base Connections
Jaswant N. Arickar and C.V.R. Murty

166 Errata
Design Tables for Top- and Seat-Angle
with Double Web-Angle Connections
Paper by Yousk Kim and Wai-Fah Chen

Third Quarter 2002
Volume 39, No. 3
Composite Design Moment Capacity

\[ C = 0.85f'_c a b_e \]

Depth of compressive block:

\[ a = \frac{M_n}{0.85f'_c b_e d_e} \leq t_c, \text{in. (mm)} \]

\[ T = A_s F_y \]
Composite Steel Joist Design

- The distance “$d_e$” between the centroid of the tension bottom chord and the centroid of the concrete compression block, shall be computed using a concrete stress of $0.85f'_c$ and an effective concrete width, $b_e$.

**Effective Depth of composite Joist:**

$$d_e = d_j - y_{bc} + h_{deck} + t_c - \frac{a}{2}, \text{ in. (mm)}$$

- “$b_e$” shall be taken as the sum of the effective widths for each side of the joist centerline, each of which shall be the lowest value of the following:
  1. One-eighth of the joist span, center-to-center of supports;
  2. One-half the distance to the centerline of the adjacent joist;
  3. The distance to the edge of the slab.
Composite Steel Joist Design

The design flexural strength of the composite section, $\phi M_n$, shall be computed as the lowest value of the following limit states:

a) Bottom Chord Tensile Yielding:

$$\phi_t = 0.90$$

$$\phi M_n = \phi_t A_b F_y d_e$$

b) Bottom Chord Tensile Rupture:

$$\phi_{tr} = 0.75$$

$$\phi M_n = \phi_{tr} A_n F_u d_e$$
Composite Steel Joist Design

The design flexural strength of the composite section, $\phi M_n$, shall be computed as the lowest value of the following limit states:

c) Concrete Crushing:

$$\phi_{cc} = 0.85$$

$$\phi M_n = \phi_{cc} 0.85 f'_c b_e t_c d_e$$

d) Shear Connector Strength:

$$\phi_{stud} = 0.90$$

$$\phi M_n = \phi_{stud} N Q_n d_e$$

$$N Q_n \geq 0.5 A_b F_y$$
Composite Steel Joist Design

- Top chord must carry full non-composite load.
- Differential shear at top chord panel points is checked.
- Top chord end panel is assumed to act non-compositely.
- Top chord must have sufficient thickness for attachment of shear studs.
Minimum Top Chord Sizes for Installing Welded Shear Studs

<table>
<thead>
<tr>
<th>Shear Stud Diameter, in.</th>
<th>Minimum Horizontal Flat Leg Width, in.</th>
<th>Minimum Leg Thickness, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.375</td>
<td>1.50</td>
<td>0.125</td>
</tr>
<tr>
<td>0.500</td>
<td>1.75</td>
<td>0.167</td>
</tr>
<tr>
<td>0.625</td>
<td>2.00</td>
<td>0.209</td>
</tr>
<tr>
<td>0.750</td>
<td>2.50</td>
<td>0.250</td>
</tr>
</tbody>
</table>
Painting of CJ-Series Joists

- Normal shop practice is to provide composite joists unpainted.
- Paint hinders installation of welded shear studs.
- In some cases, CJ-Series joists have been provided with just the top chord unpainted.
Welded Shear Stud Installation

- Mark location of top chord with chalk line.
- Note the two blue chalk lines photo indicating where the center of each joist top chord leg is located.
- Deck must be tight against top chord.
- AISC requires $\frac{d_{\text{stud}}}{t_{\text{top chord}}} \leq 2.5$
- SJI testing supports $\frac{d_{\text{stud}}}{t_{\text{top chord}}} \leq 3.0$ but with a reduction in the stud capacity
Welded Shear Stud Installation

• “Strong” side preferable for shear studs but SJI has conservatively assumed studs will be installed in the “Weak” position.

• ¾” diameter shear studs were being installed at a rate of 220 studs/hour to the CJ-Series joists.

• Stud installation rate is very equivalent to the stud installation rate for WF beams.
Welded Shear Stud Installation

• Studs shall be alternately placed on each chord angle section for double angle top chords.

• When constructability does not allow this to occur, stud placement shall be limited as follows:
  – No more than three studs shall be placed consecutively on any one chord angle.
  – No more than 60% of the total number of studs shall be placed on any one chord angle.
Shear Stud Strength

- When a composite joist is loaded, the concrete slab wants to slip relative to the joist top chord toward each end of the joist.

- The shear studs are attached to the joist top chord and hence acts to limit the slip of the concrete over the joist top chord.

