Guidance for Building Design Using Steel Joist

AUGUST 21, 2024

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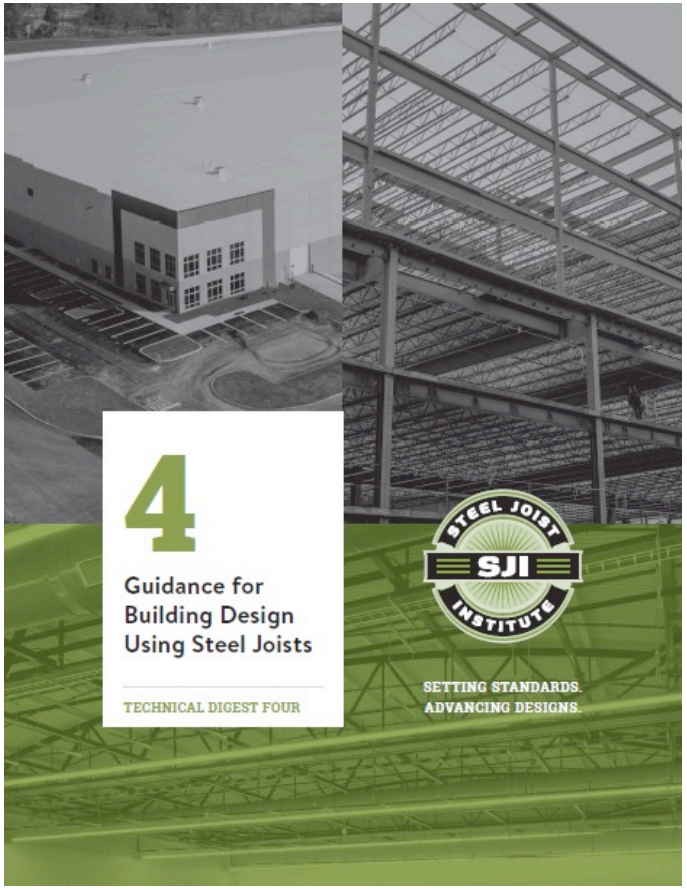
Description

This webinar will provide guidance to specifying professionals and joist manufacturers using open web steel joists and joist girders. Design considerations for both wind and seismic loads are discussed.

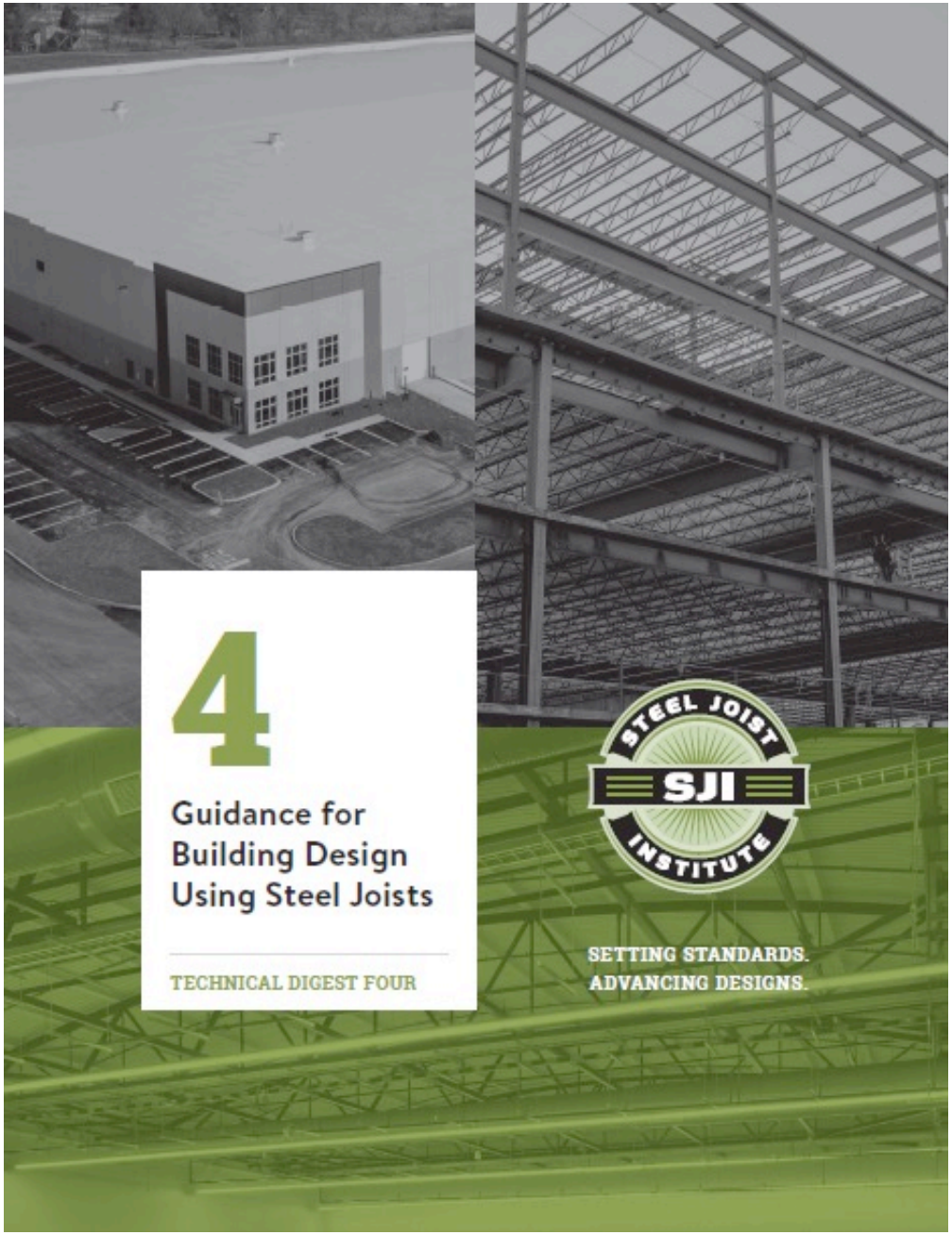
The webinar addresses the use of steel diaphragms, frames, and bracing systems and commonly used details.

SJI Technical Digest 4 is the reference for this webinar.



Learning Objectives

- **To learn about selecting optimum bay dimensions, direction of joist vs. direction of joist girders, joist spacing.**
- **To learn about the use of open web products for lateral load systems.**
- **To learn about commonly used joist and joist girder connections.**
- **To learn about design tips for effective design, and the use of SJI Tools for design assistance.**



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TD 4 Table of Contents

Systems and Selection - General Comments

The choice of the most economical structural system is dependent on several parameters. These include:

1. The building end use.
2. The building geometry.
3. Expansion joint requirements.
4. The type of roofing or framing system.
5. Future expansion requirements.

