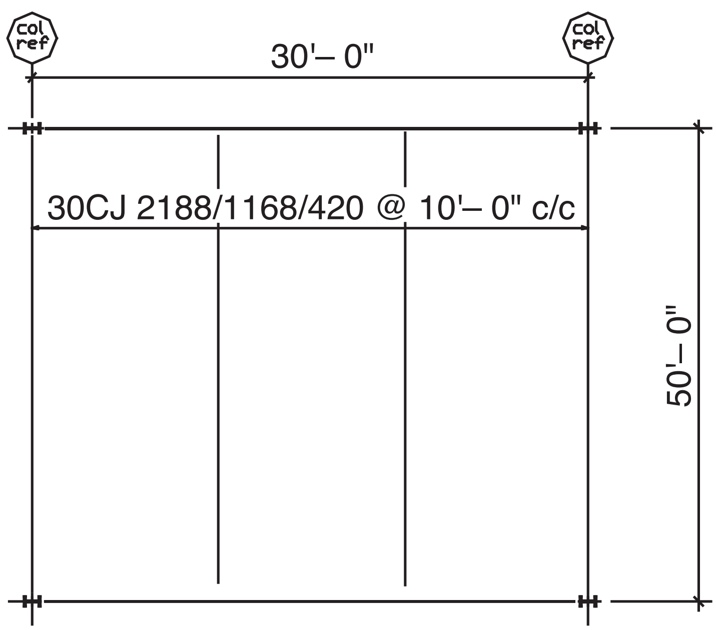
Composite Joist Design Example 1
Uniformly Distributed Loading

The purpose of this example is to demonstrate the typical use of the Composite Steel Joist Weight Tables and Bridging Tables.

Please note the load combinations shown are for this example only and it is not to be presumed that the joist designer is responsible for the applicable building code load combinations. If joist loading criteria are too complex to adequately communicate in a simple load diagram, the Specifying Professional shall provide a load schedule showing the specified design loads, load categories and required load combinations with applicable load factors.



Type of Occupancy: Office
42" ceiling to
floor height.

2 1/2" concrete on 2"
composite floor deck.

Total slab thickness = 4 1/2"

Normal Weight Concrete

<u>Joist Geometry:</u>

1)	Depth	30 in.	(813 mm)
2)	Span	50 ft.	(15.24 m)
3)	Adjacent Member Spacing (left)	10 ft.	(3.05 m)
4)	Adjacent Member Spacing (right)	10 ft.	(3.05 m)

<u>Concrete and Deck:</u>

1)	Type of Floor Deck	B Comp Floor Deck	
2)	Depth of Floor Deck	2 in.	(51 mm)
3)	Slab Thickness Above Deck	2.5 in.	(64 mm)
4)	Concrete Unit Weight	145 pcf	(2324 kg/m^3)
5)	Concrete Compressive Strength	4 ksi	(27.6 MPa)

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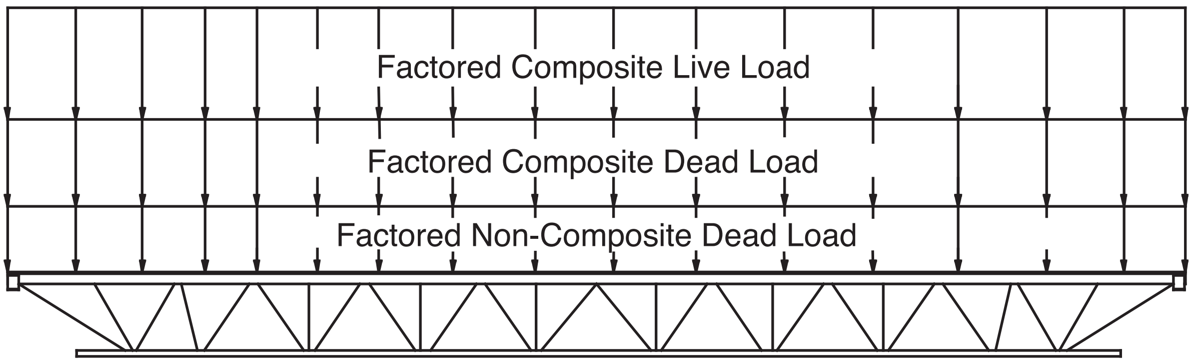
UNIFORMLY DISTRIBUTED LOADING



Nominal Loads:

1) Non-composite Construction Dead Load		
a) Concrete	43 psf	(2.06 kPa)
b) Joist and Bridging	4.7 psf	(0.23 kPa)
c) Deck	2.3 psf	(0.11 kPa)
d) TOTAL	50 psf	(2.39 kPa)
	= 500 plf	(7.3 kN/m)
2) Construction Live Load ([1]Reduced as Applicable)		
a) During Concrete Placement	14 psf	(0.67 kPa)
	= 140 plf	(2.0 kN/m)
3) Composite Dead Load		
a) Fixed Partitions	20 psf	(0.96 kPa)
b) Mechanical	7 psf	(0.34 kPa)
c) Electrical	3 psf	(0.14 kPa)
d) Fireproofing	2 psf	(0.10 kPa)
e) Floor Covering and Ceiling	3 psf	(0.14 kPa)
f) Miscellaneous Dead Loads	0 psf	(0 kPa)
g) TOTAL	35 psf	(1.68 kPa)
	= 350 plf	(5.1 kN/m)
4) Composite Live Load		
a) Live Load ([2]Reduced as Applicable)	73 psf	(3.50 kPa)
b) Moveable Partitions	0 psf	(0 kPa)
c) TOTAL	73 psf	(3.50 kPa)
	= 730 plf	(10.6 kN/m)

5) Total Factored Non-composite Dead Load, 1.2 x (1d)
= 60 psf (2.87 kPa) or 600 plf (8.76 kN/m)

6) Total Factored Composite Dead Load, 1.2 x (3g)
= 42 psf (2.01 kPa) or 420 plf (6.13 kN/m)

7) Total Factored Composite Live Load, 1.6 x (4c)
= 116.8 psf (5.59 kPa) or 1168 plf (17.05 kN/m)

8) Total Factored Composite Design Load, (5) + (6) + (7)
= 218.8 psf (10.48 kPa) or 2188 plf (31.93 kN/m)

[1]When estimating construction live loading on a composite steel joist it is suggested that the construction live loading be adjusted for tributary area as follows:

For U.S. Customary units

$L_c = 20R_1$ where $12 \leq L_c \leq 20$, lb/ft.^{2} (EX1)

$R_1 = 1$	for $A_t \leq 200$ ft.^{2}
$R_1 = 1.2 - 0.001A_t$	for 200 ft.$^2 < A_t <$ 600 ft.^{2}
$R_1 = 0.6$	for $A_t \geq 600$ ft.^{2}

Where:

L_c = Construction live load (reduced)
A_t = Tributary floor area over one joist supporting the construction live load, ft.^{2} (m^2)

For Metric units

$L_c = 0.96R_1$ where $0.58 \leq L_c \leq 0.96$, kN/m^2 (EX2)

$R_1 = 1$	for $A_t \leq 18.58$ m^2
$R_1 = 1.2 - 0.01076A_t$	for 18.58 m$^2 < A_t <$ 55.74 m^2
$R_1 = 0.6$	for $A_t \geq 55.74$ m^2

L_{const} = 20 psf	(0.96 kPa)
A_t = 50 ft. x 10 ft. = 500 ft.^{2}	(46.45 m^2)
$R_1 = 0.70$	

Therefore, from Equation EX1 (EX2), L_c = 20 psf x 0.70 = 14 psf (0.67 kPa)

[2]Floor Live Loading is allowed to be reduced per ASCE 7-05, Section 4.8 as long as the specified provisions are met.

For U.S. Customary units

$$L_c = L_0 \left[0.25 + \frac{15}{\sqrt{K_{LL}A_T}}\right] \qquad \text{(EX3)}$$

Where:

L = Reduced design live load per ft.^{2} (m^2) of area supported by joist
L_o = Unreduced design live load per ft.^{2} (m^2) of area supported by joist (see ASCE 7-05, Table 4-1)
K_{LL} = Live load element factor (see ASCE 7-05, Table 4-2)
A_T = Tributary area in ft.^{2} (m^2)

For Metric units

$$L = L_o \left[0.25 + \frac{4.57}{\sqrt{K_{LL}A_T}}\right] \qquad \text{(EX4)}$$

L_o = 100 psf (4.79 kPa)
K_{LL} = 2 for interior joists from ASCE 7-05, Table 4-2
A_T = 50 ft. x 10 ft. = 500 ft.^{2} (46.45 m^2)
K_{LL} A_T = 2 x 500 ft.^{2} = 1000 ft.^{2}

Since K_{LL} A_T > 400 ft.^{2} (37.16 m^2), the joist is permitted to be designed for a reduced live load according to Equation EX3 (EX4).

$$L = 100 \text{ psf x} \left[0.25 + \frac{15}{\sqrt{(2)(500)}}\right] = 100 \text{ psf x } 0.73 = 73 \text{ psf (3.50 kPa)}$$

