Part 1: Evaluation and Modification of Open Web Steel Joists and Joist Girders

OCTOBER 17, 2018

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Polling Questions

- 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.

Learning Objectives

- Identify the key characteristics of in place joists.
- Teach you how to determine who the original manufacturer was and whether they can provide any additional documentation.
- Show you how to verify the original design loads and evaluate the joist for the new loads.
- As part of the evaluation, procedures will be discussed to identify the joist components and connections that are inadequate.

Introduction

- **Commercial manufacturing of open web steel joists began in 1923**

- **The Steel Joist Institute was formed in 1928**
  - **Open Web Steel Joist use has continued to grow**
  - **There are millions of Open Web Steel Joists in service**

Introduction (cont'd)

Evaluation and Modification of joists are required for many reasons:

- **Building renovations**
- **Addition of roof top units**
- **Conveyor loads**
- **Field deviations – Dimensional changes**
- **Other changes not contemplated in the original design**
- **Damage to the joists**

New Resource Available

SJI Technical Digest No. 12
Evaluation and Modification of Open-Web Steel Joists and Joist Girders

- **Present procedures**
- **Suggest details for modification or strengthening**

SJI Technical Digest No. 12

Evaluation and Modification of Open-Web Steel Joists and Joist Girders
Price: $30

Order from:
www.steeljoist.org

SJI Technical Digest No. 12

Background	
Glossary	
Chapter 1	Evaluations of Existing Joist Strength
Chapter 2	Methods of Supporting Additional Load
Chapter 3	Design Approaches For Strengthening Joists
Chapter 4	Design Approaches For Modifying Joists - Shortening And Lengthening
Chapter 5	Other Considerations
Chapter 6	Summary
References	
Appendix A	Joist Investigation Form
Appendix B	Common Properties of Equal Leg Angles With Leg Sizes 2 In. or Less

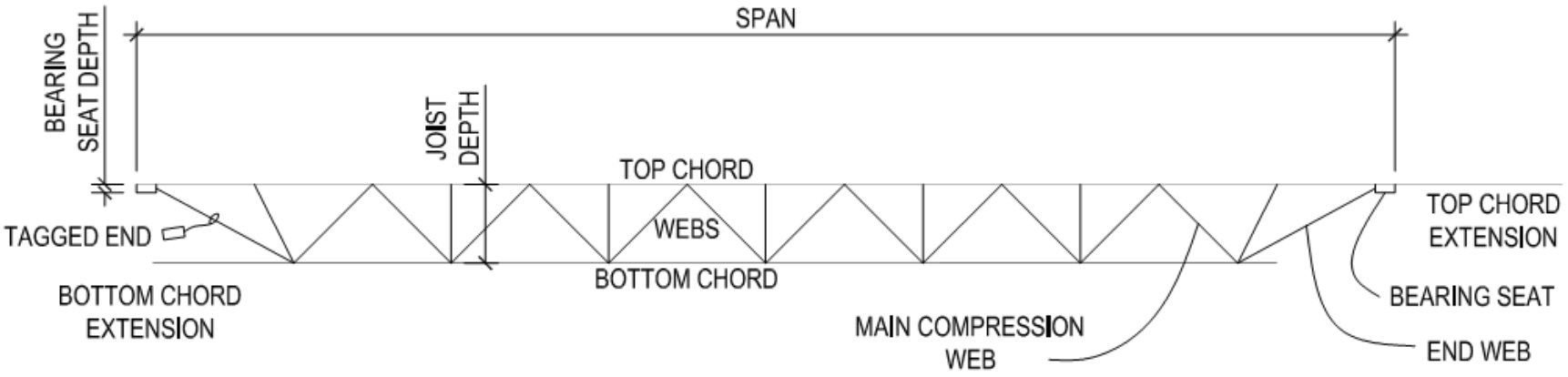
Glossary of Terms

- Allowable Strength Design (ASD)
- Allowable Strength
- Available Strength
- Bearing
- Bridging
- Buckling
- Buckling Strength
- Camber
- Chords
- Cold-Formed Steel Structural Member
- Composite Section
- Connection
- Deck
- Design Load
- Design Strength
- End Diagonal or Web
- End Welds
- Existing Member
- Filler
- Joint
- Joist
- Joist Girder

Glossary of Terms

- Load
- LRFD (Load and Resistance Factor Design)
- Material
- Nominal Strength
- Preload Force
- Reinforcing Member
- Required Strength
- Resistance Factor, Φ
- Safety Factor, Ω
- Slenderness Ratio
- Span
- Specified Minimum Yield
- Stress
- Specifying Professional
- Splice
- Stability
- Standard Specifications
- Structural Analysis
- Tagged End
- Webs
- Yield Point
- Yield Strength
- Yield Stress

Glossary of Terms



Evaluation of Existing Joist

Find construction documents

- Contract drawings and/or joist erection plan

Onsite Investigation

- Joist tag

Contact Joist Manufacturer

- See if calculations are available. In most cases the manufacturer will have a minimal cost to locate, copy and send information on old projects.

Determine the specification in which the existing joist were designed.

2015 SJI Catalog

K-Series Standard Specifications

- K-Series Load Tables
- KCS Joists

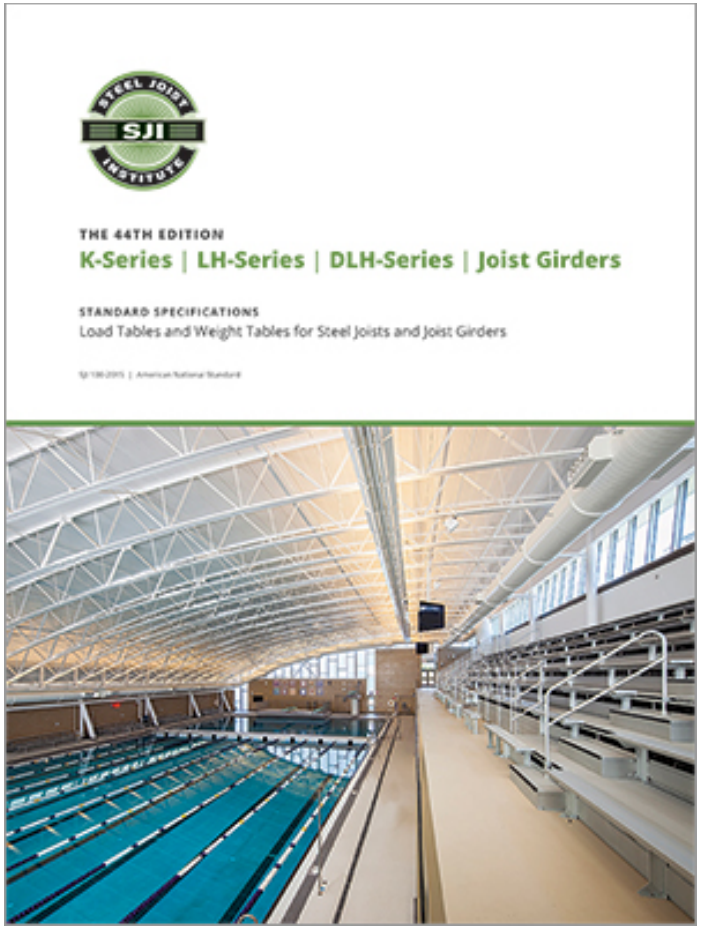
LH- and DLH-Series Standard Specifications

- LH- and DLH-Series Load Tables

Joist Girders Standard Specifications

- Joist Girder Weight Tables

Order from:
www.steeljoist.org



Evaluation of Existing Joist

Find construction documents

- **No Contract drawings and/or joist erection plan**

Onsite Investigation

- **No Joist tag - then document joist in question**

Complete the Joist Investigation Form

Contact SJI for assistance

Chapter 1
Evaluation of Existing Joist Strength

Determine Capacity of Existing Joist System

- **As-built design of joists**
- **Existing joists possibly over specified**
- **Building usage may have changed**
- **Have joists been damaged**

As – Built Design of Joists

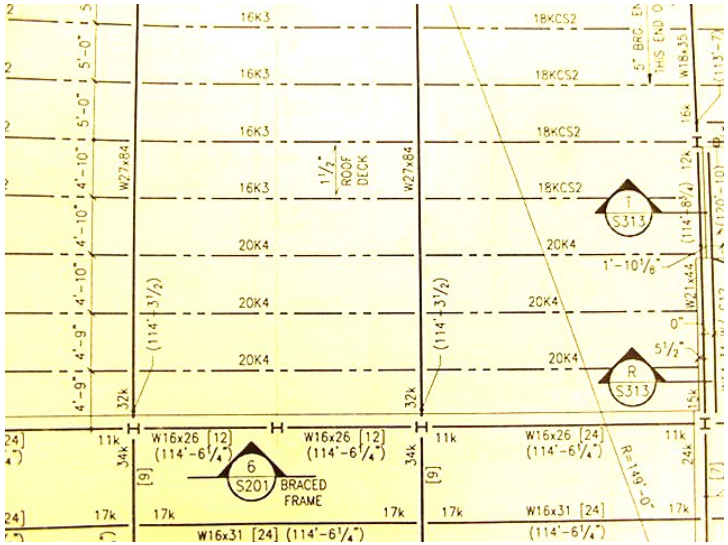
How to determine

- **Original contract structural documents**
- **Final joist erection drawings**
- **Year job was constructed**
- **Joist manufacturers identification tag**
- **Field investigation and measurements**

Joist Drawings

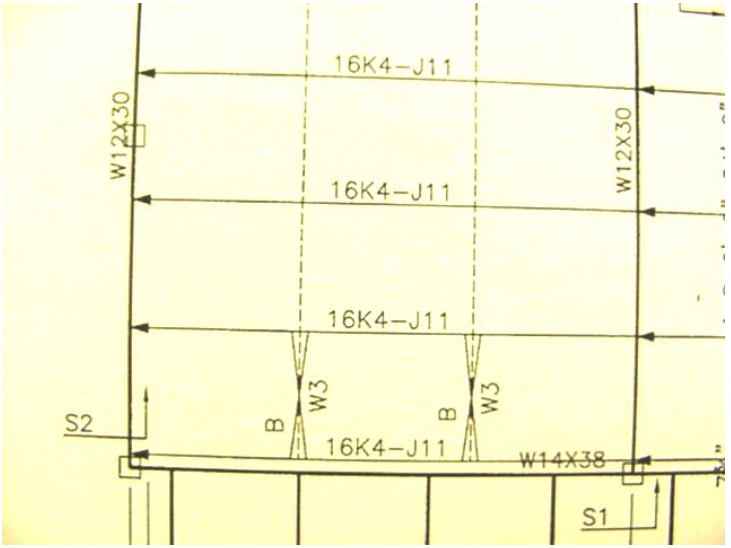
Structural Drawing

- Designation
- Joist Spacing



Erection Drawing

- Designation
- Joist Spacing
- Mark Number



Joist Identification Tag

Joist tag information

- **Joist manufacturer's name**
- **Joist manufacturer's job number**
- **Erection mark number, e.g. J1 or T3**

Joist Investigation Form

Steel Joist Institute Assistance

- Fill out the form online
- Download from SJI website
  - www.steeljoist.org
- Return to SJI office or manufacturer for assistance
- Appendix A of TD 12

STEEL JOIST INSTITUTE

steeljoist.org

Please complete the following form and email it to sji@steeljoist.org or fax it to 843-407-4044.

Date: _____

Name: _____

Company: _____

Phone: _____ Fax: _____ Cell: _____

Email: _____

Project Details

Jobsite Location City/State: _____

Project Name: _____

Why are you requesting this information? Select all that apply.