Systems and Selection - General Comments

Framing systems can be mixed to provide the optimum structure. For example, moment frames in one direction and braced frames in the perpendicular direction.

The optimum framing system generally consists of braced frames in both directions with the use of diaphragms to transfer wind and seismic loads to the vertical bracing elements. This framing system should always be evaluated by the Engineer of Record (EOR) as a first option.

Systems and Selection - General Comments

Only if, the building footprint or other lateral bracing restrictions prevents the use of vertical bracing should moment frames be considered.

As a “rule of thumb,” when the length to width ratio of the building exceeds 4 to 1, roof diaphragm forces become large, so that the use of roof diaphragms to transfer lateral loads to perimeter bracing may not be practicable. In addition, the forces in struts, vertical bracing, and foundation uplift forces may become excessively large.

Systems and Selection - General Comments

For **seismic design** ordinary moment frames have been limited to single story buildings based on current requirements for seismic design; in particular, the use of strong beam weak column systems which are typically necessary when using joist girders in lieu of WF girders.

The flexural strength and stiffness of joist girders is usually significantly larger than the most reasonable column sections. More importantly, joist girders exhibit poor hysteresis behavior under inelastic cyclic loading.

Preliminary Design

Preliminary design is the most important aspect of designing a structural system. Starting with the wrong concept will lead to problems.

Preliminary Design

1. Select the serviceability criteria for the horizontal framing.
2. Select the lateral drift criteria.
3. Determine the fire protection criteria.
4. Determine any loss prevention requirements such as FM Global requirements.
5. Select the direction of roof drainage.
6. Select the structural system, i.e., braced frames, moment frames, or shear walls.
7. Determine the loads on the structure.
8. Determine the type of connections to use.

Bay Dimensions

The designer may or may not have the opportunity to select the bay size for a proposed project. Owner requirements and functional requirements often dictate a certain bay size.

- Area, bay size, plant layout, future expansion.
- Clear heights.
- Relations between functional areas, production flow, acoustical considerations.
- Exterior appearance.
- Materials and finishes.
- Machinery, equipment, storage requirements, and loadings.

Bay Dimensions

- The building footprint which is often dictated by the building site, has an impact upon the bay size selected.
- Bay sizes ranging from 30’ x 30' to 60' x 60' have proven to be economical.
- Square bays have been shown to provide greater economy than rectangular bays.
- Gravity loads have the greatest impact on the optimum bay size. Lighter roof loads allow larger bays without cost penalty.

Bay Dimensions

When the structure has a high ratio of perimeter length to enclosed area, e.g., a long narrow building, then a 30’ x 40' or a 30’ x 50' bay where the 30' dimension is parallel to the long building dimension often prove to be the most economical.

Bay Dimensions

For structures with a low ratio of perimeter length to area, e.g., square buildings of significant size, the percentage of steel that would be contained in the wall framing is less of a cost factor, and thus a 40’ x 40' bay often proves to be the most economical system. Larger bays of 40’ x 50', 50’ x 50' or 40’ x 60' are also economical.

Bay Dimensions

Soil conditions have only a minor impact on the selection of the bay size when shallow foundations can be used. However, if poor soils exist and deep foundations are required, larger bays will tend to be more economical because of the reduced number of deep foundations. This assumes, of course, that the floor slab can be placed on grade and there does not have to be a structural floor system.

Direction of Joist Span

- Generally, it is best to span the joist in the long direction when a rectangular bay has been selected.
- Examine alternate framing schemes for a given project using the “SJI Roof Bay Tool”.

Joist Spacing

Joist spacing should be maximized. The fewer number of pieces which need to be erected will reduce the cost of the erected steel.

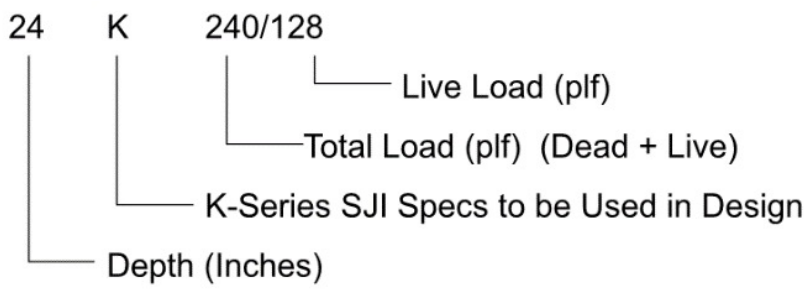
Longer joists should be spaced further apart since each one requires significant shop labor.

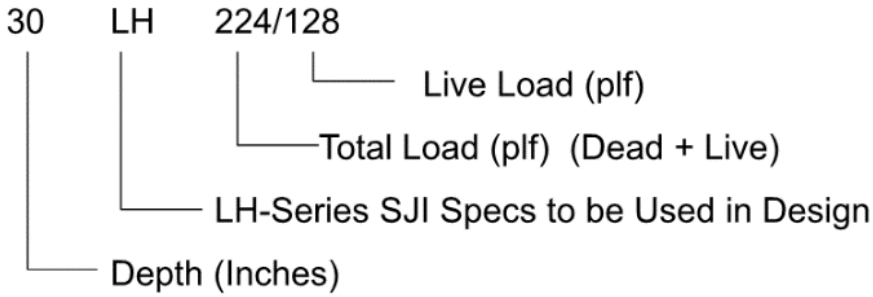
Joists should be spaced to maximum value of the deck, but with spaces no greater than those recommended for construction practice as contained in the SDI Steel Deck Institute Specification (SDI, 2022).

Load/Load Joists

Uniform load-per-foot designated joists (load/load joists) are an alternative to the standard SJI K, LH, and DLH-Series joists. They are used when the specifying professional wants to optimize the joist cost.

Using the load/load designation provides the breakdown of loading for the required building code load combinations. The designation takes the following form:





Load/Load Joists

- Additional joist depths can be specified when the load/load designation is used:
  - The additional depth options can be beneficial on projects where the specifying professional wants to maximize the joist depth based on the project limitations.
  - If a fractional depth is desired, contact a joist manufacturer for limitations.
  - When a load/load designation is used, the specifying professional must provide the deflection criteria on the construction documents.

Joist and Joist Girder Depth

The optimum joist girder depth (in inches) is approximately equal to the span of the girder in feet. The specifying professional should generally follow this rule of thumb. However, for expensive wall systems, such tilt up and precast systems, a one-foot savings in height of structure may prove more economical as compared to the extra cost of shallower joists and joist girders.

Polling Question 1

For a rectangular bay what is the generally the best direction to span the joists?

A. The long direction

B. The short direction

Column Selection

- Interior columns can normally be braced only at the top and bottom, thus square HSS columns are desirable due to their equal stiffness about both principal axes.
- My experience is that when the building height is greater than 28 feet HSS columns are less expensive than W shapes.
- W shapes may be more economical than HSS for exterior columns because the wall system (girts) may be used to brace the weak axis.

