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Challenges for Designers of Crane-Supporting Steel Structures

November 10, 2021

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Course Description – Submitted for AIA CE Credit

Challenges for Designers of Crane-Supporting Steel Structures
November 10, 2021

This webinar will review the unique considerations related to the design of crane-supporting steel structures. It will cover typical framing systems used to support top-running cranes and basic terminology. Other topics include different types of potential crane forces, key design elements, and erection considerations.

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Learning Objectives – Submitted for AIA CE Credit

- Describe how to develop a plan and cross-sectional layout of a crane building, with consideration of various clearance requirements for crane parts and occupants.
- List the types of forces that act on supporting structures due to crane operations.
- Identify details in crane-supporting structures that are sensitive to fatigue.
- List considerations made by the fabricator and erector to meet the tolerances for crane-supporting structures.

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Challenges for Designers of Crane-Supporting Steel Structures

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Vice President, CSD Structural Engineers

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1. Introduction

The purposes of this presentation are:

- To acquaint those who have limited experience with design and construction of crane-supporting steel structures
- To identify and discuss challenges that a structural engineer might face while designing and preparing contract documents for these structures
- To provide advice on how to avoid pitfalls
- To provide advice on possible solutions to challenges
- Focus will be on electric travelling overhead cranes

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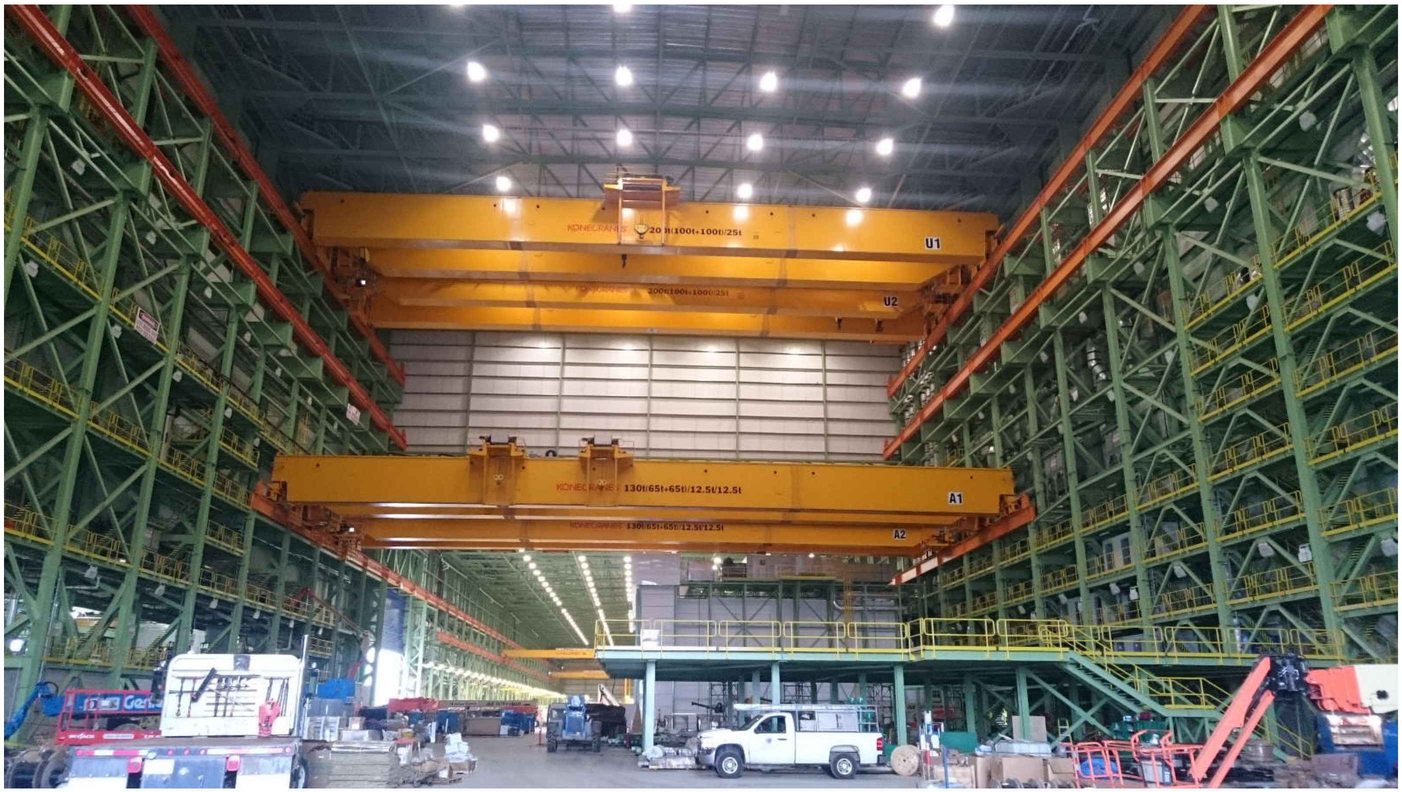
A Complex Structure



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A More Typical Structure

Characteristics that Make These Structures Unique

- Potentially very large moving, impactive and repetitive loads
- Consideration of unique strength and serviceability requirements
- Clearance considerations for the crane (s)
- Unique framing systems required to accommodate geometry and loading requirements
- Providing appropriate loading criteria for the structure
- Providing appropriate fatigue resisting details
- Providing appropriate fabrication and erection tolerances
- Requirements for inspections, certifications, evaluations

Scott will now provide an overview of cranes and buildings that support cranes

We'll call this Part 2

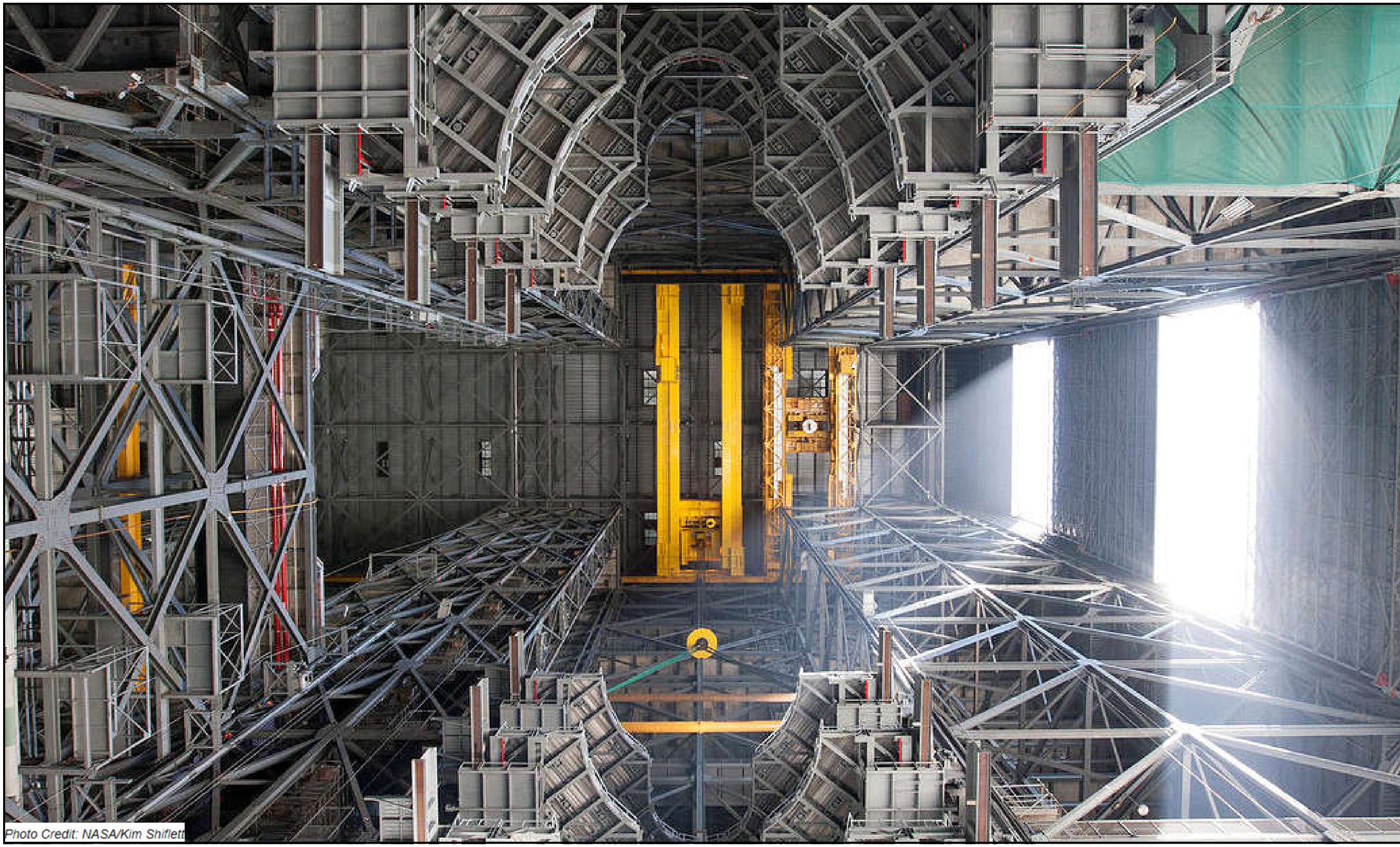

Photo Credit: NASA/Kim Shiflett

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2. Structure Supported Cranes

- Multiple girder top running cranes
- Single girder top running cranes
- Underhung cranes
- Semi-Gantry cranes
- Monorails
- Traveling jib cranes
- Column mounted jib cranes

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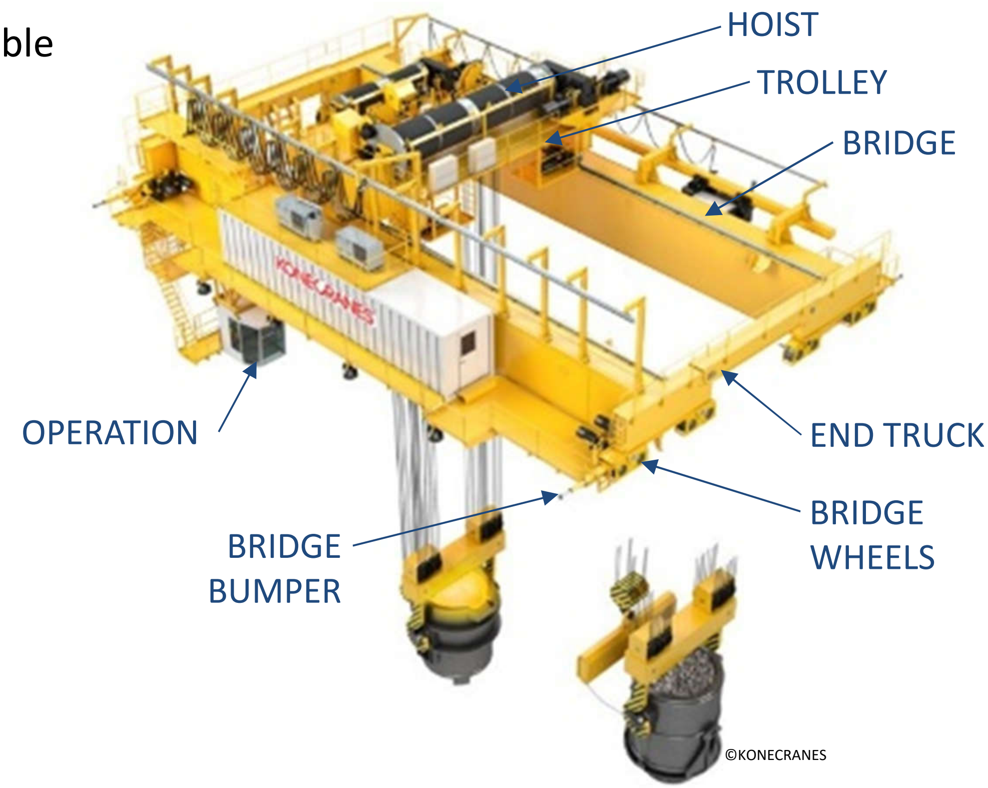
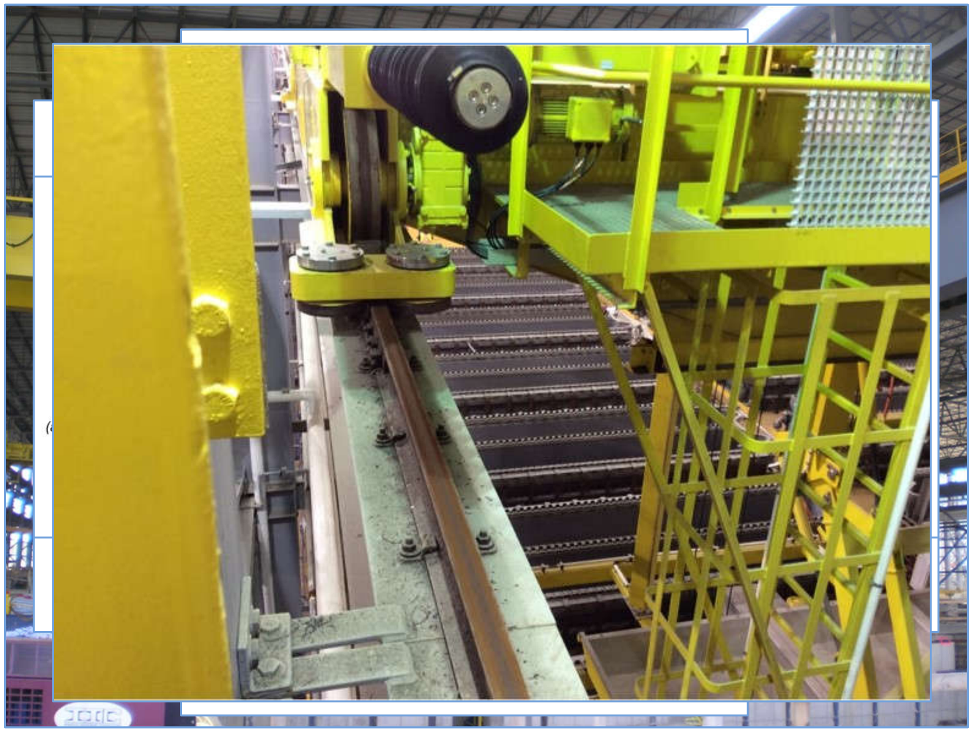
Top Running Electric Overhead Traveling Cranes