☐ Evaluation ☐ Field or erection problem ☐ Inspection ☐ Legal issue
☐ New construction ☐ Rehabilitation or reuse ☐ Seismic retrofit
☐ Structural problem ☐ Other, describe _____

Supplementary Information

What year was the building constructed or approximate age of the structure? _____

Who was the joist manufacturer? _____

Is there a tag on the joist? ☐ No ☐ Yes, provide tag information _____

What type of trusses are the joists? ☐ Warren ☐ Modified Warren ☐ Pratt ☐ Other, describe or sketch _____

What are the joists used for? ☐ Roof loading ☐ Floor loading

234 W. Cheves Street • Florence, SC 29501 • T (843) 407-4091 • F (843) 407-4044

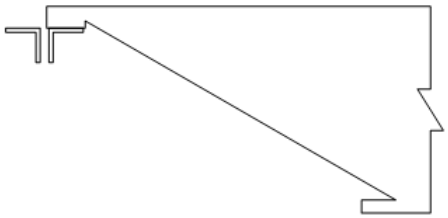
Field Investigation

Helpful and Required Information

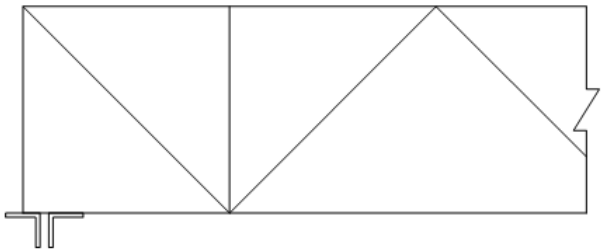
- Loading on the joists
- Information from the joist tags
- Joist configuration
- Joist span
- Joist spacing
- Joist depth or height
- Bearing condition
  - Underslung or Bottom Bearing

Bearing Condition

UNDERSLUNG



BOTTOM CHORD BEARING



Field Investigation

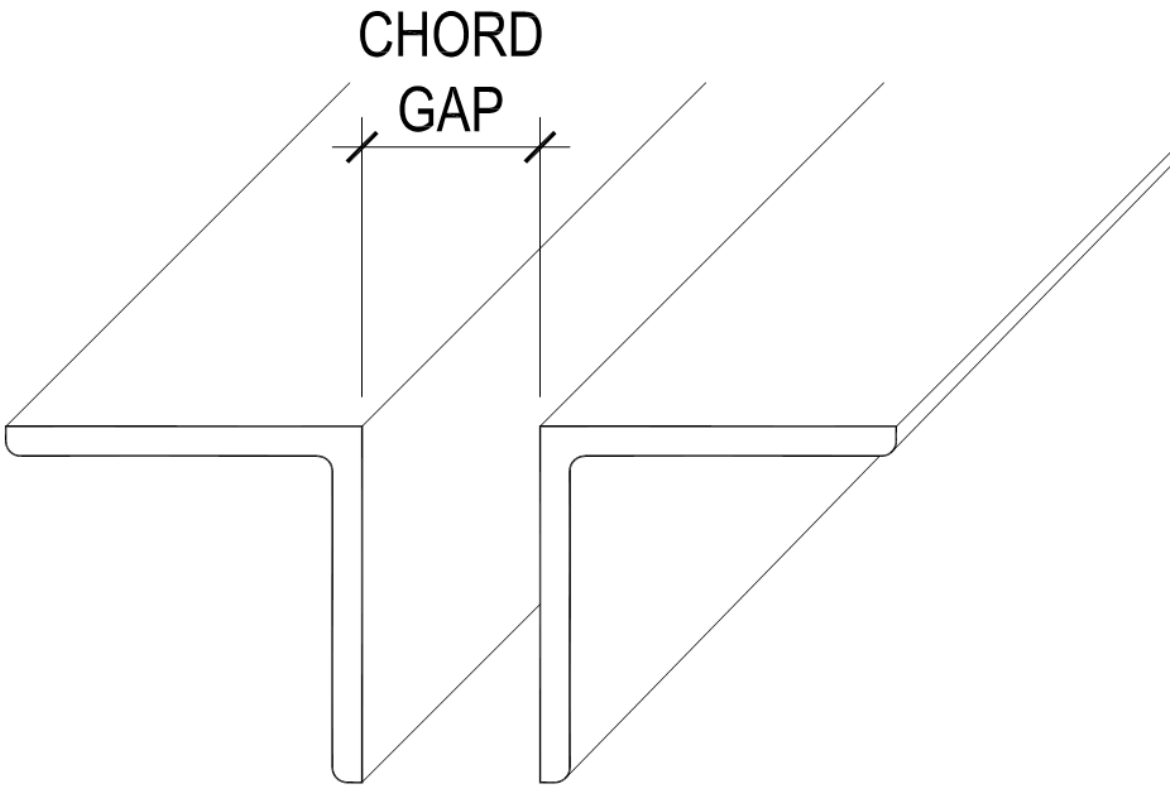
Type of Web Members

- **Rod webs**
- **Crimped Angle webs**
- **Angles welded to the outside of chords**
- **Cold-formed sections**

Also Take Note of

- **End Diagonal type**
- **Eccentricities**
- **Weld Sizes and lengths, welded connections are designed for the design requirements not the overall strength of the member**
- **Panel Point spacing**

Type of Chord Members



Type of Web Members

Rod webs

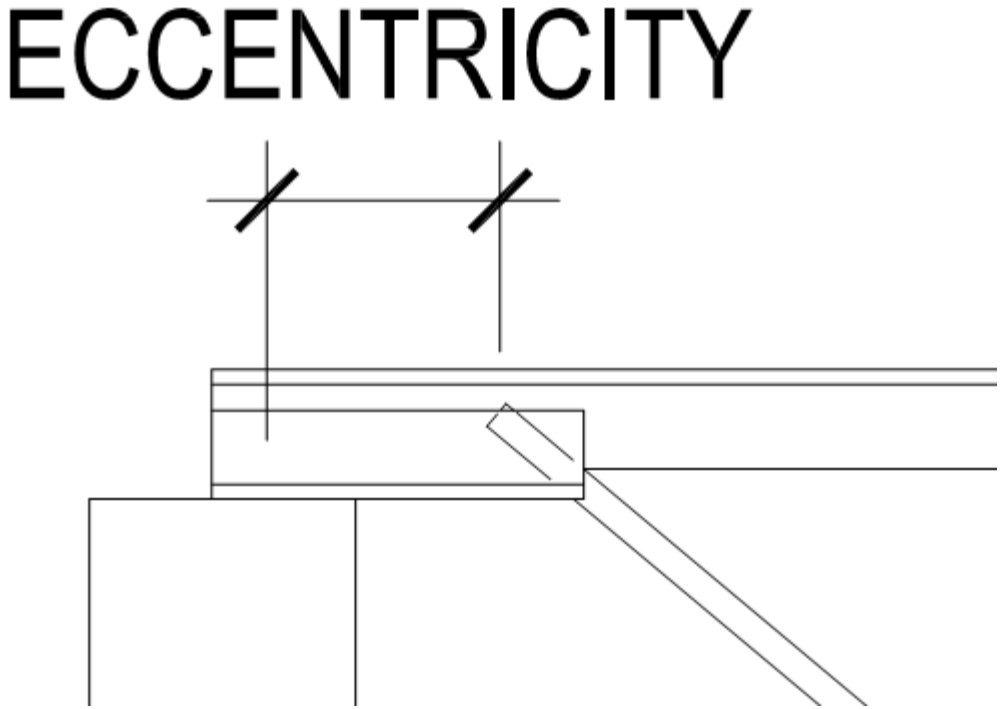
Type of Web Members

Crimped Angle webs

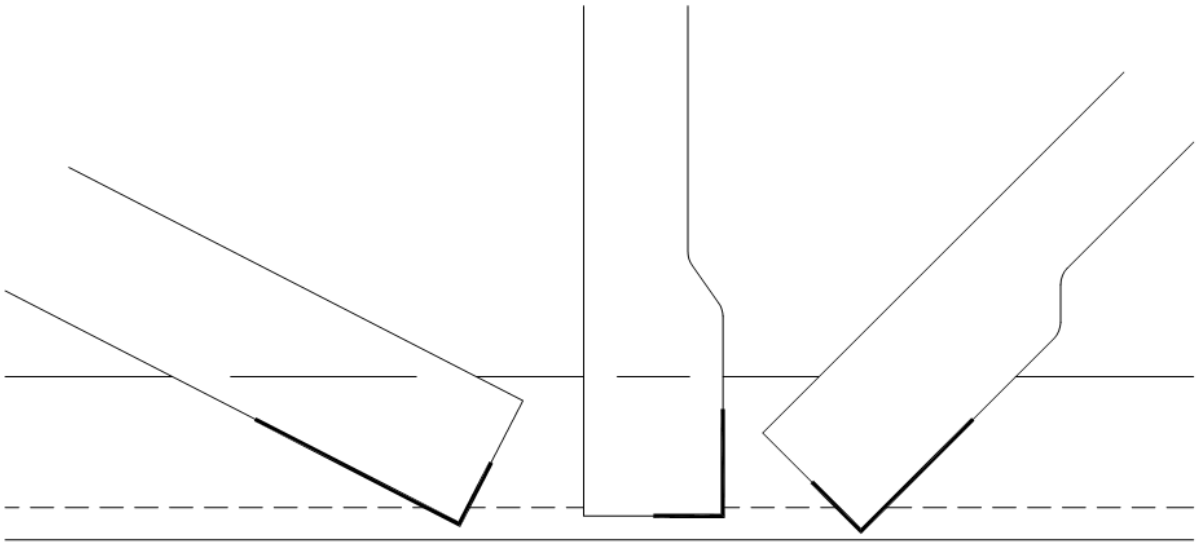
Type of Web Members

Angles welded to the outside of chords

Bearing Eccentricity



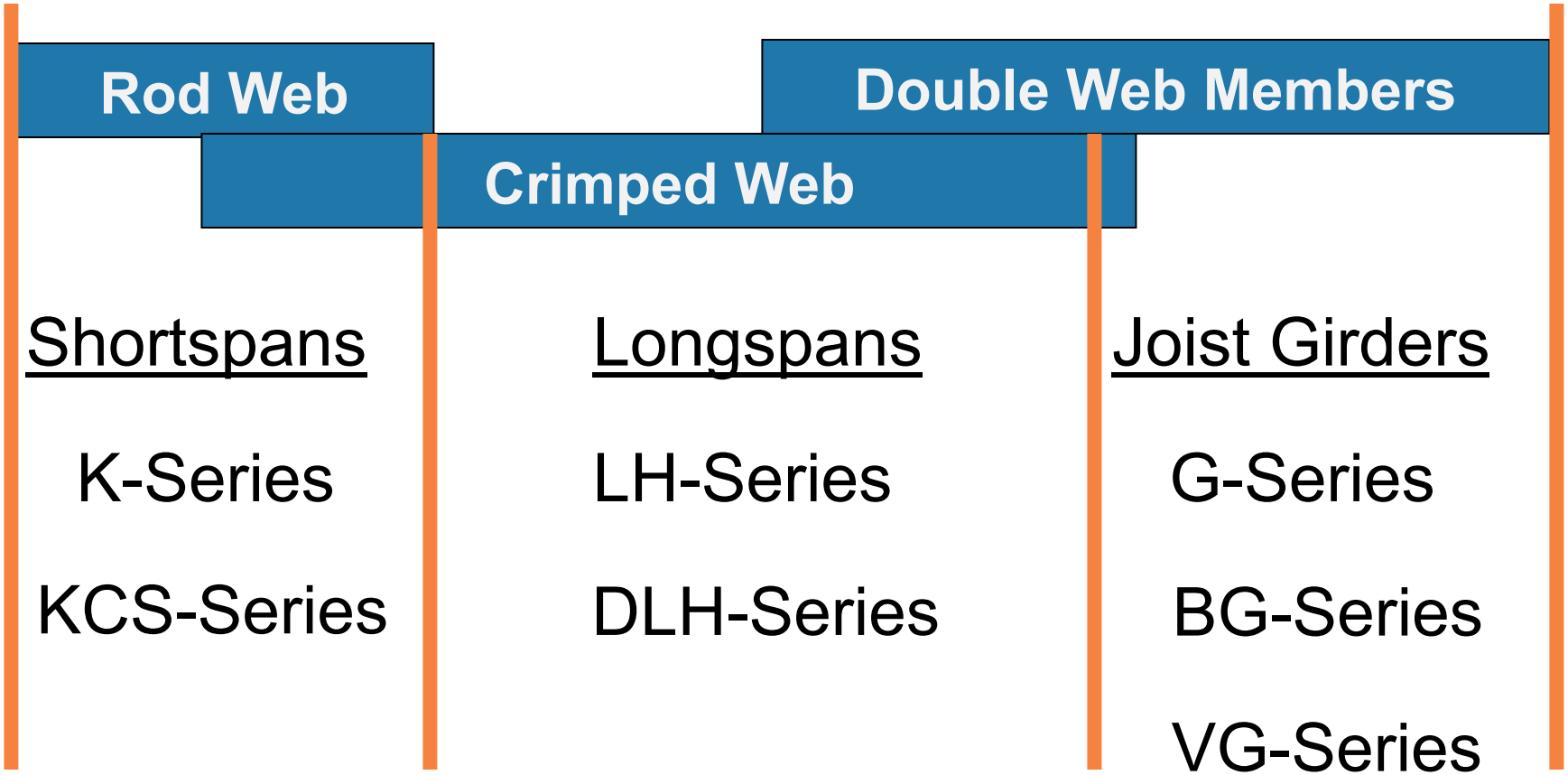
Weld Location



Welded Connections

Weld Sizes and Lengths are designed for the original design requirement, not the overall strength of the member.