Framing Systems

The selection of “the best” framing scheme for a single-story building is dependent on numerous considerations, and often depends on the owner’s requirements. It may not be possible to give a list of rules by which the best such scheme can be assured.

Consideration must include:

- Cost of foundations
- Cost of the wall system
- The lateral load system

Framing Systems

For single story structures the optimum framing system generally consists of braced frames or shear walls using a roof diaphragm to transfer lateral loads to the vertical bracing elements. Consider this system first.

However, consider:

- The vertical bracing and foundation uplift forces can become large.
- Interior bracing may interfere with plant operations.
- Wall bracing and shear walls interfere with future expansion.

As a “rule of thumb,” when the length to width ratio of the building exceeds 4 to 1, roof diaphragm forces become large so that the use of roof diaphragms to transfer lateral loads to perimeter bracing may not be practicable.

Framing Systems

- Braced Frames
- Ordinary Moment Frames (OMF)
- Ordinary Moment Frames (OMF) in Seismic Areas
- Shear Walls

Braced Frames

Bracing Configurations

- Chevron
- Inverted Chevron
- Eccentric Bracing
- Single X-bracing
- K braces

Joists and joist girders can be used as the horizontal member, except in eccentric braced frames.

Overhead doors and exits must be avoided.

Ordinary Moment Frames (OMF)

When moment frames are required in only one direction, the framing scheme should be such that the joist girders are part of the moment frames.

If moment frames are required in both directions, the framing scheme that creates the smallest end moments in the joists should be examined first.

Ordinary Moment Frames (OMF) in Seismic Areas

- When designing per the AISC Seismic Provisions, the joist/joist girder moment frame structures are categorized as an Ordinary Moment Frame (OMF) with design and detailing requirements specific to an OMF outlined in Section E.1.
- The predominant requirement for an OMF frame is that the beam to column moment connection be designed for a moment equal to $1.1R_yF_yZ/\alpha_s$ of the beam, or the maximum moment that can be developed by the system (see AISC Seismic Provisions, Section E.16b.(b).

Shear Walls

Shear walls are frequently used rather than braced frames. Common situations are tilt-up, precast, or masonry surrounding the exterior or interior of the building.

The design of shear walls is not treated in TD 4.

Roof Diaphragms

- Diaphragm Chords
- Shear transfer Details
- Collectors (Drag Struts)
- Expansion Joints

Roof Diaphragms

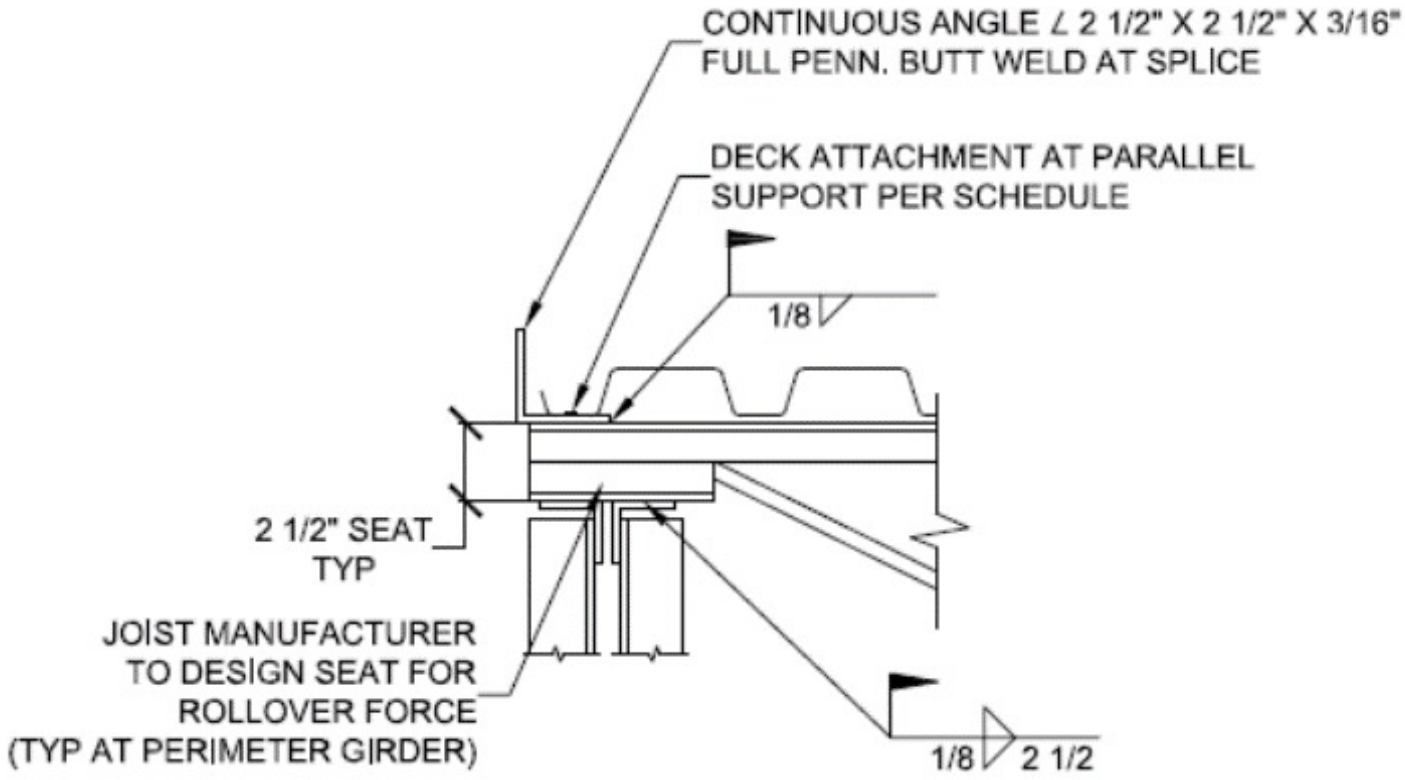
- Refer to the Steel Deck Institute (SDI) “Diaphragm Design Manual” (DDM04), Fourth Edition, Steel Deck Institute, (SDI, 2019) for guidance on the design of diaphragms.
- Loads are transferred into and out of the roof diaphragms to other structural elements.
- Typically, the shears in the diaphragm are transferred to a “collector” member, which “drags” the force to a horizontal beam or joist.
- For braced frames, the force is then transferred to the vertical bracing where it is transferred to the foundation system.