- Crane Manufacturer's Association of America (CMAA) Specification #70 (double girder) and #74 (single girder) (2020)
- Crane components
  - Hoist
    - Hook, Magnet, Clam Shell, Stacker
  - Trolley
    - Rotating trollies, Multiple hoists
  - Bridge
  - End trucks
    - 2 and 4 wheel common
  - Wheels
    - Double flange, single flange, flangeless
  - Bumpers
    - Mechanical and hydraulic
- Operation
  - Cab, Radio, Pendant



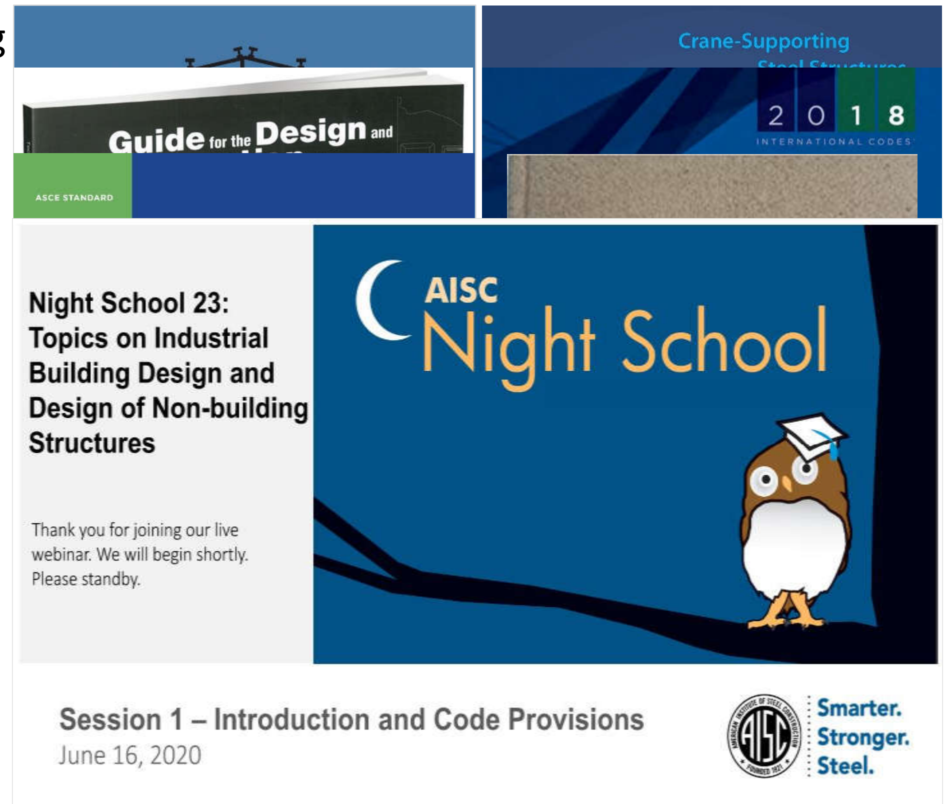
Runway Structure Components



- Crane Columns
  - Bracketed, Stepped, Leaning / Independent, Battened, Laced
- Crane Runway Beams & Girders
  - Wide Flange, Reinforced Wide Flange, Plate Girders, Back-up System
- Bearing Seats
- Tie-back Connection
- Rail
  - American (ASCE & ASTM A759)
  - European Rail (DIN 536)
- Rail Attachment
  - J bolts
  - Proprietary Welded
  - Proprietary Bolted Clips

Available Reference Information

- AISC Design Guide 7: Industrial Building Design (3rd Edition)
- CISC Crane Supporting Steel Structures (3rd Edition, 4th Edition being printed)
- AIST Technical Report 13 (2021)
- International Building Code (2018)
- ASCE 7 (2016)
- Whiting Crane Handbook (3rd Edition)
  - (Historical Reference)
- DIN EN 1501
- AISC Night School 23: Topics on Industrial Building Design (2020)
- Other MFG published crane data / Company Database / AISC Engineering Journal Articles



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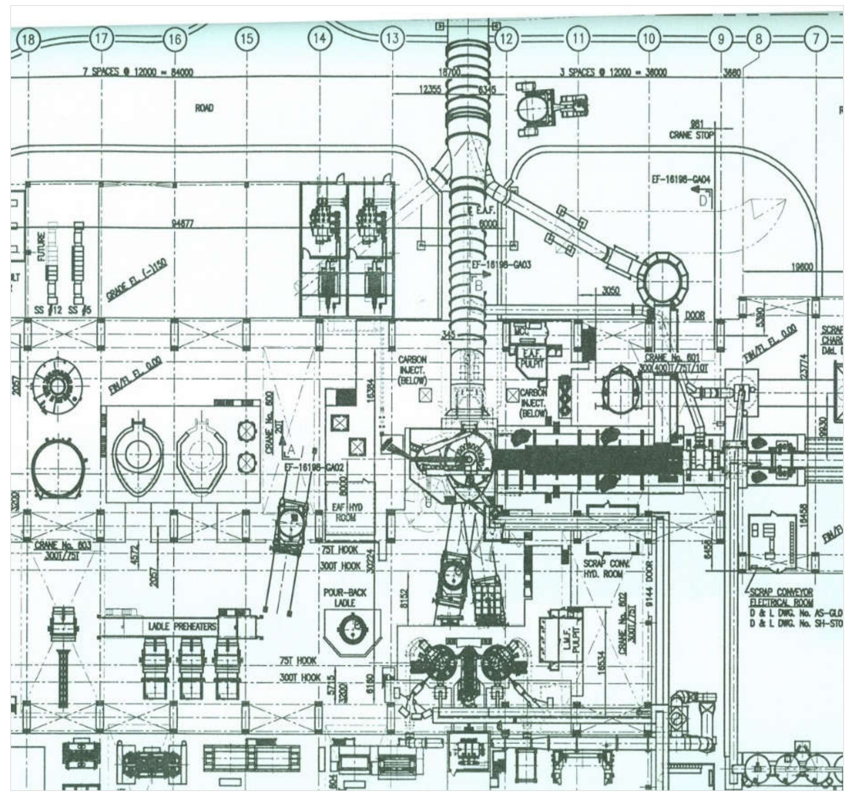
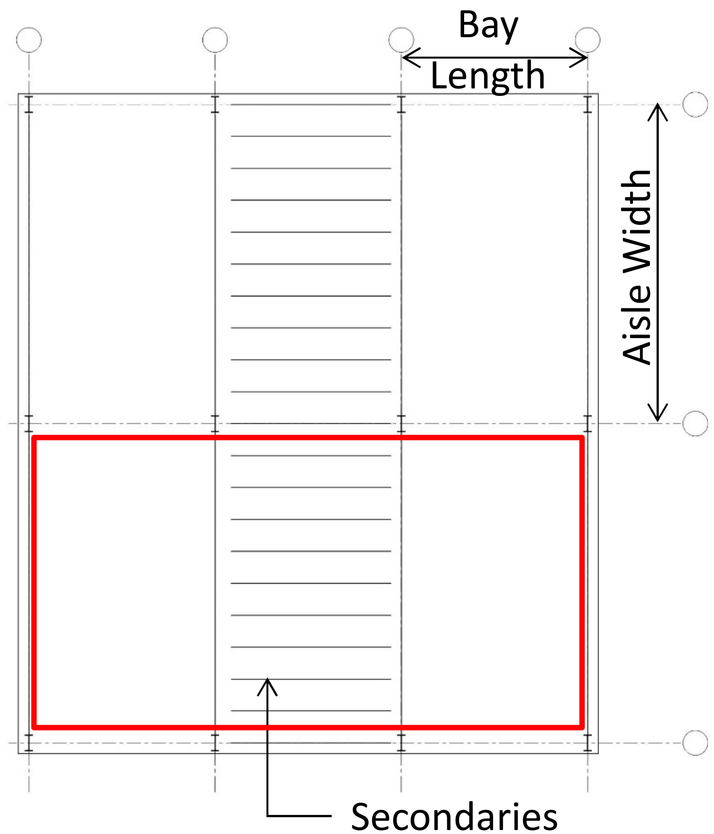
Part 3-Framing- It Starts with a Plan…

- General Arrangement (GA) drawing
- Structural Engineer's best opportunity to have input on optimizing framing layout
    - Bay width
    - Eave height
    - Girt line
    - Roof plenum
- Strategize crane needs with the impacts on the structure.
- Process drives the bus, the engineer's job to be sure they leave a seat for structure.



Plan Dimensional Considerations



Aisle Width:
- Typically based on equipment and owner requirements
- Common dimensions range from 40 ft. to 125 ft.

Bay Length:
- Hot Rolled Sections vs. Plate Girder Sections
- Consider secondary framing members used: light gage, hot rolled purlins and girts, or bar joists
- For light gage secondary framing, bay length commonly 20 ft. to 30 ft.
- For hot rolled secondary framing, bay length commonly 20 ft. to 40 ft.
- For bar joists, bay length commonly 20 ft. to 60 ft.

Hook Approach:
- Consider extent of hook coverage from rail to rail and at ends of an aisle.
- Consider end wall framing and impact on crane coverage

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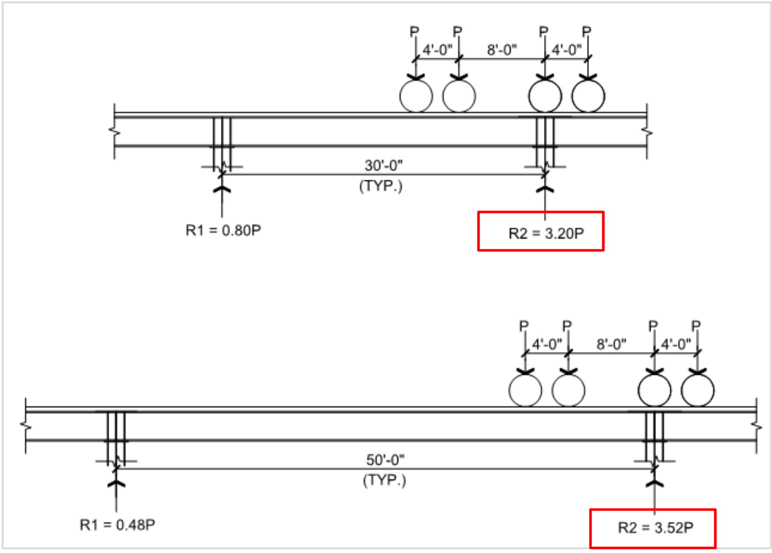
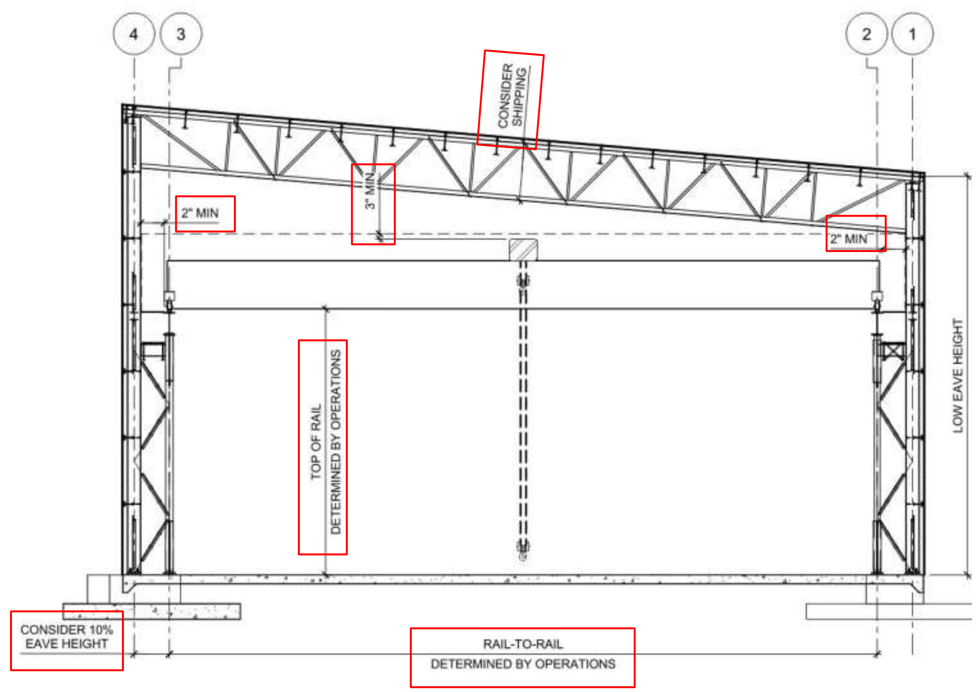
Economic Studies

- Maximum column load may not change appreciably with increased bay length
- Based on economic studies that CSD has performed most economical bay spacing is typically around 40 feet for heavy industrial facilities.
  - Incorporates consideration for cost of building superstructure, foundations, fabrication & erection.
    - Least weight is often not Least cost
    - Fewer pieces and fewer foundations often leads to reduced cost
- Crane Runway Beam >> Crane Runway Girder
- For smaller cranes less severe use, 30 feet or even less may be applicable.