Comparison of SJI Specification Types



Field Investigation

Type of Chord Members

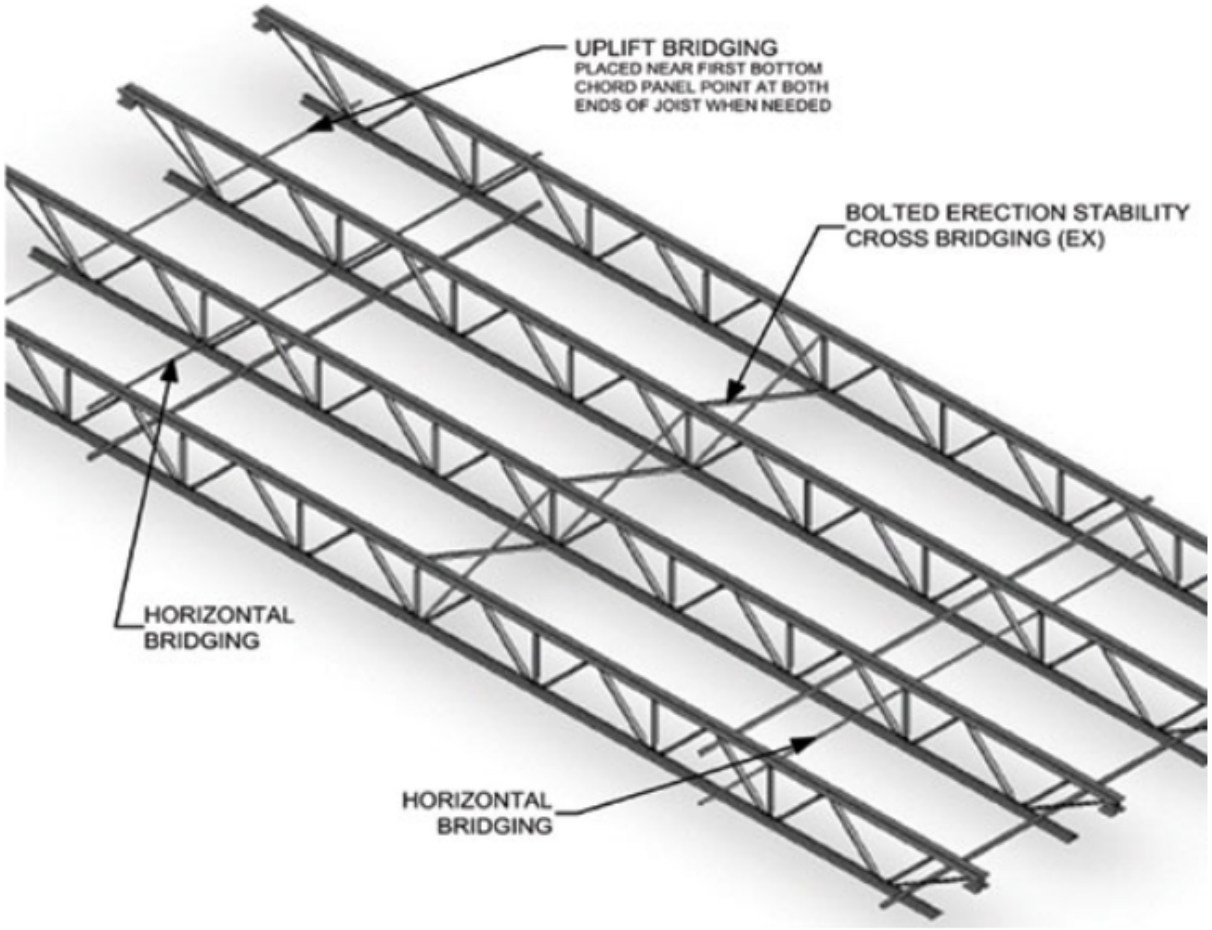
- Double Angles
  - Separation distance
  - Fillers or ties
- Cold-formed sections
- Rods
- Splices

Field Investigation

Other Items to Note

- **Type of Bridging and Locations**
- **Quality of bridging connections**
- **Anchorage of bridging**
- **Interferences**
  - **Coupon samples to determine yield strength**
- **Condition of joists and existing deck**

Types of Bridging



85 Year Steel Joist Manual

- **Specifications from 1928 to 2002**
- **Load Tables from 1928 to 2002**

85 Year Steel Joist Manual Introduction

INVESTIGATION OF STEEL JOISTS IN EXISTING BUILDINGS

I. General

First and foremost, the investigating engineer, in performing his tasks, should continually be aware of one principal consideration: *the determinations he makes affect the safety of the human beings who occupy the buildings he is investigating*.

Secondly, the task of investigating steel joists in existing buildings is difficult, at best. Personal time, effort, and patience are all required to conduct a proper study.

Thirdly, the investigating engineer should scrupulously observe the following rules:

1) Make as few *assumptions* as possible.
2) Verify by *actual observation and physical measurements* all data whenever possible.
3) Consciously look for *unusual and/or dangerous job site conditions* not specified, shown, or recorded in any documentation.
4) Double check all data.

Joist Chord Damage During Handling

Joist BC Damage During Handling

Joist TC Damage During Construction

Joist End Web Damage During Construction

Joist End Web Damage During Construction

Joist BC Damage During Construction

Joist TC Damaged During Construction

Incorrect Installation or Usage

OSHA Federal Regulation 29 CFR 1926.757 (a)(7)

No modification that affects the strength of a steel joist or steel joist girder shall be made without the approval of the project structural engineer of record.

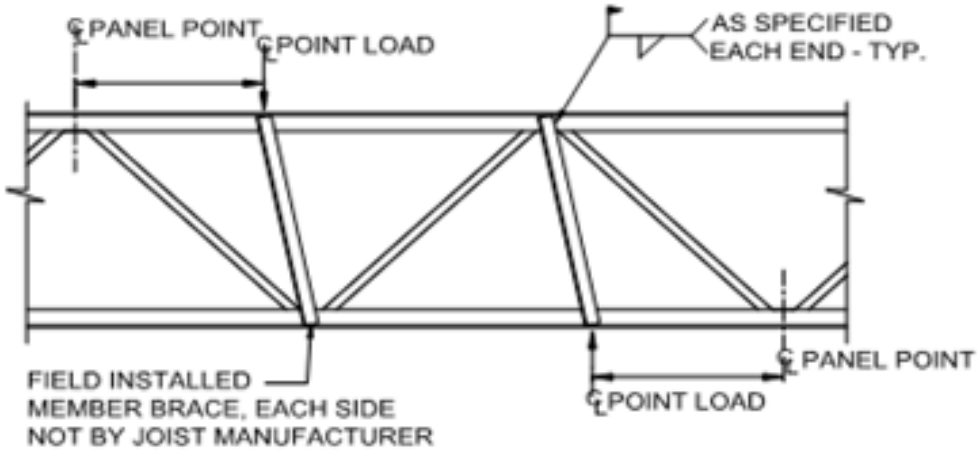
Methods to Reduce the Need for Minor Repairs

- 100 pound rule
- Add Loads
- Bend Loads
- KCS joists

100 Pound Rule

Page 15, 43rd edition of the SJI Spec

TYPICAL JOIST REINFORCEMENT AT CONCENTRATED LOADS

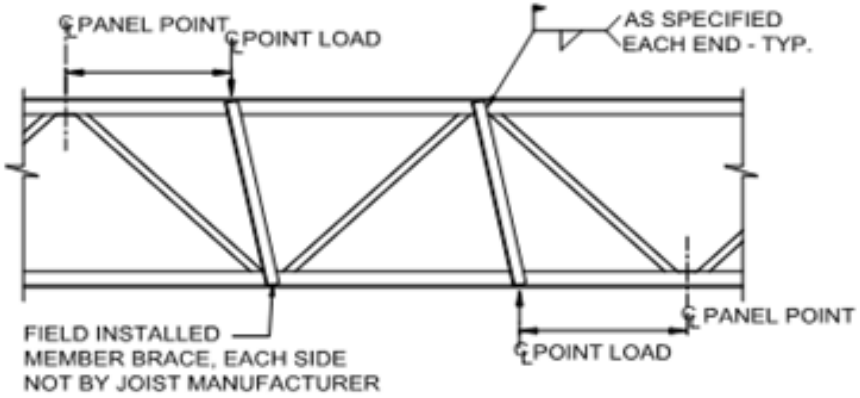


→ *For nominal concentrated loads between panel points, which have been accounted for in the specified uniform design loads, a "strut" to transfer the load to a panel point on the opposite chord shall not be required, provided the sum of the concentrated loads within a chord panel does not exceed 100 pounds and the attachments are concentric to the chord.*

100 Pound Rule

Page 15, 43rd edition of the SJI Spec

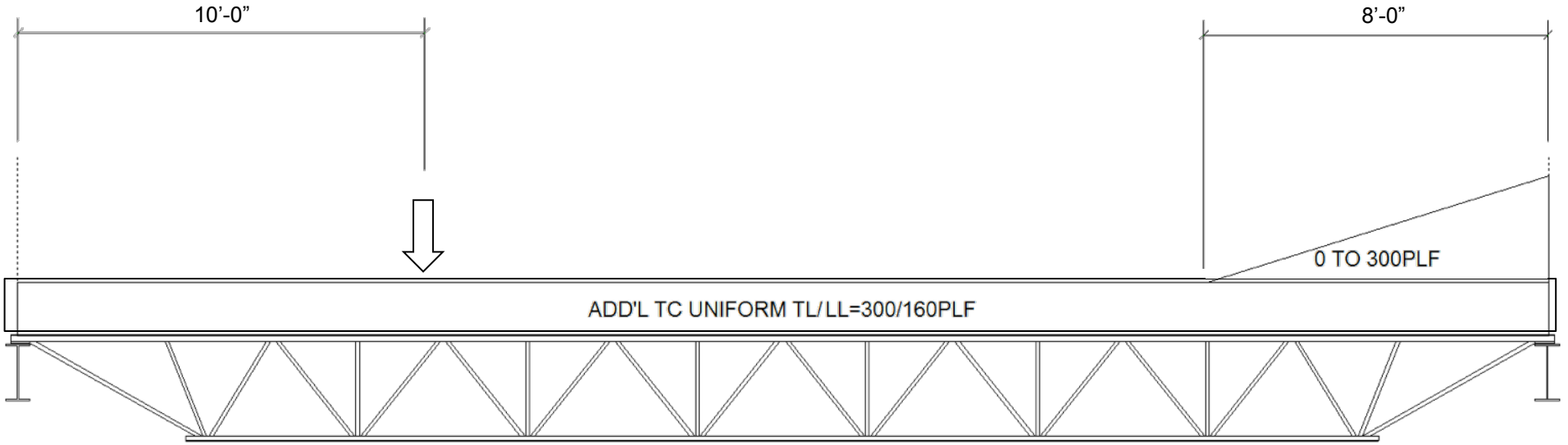
TYPICAL JOIST REINFORCEMENT AT CONCENTRATED LOADS



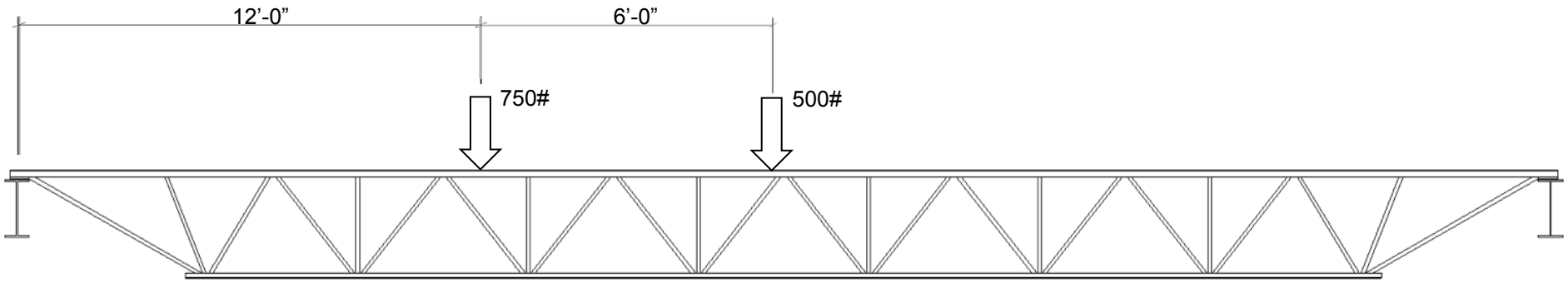
Although standard K-Series, including KCS-Series, and standard LH-Series joists are designed specifically to support uniformly distributed loads applied to the top chord, research conducted by the Steel Joist Institute, using second-order inelastic analysis, has demonstrated that the localized accumulation of uniform design loads of up to 100 pounds within any top or bottom chord panel has a negligible effect on the overall performance of the joist, provided that the load is applied to both chord angles in a manner which does not induce torsion on the chords.