Diaphragm Chords

- Joists and joist girders often act as chord members for diaphragms.
- The chord axial forces vary along the joist, or joist girder line according to the location along the length of the chord.
- They may act as a chord in one orthogonal direction and act as a continuous tie or collector in the other orthogonal direction.
- **The joist manufacturer has limited insight into the overall building design, thus clarity in presenting the loads and axial transfer details is essential.**

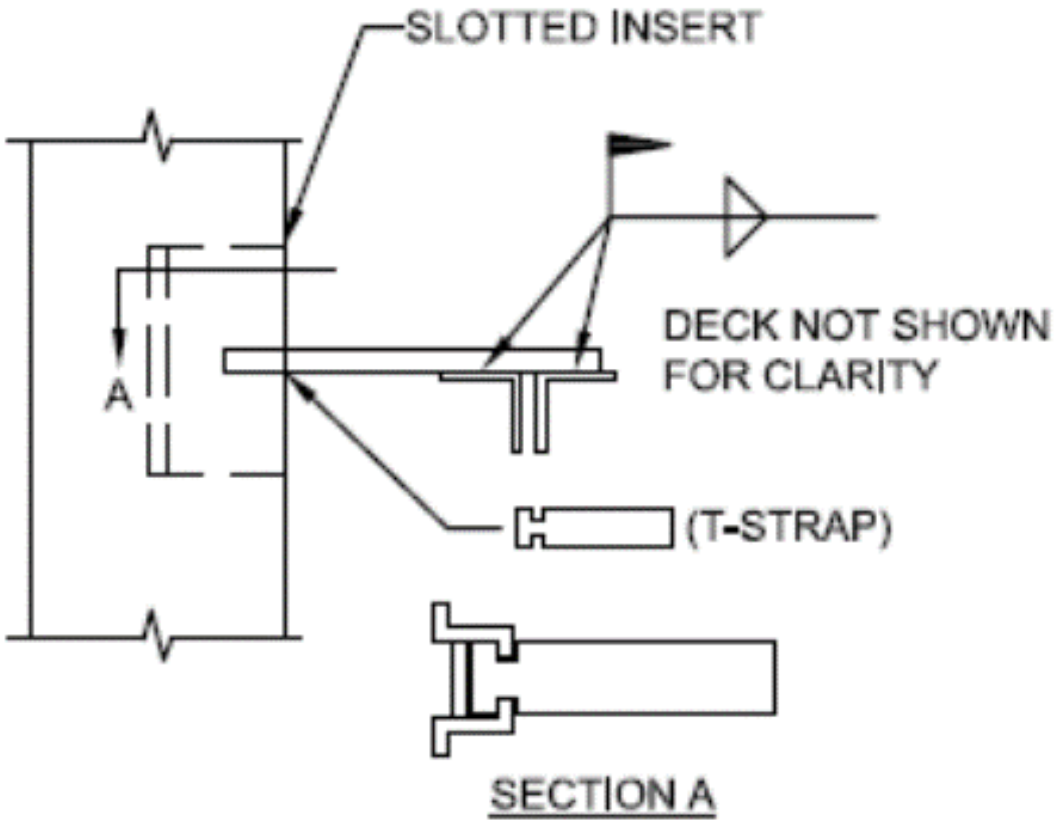
Diaphragm Shear Transfer Details

Transfer of Diaphragm Shear to Edge Angle



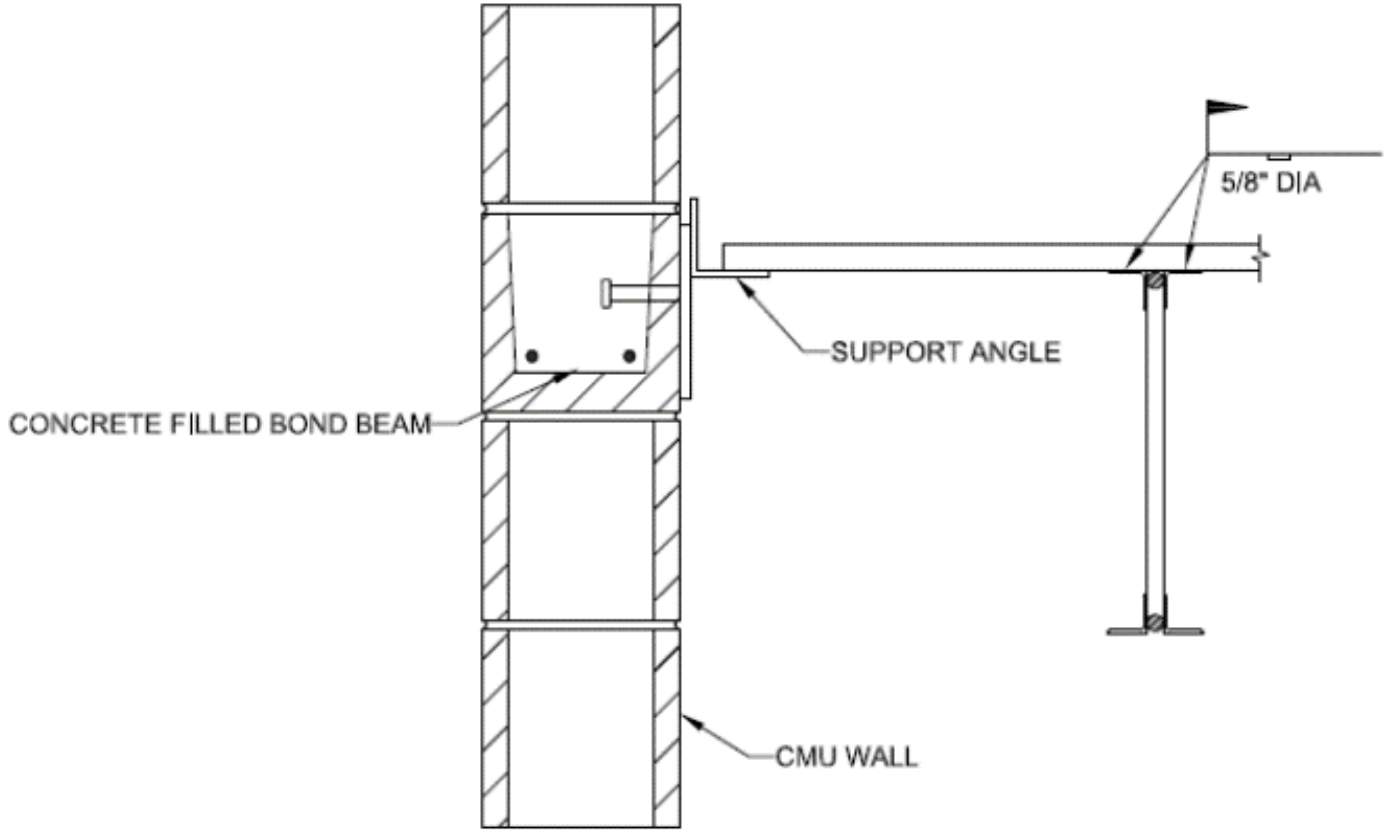
Diaphragm Shear Transfer Details

Diaphragm Shear Transfer to Precast (T-Strap)



