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Course Description

Design of Underhung Hoist and Crane Girders
May 18, 2017

Underhung crane girders are often used in manufacturing, industrial, and power plants and have particular design challenges including member continuity, laterally unsupported flanges, fatigue of the support member, and more. Many of these challenges are not considerations in more standard structural designs. This presentation discusses the challenges encountered when designing underhung crane girders and includes a design example. Topics include:

- Support structures
- Connections between the supporting members and the runway girder
- Runway girders for underslung hoists and crane runways
- Curved monorail support beams

Learning Objectives

- Identify design guidelines and reference standards for underhung crane girders.
- Determine crane loads on runway beams.
- Identify the benefits of using different types of runway members.
- Describe fatigue design considerations for projects with underhung cranes

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Design of Underhung Hoist and Crane Beams/Girders

Presented by
Lucas Pachal, PE, SE
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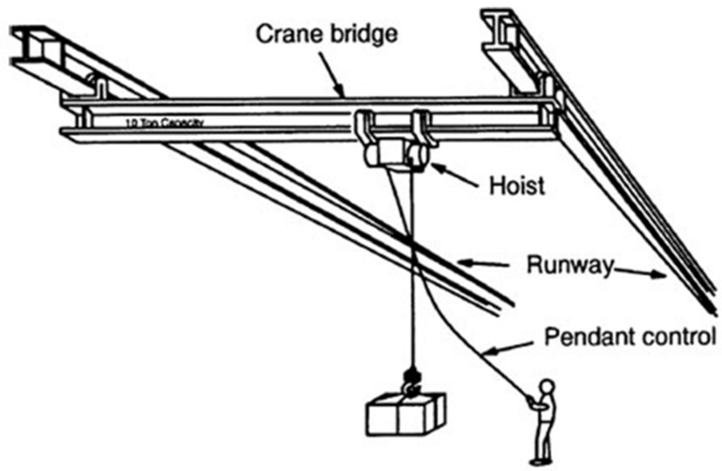
structural STEEL

Underhung Bridge Crane Schematic



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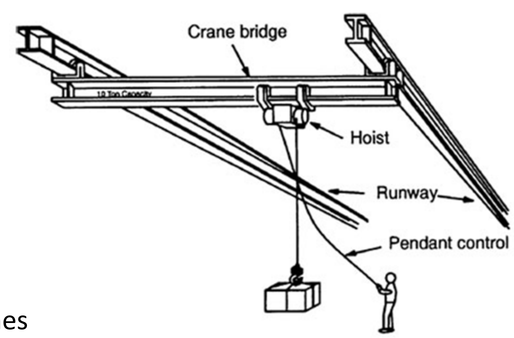
General Overview

- Common Uses:
  - Heavy Industrial
  - Manufacturing
  - Mill Buildings
  - Petrochemical
  - O&M Facilities
- Important Notes:
  - Similar to monorails
  - Top-running bridge cranes have similarities but also significant differences



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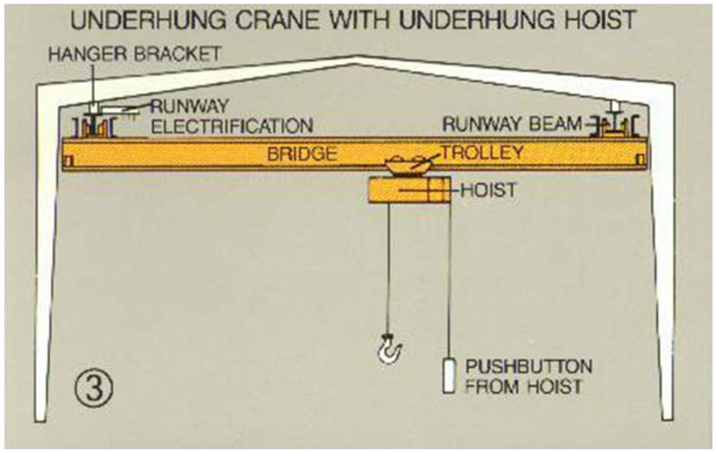
Underhung Bridge Crane System



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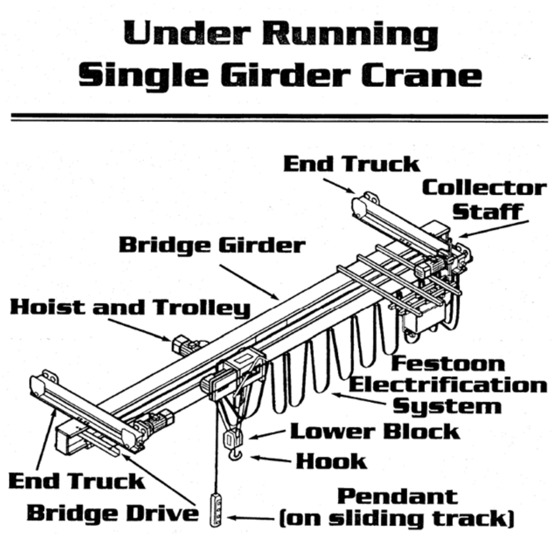
Underhung Bridge Crane System