→ Concentrated loads in excess of 100 pounds or which do not meet the criteria outlined above, must be applied at joist panel points, or field strut members must be utilized as shown in the detail above.

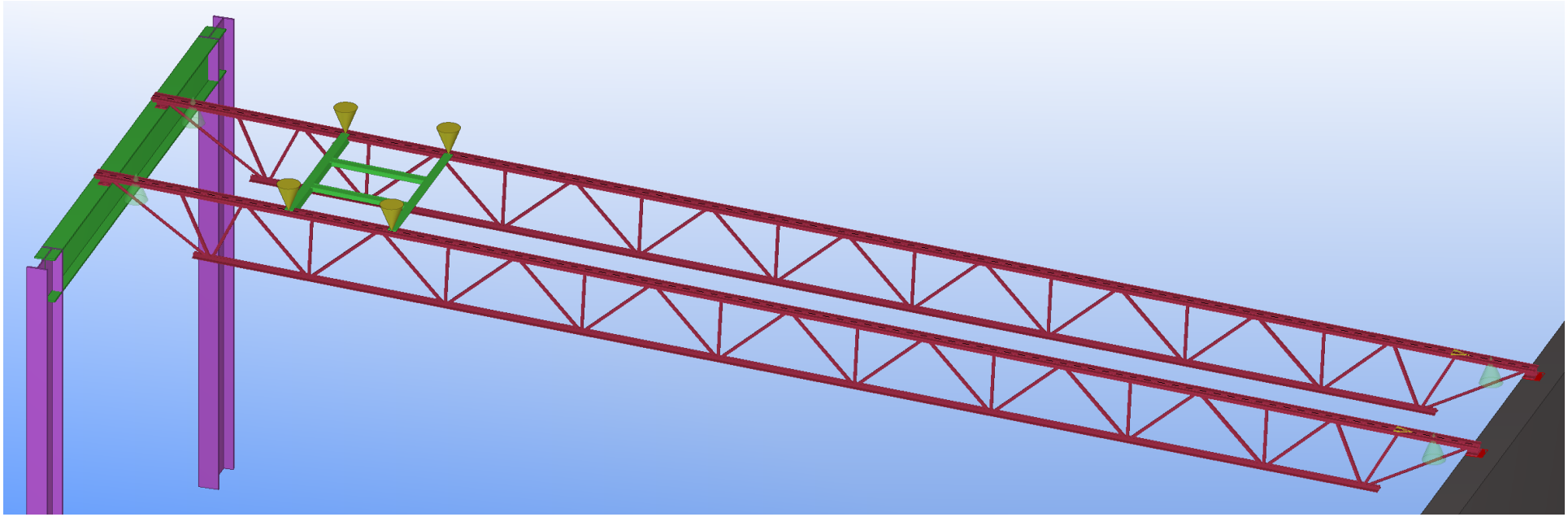
Load Diagram



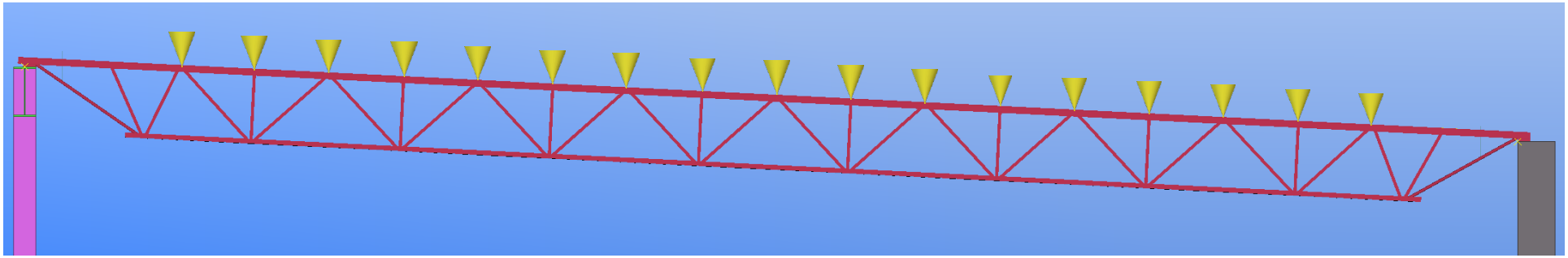
Concentrated Loads



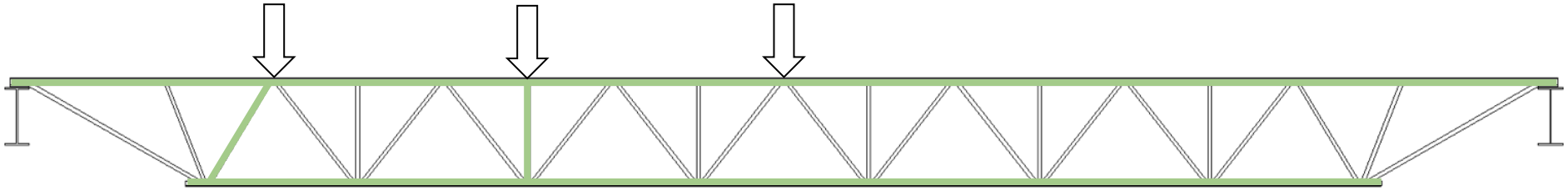
HVAC Frame



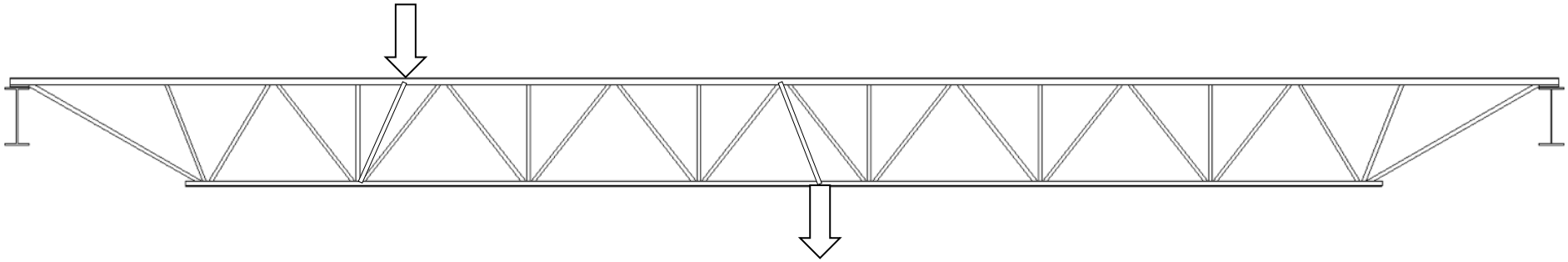
Adload



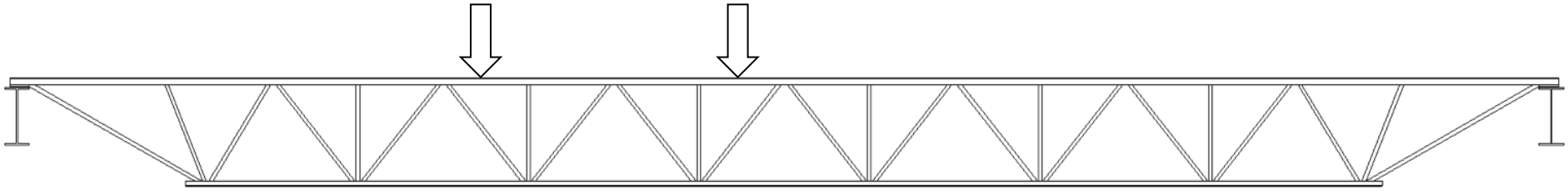
Worst Case Condition



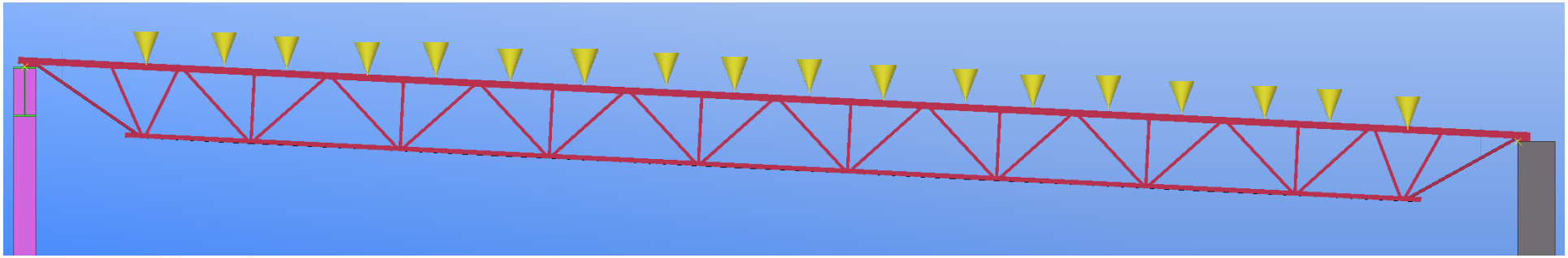
Add Web



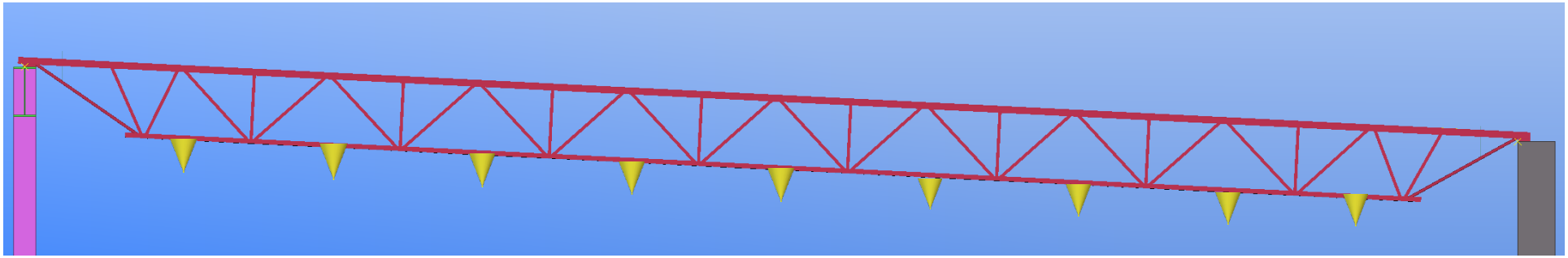
Bend Load



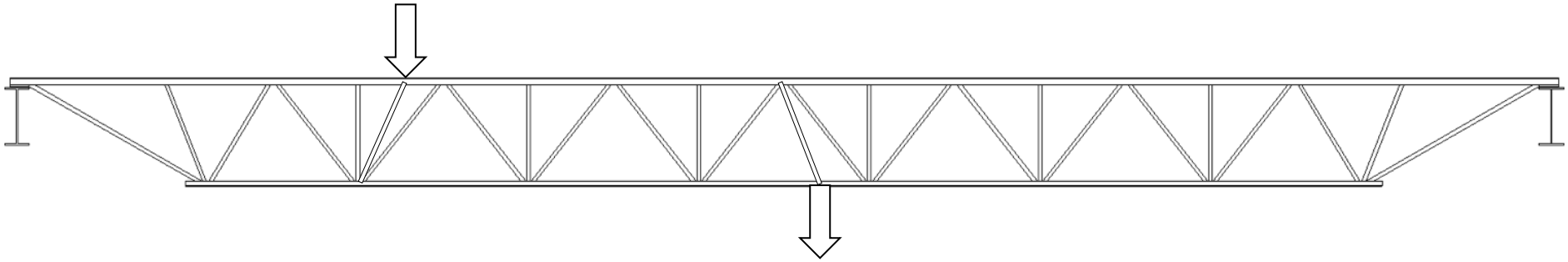
Bend Load



Bend Load



Additional Webs are Not Needed with a Bend Load



Specifying the Loads

Page 182, 43rd edition of the SJI Spec

Option 3: For additional point loads with exact locations not known along the joist or for incidental loads, any one, or both, of the following can be specified on the structural plan in addition to option 1 or 2 above:

a) "**Design for a (__) lb. concentrated load located at any one panel point along the joist**". This is referred to as an "Add-Load".

b) "**Design for additional bending stresses resulting from a (__) lb. concentrated load located at any location along (____) chord**". This is referred to as a "Bend-Check" and can be specified on **top** chord, **bottom** chord, or **both top and bottom** chords. This can be used when the concentrated load is already accounted for in the joist designation, uniform load, or specified Add-Load yet this specified amount of load shall be permitted to also be located at any location between panel points. The additional bending stresses as a result of this load are then designed for. A Bend-Check load shall not exceed (Add-Load + 400 lbs.) A Bend-Check load can be specified by itself without an Add-Load.