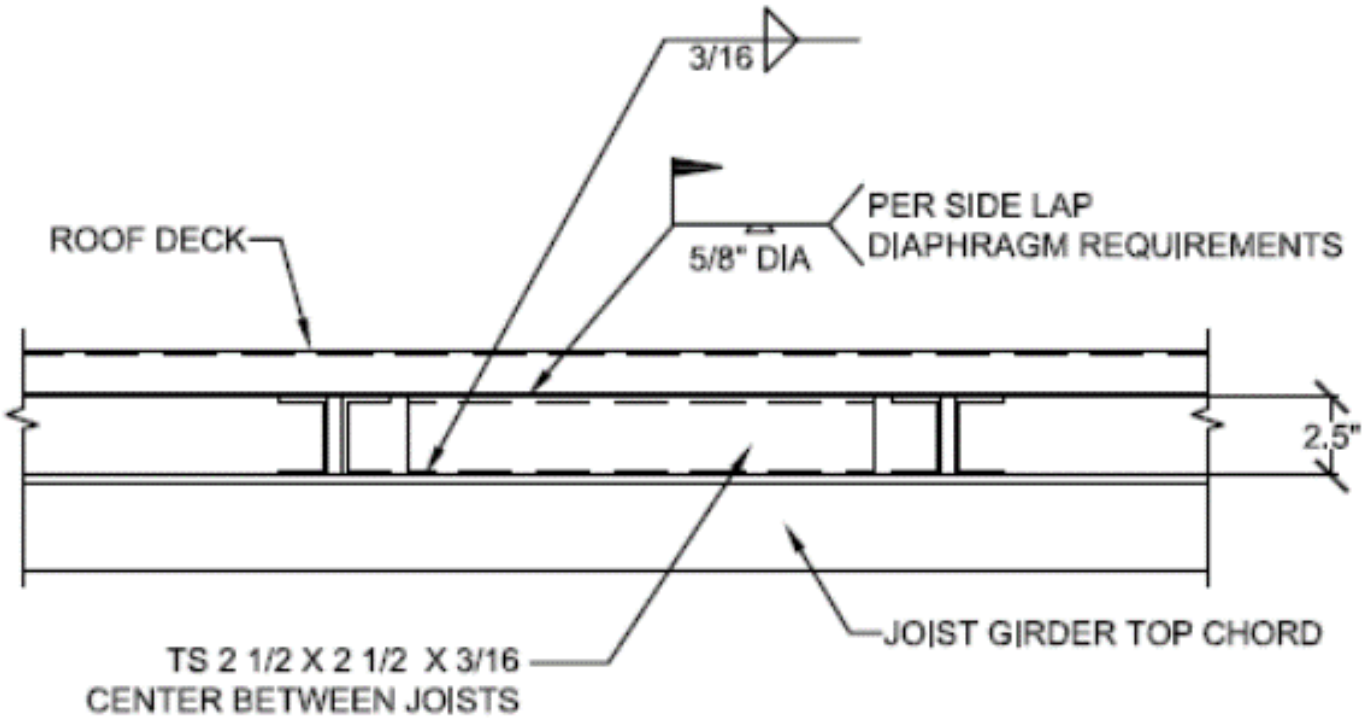
Diaphragm Shear Transfer Details

Diaphragm Shear Transfer to Masonry



Collectors (Drag Struts)

Shear Transfer Member with K Joist



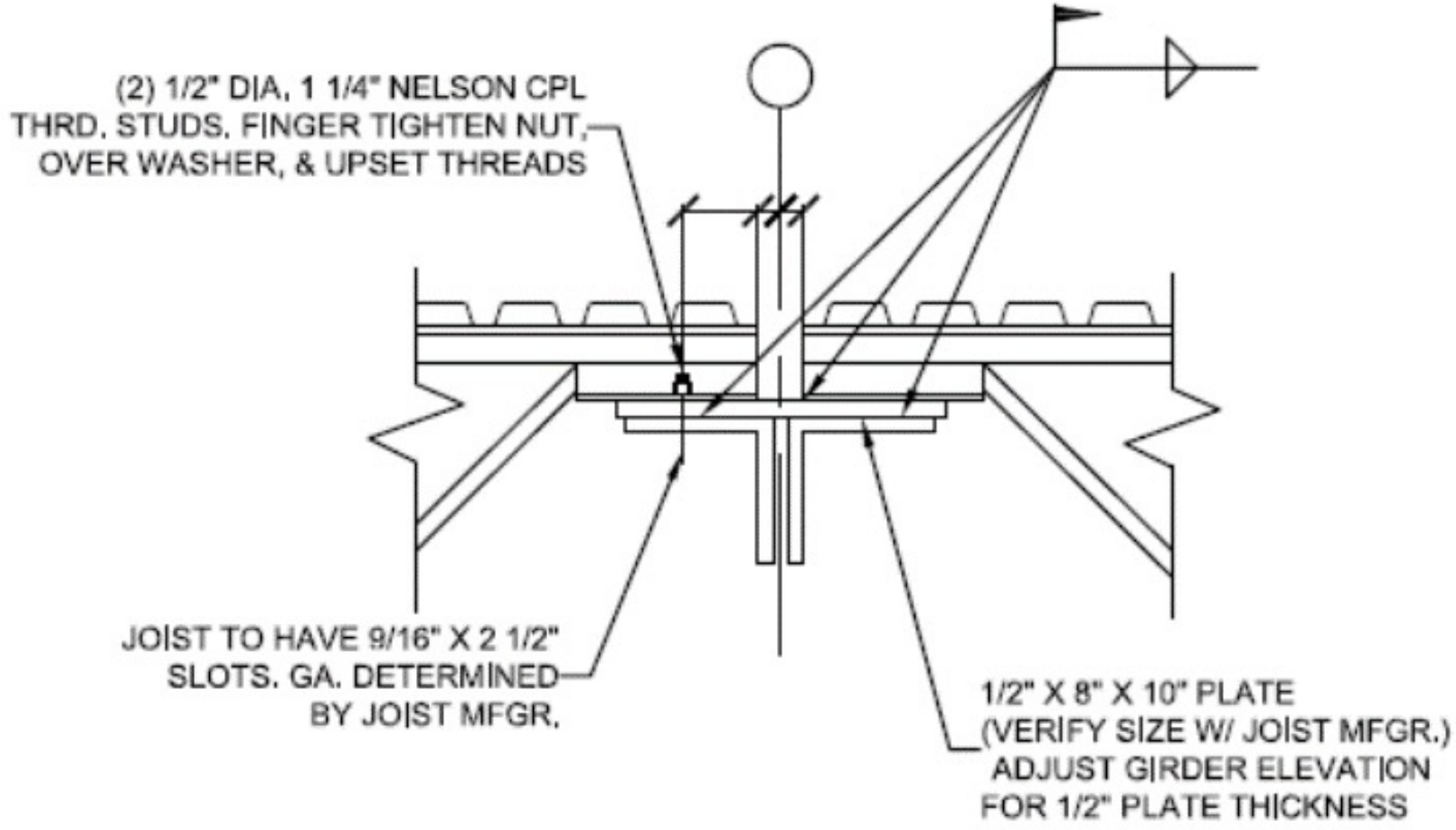
Force Transfer to Vertical Bracing

Expansion Joints

Several situations arise with respect to expansion joints.