- Shear stud located near the left joist support following a full scale load test. **Note** how the shear stud is bent to the left by the concrete slab moving from right to left.
Shear Stud Layout in “Strong” Position
Shear Stud Layout in “Weak” Position
Composite Joist Camber

- When do you want the floor flat?
- Option 1: Camber only for full non-composite dead load
- Option 2: Camber for full non-composite dead load + 50% composite dead load + 25% composite live load
Composite Joist Camber
Composite Joist Camber

- Concrete placed to a constant thickness
- Simple Pinned – Pinned End Restraint
UL Fire Tests
Floor Vibration - CJ-Series Composite Steel Joists with Flush Framed Top Chord Bolted Seats

- Excellent floor vibration characteristics equivalent to wide flange beam construction

\[
\frac{a_p}{g} = \frac{P_o e^{-0.35 f_n}}{\beta W} \leq \frac{a_o}{g}
\]

- Wide flange beams and joists with flush framed top chord bolted connections, increase W by 50% to account for energy transfer across the girder into the adjacent bay

- Net effect is a reduction in the acceleration by at least 33% vs. joists with standard seats.

Eqn 2-6, AISC DG 11, 2nd Edition
Floor Vibration of CJ-Series Joists with Flush Framed Top Chord Bolted Connections

• Dr. Brad Davis, University of Kentucky measuring floor vibration in a retail distribution center.

• CJ-Series joists measured were fabricated utilizing Vulcraft’s flush framed top chord bolted connection.

• Excellent floor vibration behavior was noted.

• Vibration behavior was equivalent to that of wide flange beams framing into wide flange girders.

• Future release of FloorVibe 3.1 to handle joists with flush framed top chord bolted connections.
FloorVibe 3.0

FloorVibe 3.0
Software for Analyzing
Floors for Vibrations Criteria Based on
AISC/CISC Design Guide 11
SI Technical Digest 5

SEI
Structural Engineers, Inc.
537 Wisteria Drive
Radford, VA 24141
540-731-3330 Fax 540-639-0713
tmmurray@floorvibe.com
http://www.floorvibe.com
SJ1 Floor Bay Tool

For composite joists only, a joist depth must be entered in D49.
### Total Cost, $/sf for Noncomposite vs. Composite Joist Design

<table>
<thead>
<tr>
<th>Design Methodology</th>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
<th>Run 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joist Span, ft.</td>
<td>LRFD 40.0</td>
<td>LRFD 40.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joist Girder Span, ft.</td>
<td>30.0</td>
<td>30.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deck Profile &amp; Gage</td>
<td>2 - 22 Gage</td>
<td>2 - 22 Gage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tot. Slab Depth &amp; Type</td>
<td>5.5 in. NW Comp</td>
<td>5.5 in. NW Comp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reinforcement</td>
<td>6x6-W2.1xW2.1</td>
<td>6x6-W2.1xW2.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deck Span, ft.</td>
<td>6.00</td>
<td>6.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-Bridging Rows</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-Bridging Rows</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joist Size</td>
<td>28LH12</td>
<td>28CJ1222/719/72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Studs/bay &amp; Diameter</td>
<td>0</td>
<td>(90) 3/4&quot; Studs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joist Seat Depth, in.</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joist Girder Size</td>
<td>36G5N38.2F</td>
<td>36G5N37.7F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete, cu yd/bay</td>
<td>17.0</td>
<td>17.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reinf Weight, psf</td>
<td>0.29</td>
<td>0.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stl Wt (w/o Reinf), psf</td>
<td>7.75</td>
<td>6.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Cost, $/sf</strong></td>
<td><strong>$11.64</strong></td>
<td><strong>$10.64</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Concrete volumes are based on SDI's conservative slab weight estimates. The volumes are not precise.*
Kohl’s Department Stores

More than 1,140 stores in U.S.
More than 650 stores with CJ-Series Composite Steel Joists
Fan Pier Parcel I, Boston, MA Office Building
EOR: McNamara Salvia Structural Engineers, Boston, MA
Fan Pier Parcel I, Boston, MA Office Building

- 17 stories of CJ-Series Composite Joists
- 30CJ, 45 – 59’ foot spans, 10 foot c/c joist spacing
- 6 ¼” light weight slab on 3” VLI composite deck
- LL = 100 psf
- 22” x 56” Vierendeel opening at mid-span
- Ieff = 7,500 in⁴
- Joists flush with composite WF Girders
- Spray on fire proofing
Retail Distribution Centers
Retail Distribution Center

• Panelized roof joists installed first protecting work area from weather.