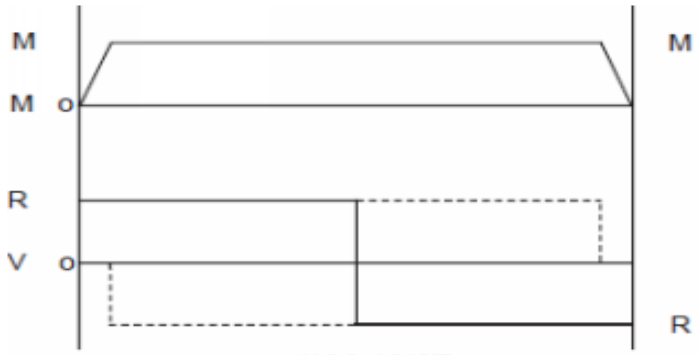
c) Both (a) and (b) above can be specified with equal concentrated loads for each; or simply denote "**Design joist for a (__) lb. concentrated load at any location along the (___) chord.**"

KCS Joists

KCS- Series joist advantages:

1. Provides a versatile **K-**Series Joist that can be easily specified to support uniform and non-uniform loads plus concentrated loads applied at panel points.
2. Eliminate many repetitive load diagrams required on contract documents and allow some flexibility of load locations.

KCS-Series joist chords are designed for a flat positive moment envelope. The moment capacity is constant at all interior panels.
All webs are designed for a vertical shear equal to the specified shear capacity and interior webs will be designed for 100% stress reversal.



KCS JOIST
SHEAR AND MOMENT ENVELOPES

Both LRFD and ASD **KCS**-Series joist load tables list the shear and moment capacity of each joist. The selection of a **KCS**-Series Joist requires the specifying professional to calculate the maximum moment and shear imposed and select the appropriate **KCS**- Series Joist.

Analysis Considerations

To Analyze Joist Capacity

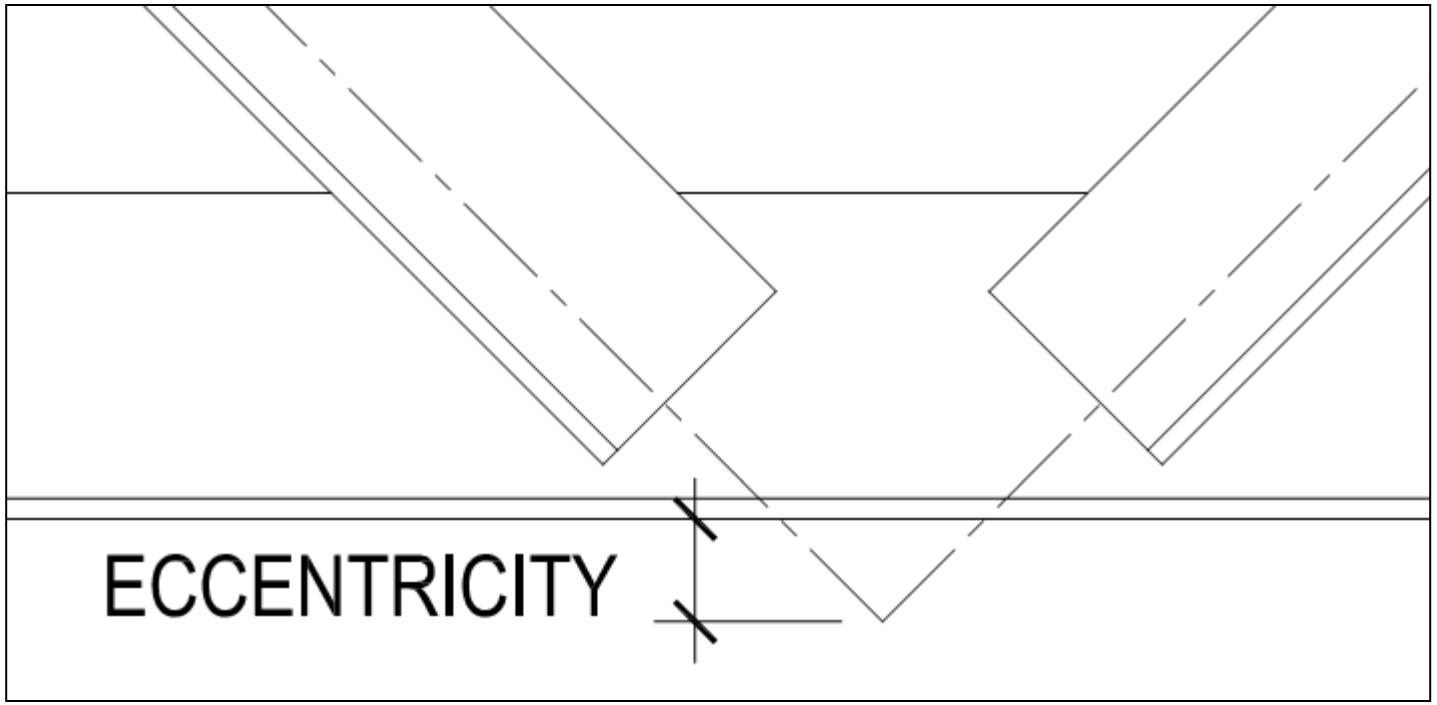
- **Pinned connections are assumed for web members**
- **Specifications for K-Series joists in the 2015 spec has changed.**
  - **Prior to 2015 bending in K-series from uniformly applied loads was neglected provided the top chord panel spacing did not exceed 24 inches.**
  - **In 2015 the bending from uniformly applied loads are considered, regardless of the panel spacing.**
  - **However the K factor in the slenderness ratio is 0.75 in 2015 and 1.0 prior.**
- **Consequently a decision needs to made regarding which spec is to be used for the evaluation of joists.**

Analysis Considerations (con't)

To Analyze Joist Capacity

- **A first-order analysis is used**
- **The SJI permits eccentricities to be neglected when**
  - **For K-Series, the "3/4 Rule" is followed - Spec 4.5 (c)**
  - **For all other joist series, when the eccentricity "… does not exceed the distance between the centroid and back of the chord"**

Web Eccentricity



Polling Question

What information is available on the joist tag?

a) Manufacturers Name

b) Project Number

c) Mark Number

d) All of the above

Example 1.1 Determine if a Joist Requires Reinforcement

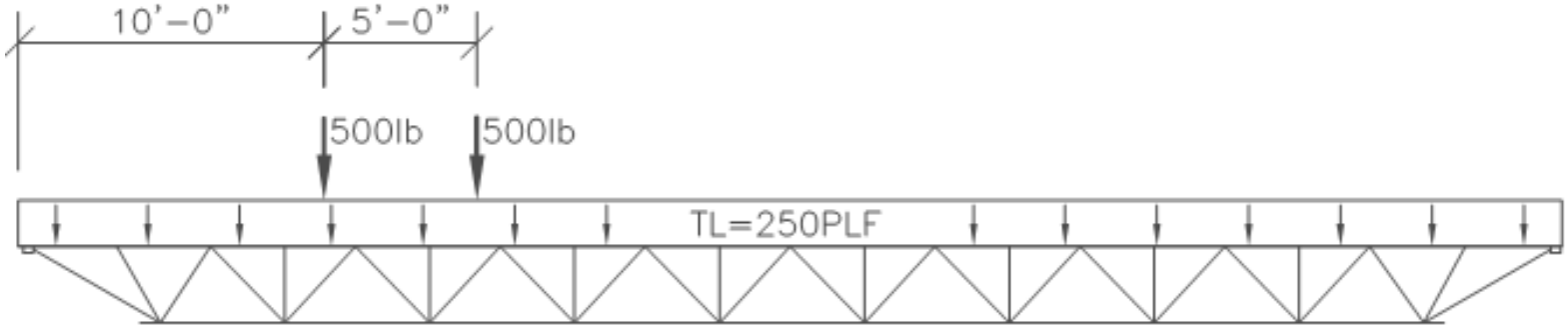
Scenario- K- series joist pre 2015 spec.

- **A roof top unit is to be added to two 24K7 joists spanning 40 feet**
- **Unit adds two, 500 lb. point loads to each joist**
  - **Located 10 ft. and 15 ft. from one end**
- **It has been determined that the uniform load on the joist is 250 PLF**