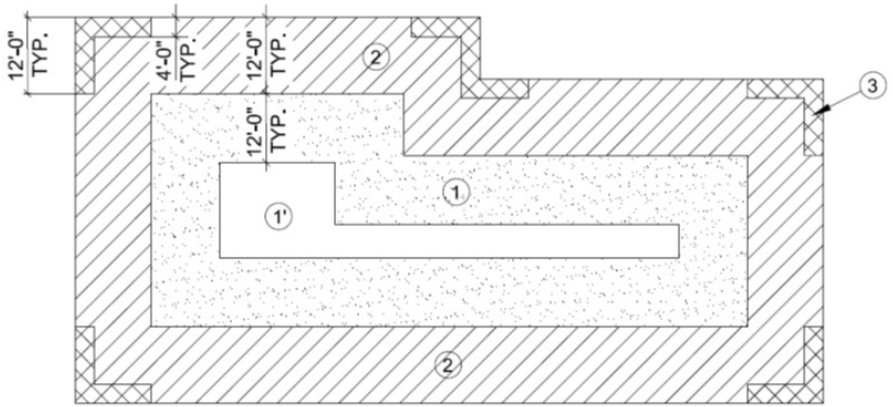
- Bridging cannot be extended though an expansion joint.
- It is recommended that a row of diagonal bridging be placed on each side of the expansion joint.

Expansion Joints



Wind Pressures

- Don’t forget about downward wind pressures.
- Wind Uplift. Provide a Key Plan.



UPLIFT DIAGRAM

REF : 1/S001

NET UPLIFT LOADING:

TRIBUTARY AREA	ZONE 1'	ZONE 1	ZONE 2	ZONE 3
100 SQ FT	-45.0 PSF	-82.4 PSF	-110.4 PSF	-152.4 PSF

A) WIND PRESSURES DETERMINED IN ACCORDANCE WITH ASCE 7-22
B) NET UPLIFT PRESSURES TABULATED ARE THE RESULTS OF THE LOAD COMBINATION 0.6D + 0.6W

Multi-Story Buildings

- Floor Joists
- Composite Joists
- Flush Frame Connections

Multi-Story Buildings

Floor Joists:

- Since floor loads are generally greater than roof loads, heavier joists are used as compared to roofs. Additionally, floor-to-floor heights are generally more important, resulting in the use of heavier joists due to using joists with less depth.
- The specifying professional should examine the SJI LH-Series load tables to determine maximum joist sizes and depths that can support floor loads.
- Be aware that seat depths add to the floor-to-floor height.

Multi-Story Buildings

Composite Joists (CJ Series)

- Composite joists in conjunction with composite decks are an excellent choice in the framing of multi-story buildings.
- Economical joist spacing is often up to ten feet. The larger spacing in conjunction with floor dead and live loads may limit the use of K- Series, and LH- Series joists.

Multi-Story Buildings

Flush-Frame Connections

- When there is a concern about reducing floor-to-floor heights, Flush-Frame connections should be considered.
- Flush-Frame connections can significantly reduce floor vibration.