Camber and Deflection (unfactored load):

1) Loads to Camber For:

a)	Non-composite Dead Load	(1d) x 100%	50 psf	(2.39 kPa)
b)	Composite Dead Load	(3g) x 50%	17.5 psf	(0.84 kPa)
c)	Composite Live Load	(4c) x 10%	7.3 psf	(0.35 kPa)

2) Maximum Allowable Live Load Deflection, Span/360
= (50 x 12)/360 = 1.67 in. (42.3 mm)

3) Maximum Deflection, $\frac{\text{SPAN}}{240} = \frac{(50)(12)}{240}$ = 2.5 in. (63.5 mm)

Determine joist weight per foot, quantity and size of shear studs, anticipated floor deflections, number of bridging rows required and maximum circular duct size opening.

Solution

Factored Design Loads:

W	*Non-composite DL*	=	600 plf	(8.76 kN/m)
W	*Composite DL*	=	420 plf	(6.13 kN/m)
W	*Composite LL*	=	1168 plf	(17.05 kN/m)
W	*TL*	=	2188 plf	(31.93 kN/m)

Determine the allowable joist depth:

42 in.	(1067 mm) Ceiling to floor height
-4.5 in.	(114 mm) Slab depth
-5.5 in.	(140 mm) Ceiling to bottom chord
32 in.	(813 mm) Joist depth

JOIST SELECTION:

The proper joist shall be selected from the **Design Guide LRFD Weight Table for Composite Steel Joists, CJ-Series – Normal Weight Concrete** for a joist with a 50 foot (15.2 m) span, maximum allowable depth of 32 inches (813 mm), normal weight concrete, a total factored composite design load of 2188 plf (31.93 kN/m) and composite live load of 1168 plf (17.05 kN/m).

Choose the column in the table that is equal to or greater than the calculated total safe factored uniformly distributed load and a row where: (1) the joist depth does not exceed the allowable depth, and (2) the least weight per foot. The joist spacing, **Js** in the column selected should be less than or equal to the actual spacing of the joists. However, should the joist spacing be less than the **Js** value chosen, then the concrete capacity would need to be checked, since it would likely have a lower **W360** value and a lower total load carrying capacity. The **SJI Composite Joist Floor Design Parameters Checklist** found in the **Code of Standard Practice for Composite Steel Joists** needs to be filled out. This information should be forwarded to a Steel Joist Institute member company requesting that a composite joist design be checked.

In this example choose the column headed by total factored load of 2200 plf (32.11 kN/m) and the 30 inch (762 mm) joist depth row (Note: The 30 inch joist depth was selected over the allowable 32 inch joist depth for three reasons: (1) the 30 inch joist weight per foot was less than the 32 inch joist and the number of shear studs was the same for both the 30 and 32 inch joist depths; (2) the composite live load is greater than what is required; and (3) the 30 inch deep joist will allow more available space beneath the joist for mechanicals, light fixtures, etc.).

Wt = 34.67 plf (0.51 kN/m; 51.62 kg/m)
W360 = 1236 plf (18.19 kN/m)
N-ds = 46 – 3/4 in. (19 mm)

BRIDGING AND NOMINAL HORIZONTAL TOP CHORD FORCE (Pbr) SELECTION:

From the **Design Guide LRFD Weight Table for Composite Steel Joists, CJ-Series – Normal Weight Concrete**, use the same column and row selection for the joist selection (2200 plf; 30 inch joist depth) and determine the number of rows and type of bridging:

For this example, two rows of horizontal bridging **(2H)** are required.

For the bridging member size(s) and the nominal horizontal top chord force go to the **Design Guide LRFD Bridging Table for Composite Steel Joists, CJ-Series – Normal Weight Concrete** and choose the column at or nearest the actual joist spacing and the joist depth row based on the joist selection above (Note: This approach is conservative since the nominal horizontal top chord force, **Pbr** will be larger than the actual top chord force, but since the bridging size is also based on the length of bridging, the distance nearest the actual spacing of the joists needs to be considered to size the bridging. This is an estimate and the actual size of the bridging may change when the final design is performed by the joist manufacturer).

For this example, choose the column with **Js** = 10 feet and the row for a 30 inch deep joist. The bridging size is L2.5 x 2.5 x 0.187 and the nominal horizontal top chord force, **Pbr** is 1423 lbs (Note: The nominal horizontal top chord force is used to determine the connection for the termination of the bridging row).