Determine if the joist must be reinforced

Load Diagram

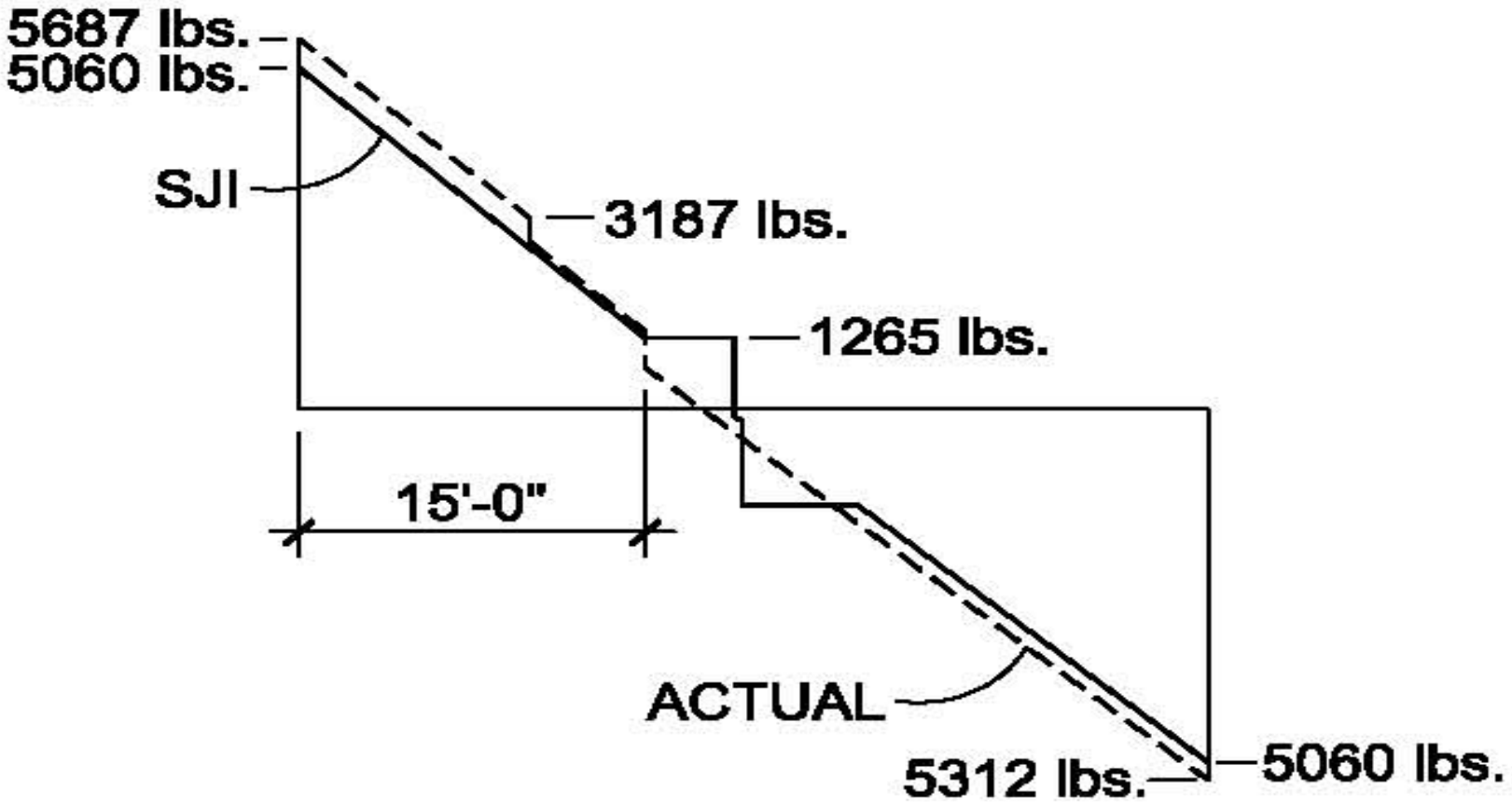
ORIGINAL DESIGN LOADS



ACTUAL LOADS

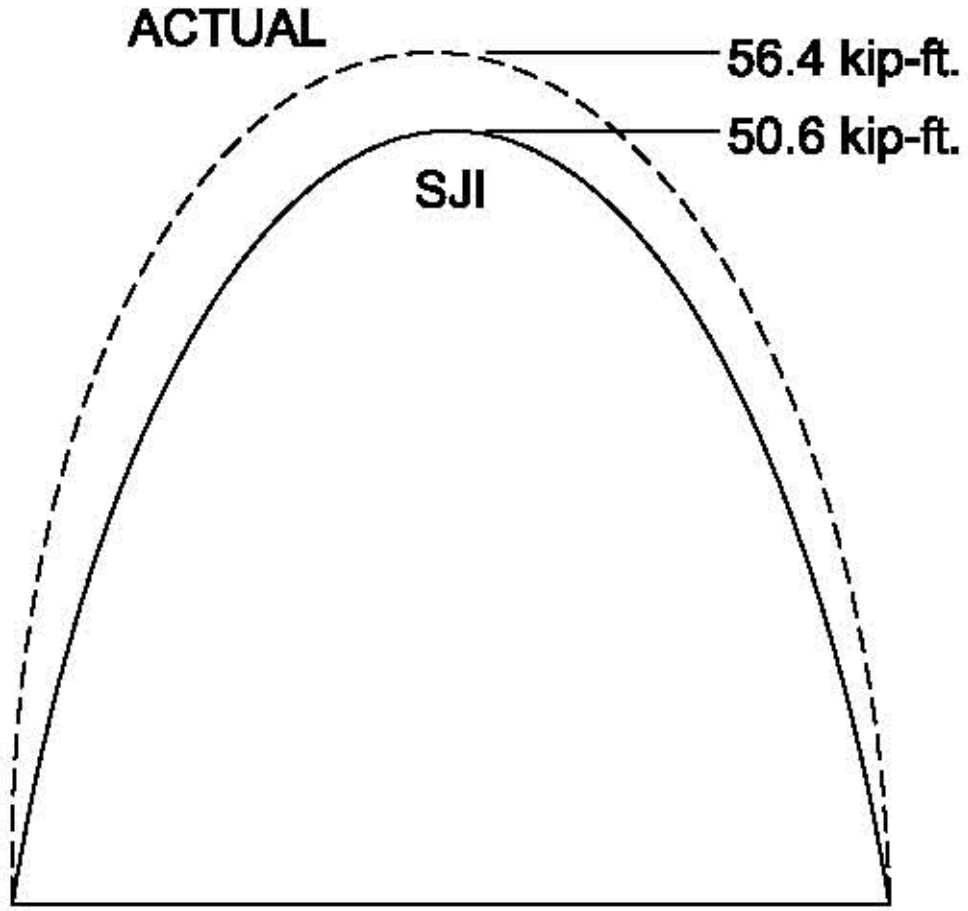
Example 1.1

Shear Envelope for 24K7 Joist

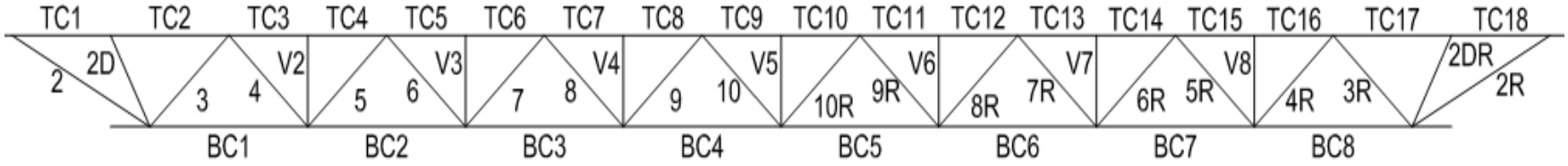


Example 1.1

Moment Diagram for 24K7 Joist



Joist Diagram



Existing Top Chord Review

Forces are compression

TC are continuous and segments 7 thru 12 have a larger axial force than the maximum in a 24K7.

TC Segment Number	24K7 Axial Design Force	Revised Loading Required Axial Force
1	9937	11319
2	9477	10861
3	16924	19704
4	16924	19704
5	22207	25863
6	22207	25863
7	25374	29194
8	25374	29194
9	26429	29548
10	26429	29548
11	25374	27841
12	25374	27841
13	22207	24038
14	22207	24038
15	16924	18132
16	16924	18132
17	9477	10075
18	9937	10532

Existing Bottom Chord Review

Forces are tension.

BC are continuous and segments 3 thru 6 have a larger axial force than the maximum in a 24K7.

BC Segment Number	24K7 Design Axial Force	Revised Loading Required Axial Force
1	13525	15606
2	19834	23322
3	24054	27948
4	26165	29600
5	26165	28955
6	24054	26202
7	19834	21352
8	13525	14426

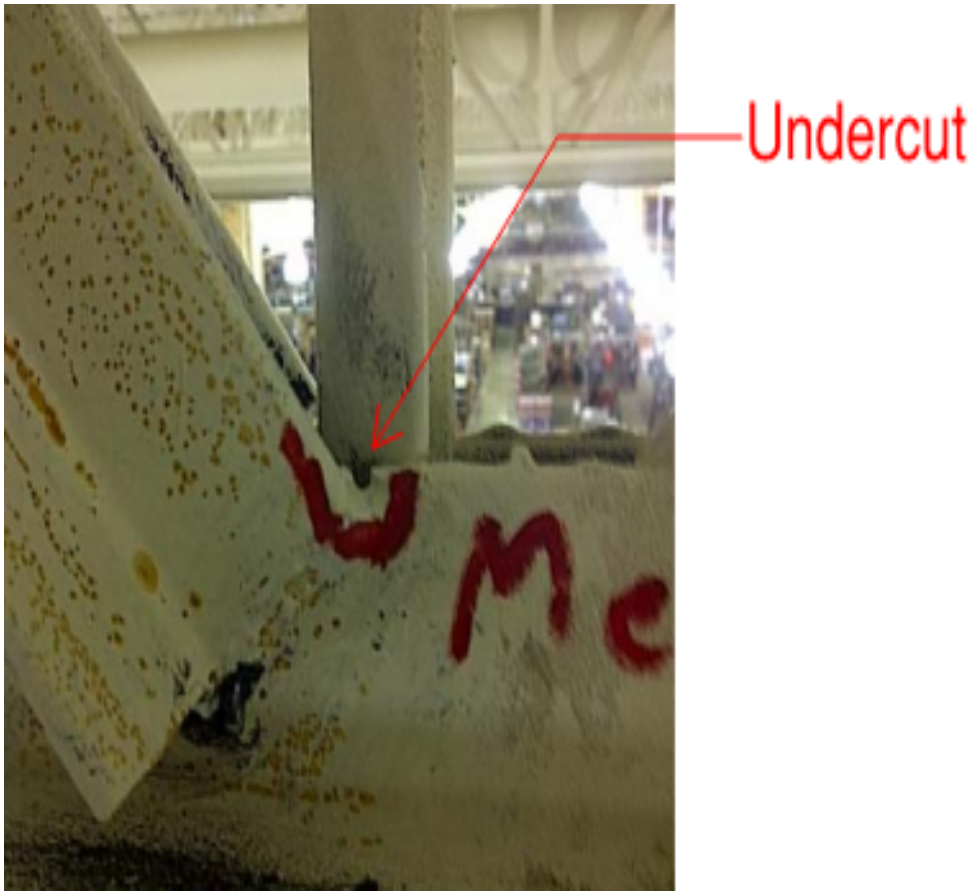
Existing Web Review

- All the webs have higher axial forces.
- Note the minimum shear used to determine the web axial force = 25% of the end reaction.
- Actual vs. Required weld lengths need to be checked.
- Design software can change the values.

Web Number	24K7 Axial Force	Revised Loading Axial Force
2	+ 11021	+ 12539
2D	- 1128	- 1133
3	- 5608	- 6555
4	+ 4709	+ 5662
V2	- 600	- 606
5	- 4033	- 4998
6	+ 3287	+ 3510
V3	- 635	- 581
7	- 2560	- 2882
8	+ 1828	+ 2061
V4	- 638	- 948
9	-1828	-2061
10	+ 1828	-2061
V5	- 635	- 665
10R	+ 1828	+ 2061
9R	-1828	-2061
V6	- 638	- 649
8R	+ 1828	+ 2265
7R	- 2560	- 2990
V7	- 635	- 645
6R	+ 3287	+ 3711
5R	- 4033	- 4450
V8	- 600	- 610
4R	+ 4709	+ 5120
3R	- 5608	- 6011
2DR	- 1128	- 1135
2R	+ 11021	+ 11668

Field Repairs

Field workmanship can weaken the joist



Field Repairs

Poor field workmanship can cause concern.

Actual Member Load Carrying Capacity

- Evaluate the actual member to see what the actual member capacity might be.
- Evaluate any conservative design assumptions to see if a more accurate condition occurs.
- Evaluate the length and placement of weld.
- Determine the risk of repair verses the in place capacity.
- Use Engineering Judgment.