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Underhung Bridge Crane System

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Underhung Bridge Crane System

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Underhung Bridge Crane Systems

- ***Single Girder Bridge Crane***
  - ≤10 Ton Capacity
  - ≤175 Foot Span (Multi-Runway Cranes)
- ***Double Girder Bridge Crane***
  - ≤ 15 Ton Capacity
  - ≤ 200 Foot Span (Multi-Runway Cranes)
- Capacity possible up to 25T
- Practical limit of 15T
- Typical capacities of 1T to 7.5T

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Underhung Bridge Cranes - Overview

- Introduction
- Design Guidelines And Reference Standards
- Design Considerations
- Typical Construction Details
- Example Problems
- Related Topics
- Enclosed Track And Patented Track Systems
- Summary, Conclusions And Lessons Learned
- References And Technical Resources

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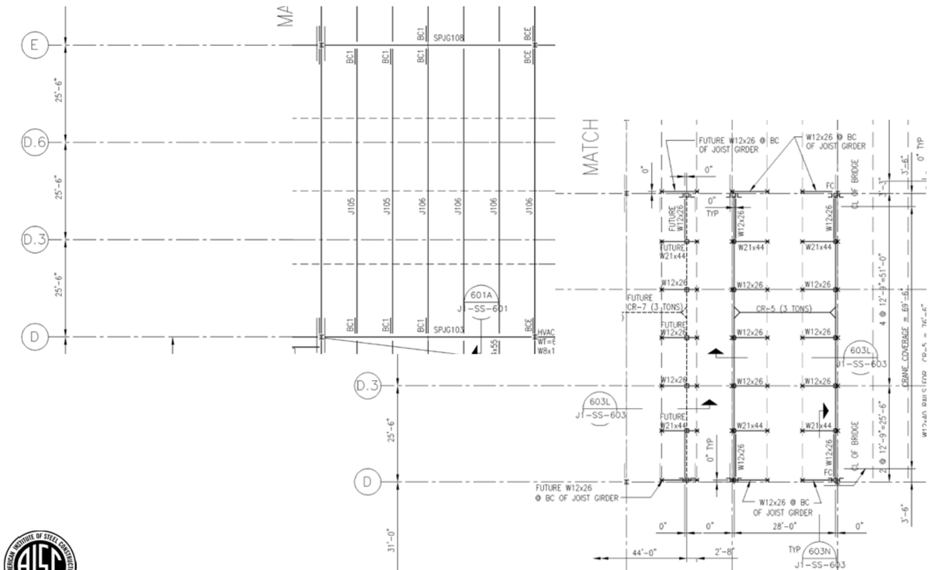
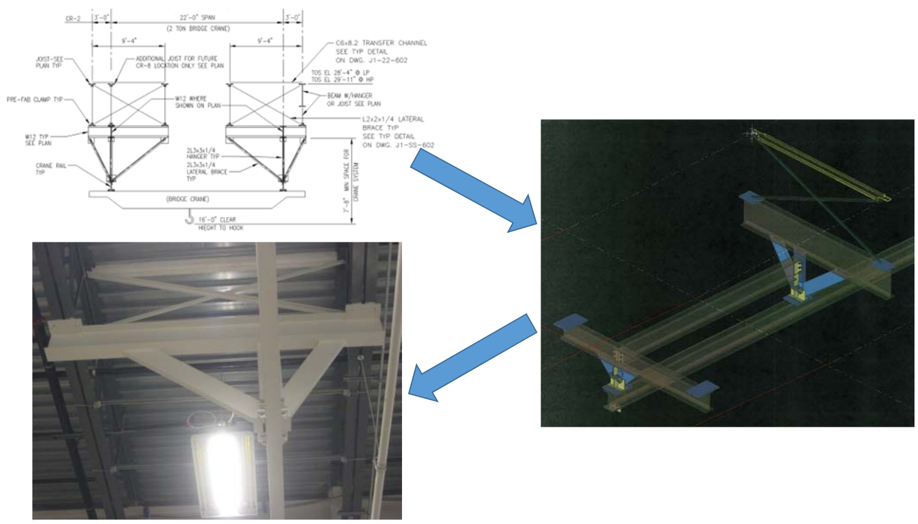
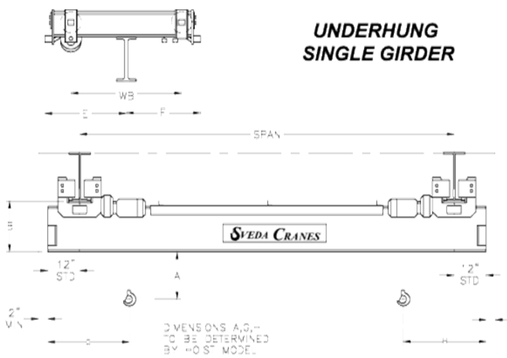
Introduction-Typical Framing Plan