Cross Section Considerations

- Rail height and Rail-to-Rail dictated by operations and hook clearance.
- Laced/Batten column gage: 10% of eave height as starting point
- Primary roof framing depth: consider shipping restrictions to avoid field-erected framing.
- OSHA 1910.179(b)(6)(i) requires a minimum of 3 in. overhead and 2 in. laterally from crane to nearest obstruction.
  - Consider roof framing deflection and field splice connections.
  - Consider rail alignment tolerance, crane wheel “float”, and other fabrication and erection tolerances.

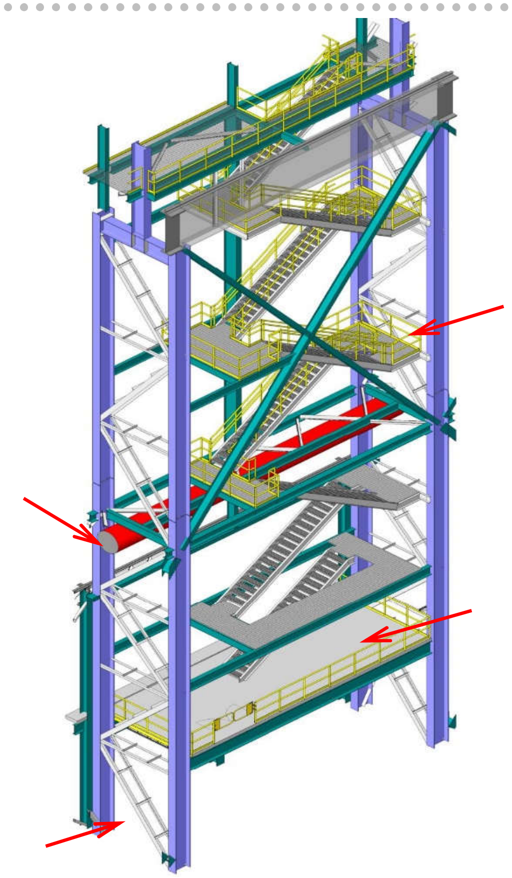


Further Cross Section Considerations

- Clearance above crane should consider
  - Employee access headroom
  - Lighting
  - Maintenance hoists.
  - AIST suggests a minimum of 12” above trolley
- Crane side clearance must also consider
  - Employee access (minimum of 18”)
  - Tieback geometry
  - Future cranes upgrades
- Upgrades of existing facilities must consider existing clearances

Additional Cross Section Considerations

- Integration of stair towers
- Laced/Battened columns should consider
  - Passage of electrical
  - Process piping loops
  - Duct openings,
  - Material handling
- Consider column gage spaces for
  - Employee break areas
  - Offices
  - Restrooms
- Designated Employee Travel
  - Consider IBC and OSHA clearances
  - Plan for 3’-0” x 6’-8” aisle way



End of Part 3

Bob will now talk about forces

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4. Forces

Discussion on loads/forces from cranes:

- Configurations
- Guidance methods for cranes
- Crane vertical, lateral and longitudinal loads
- Skewing forces
- Seismic forces
- References

Contrasting Configurations

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Guidance Methods for Cranes

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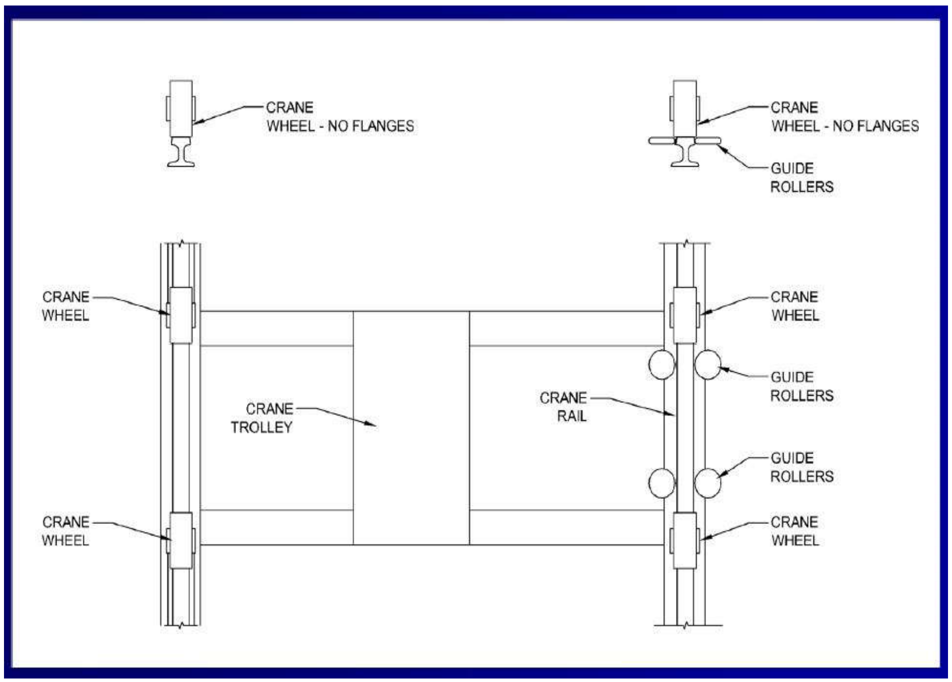
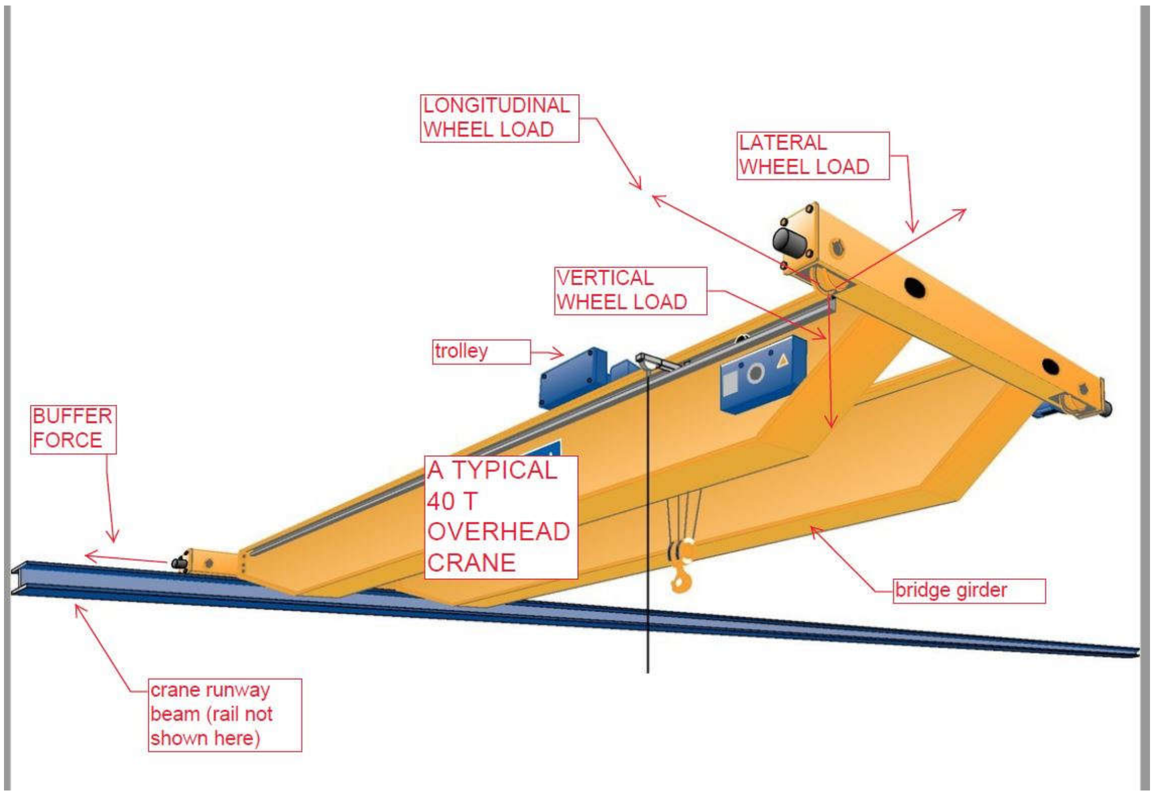
Cranes with Guide Rollers



- Note that the distribution of lateral forces will be significantly different from normal North American practice
- Crane rails should be suitable for these guide rollers

Forces From Cranes



Obtaining Reliable Crane Loads

- Crane manufacturer's GA drawings if possible
- Might need to weigh the crane in place if in doubt
- Vertical wheel loads are usually provided
- Calculate lateral loads for cranes with double flange wheels in accordance with governing codes and standards
- Obtain lateral loads for cranes with guide rollers from the crane manufacturer

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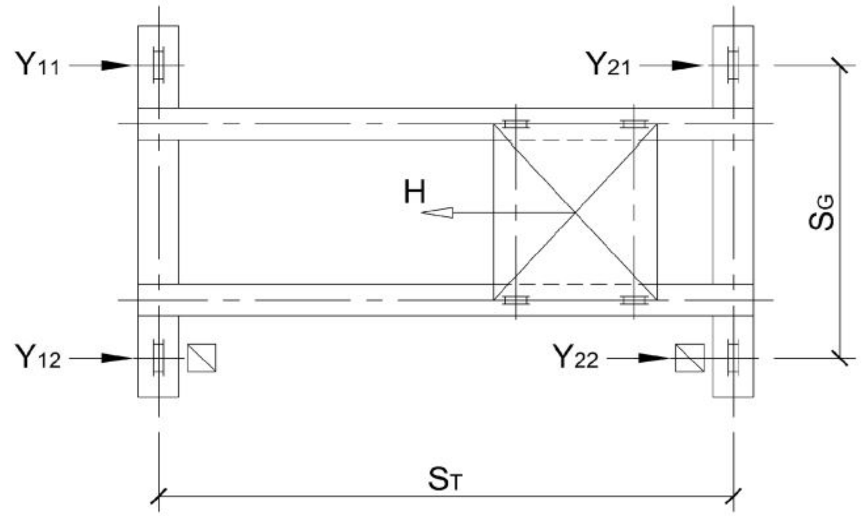
Crane Lateral Loads-North American Practice

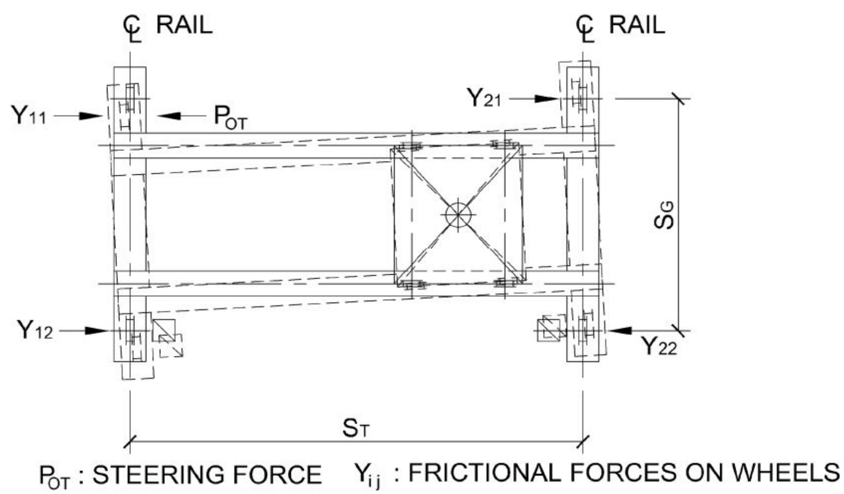
- All lateral loads lumped together
- Called side thrust
- Skewing may or may not be added



H = 0.20(TROLLEY WEIGHT + LIFTED LOAD)
Yij = RESULTING LATERAL FORCES TO SUPPORTING CRANE RUNWAY GIRDERS

Skewing

- Also known as oblique travel
- Caused by crane wanting to travel not exactly in line with the rails
- P_{OT} is the skewing force
- The other forces are compensating forces, no net lateral load
- Detailed calculations are complex, best done by the crane supplier
- CMAA 70 provides approximations