Example 1.1a

Original Loads

- Assume 20 psf DL
- Assume 30 psf LL
- Assume 5’ joist spacing
- Total uniform load 250 plf

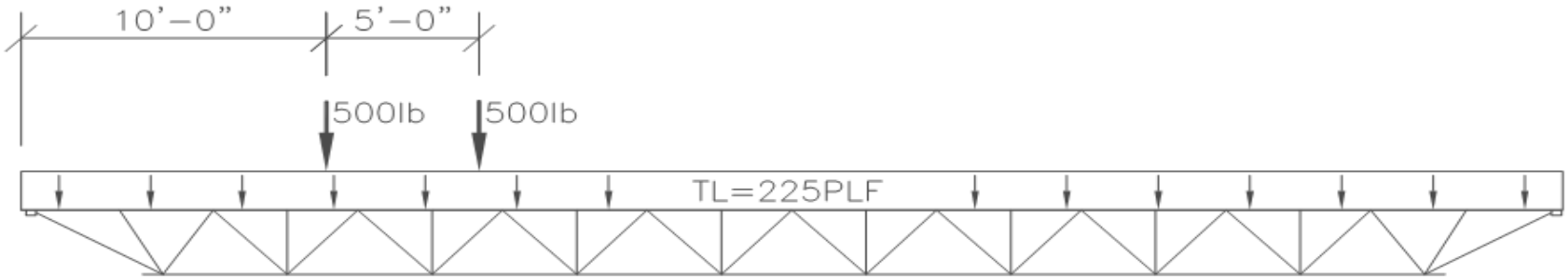
Revised Loads

- Assume 15 psf DL
- Assume 30 psf LL
- Assume 5’ joist spacing
- Total uniform load 225 plf

Example 1.1 a

Load Diagram

ORIGINAL DESIGN LOADS



ACTUAL LOADS

Example 1.1a

Top Chord Review

- **Forces are compression.**
- **Fewer segments have interaction ratios over 1.0**

TC Segment Number	24K7 Design Axial Force	Revised Loading Required Axial Force
1	9937	10327
2	9477	9916
3	16924	18015
4	16924	18015
5	22207	23646
6	22207	23646
7	25374	26661
8	25374	26661
9	26429	26911
10	26429	26911
11	25374	25309
12	25374	25309
13	22207	21822
14	22207	21822
15	16924	16443
16	16924	16443
17	9477	9129
18	9937	9541

Example 1.1a

Bottom Chord Review

- Forces are tension
- Segments 4 thru 5 have a larger axial force than the maximum in a 24K7
- About a 3% greater force

BC Segment Number	24K7 Design Axial Force	Revised Loading Required Axial Force
1	13525	14256
2	19834	21342
3	24054	25547
4	26165	26989
5	26165	26344
6	24054	23802
7	19834	19373
8	13525	13076

Example 1.1a

Web Review

- **Many webs still have higher axial forces.**
- **The minimum web shear to calculate the web force = 25% of the end reaction.**
- **Actual capacities need to be reviewed verses required forces.**
- **Actual vs. Required weld length need to be verified.**

+ tension
- compression

Web Number	24K7 Design Axial Force	Revised Loading Required Axial Force
2	+ 11021	+ 11441
2D	- 1128	-1021
3	- 5608	-5998
4	+ 4709	+ 5194
V2	- 600	-546
5	- 4033	-4598
6	+ 3287	+ 3184
V3	- 635	-518
7	- 2560	-2627
8	+ 1828	+1879
V4	- 638	-885
9	-1828	-1879
10	+ 1828	-1879
V5	- 635	-602
10R	+ 1828	+ 1879
9R	-1828	-1879
V6	- 638	-586
8R	+ 1828	+ 2083
7R	- 2560	-2736
V7	- 635	-582
6R	+ 3287	+ 3384
5R	- 4033	-4049
V8	- 600	-551
4R	+ 4709	+ 4652
3R	- 5608	-5454
2DR	- 1128	-1021
2R	+ 11021	+ 10570

Example 1.1b

- An alternate approach would be to check the manufactured joist using the actual design dead and live loads in place of the load capacity from the SJI tables.
- From a review of the structural drawings the joist spacing is found to be 6 feet o.c. and the roof slope is ½:12.
- A check of the roof materials found that the actual roof dead load, including an allowance for the joist weight, is 15 psf.

Example 1.1b

The roof live load can then be calculated based on IBC Equation 16-26

$$L_r = L_o R_1 R_2$$

where: $L_o = 20$ psf

$R_1 = 1.2 - 0.001A_t$ and $A_t = 6 \times 40 = 240$ sq. ft.

$= 1.2 - 0.001(240) = 0.96$

$R_2 = 1$ (for roof slope < 1:12)

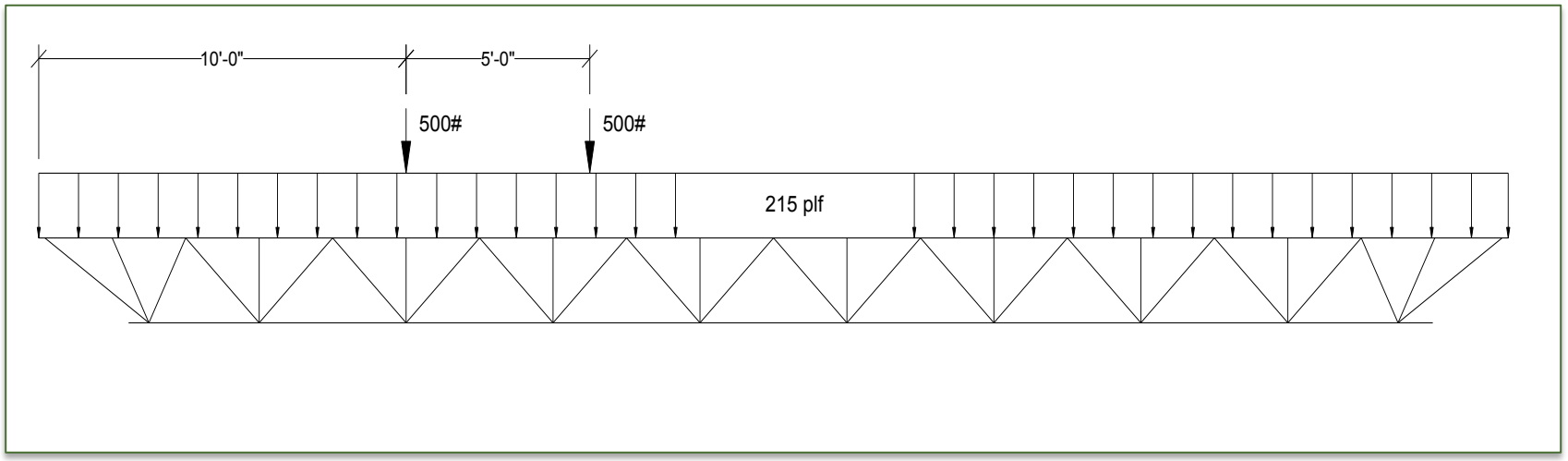
then: $L_o = 20(0.96)(1) = 19.2$ psf

and the joist $LL = 19.2(6) = 115.2$ plf

$DL = 15(6) = 90$ plf

Example 1.1b

The manufactured joist can now be checked using the actual design loads DL = 90 plf & LL = 115 plf along with the two additional 500# loads.



Example 1.1b

Top Chord Review

- **Forces are in Compression.**
- **Comparison of Top Chord axial forces for 24K7 joist and for same joist with revised loads.**
- **The top chord panels are acceptable.**

TC Segment Number	24K7 Design Axial Force	Revised Load Required Axial Force
1	9937	9440
2	9477	9116
3	16924	16719
4	16924	16719
5	22207	21962
6	22207	21962
7	25374	25078
8	25374	25078
9	26429	24859
10	26429	24859
11	25374	23344
12	25374	23344
13	22207	20101
14	22207	20101
15	16924	15129
16	16924	15129
17	9477	8321
18	9937	8645

Example 1.1b

Bottom Chord Review

- **Forces are in tension.**
- **Comparison of Bottom Chord axial forces for 24K7 joist and for same joist with revised loads.**
- **All Bottom Chord panels are acceptable.**

BC Segment Number	24K7 Design Axial Force	Revised Loads Plus Conc. Loads Required Axial Force
1	13525	13188
2	19834	19819
3	24054	23673
4	26165	24969
5	26165	24318
6	24054	21938
7	19834	17831
8	13525	11995

Example 1.1b

Web Review

- **Webs 3, 4, 8, & 8R have higher axial force. Web 10 has force/stress reversal.**
- **Note the minimum shear for calculating web axial force = 25% of the end reaction.**
- **Design software can change the values.**

Web Number	24K7 Axial Force	Actual Loads Axial Force
2	+ 11021	+ 10458
2D	- 1128	-745
3	- 5608	-5626
4	+ 4709	+4880
V2	- 600	-496
5	- 4033	-4283
6	+ 3287	+2961
V3	- 635	-522
7	- 2560	-2364
8	+ 1828	+1941
V4	- 638	-449
9	-1828	-1674
10	+ 1828	-1674
V5	- 635	-536
10R	+ 1828	+1674
9R	-1828	-1674
V6	- 638	-529
8R	+ 1828	+1942
7R	- 2560	-2539
V7	- 635	-513
6R	+ 3287	+3136
5R	- 4033	-3733
V8	- 600	-488
4R	+ 4709	+4330
3R	- 5608	-5077
2DR	- 1128	-741
2R	+ 11021	+9577

Chapter 2
Methods of Supporting Additional Load

Options Before Strengthening

- Capacity of joist needs to be determined
  - Can joist safely support new loads?
  - What are the actual loads?
  - What are the actual load cases?
  - Are stress ratios over 1.0 permitted?

Chapter 2
Methods of Supporting Additional Load

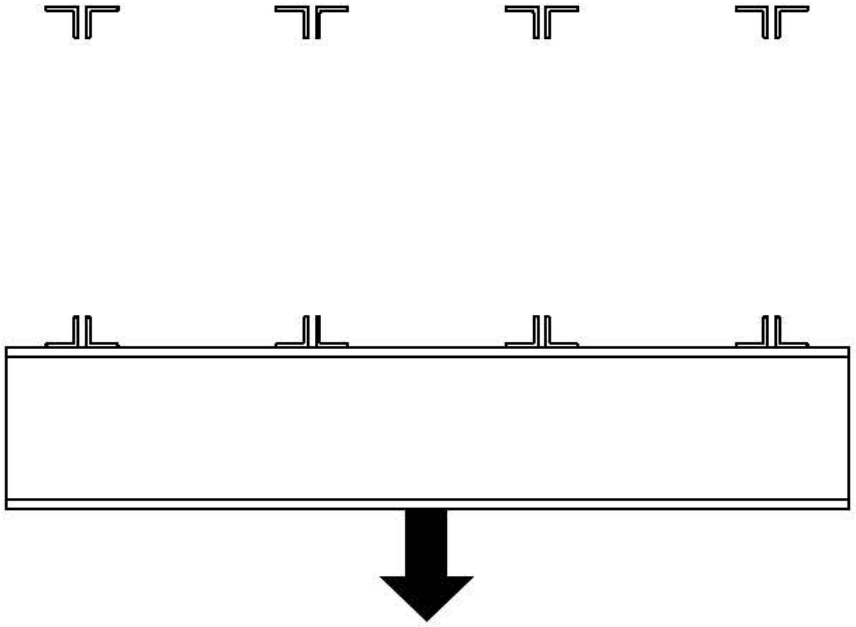
Options Before Strengthening

- Extensive reinforcement may not be practical
  - Option #1 - Load distribution
  - Option #2 - Add new joists or beams
  - Reinforce existing joists

Load Distribution

Member with Suitable Stiffness Required

- **Place member under or through the joists**
- **Concentrated load distributed to several joists**



Load Distribution

Relative Stiffness is Defined by Beta

$$\beta = \sqrt[4]{\frac{(K/S)}{(4EI)}} \qquad \text{Eq. 2-1}$$

Where,

K = stiffness of the joist, kips/in.
S = spacing of the joists, in.
E = modulus of elasticity for the beam, ksi
I = moment of inertia of the beam, in.4
β = characteristic parameter, 1/in.

Load Distribution

$$\beta = \sqrt[4]{\frac{(K/S)}{(4EI)}}$$

If S is less than π/4β

- **The spacing limit is not exceeded**
- **S = spacing of the joists, in.**

If the length of the beam is less than 1/β

- **The beam may be considered rigid**
- **Joist reactions may be determined by static equilibrium.**

Example 2.1 Underhung Monorail Beam Using Load Distribution

This example will illustrate:

- **How load distribution can eliminate the need for strengthening**
- **How to minimize the amount of strengthening by reducing the load to each joist**
- **How to design the distribution beam placed beneath the joist bottom chord**

Example 2.1 Underhung Monorail Beam Using Load Distribution

Given Conditions:

- **Hang new underhung monorail beam from the bottom chord of several joists**
- **Joists are 30K12 spanning 36’-0”**
- **Joists are spaced 2’-6” o.c.**
- **Monorail adds a 1200 lb. concentrated load**
  - **Concentrated load located 10’-0” from joist end**

Example 2.1 Underhung Monorail Beam Using Load Distribution

Determine the stiffness of the joists:

Determine approx. moment of inertia from

$$I_j = 26.767(W_{LL})(L^3)(10^{-6})$$

Eq. 2-2

where,

WLL = nominal live load that will produce an approximate deflection of Span/360
(RED figure in the Load Table)

L = (Span – 0.33), ft.