NON-COMPOSITE EFFECTIVE MOMENT OF INERTIA SELECTION:

To determine the Non-composite Effective Moment of Inertia of the joist go to the **Design Guide LRFD Bridging Table for Composite Steel Joists, CJ-Series – Normal Weight Concrete** and choose the same column and row used in making the joist selection.

For this example, use the column labeled 2200 plf and the row labeled 30 inch joist depth.

$I_{\text{non-comp eff}}$ = 1448 in.^{4} (6.03 x 10^8 mm^4)

Deflection:

$$\Delta_{\text{non-composite DL}} = \frac{5(W_{\text{non-composite DL}})(\text{Design Length})^4(1728)}{384 E_S\, I_{\text{non-comp eff}}}$$

Where:

Design Length	=	Span – 4 in. = 49.67 ft. (15.14 m)
E_S	=	Modulus of Elasticity of steel (psi)
$I_{\text{non-comp eff}}$	=	Moment of Inertia of Non-composite joist (in.^{4})

$$\Delta_{\text{non-composite DL}} = \frac{5(500)(49.67)^4(1728)}{384(29{,}000{,}000)(1448)}$$

$$\Delta_{\text{non-composite DL}} = 1.63 \text{ in. } (41.4 \text{ mm}) = L/368$$

$$\Delta_{\text{Composite DL}} = \left[\frac{W_{\text{Composite DL}}}{W_{360}}\right]\left[\frac{L}{360}\right] = \left[\frac{350}{1236}\right]\left[\frac{(49.67)(12)}{360}\right] = 0.47\text{ in. }(11.9\text{ mm}) = L/1280$$

$$\Delta_{\text{Composite LL}} = \left[\frac{W_{\text{Composite LL}}}{W_{360}}\right]\left[\frac{L}{360}\right] = \left[\frac{730}{1236}\right]\left[\frac{(49.67)(12)}{360}\right] = 0.98\text{ in. }(24.8\text{ mm}) = L/614$$

$\Delta_{TL} = \Delta_{\text{Non-composite DL}} + \Delta_{\text{Composite DL}} + \Delta_{\text{Composite LL}}$

Δ_{TL} = 1.63 in. + 0.47 in. + 0.98 in. = 3.08 in. (78.2 mm) = $L/195$

Camber:

Camber joist for 100% x $\Delta_{\text{Non-composite DL}}$ + 50% x $\Delta_{\text{Composite DL}}$ + 10% x $\Delta_{\text{Composite LL}}$

Joist Camber = 1.0 x 1.63 in. + 0.50 x 0.47 in. + 0.10 x 0.98 in. = 1.96 in. (49.9 mm)

EFFECTIVE MOMENT OF INERTIA SELECTION:

To determine the Effective Moment of Inertia of the joist go to the **Design Guide LRFD Weight Table for Composite Steel Joists, CJ-Series – Normal Weight Concrete** and choose the same column and row used in making the joist selection.

For this example, use the column labeled 2200 plf and the row labeled 30 inch joist depth.

I_{eff} = 3596 in.^{4} (14.97 x 10^8 mm^4)

The published value of **W360** takes into account the reductions in effective transformed moment of inertia associated with web deformations and interfacial slippage. Therefore, the above value of **I_{eff}**, has been reduced to account for these behaviors. In deriving **W360**, an interfacial slippage factor of 1.05 was assumed.

Therefore, taking out this effect, $I_{\text{e composite without slippage}}$ can be given as:
$I_{\text{e composite without slippage}}$ = 1.05 I_{eff} = 1.05 (3596 in.^{4}) = 3776 in.^{4} (15.72 x 10^8 mm^4)

Design Summary:

The composite steel joist designation: **30CJ 2188/1168/420**

30	CJ	2188	1168	420
Depth (in.)	Composite Joist Series	Total Factored Composite Design Load (plf)	Total Factored Composite Live Load (plf)	Total Factored Composite Dead Load (plf)

Bridging:

Use **2 rows of 2L's 2.5 x 2.5 x 0.187**

Joist weight = 34.67 plf (0.51 kN/m; 51.62 kg/m)

$\Delta_{\text{Non-composite DL}}$ = 1.63 in. (41.4 mm)

$\Delta_{\text{Composite DL}}$ = 0.47 in. (11.9 mm)

$\Delta_{\text{Composite LL}}$ = 0.98 in. (24.8 mm)

Camber = 1.96 in. (49.9 mm)

Quantity and Type of Shear Studs, N - ds = 46 – 3/4 in. (19 mm)

Duct Opening Available:

From the Approximate Duct Opening Sizes table located in the front portion of the catalog, a 15 in. (381 mm) circular duct is permissible to pass through the web openings of a 30 in. deep composite steel joist.