Multi-Story Buildings

Examples of Flush-Frame Connections

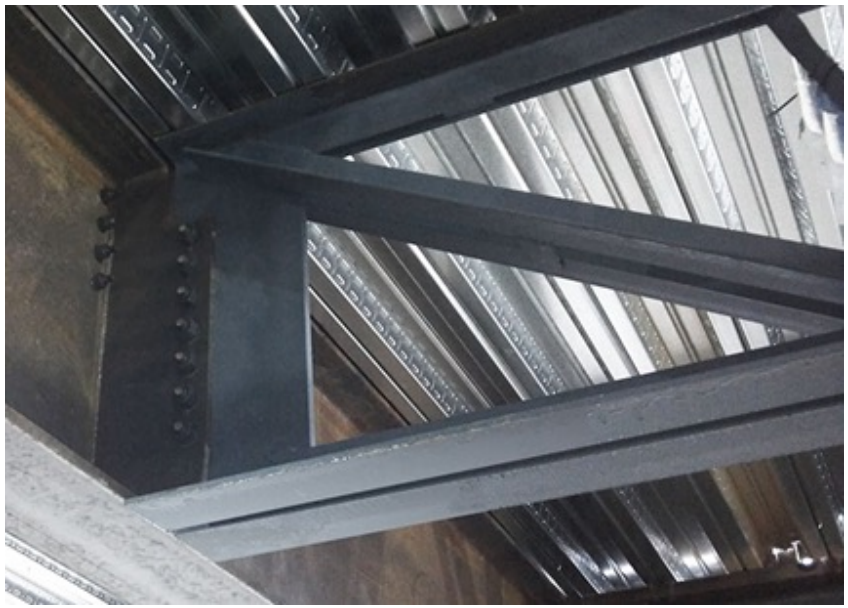
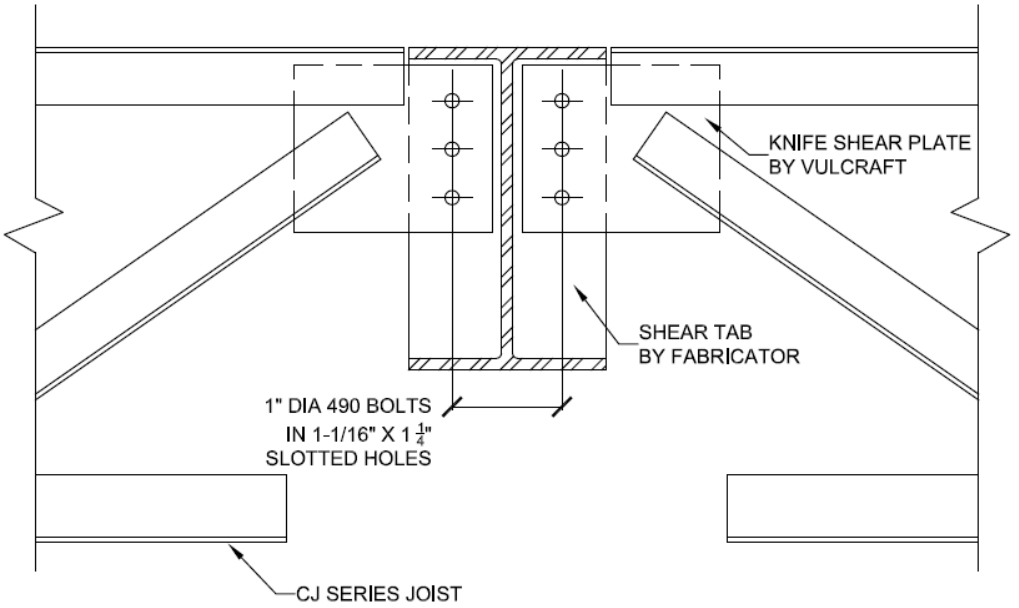
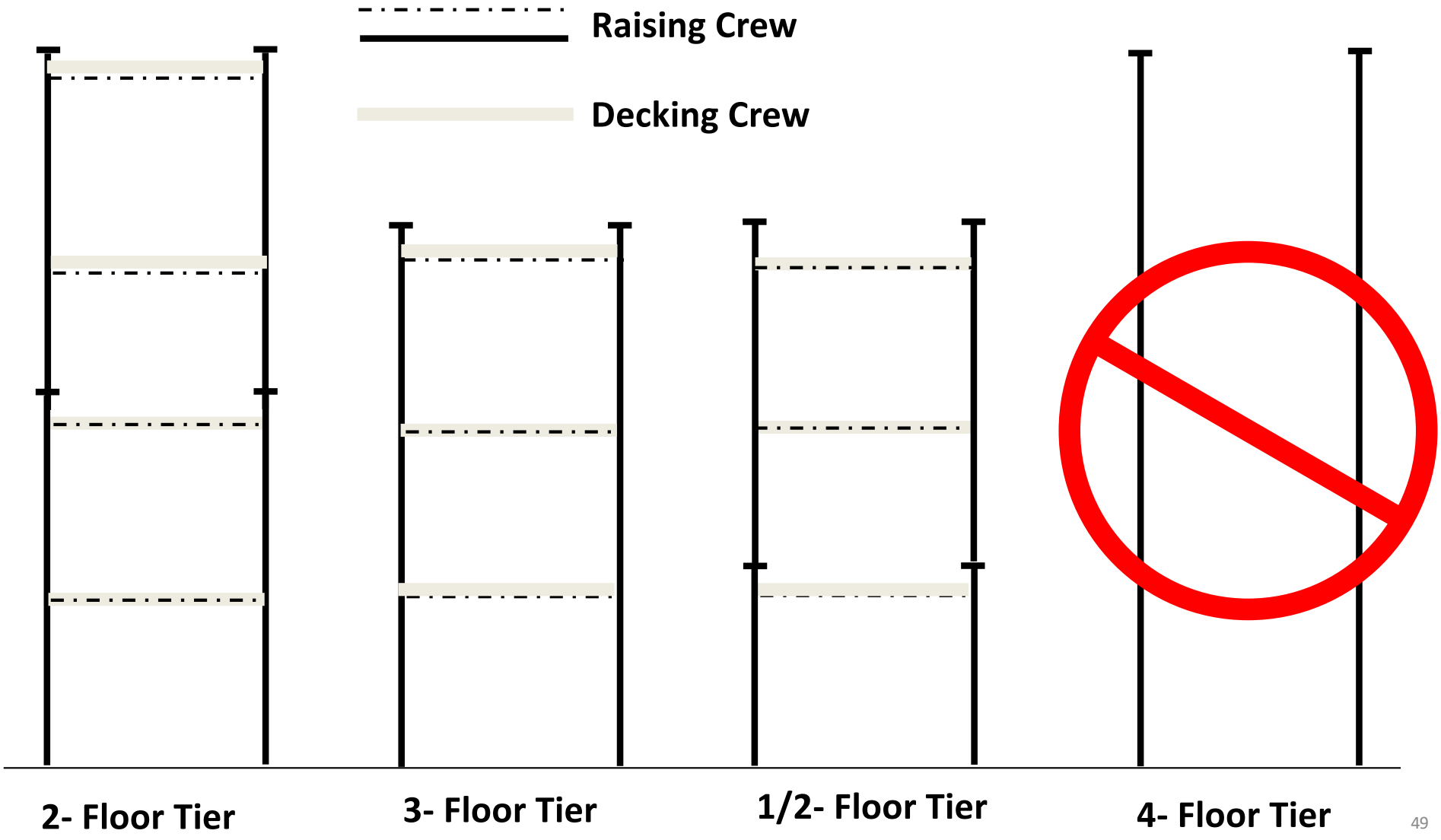


Photo courtesy of Vulcraft Corporation



Maximum Practical Column Lengths



Chapter 3 - Design Tips for Effective Design

Designers often spend most of their time on analysis and member strength design, and an insufficient amount of time on connection design and design considerations other than strength.

Paraphrasing Hardy Cross:

First design the structure using your best judgement, **then** analyze the structure. If your numbers do not support your design, **then** re-evaluate your numbers. If the numbers still do not support your design, **then** evaluate where your judgement may be in error.

Design Tips - General Considerations

- Design for serviceability first, then check strength.
- Communicate with joist manufactures, steel fabricators, detailers, and erectors.
- Read the SJI Code of Standard Practice and the AISC Code of Standard Practice
- Read ASTM A6.
- Keep the design simple.
- Provide understandable plans.

Design Tips - General Considerations

- Indicate if camber is required for structural steel
- Specify the required camber for composite joists.
- Provide column schedules in the plans.
- Minimize changes.
- Release for mill orders and detailing only when complete.
- Answer the detailer's questions promptly; this means REALLY FAST.

Design Tips - General Considerations

- Approve shop drawings and joist placement plans in a timely manner
- Use maximum practical column lengths for shipping, handling, and erection.
- Show all equipment and their weights/loads on the structural drawings.

Design Tips - Connections

- Time spent on connection design should be consistent with time spent on analysis and member design.
- Framing decisions must be made along with connection decisions.
- Use field bolted moment connections.
- If you are not designing the connections, show all reactions on the drawings: axial, shear, moment, and transfer forces with each set of force than for the same load combination.

Design Tips - Connections

- Design connections for the actual forces.
- Show beam and joist and joist girder reactions on the plans.
- Show special connections.
- If possible do not use W6 and W8 columns.
- Don’t require bolting and welding to the same member.

Design Tips - Connections

- Show all forces for complete load path and provide equilibrium at each joint.
- Transfer forces should include all drag strut forces and diaphragm connection details.
- Consider modifying work points for extreme connection geometry.
- Avoid through plates on HSS columns.

Design Tips - Welding

- Make sure that there is adequate access for welding.
- Keep fillet weld sizes at or below 5/16 in.
- Use multi-pass fillet welds rather than groove welds.
- Weld one side of a piece if possible.
- Use intermittent fillet welds when possible.

Design Tips - Welding

- Avoid the weld all around symbol.
- Eliminate overhead welding.
- Do not specify welded sidelaps for deck.
- Do not weld joist or joist girder bottom chord to stabilizer plates.