Example 2.1 Underhung Monorail Beam Using Load Distribution

Determine the stiffness of the joists:

Determine approx. moment of inertia from

$$I_j = 26.767\left(W_{LL}\right)\left(L^3\right)\left(10^{-6}\right)$$ **Eq. 2-2**

From the Load Table, the live load deflection for a 30K12 joist with a 36’ -0” span is:

WLL = 392 plf

I_j =26.767(392)(35.65^3)(10^{-6})=476 in4

Example 2.1 Underhung Monorail Beam Using Load Distribution

Divide Ij by 1.15 to account for shear deflection:

$$I_{j,eff} = \frac{476}{1.15} = 414 in.^4$$

$$K = \frac{P}{\Delta}$$

From AISC Manual of Steel Construction, Table 3-23 for a simple beam- concentrated load at any point:

$$\Delta = \frac{Pa^2b^2}{3EIL}$$

$$K = \frac{P}{\Delta} = \frac{P}{\frac{Pa^2b^2}{3EI_{j,eff}L}} = \frac{3EI_{j,eff}L}{a^2b^2}$$

$$K = \frac{3(29000)(414)(35.67)(12)}{[(26)(12)]^2[(10)(12)]^2} = 11.0\ k/in.$$

Example 2.1 Underhung Monorail Beam Using Load Distribution

Determine the beam size necessary to distribute the load to three (3) joists:

Try W16 x 26 Ix = 301 in.4

$$\beta = \sqrt[4]{\frac{(K/S)}{(4EI)}} = \sqrt[4]{\frac{11.0/30}{(4)(29000)(301)}} = 0.0101\ in.^{-1}$$

Check if spacing,

$$S < \frac{\pi}{4\beta} = 77.6\ in.$$

S = 30 in. < 77.6 in. Therefore, OK

Example 2.1 Underhung Monorail Beam Using Load Distribution

Determine the beam size necessary to distribute the load to three joists:

For W16 x 26 $\beta = 0.0101$ in.-1

Check the length of monorail support beam

Beam Length L= 5.0 ft. = 60 in.

$$L < \frac{1}{\beta} in.$$

1/β = 1/0.0101 = 98.8 in.

60 in. < 98.8 in. Therefore, OK

Example 2.1 Underhung Monorail Beam Using Load Distribution

Solve for the reaction at each joist:

Since the beam can be considered rigid,

1200 lbs. can be uniformly distributed to each joist support

1200 lbs. / 3 = 400 lbs. additional load

Note: Don't forget to include the beam self-weight. It might not be insignificant.

Reinforcing / Replacing / Adding

Considerations:

- **Cost**
- **Time - Eng'g and Labor for Field Reinf.**
  Manuf'g and Installing a New Joist,
- **Difficulty of repair - Interferences, Access**
- **Effectiveness of Reinforcing -**
- **Skill of workman**

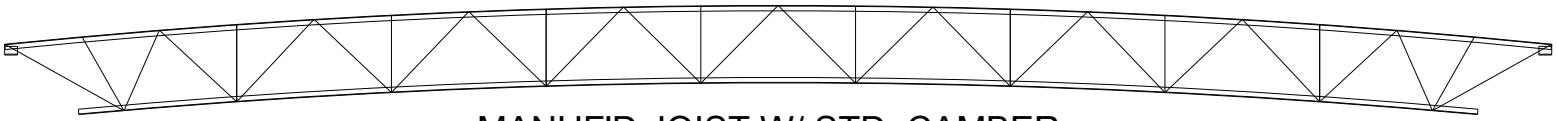
Reinforcing / Replacing / Adding

Considerations:

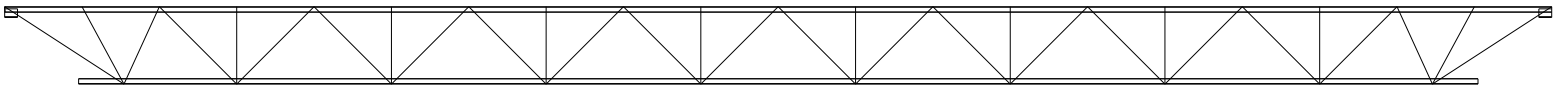
- **Existing interferences**
  - **Piping, electrical conduits, other interferences**
  - **Removing or relocating could be at a greater expense than reinforcement**
- **Camber**
  - **May need to reduce camber in new joists**
  - **Joists can be ordered with shallower seat depths and then shimmed in the field**
  - **The joist can be supplied with a splice so two individual pieces can be installed and bolted at the center**
- **Lateral Stability of the joist top chord**
  - **Shoot pins through the chord, decking, and slab**
  - **Rely on bridging to provide lateral support**

Reinforcing / Replacement / Adding

Camber – Joists manufacturers rigging tables are set up for SJI standard camber. If replacing or adding a joist, specify zero or no camber.



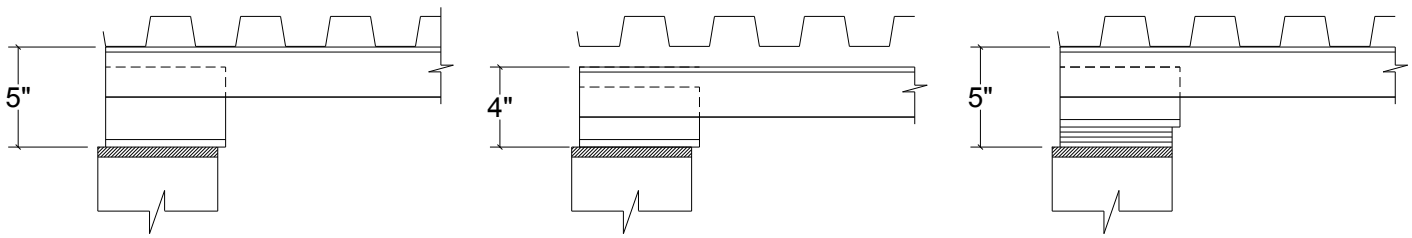
MANUF'D JOIST W/ STD. CAMBER
PRIOR TO INSTALLATION



JOIST AFTER INSTALLATION
WITH DEAD LOADS APPLIED

Reinforcing / Replacing / Adding

Bearing Seat Depth – Specify a shallower seat depth and then shim to raise top chord to deck.



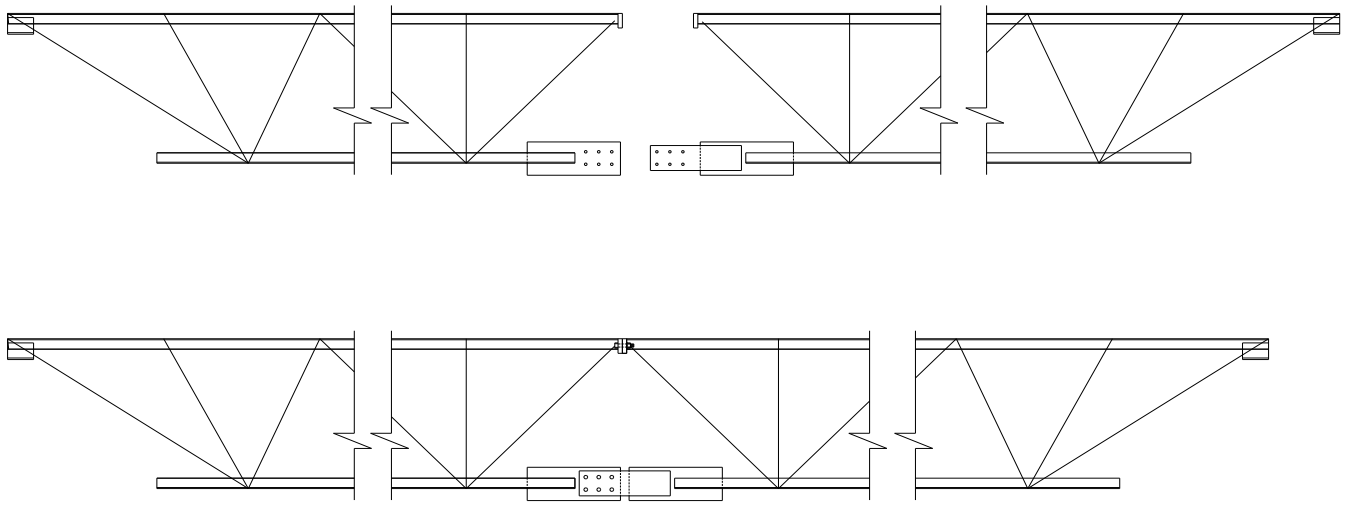
INSTALLED BEARING SEAT FOR EXISTING JOIST

NEW JOIST W/ SHALLOWER BEARING SEAT PRIOR

NEW JOIST W/ SHALLOWER BEARING SEAT AND SHIMMS

Reinforcing / Replacing / Adding

SPLICE – Using a joist w/ a field bolted splice allows each half of the joist set in place and then mated together.



JOIST w/ BOLTED SPLICE

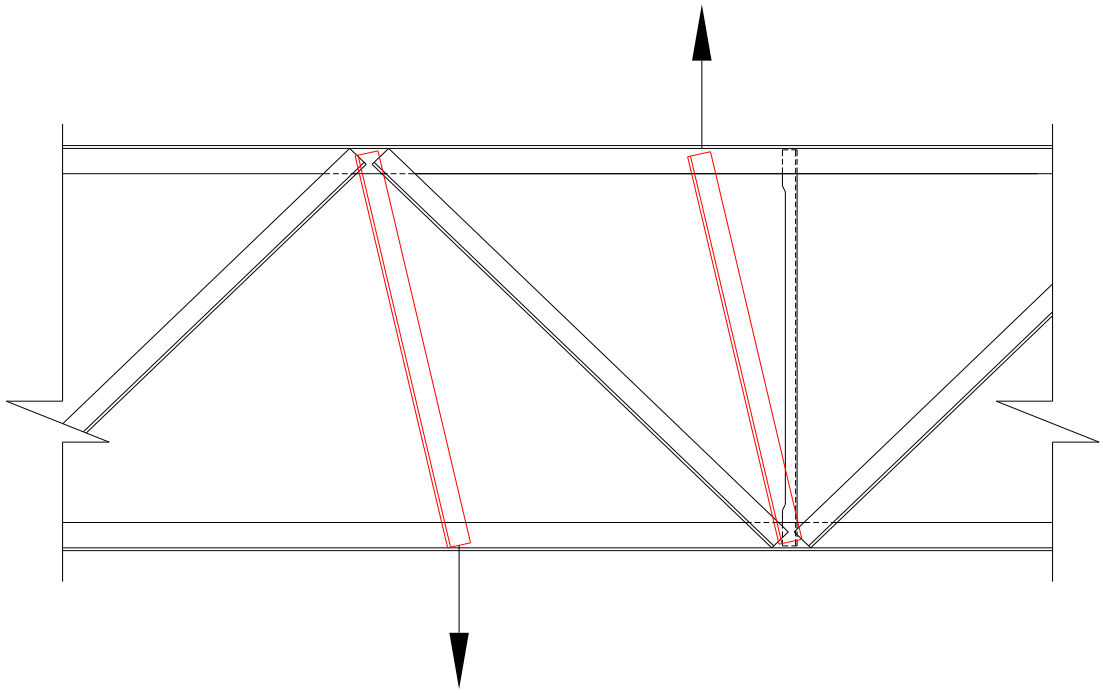
Reinforcing Existing Joists

The following will impact reinforcement of both chord and web members:

- **Rod web joists**
  - **New reinforcing webs can be easily added on the outside of the chords.**
  - **Chords are typically thin angles.**
- **Crimped angle web joists**
  - **New reinforcing webs can be easily added on the outside of the chords.**
  - **If chords and webs need to be reinforced there could be interferences which affect how the reinforcement is done.**

Reinforcing Existing Joists

For larger LH-Series and Joist Girders - Double angle diagonal webs may intersect at a bottom chord panel point there will not be room to add and weld a reinforcing web at that panel point to pick up a load. The chord will have to be checked for local bending.



Reinforcing Existing Joists

The following will impact reinforcement of both chord and web members:

- **Chord and web yield strength**
  - **Recent manufacturing (15 – 20 years) has used 50 ksi steel for chord and webs.**
  - **Older joists may have been manufactured using 36 ksi steel and test coupons may be required to determine the Yield Strength of the joist members.**

Reinforcing Existing Joists

Other considerations:

- **Additional weld may be required even though web member size is sufficient for new loads**
- **Accessibility to reinforce either chord or webs**
  - **May only be able to reach one side of the joist**
- **Eccentricities**

Evaluation and Modification of Open-Web Steel Joists and Joist Girders

Part 2 - Modification

This webinar will provide more information on the field modification of open web joists.

Date: November 21, 2018
Time: 11:00 am EDT
Register: www.steeljoist.org

Earn your PDHs

Polling Question

Which has the bigger effect on the cost of an on site field repair?

a) Material

b) Labor

THANK YOU