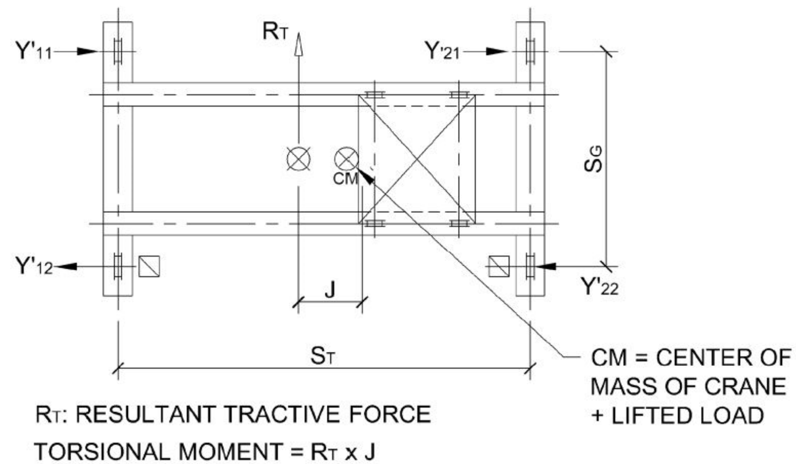
Comments on Skewing

Causes of skewing:

- Non-synchronized drive systems
- Crane out of square in plan
- Different wheel diameters
- Misaligned rails
- Tapered wheels
- Dynamic asymmetry
- May only be important for wheel and rail wear, and forces on the rail attachments (clips)

Other Jurisdictions-Europe, South Africa, Australia

- Dynamic asymmetry
- Also called acceleration of the crane
- A twisting motion in plan
- Complex calculations best done by crane supplier



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A Few Comments on Seismic Considerations

- Hoisted load not usually included, just dead load of the crane
- Hold down devices sometimes used
- ASCE/SEI 7 Chapter 15 (non-building structures) presents options
- Challenges include assessing the interaction of the crane, the crane runway beams and the remainder of the building structure
- Examples for reference include a presentation by my colleague Jules Van de Pas, *Crane Girder Design.* 2018 Structural Engineering Conference, University of Kansas.
- AISC publishes the “Seismic Design Manual” and provides other resources
- ASCE/SEI 7 , Chapter 15 provides design requirements

End of Part 4

Scott will discuss load combinations

5. Load Combinations

- IBC and ASCE 7 do not specifically address the combination of various crane configurations and crane forces. Treating cranes as simply live load.
- Technical Report #13 and DG 7 provide guidance on combining the various forces from a crane or multiple cranes.
- Technical Report #13 and DG 7 include load combinations for ASD, LRFD, and Fatigue.
- Technical Report #13 and DG 7 load combinations utilize Principal loads with Companion Loads.

IBC / ASCE 7 LRFD LOAD COMBINATIONS

1	$1.4D$
2	$1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$
3	$1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (1.0L \text{ or } 0.5W)$
4	$1.2D + 1.0W + 1.0L + 0.5(L_r \text{ or } S \text{ or } R)$
5	$0.9D + 1.0W$
6	$1.2D + E_v + E_h + L + 0.2S$
7	$0.9D - E_v + E_h$

Report #13 and DG 7 LRFD LOAD COMBINATIONS

1	$1.4D$
1a.	$1.4D+1.4C_{dm}$
2.	$1.2D+1.6L+0.5(L_r \text{ or } S \text{ or } R)$
2a.	$1.2(D+C_{dm})+1.6L+1.0(C_{vm}+C_{ss}+C_{ls}) +0.5(L_r \text{ or } S \text{ or } R)$
2b.	$1.2(D+C_{dm})+1.6(C_{vm}+C_{ss}+C_{ls})+L+0.5(L_r \text{ or } S \text{ or } R)$
2c.	$1.2(D+C_{ds})+1.6(C_{vs}+C_i+C_{ls})+L+0.5(L_r \text{ or } S \text{ or } R)$
3.	$1.2D+1.6(L_r \text{ or } S \text{ or } R)+(L \text{ or } 0.5W)$
3a.	$1.2(D+C_{dm})+1.6 (L_r \text{ or } S \text{ or } R)+1.0(C_{vm}+C_{ss}+C_{ls})+(L \text{ or } 0.5W)$
4.	$1.2D+1.0W+L+0.5(L_r \text{ or } S \text{ or } R)$
4a.	$1.2D+1.2C_{dm}+1.0W+L+C_{vm}+0.5(L_r \text{ or } S \text{ or } R)$
5.	$1.2D+1.0E+L+0.2S$
5a.	$1.2D+1.2C_{dm}+1.0E+C_{vs}+L+0.2S$
6.	$0.9D+1.0W$
7.	$0.9D+1.0E$
7a.	$0.9D+C_{dm} \text{ (or } C_{ds})+1.0E$
8.	$1.2D+1.2C_{ds} +1.0C_{vs} +1.0C_{bs}$
9.	$0.9(D+C_{ds})+1.6C_{vs(min)}+1.6C_{ss}$
10.	$0.9(D+C_{ds})+(1.6C_{ls} \text{ or } 1.0C_{bs})$

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Load Combination Details

- Crane "Dead" vs Crane "Live"
  - Bridge and Trolley are known "constant" loads defined by the crane manufacturer.
  - Lifted load, Crane Lateral, Crane Tractive, Crane Bumper are variable and considered Live Loads.
- Dynamic Crane Live Loads
  - Crane vertical impact and crane lateral are not combined
  - Previous versions of AIST Technical Report #13 had these combined
  - Peak response very unlikely to occur simultaneously for typical crane operations

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Multiple Cranes and Multiple Aisles

- Crane Vertical
  - Maximum response from single or multiple cranes in multiple aisles
  - Cranes positioned for worst case
- Crane Lateral & Crane Longitudinal Forces
  - 100% of 1 crane or
  - 50% of multiple cranes in a single aisle or
  - 50% of 1 crane in multiple aisles
- Coordinate with the Owner / Operators
  - Develop an understanding of how the facility will be used
  - Varies by project

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Before We Hit “Run”…

- When considering all load combinations and load positions
  - a single aisle 2-D frame > 400 load combinations.
  - a two aisle 2-D frame >1100 load combinations.
- Modern analysis software can handle this **but** the engineer should be aware of the solution before running the final analysis.
- Develop a feel for the structure…
  - What combinations do we expect to control
  - Can we eliminate combinations to simplify and speed-up analysis
  - Before you run analysis, have a sense of the answer.
  - The final analysis should be final verification rather than the means to a solution.

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Existing Structures and Crane Upgrades

- ASD vs LRFD
- Coordination with the Facility Operations Management
  - Typical operations with multiple cranes in an aisle
  - Proximity sensors or Bumper Extensions to ensure minimum spacing
  - Appreciable capacity by maintaining minimum spacing?
- Actual weight of crane bridge and trolly may be estimated. Consideration may be given to weighing these elements.
- Review of crane wheel loads
  - Depending on the end truck and bridge beam configuration, there may be appreciable differences. Request specific loads at each wheel.
- Crane impact and crane lateral forces
  - Previous design may have considered simultaneously
- Refer to Tim Bickel's NASCC 2021 Talk "Industrial Crane Runway Capacity Upgrades"

End of Part 5

Bob will discuss structural design considerations

6. Structural Design Considerations

Discussion on components of the crane-supporting structure including:

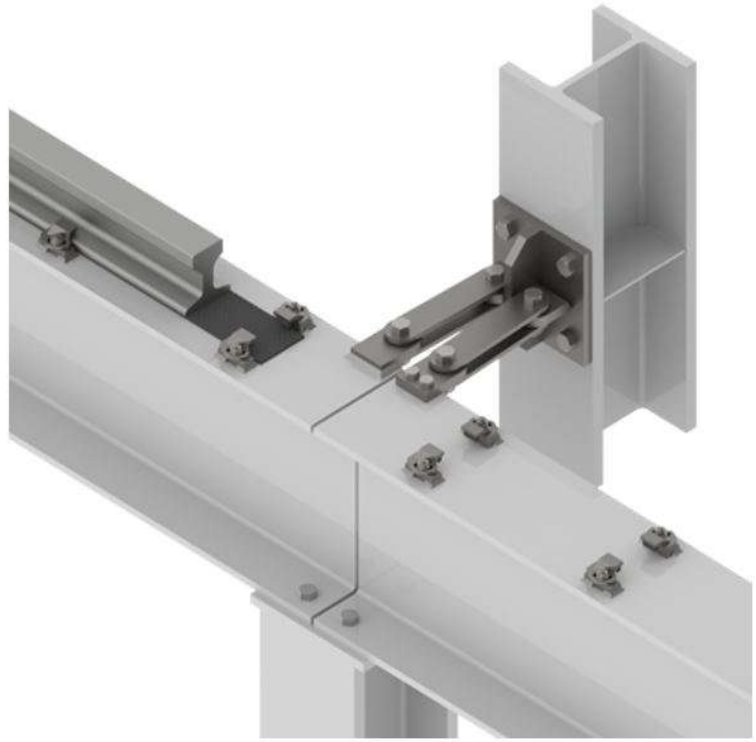
- Crane runway beams and accessories
- Building frames, including stepped columns
- Fatigue design
- Unusual considerations-cranes with guide rollers
- Influence of foundation conditions
- For seismic design considerations, refer to references in part 4. Also, search the web for tips.

Considerations and References

- Design for strength and serviceability
- Design for life span
- Design for tolerances
- Accessories, such as rail clips, tie backs
- Cover plates, cap channels
- Simple or continuous spans
- Monosymmetric beams, Stepped Columns
- Web stiffeners
- Long spans

- To AISC 360 and AISC DG 7
- Fatigue, same references
- AISC DG 7, AIST 13, CISC
- AISC DG 7, CISC
- AISC DG 7, CISC
- AISC DG 7, CISC
- AISC 360, DG 7, CISC
- AISC DG 7, CISC
- AISC DG 7

Runway Beams Accessories-See DG's for Options



Bearing Details

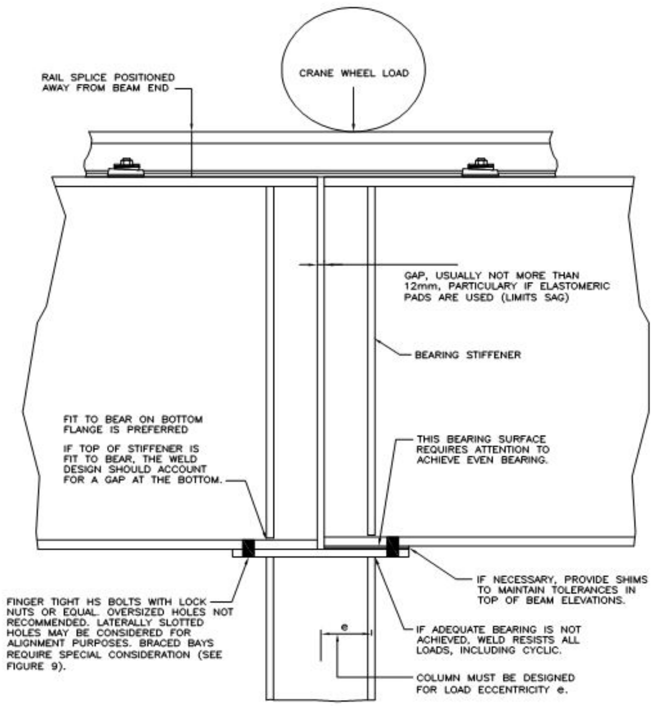


Figure 18. Bearing detail suitable for all classes of service.

- Weld at the column cap
- Bolts outside the column cap
- Eccentricity
- Shims as necessary
- Slotted Holes for alignment
- Stiffeners fit to bear
- Gap between beams
- Rail splice

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Frame Design

Important goals are to:

- Achieve the required crane rail placement tolerances no matter what the height
- Limit building sway
- Limit change in distance rail-to-rail

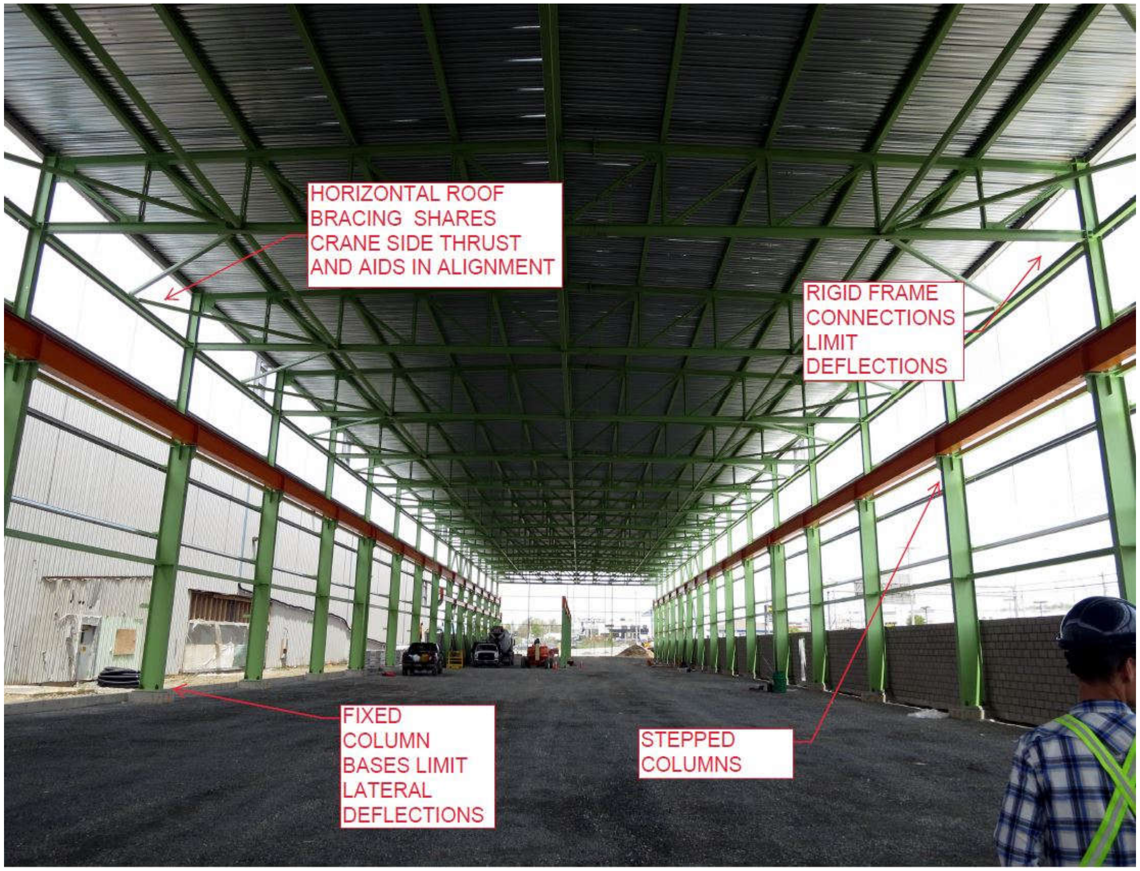
Challenges include:

- Stepped columns
- Foundation conditions
- Appropriate load combinations
- Achieving deflection limitations

Foundation Considerations

- Fixed bases recommended for frame rigidity
- Anchor rods should be pre tensioned if repeated uplift
- Be aware of possible settlements, differential settlements
- Do not grout under the base plates before the tolerance for setting the crane runway beams is assured

Good Practice in Frame Design



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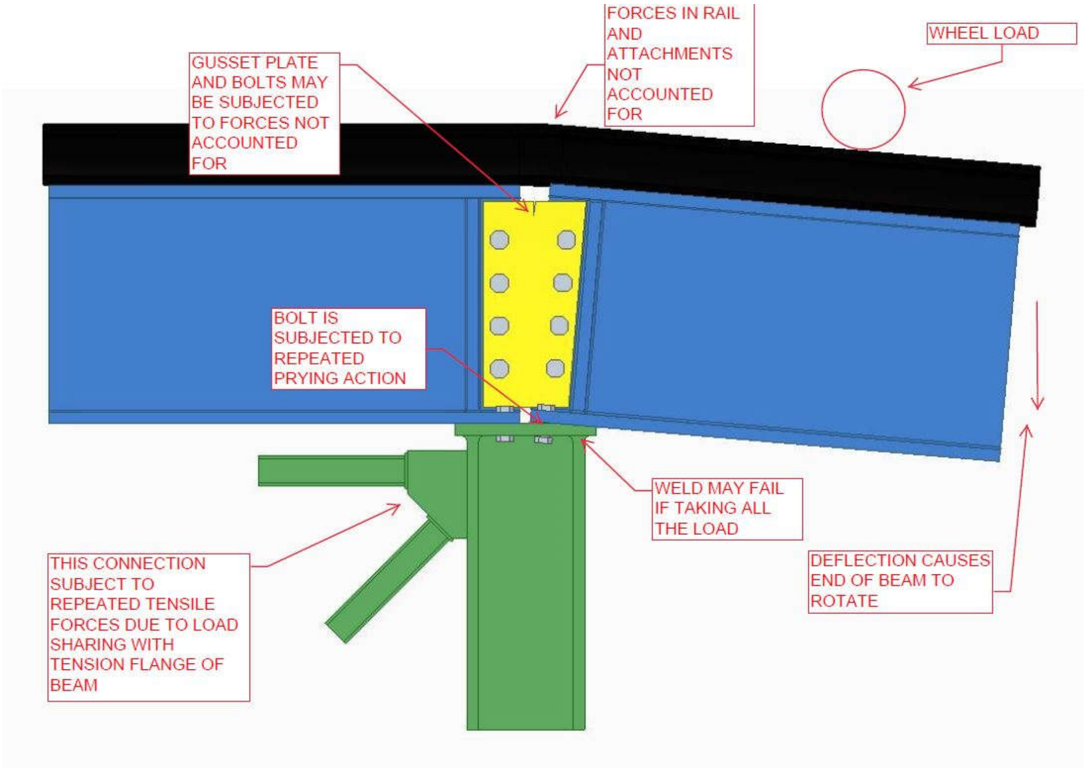
Design for Fatigue

The goal is to provide details that will not fail due to repeated loads for the life of the structure. Challenges include:

- Avoiding fatigue prone details
- Determining the appropriate number of load cycles
- Choosing suitable and economic details

Fatigue Prone Details



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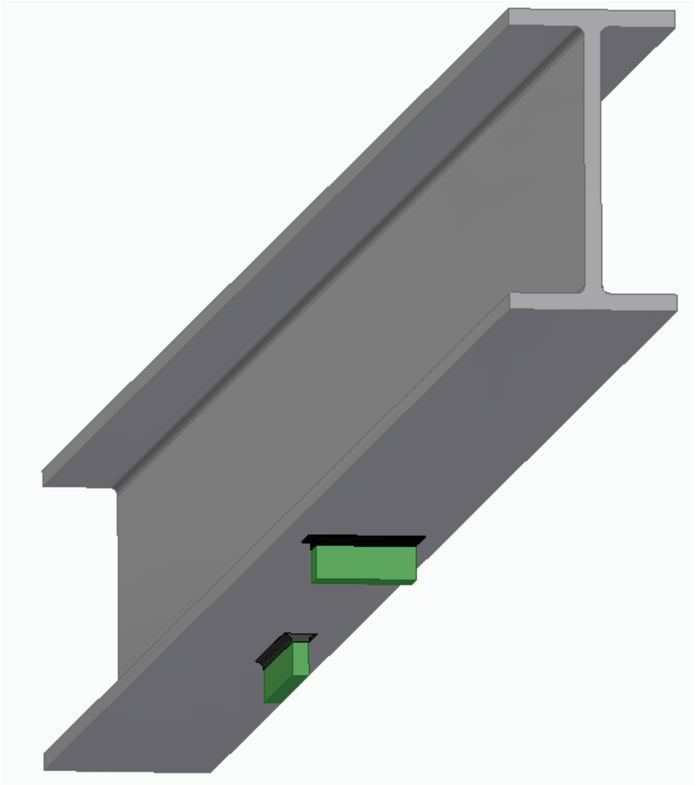
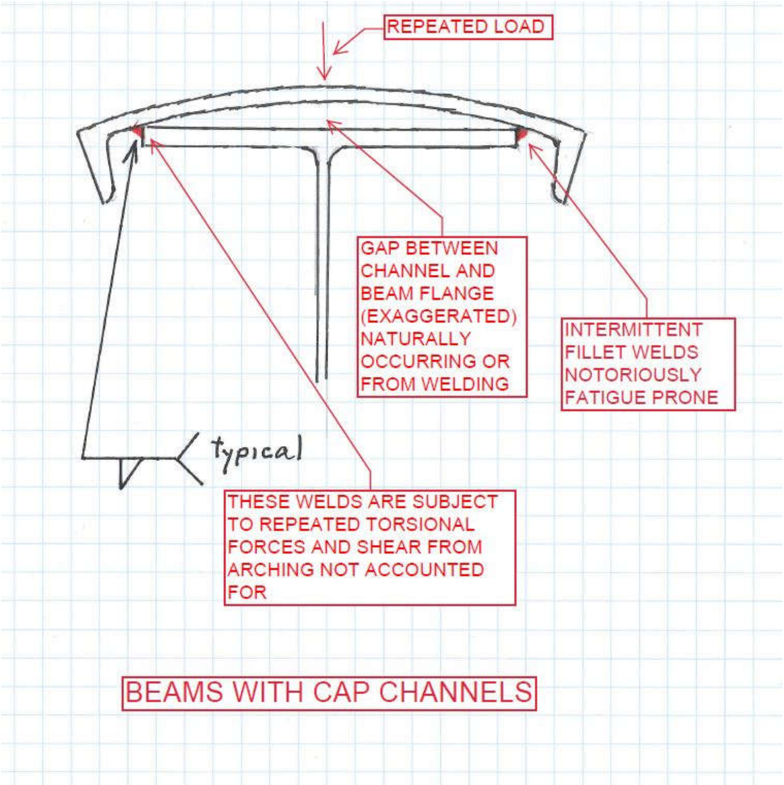
Fatigue Prone Details Cont'd





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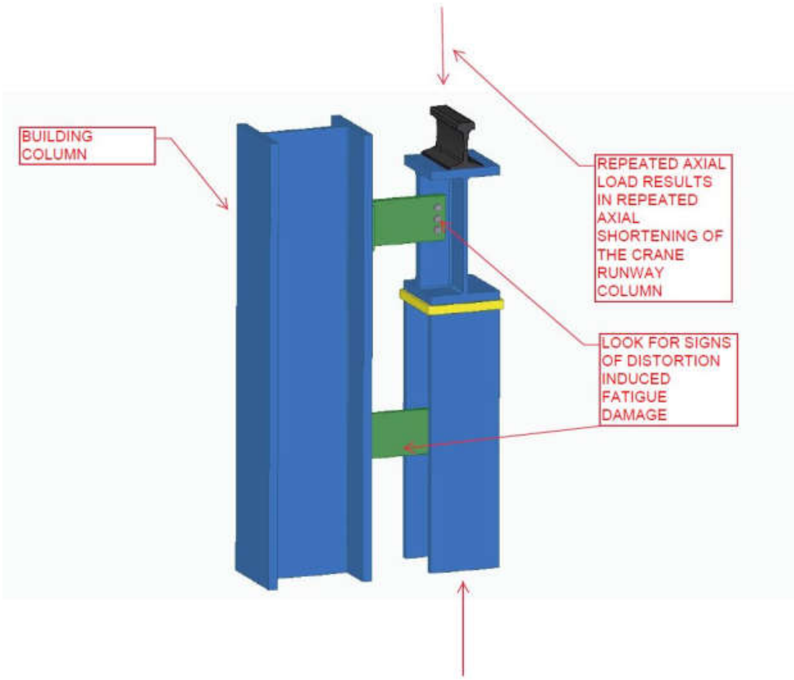
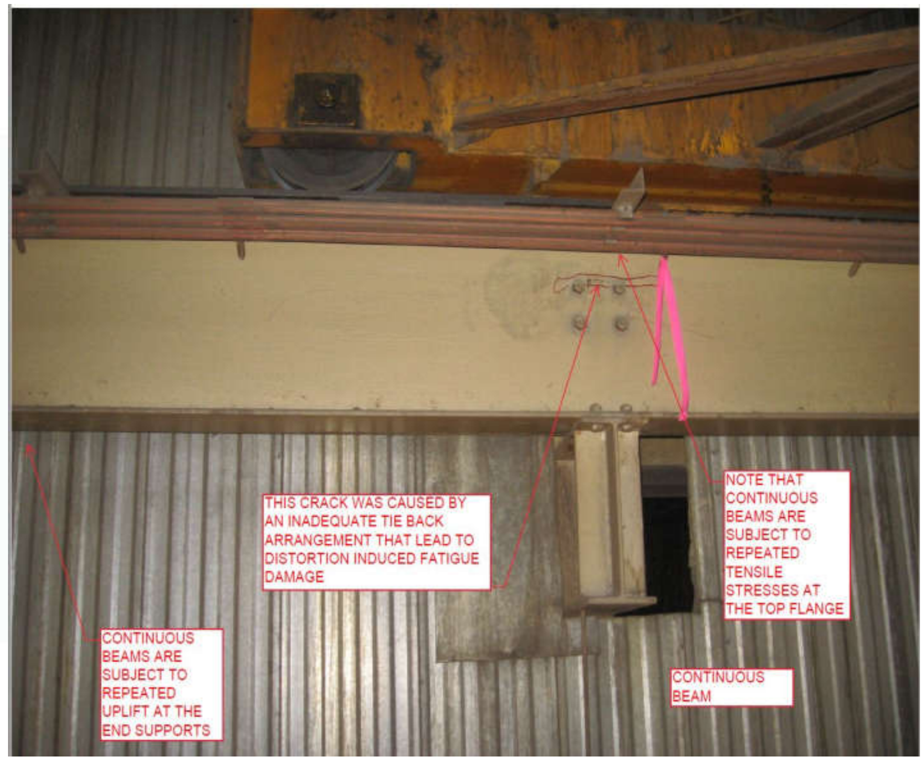
Fatigue Prone Details Cont'd





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Determining the Appropriate Number of Cycles

- Class of structure
- Related to crane service
- Related to duty cycles
- AISC DG 7, AIST RPT 13
- CISC Design Guide
- CISC Design Guide

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Fatigue Design-Constant Magnitude Cycles

- On the right you see the important formulas for checking fatigue by number of cycles, stress range and category
- Note that the number of cycles to failure varies inversely as the stress range to the third or fifth power

In plain material and welded joints, the range of stress due to the applied cyclic loads shall not exceed the allowable stress range computed as follows.