• Panelized CJ-Series joists lifted into place next on 5\textsuperscript{th}, 4\textsuperscript{th}, 3\textsuperscript{rd}, and 2\textsuperscript{nd} floors.

• Significant reduction in erection time and reduced erector fall hazards.
Extended Girder Shear Plates to Facilitate Panelized CJ-Series Joist Erection
Non-extended Girder Shear Plates & Flush Framed Top Chord Bolted Connection
CJ Joist Weight vs. Alternatives

Span: 50 feet    LL: 150 psf    6 ft o.c.    Max LL Defl = L/360

**Design 1:** 34CJ1980 / 1440/80 @ 33 plf

**Design 2:** Standard Non-composite Joists
Alternative 34LH 1980 / 1440 @ 48 plf

**Design 3:** Structural Steel Alternative
Composite W24 x 68

**Design 4:** Structural Steel Alternative
Non-composite W27x84
SJI CJ-Series Joists vs. Composite Wide Flange for 50’ Span, LL = 150 psf, Max LL Defl = L/360
Summary

• Composite steel joists provide an efficient and economical floor system.

• Flatter floors as joists are fabricated in special rigging tables.

• Floor to floor heights can be reduced when utilizing composite steel joists since mechanical systems can be routed through the open web steel joists.

• When utilizing composite steel joists large column free areas can be provided allowing increased flexibility for laying out floor plans.

• Reductions in structural steel framing weights varying from 30 – 50% have been achieved through the use of efficient composite steel joist designs with spans of 45- 50 feet.

• CJ-Series joists with flush framed top chord bolted connections frame flush with the top of the girders. Ease in making the girders composite easily reduces the girder weights by 20% vs. noncomposite girders.
Summary

• CJ-Series joists with flush framed top chord bolted connections provide vibration characteristics equivalent to wide flange beam framing.

• Flush framed top chord bolted joist connections have the potential to reduce concrete floor accelerations by a minimum of 33% versus joists with standard seats given the same depth of steel joist.

• For seismic regions being able to easily met floor vibration criteria without having to increase the concrete slab thickness is an enormous advantage.

• Quick delivery of CJ-Series joists given no mill order lead times.

• For large projects, panelizing of CJ-Series joists can significantly reduce steel erection times and greatly improve erector safety.
Summary


• SJI’s Floor Bay Tool facilitates preparation of cost estimates for CJ-Series steel joist floor systems. https://steeljoist.org/product-category/design-tools/

• RISAFLOOR 15 to be released in October, 2020 will provide Engineers an easy efficient way to determine preliminary CJ-Series joist weights, shear stud quantities, and associated cost savings.
SJI 2\textsuperscript{nd} Edition Composite Steel Joist Catalog 200 - 2015

On the Cover:
University of Colorado Boulder Recreational Services Ice Rink, Tennis Courts on roof- 116 foot span CJ-Series joists
POLLING QUESTION

Which of the following is an advantage of CJ-Series composite steel joists?

a) Mechanical ducts and piping can be run through the open webs
b) Reductions in overall floor to floor height of the structure
c) Reduced structural steel framing weights of 30 – 50%
d) All the above
RISA has been developing leading edge structural design and optimization software for over 30 years. Our products are used around the world for buildings, stadiums, bridges and everything in between. The seamless integration of RISAFloor, RISA-3D, RISAFoundation & RISACollection creates a powerful structural design environment, ready to tackle your next design challenge.
RISAFLOOR

RISAFloor designs and optimizes building systems constructed of steel (composite and non-composite), open web steel joists, cold-formed steel as well as combinations of materials. Automatic live load reduction, additive or exclusive floor area loads, vibration calculations and more make RISAFloor the first choice for the design of all types of steel building systems.
Live Demo
POLLING QUESTION

How likely are you to specify composite steel joists now that they can be designed in structural analysis software?

a) Not Likely
b) Somewhat Likely
c) Very Likely
POLLING ANSWERS

Question 1: Which of the following is an advantage of CJ-Series composite steel joists?

a) Mechanical ducts and piping can be run through the open webs
b) Reductions in overall floor to floor height of the structure
c) Reduced structural steel framing weights of 30 – 50%
d) All the above

Question 2: How likely are you to specify composite steel joists now that they can be designed in structural analysis software?

a) Not Likely
b) Somewhat Likely
c) Very Likely
Contact Info for Additional Questions:

David Samuelson  
Structural Research Engineer  
Nucor – Vulcraft\Verco Group  
E-mail: dave.samuelson@nucor.com  
Phone No. (402) 844-2592

Ben Follett  
Product Marketing Manager  
RISA  
E-mail: benf@risa.com  
Phone No. (949) 951-5815  
https://www.risa.com/
THANK YOU