Design Tips - Bolting

- Make sure that there is adequate access for bolting.
- Limit bolt diameters to 1-1/8 in.
- Limit different bolt grades and sizes.
- Use ASTM A325 bolts if possible.
- Use snug tight bolts when possible.
- Use N type bolts rather than X bolts.

Design Tips - Member Design

- Minimize the number of anchor rods per column. (OSHA minimum is 4) and use simple arrangements.
- Use materials that are readily available.
- Check for camber differences on adjacent members, especially when adjacent parallel member ends are staggered.

Design Tips - Member Design

- Make sure members have sufficient width for elements bearing on them.
- Avoid beams with 4-inch flanges at:
  - Spandrel beams with adjustable edge form.
  - Beams requiring bolted flange connections.
  - Locations where joists frame from each side.
- Have steel deck span all in the same direction if possible.
- Avoid moment connections into the weak axis of columns.
- Reduce joist spacing in snow drift areas.

Design Tips - Member Design

- Use beams rather than joists when many concentrated loads are present.
- Repeat member sizes whenever possible.
- Minimize field work.
- Minimize the need for stiffeners and doubler plates.
- Avoid members meeting at acute angles.
- Revised plans should clearly show what was revised from the previous set.
- Use wide spacing for joists, e.g., 6', 8', 10'.

Design Tips - Erection

- Provide permanent bracing that can be used a temporary bracing when possible.
- Provide straight forward connections that can be erected without added temporary provisions.
- Make sure that all beams and joist girders can be brought into place without interference.
- Provide construction tolerances in your design.
- As the specifying professional, design the anchorage for joist bridging.

SJI Tools Applicable to this Webinar

Roof Bay Analysis Tool

The design tool assists the specifying professional with selecting optimal bay sizes and framing options. The tool provides several input options allowing for customization based on project criteria and designer preference as well as owner and code requirements and a ponding analysis option.

Floor Bay Analysis Tool

The floor bay analysis tool assists the specifying professional with selecting optimal bay sizes and framing options. The tool provides several input options allowing for customization based on project criteria, designer preference, owner, and code requirements. The tool includes the floor bay vibration analysis.

SJI Tools Applicable to this Webinar

Floor Bay Comparison Tool

The floor bay analysis tool provides the specifying professional a means to compare weight and cost of six different floor systems. Comparisons are made between standard joist supported by joist girders, composite joists supported by joist girders, composite joists supported by composite WF girders, composite joist supported by non-composite WF girders, and composite WF beams supported by composite WF girders. Joist seat types can be modified to determine floor walking vibration differences.

SJI Tools Applicable to this Webinar

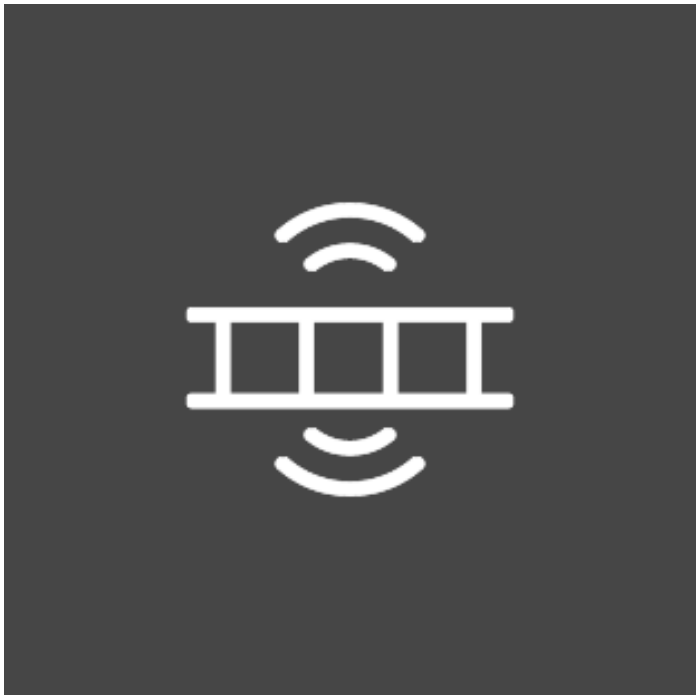
Joist Girder Moment Connection Design Tools

Six different joist girders to column connection designs are included in this tool. Connection designs are presented for single-story and multi-story columns. These design tools assist the specifying professional, the connection designer, and the steel fabricator with the complex task of designing appropriate connections between joist girders and columns. The tools can be utilized for wide flange and HSS columns.

Floor Bay Analysis Tool Demonstration

SJI Design Tools

- Free downloads
  - Steel Joist Uplift Analysis Tool
  - Joist Girder Analysis Tool
  - Joist and Joist Girder Reinforcement Tool
  - Historical Load Tables
  - Roof Bay Analysis Tool w/ Ponding Analysis
  - Floor Bay Analysis Tool w/ Vibration Analysis
  - Joist Girder Moment Connection Design Tools
  - Virtual Joists
  - Virtual Joist Girders
- Floor Vibration Analysis



SJI Publications

Technical Digests

- #1 Utilizing and Specifying Steel Joists
- #2 Bridging and Bracing of Steel Joists and Joist Girders
- #4 Guidance for Building Design Using Steel Joists
- #5 Vibration of Steel Joist – Concrete Floors
- #6 Design of Steel Joist Roofs to Resist Uplift Loads
- #7 Special Profile Steel Joists and Joist Girders
- #8 Welding of Open Web Steel Joists and Joist Girders
- #9 Handling and Erection of Steel Joists and Joist Girders
- #10 Design of Fire-Resistive Assemblies With Steel Joists
- #11 Design of Lateral Load Resisting Frames Using Steel Joists and Joist Girders
- #12 Evaluation and Modification of Open Web Steel Joists and Joist Girders
- #13 Specification and Design of Composite Steel Joists
- Design Guide 40 Rain Loads and Ponding

Catalogs

- 45th Edition Standard Specifications Load Tables and Weight Tables for Steel Joists and Joist Girders - Free download
- Second Edition CJ-Series Composite Steel Joists – Free download
- 95 Years of Open Web Steel Joist Construction

SJI Webinars

- Earn PDHs with the 2024 webinars:
- Our next FREE live webinar is on September 18:
  - It's Joist That Simple: System Design and Structural Reliability
- Webinars On Demand
  - Watch 60+ pre-recorded webinars. Order the online accompanying quiz to earn your PDHs.
  - Topics include:
    - Lateral Loads
    - Floor Systems
    - Uplift
    - Special Profiles
    - Ponding
    - Bridging
    - Vibration
    - Roofs
    - CJ-Series Composite Steel Joists
    - Building Retrofit
    - Welding
    - Connections
    - Design Tools
    - Fire
    - Ethics
    - Joists 101

Polling Question 2

Flush Frame connections can significantly reduce floor vibrations.

A. True

B. False

Q&A SESSION

THANK YOU

AUGUST 21, 2024

Presented by:
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