(a) For stress categories A, B, B′, C, D, E and E′, the allowable stress range, F_{SR}, shall be determined by Equation A-3-1 or A-3-1M, as follows:

$$F_{SR} = 1{,}000\left(\frac{C_f}{n_{SR}}\right)^{0.333} \geq F_{TH} \quad \text{(A-3-1)}$$

$$F_{SR} = 6\,900\left(\frac{C_f}{n_{SR}}\right)^{0.333} \geq F_{TH} \quad \text{(A-3-1M)}$$

where

C_f = constant from Table A-3.1 for the fatigue category
F_{SR} = allowable stress range, ksi (MPa)
F_{TH} = threshold allowable stress range, maximum stress range for indefinite design life from Table A-3.1, ksi (MPa)
n_{SR} = number of stress range fluctuations in design life

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Fatigue Resistance Curves

3.3 PLAIN MATERIAL AND WELDED JOINTS

Stress Categories

A, B, ,B', C, D, E, E', and G

As defined in Table A-3.1

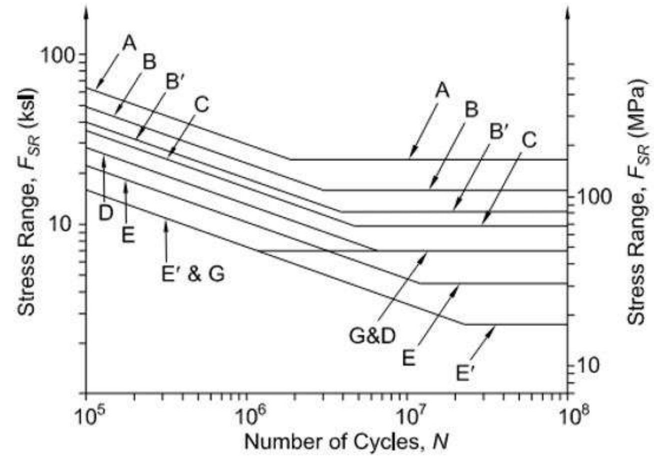


Fig. C-A-3.1. Fatigue resistance curves.

Cycles of Varying Intensity (Varying Stress Ranges)

- The engineer will encounter a loading spectrum that includes varying stress ranges and will be looking for expeditious solutions.
- There is more than one way to do this.
- The author finds that calculating the equivalent number of cycles at the maximum stress range is a useful approach.

Equivalent Number of Cycles by the P-M Rule

The total or cumulative damage that results from fatigue loading, not applied at constant amplitude must satisfy the Palmgren-Miner Rule:

$$\sum\left[\frac{(nN)_i}{N_{fi}}\right] \leq 1.0$$

where:

$(nN)_i$ = number of expected stress range cycles at stress range level i.

N_{fi} = number of cycles that would cause failure at stress range i.

In a typical example, the number of cycles at load level 1 is 208 000 and the number of cycles to cause failure at load level 1 is 591 000. The number of cycles at load level 2 is 104 000 and the number of cycles to cause failure at load level 2 is 372 000. The total effect or "damage" of the two different stress ranges is

$$\frac{208\,000}{591\,000} + \frac{104\,000}{372\,000} = 0.63 < 1.0 \quad \text{OK}$$

Example of a Duty Cycle

Percent of Maximum Wheel Loads	Number of Cycles, N	Description
100	62 500	Fully loaded crane
80	62 500	*
60	62 500	*
40	62 500	*
30	250 000	Unloaded crane

* Loads and trolley positions vary.

Calculate the Equivalent Number of Full Cycles

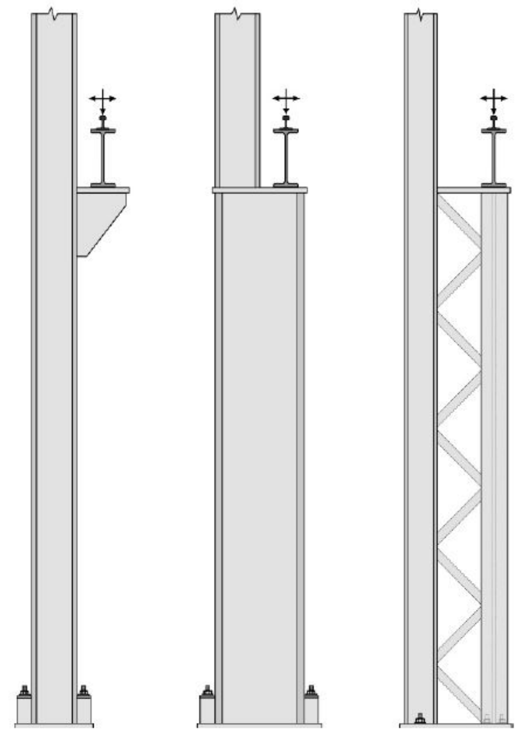
The equivalent number of cycles at full wheel loads is calculated as follows:

$$N = 62\,500 + 62\,500\left(0.8^3 + 0.6^3 + 0.4^3\right) + 250\,000 \times 0.3^3$$
$$= 62\,500 + 49\,500 + 6\,750 = 118\,750 \quad \text{cycles}$$

The supporting structure should be designed for, say, 120 000 full cycles.

Stepped Columns (also called segmented columns)

- A change in axial load or a change in section along the length of a column would qualify it as a stepped or segmented column
- Examples are shown on the right. Addition of a mezzanine would qualify
- If battened columns are to qualify there must be adequate shear flow



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AISC permits three methods of stability design

- The traditional way to analyze stepped columns was by the effective length method where a "K" factor is applied to the whole column length
- While this method is allowed, the preferred method is direct analysis
- We will examine this approach

Chapter C, AISC 2016

- Lists three sanctioned methods of stability design
  - Direct Analysis Method (DM)
  - Effective Length Method (ELM)
  - First-Order Analysis Method (FOM)
- Specifies the DM as the "preferred" approach

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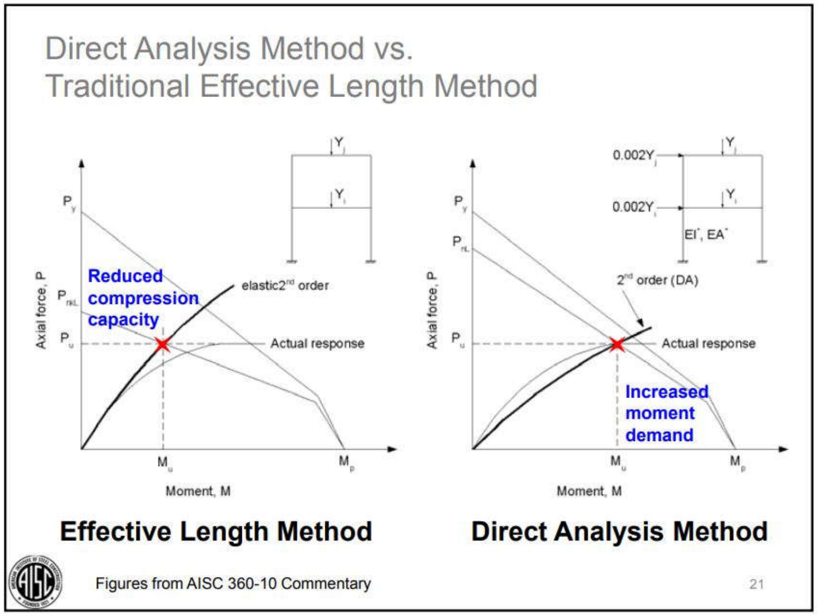
The difference between ELM and DM

- Instead of reducing compressive capacity we increase the moment demand by introducing notional loads (0.2 % of gravity loads) and
- We also reduce all stiffness that contributes to stability of the structure.



Modelling the structure

- We need to include a sufficient number of joints to be able to determine PΔ and Pδ delta effects
- The example on the right is from the 3rd edition of the AISC Design Guide 7

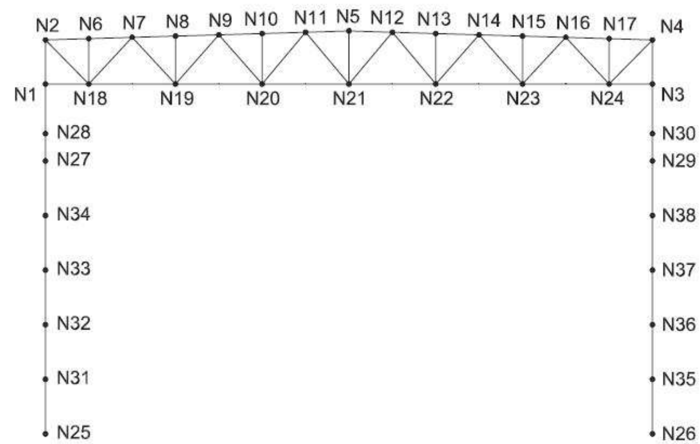
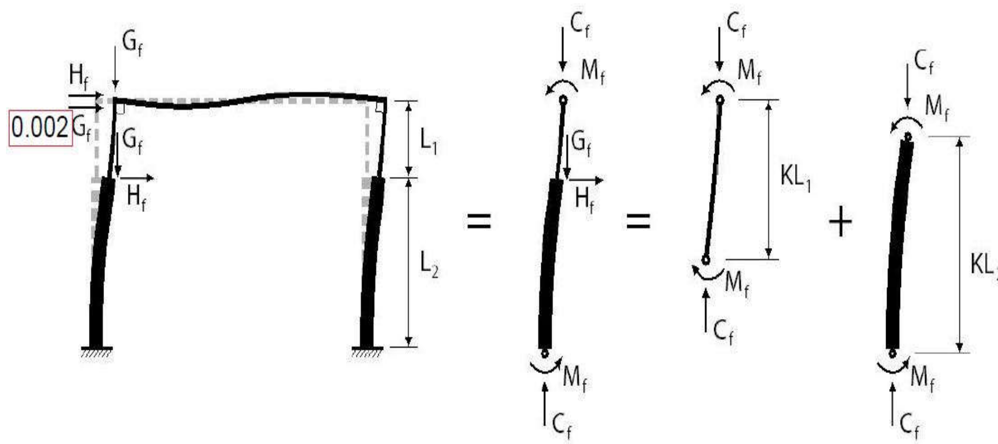


Fig. 16-23. Frame model.

AISC DESIGN GUIDE 7 / INDUSTRIAL BUILDING DESIGN

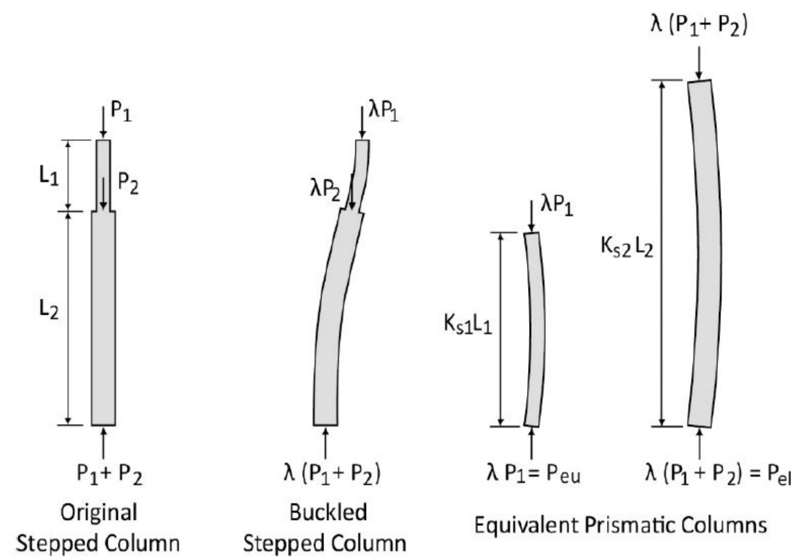
Application of notional loads

- If side thrust is present it is usually not necessary to apply the notional load at runway level because it would be so much less than the side thrust
- If there is no side thrust then a notional load of $0.002G_f$ should be applied at runway level



Equivalent prismatic columns

- For stepped columns we often have a change in shape or axial load and no strut at the change. There can be no hinge at that location. This is how one might account for that situation.
- K=1.0 for the whole column and for the equivalent prismatic columns
- We need to find the strength of the individual segments by doing a buckling analysis
- The equivalent prismatic column has the same buckling load as the stepped column under a given loading condition
- Note that different loading conditions may govern each segment



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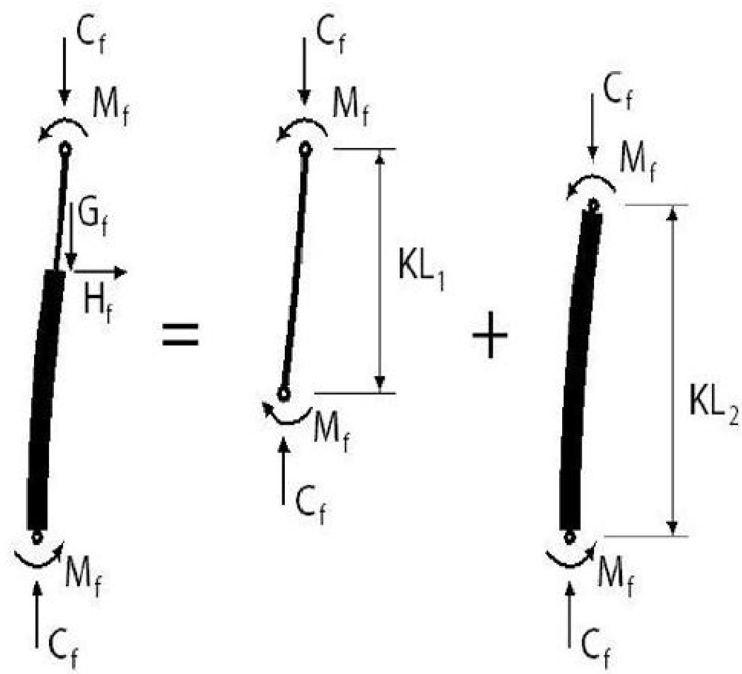
To determine the compressive strength of the column segments

For each segment the buckling load $=(\pi^2 EI_x/K_x^2L_x^2)$

- From the above Kx for each segment can be determined
- Find the factored axial strength for each segment using KxLx
- Check the segment as shown on a previous slide and here



*See the new AISC *Design Guide 25: Frame Design Using Nonprismatic Members* (2nd Ed.) for a detailed discussion of stability design for nonprismatic members, including stepped columns.

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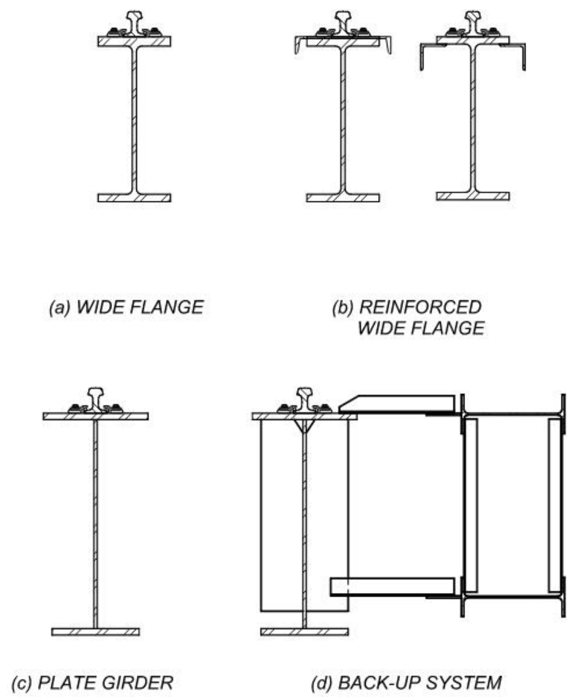
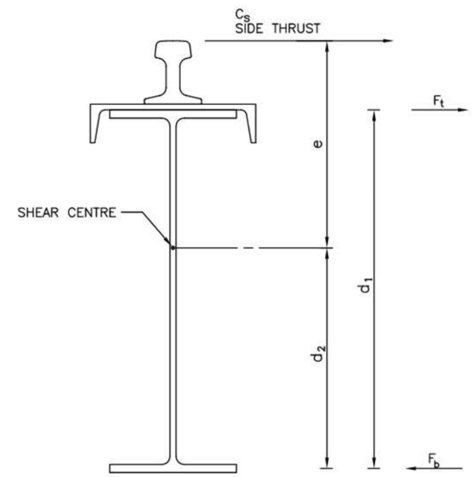
Crane Runway Beam and Girder Design

- Reference AISC DG 7 for recommended design procedure for runway beam, reinforced runway beam and plate girder design.
- Reference AISC DG 7 and CISC DG for selection of complete design examples for runway beams and girders
- Commonly start with vertical and horizontal stiffness then assess strength and fatigue.
- Provide compact top flange and webs
- AIST TR#13 recommends back-up system at top and bottom flange for spans >50'. Previous versions required for >36'. Remember always exceptions.
- For longer spans, effect of rail mis-alignment and sweep considerations become considerable.



Eccentric horizontal load at rail.

- Standard practice is to assume horizontal load is resisted by top flange
- Reference AISC DG 7 Chapter 14 and CISC DG Chapter 5 for additional commentary
- Moment about shear center is approximately equal to resisting moment required by flanges
- Consideration can be given to applying F_t at the shear center of the composite top flange.



$$\sum M_b = 0 = C_s(e + d_2) - F_t d_1$$
$$\therefore F_t = C_s\left[\frac{e}{d_1} + \frac{d_2}{d_1}\right]$$
$$\sum F_x = 0 \therefore F_b + C_s = F_t$$
$$F_b = C_s\left[\frac{e}{d_1} + \frac{d_2}{d_1} - 1\right]$$

For many cases, $e \approx \frac{d_1}{2}$, $d_2 \approx \frac{d_1}{2}$, and satisfactory results are obtained by applying all the side thrust to the top flange.

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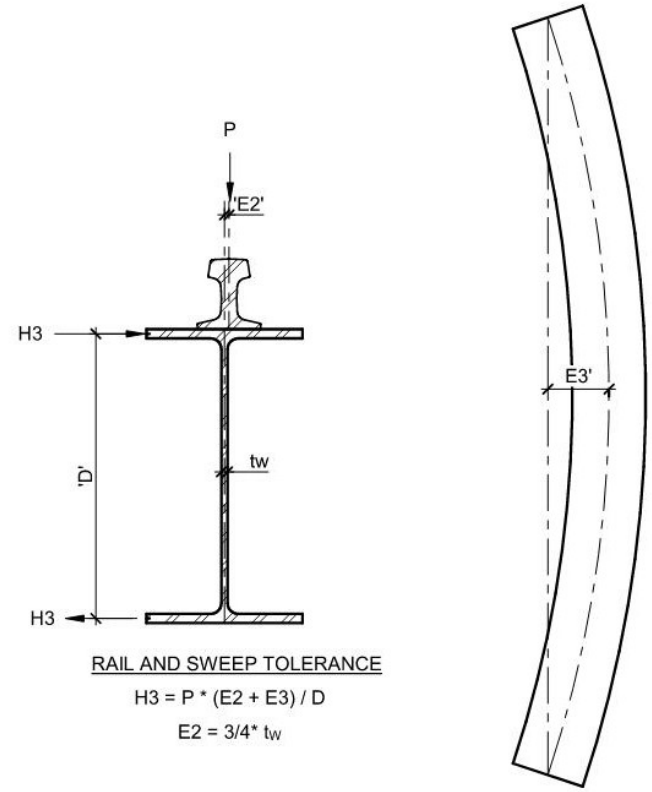
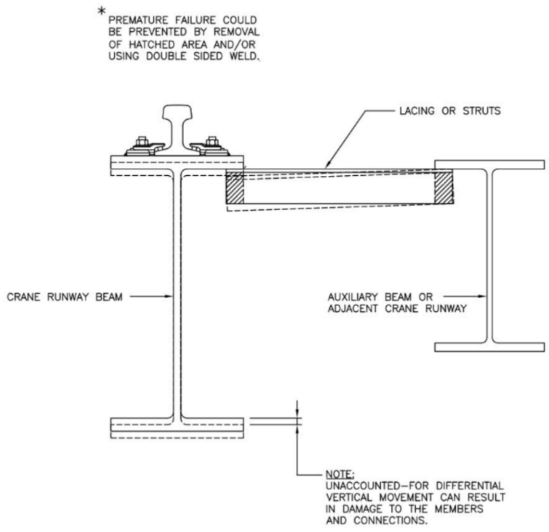
Consideration of Rail and Sweep Tolerance

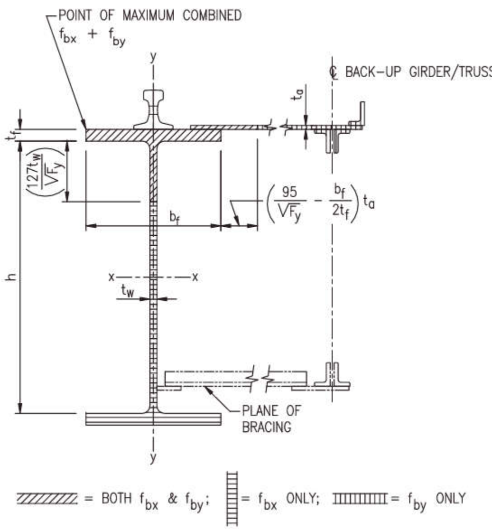
- Consideration should be given to torsion induced by potential rail position and runway beam/girder sweep tolerances.
- Rail position over web equal to 75% of supporting web thickness
- Allowable sweep in runway beam ¼" in 50 feet
- Engineer should consider mechanism used to resist potential torsion.
- Requires iteration to reach convergence



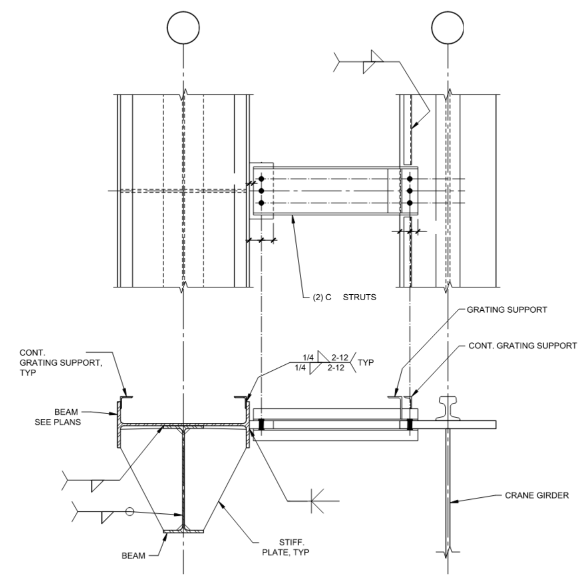
Backup Systems



HORIZONTAL TRUSS



APRON PLATE



BACKUP BEAM

- Must consider erection/fabrication tolerance in connection design… Adjustments?
- Must consider fixity of end connection under vertical deflection.
- Bolted vs welded end connections…. Must consider fatigue

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End of Part 6

Scott will discuss tolerances

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7(a) Crane Support Structure Fabrication Tolerances

- ASTM A6 Mill Tolerances and AISC *Code of Standard Practice* tolerances typically are not tight enough for crane supporting structures.
- Additionally, some tolerances applicable to crane supporting structures are not addressed by these standards.
- Tolerances should be clearly indicated in the project specification or on the project drawings.
- Tolerances should be reviewed for each project for applicability.
- Fabricator is responsible for adhering to these tolerances.

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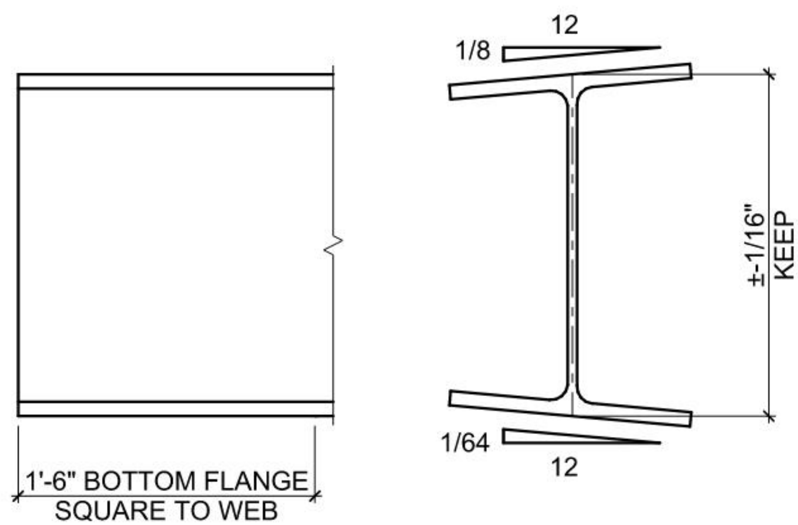
Crane-Supporting Structure Fabrication Tolerances

<u>Crane Runway Beams & Girders</u>

DG #7 Chapter 15 and Technical Report #13 Section 5.18

- Sweep: ¼” per 50 feet
- Camber: +¼” and -0” per 50 feet. Place positive camber <u>UP</u>
- Bottom Flange Flatness: ±1/32” over last 18” of girder ends
- Bottom Flange Perpendicularity: ± 1/64” per 12” of flange width
- Top Flange Perpendicularity: ± 1/8” per 12” of flange width
- Girder End Depth: ± 1/16”

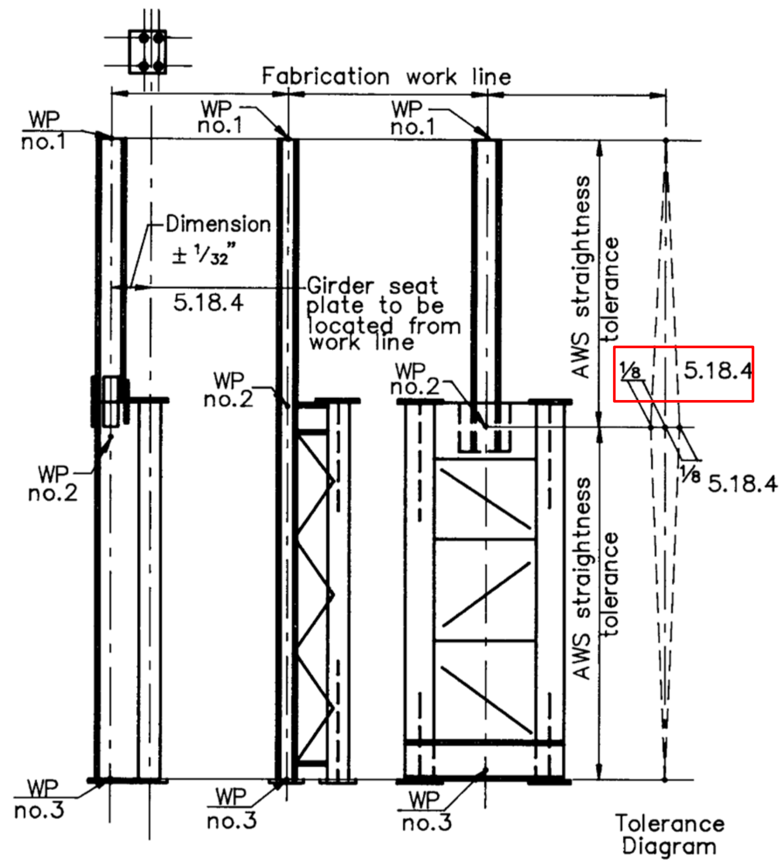


Fabrication Tolerances

Crane Runway Columns

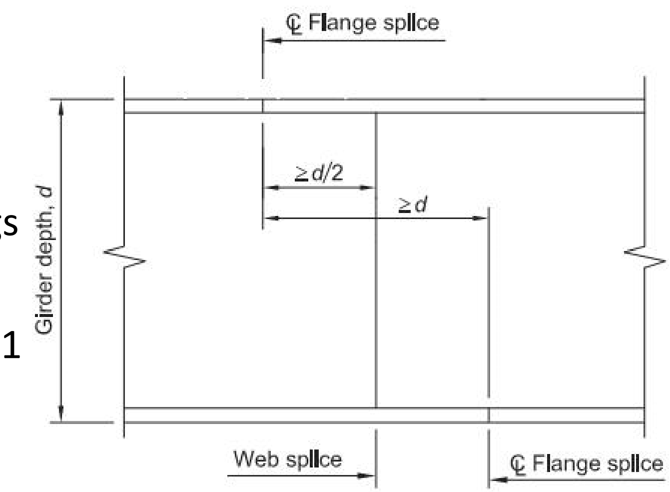
DG #7 Chapter 15 and Technical Report #13 Section 5.18

- Straightness: ±1/8” at WP2
  Between work points, *ASTM A6* mill tolerance or *AWS* straightness tolerance controls.
- Bearing Surfaces: Surfaces finished in accordance with AISC 360 Chapter M
- Column Squareness: Surface cut square to column axis within ±1/64” per 12” of column depth and width



Fabrication Considerations

- Shop splices in plate member Crane Runway Girders
  - AISC Design Guide 7 Section 14.2
  - Spices on opposite side of runway should not align
  - Communicate these requirements on Design Drawings
- Inspection Requirements
  - Crane runway beam/girder welds shall meet AWS D1.1 requirements for cyclically loaded structures.
  - This shall clearly be indicated within drawings, specifications and/or Statement of Special Inspection.
  - Material splices 100% Ultrasonic inspection at CJP welds
  - Flange to Web Welds: 100% Ultrasonic at CJP welds or 100% liquid penetrant or magnetic particle inspection at fillet welds.



Fabrication Considerations

- Fabricator Limitations
  - Long spans and heavy plate girder sections may be limited by shop crane capacity.
- Web plate vs Stiffeners
  - For common spans (<50 feet) thicker web plates more economical
  - Additional stiffener plates require material, manpower, and inspection
- Rail attachment
  - Welded rail clips commonly provided by crane supplier
  - Coordinate installation of welded base
  - Shop control & ease of access

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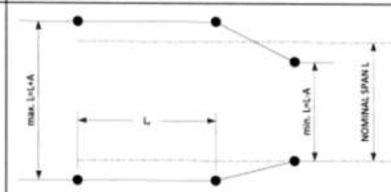
Fabrication Considerations

- Shipping restrictions
  - Subject to <u>each</u> State Ordinances
  - Typical limits are 8'-6" wide by 13'-6" tall without permit.
  - Reasonable maximum of 14 feet in width with typical permits without considerable cost (permits, escorts, road limits)
  - Shipping length maximum roughly 100 feet. However, mill roll lengths generally between 60 and 80 feet make natural splice locations.
  - Many websites available to point to individual State Ordinances.
  - And remember…

    Every rule has exceptions

7(b). Erection Tolerances, Starting with Crane Rails

- CMAA 70 provides crane rail erection tolerance requirements for:
  - Span, Straightness, Elevation, Rail-to-Rail Elevation
- AIST Technical Report #13 more stringent tolerances than similar CMAA 70 requirements. Owner & Engineer must consider **when** they are required.
- For both instances, crane rail centerline **shall not** deviate from crane runway girder centerline by a maximum of ¾*web thickness of the supporting runway girder. Note, rail attachment clips allow for +/-3/8”.

ITEM	FIGURE	OVERALL TOLERANCE		MAXIMUM RATEOF CHANGE
CRANE SPAN (L)		$L \le 50'$ $50' < L \le 100'$ $L > 100'$	$A = 3/16"$ $A = 1/4"$ $A = 3/8"$	$1/4" / 20' - 0"$
STRAIGHTNESS (B)		$B = 3/8"$		$1/4" / 20' - 0"$
ELEVATION (C)		$C = 3/8"$		$1/4" / 20' - 0"$
RAIL-TO-RAIL ELEVATION (D)		$L \le 50'$ $50' < L \le 100'$ $L > 100'$	$D = \pm 3/16"$ $D = \pm 1/4"$ $D = \pm 3/8"$	$1/4" / 20' - 0"$

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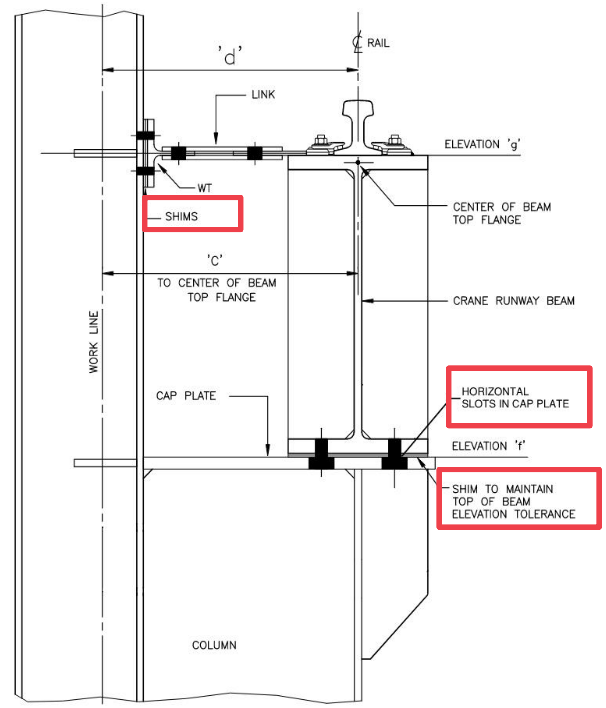
Runway Beam/Girder Erection Tolerances

- Tolerances provided by AIST Technical Report 13
  - Center of girder at top flange (c)
  - Center line of rail (d)
  - Elevation of Girder Seat (f)
  - Girder to Girder Elevation (g)
- Erection aids for meeting tolerances
  - Tie back shims
    - Detail to allow for erection & fabrication tolerance
  - Bearing seat shims
    - Detailed shims. Avoid finger shims. Consider pre-installing in shop.
  - Horizontal slots in girder to cap plate bolts
    - With account for erection & fabrication tolerance
  - Consider center punch on cap plate



DIMENSIONS	TOLERANCE
c	ERECTION TOLERANCE +/-1/8 IN.
d	ERECTION TOLERANCE is +/-3/8 IN. OR NOT GREATER THAN 0.75 x GIRDER WEB THICKNESS, WHICHEVER IS LESS.
f	ERECTION TOLERANCE +/-1/8 IN.
g	ERECTION TOLERANCE—TOP FLANGE CENTRELINE ELEVATION OF ADJACENT GIRDERS TO VARY NOT MORE THAN +/-1/16 IN.

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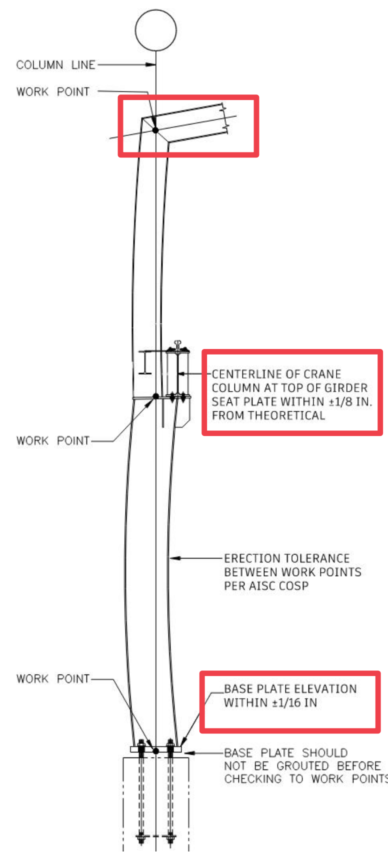
Crane-Supporting Column Erection Tolerances

- Tolerances provided by AIST Technical Report 13
  - Centerline of column at crane runway beam bearing seat
  - Base plate elevation
  - Anchor rod tolerances per ACI 318
- Erection aids for meeting tolerances
  - Sufficient grout thickness
  - Added survey targets at cap plate
  - Built-in adjustment at rafter/truss connection



Tolerance and Alignment

Turnover Survey

- EOR to suggest to Owner this be required as part of the turn-over documentation from Contractor to Owner
- Owner define fixed site benchmark used for future surveys
- Survey data for
  - Rail Alignment
  - Crane column base plate location and elevation
  - Crane column cap plate location and elevation below crane girder

Additional Erection Considerations

- Roof trusses and sway frames.
  - Erection in pairs
  - Stability during erection
- Align bottom chord bracing with vertical bracing.
  - Erection can proceed limiting additional temporary bracing
- Overhead Crane Installation
  - Coordinate temporary opening requirements

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The End

Thank you for your attention!

AISC | Questions?

Smarter.
Stronger.
Steel.

CEU / PDH Certificates

For those participating at their own connection…

- Reporting attendance is not necessary.
- Certificates will be issued based on AISC's attendance record.
- You will be receiving certificates via email from registration@aisc.org.

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Stronger.
Steel.

CEU / PDH Certificates

For those participating at one connection with a group…

- Main registrant will report attendance via an online form. (The link will be provided in an email from registration@aisc.org.)
  - Username: Same as AISC website username.
  - Password: Same as AISC website password.
- Once attendance has been reported, each group member will be receiving certificates via email from registration@aisc.org.

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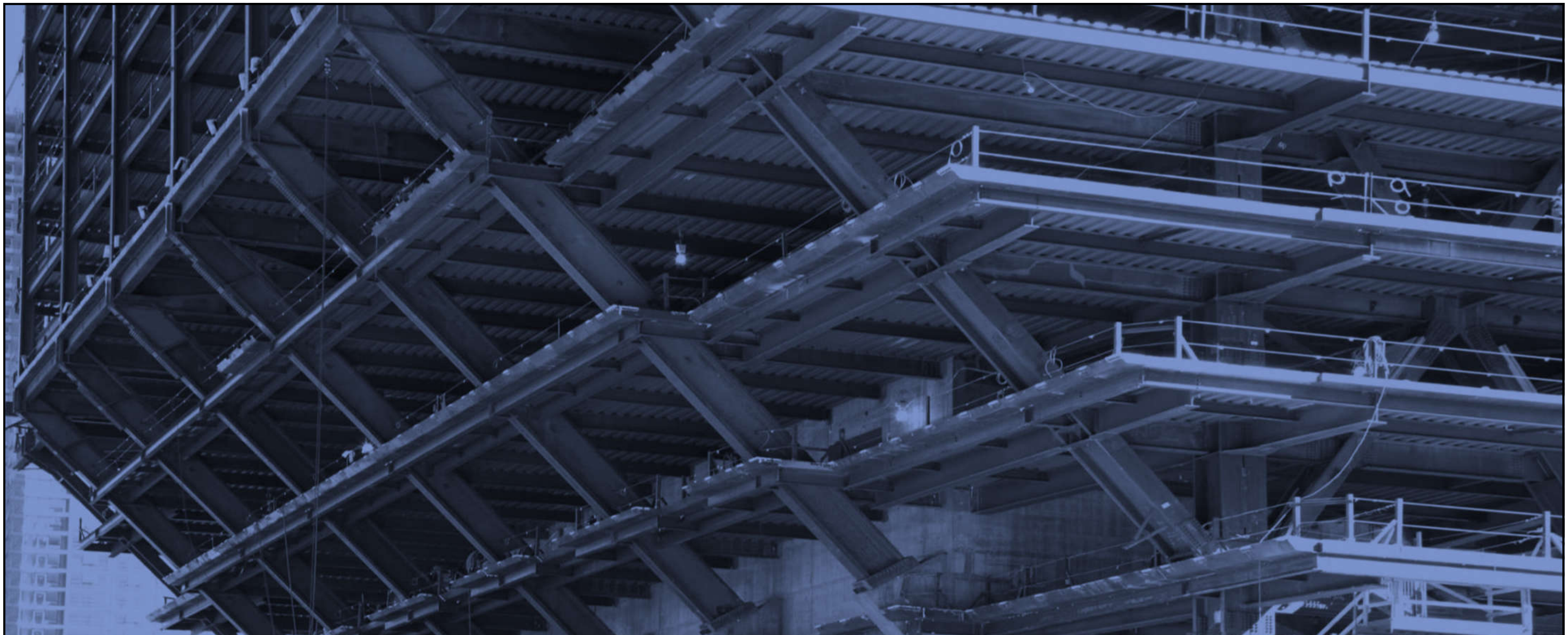

AISC | Thank you

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Steel.