Introduction-Joist Supported Crane Systems



Introduction-Underhung Bridge Crane Systems



Cap. Ton	Span	Wheel Tread Dia.	WB	B	E	F	Bridge WT.	Maximum Wheel Load
	15'-0"			11 3/8"			1,650	2,615
	20'-0"			11 3/8"			1,935	2,685
	25'-0"		4'-9"	13 3/8"	30 7/8"	30 7/8"	2,370	2,795
2	30'-0"	4"		13 3/8"			2,720	2,880
	35'-0"			16 3/8"			3,320	3,030
	40'-0"			16 3/8"			3,890	3,290
	45'-0"		6'-3"	19 3/8"	42 1/8"	42 1/8"	4,890	3,540
	50'-0"			21 3/8"			5,780	3,835
	15'-0"			11 3/8"			1,700	3,625
	20'-0"			13 3/8"			2,060	3,715
	25'-0"		4'-9"	16 3/8"	30 7/8"	30 7/8"	2,650	3,870
3	30'-0"	4"		16 3/8"			3,050	3,970
	35'-0"			19 3/8"			4,050	4,230
	40'-0"			19 3/8"			4,390	4,295
	45'-0"		6'-3"	19 3/8"	42 1/8"	42 1/8"	5,480	4,695
	50'-0"			21 3/8"			6,480	4,820
	15'-0"			16 3/8"			2,180	6,005
	20'-0"			16 3/8"			2,430	6,155
	25'-0"		4'-9"	16 3/8"	32"	32"	2,750	6,240
5	30'-0"	5"		19 3/8"			3,650	6,465
	35'-0"			19 3/8"			4,550	6,780
	40'-0"			21 3/8"			5,400	7,000
	45'-0"		6'-3"	21 3/8"	43 1/4"	43 1/4"	6,410	7,305
	50'-0"			25 3/8"			7,580	7,445
	15'-0"			16 3/8"			2,570	9,160
	20'-0"			19 3/8"			3,120	9,230
	25'-0"		4'-9"	19 3/8"			3,510	9,380
7 1/2	30'-0"	6"		19 3/8"	33 1/4"	33 1/4"	4,010	9,505
	35'-0"			21 3/8"			4,890	9,825
	40'-0"			25 3/8"			6,350	10,090
	45'-0"		6'-3"	25 3/8"	44 1/2"	44 1/2"	7,010	10,255
	50'-0"			25 3/8"			8,980	10,820
	15'-0"			19 3/8"			2,820	11,695
	20'-0"			19 3/8"			3,140	11,835
	25'-0"		4'-9"	21 3/8"	33 1/4"	33 1/4"	3,850	11,965
10	30'-0"	6"		21 3/8"			4,370	12,145
	35'-0"			25 3/8"			5,780	12,495
	40'-0"			25 3/8"			6,350	12,640
	45'-0"		6'-3"	25 3/8"	44 1/2"	44 1/2"	8,250	12,185
	50'-0"			25 3/8"			9,280	13,295

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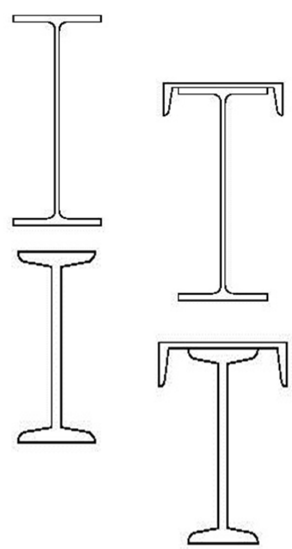
Introduction-Types of Runway Members

- W-Shape
- W-Shape + Cap Channel
- S-Shape
- S-Shape + Cap Channel
- Patented Track
- Enclosed Track



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Design Guidelines and Reference Standards

- IBC 2015
- ASCE 7-10 (ASCE 7-16)
- ANSI/AISC 360-10 (ANSI/AISC 360-16)
- ASME NUM-1 (2006)
- AISC Design Guide No. 7 "Industrial Buildings" (2004)
- AISC Design Guide No. 9 "Torsion Analysis" (1997)
- AIST Technical Report No. 13 "Design of Mill Buildings" (2003)
- CMAA 74-2015 "Specification for Top Running and Under Running Single Girder Electric Overhead Cranes Utilizing Under Running Trolley Hoist"
- AISC Free Downloads (www.aisc.org/publications)
  - AISC 360
  - Design Guides (free for members)

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CMAA 74 – 2015

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Design Considerations

Critical Design Questions?

- How many cranes on a runway?
- How many cranes can be expected to operate simultaneously?
- How often will cranes lift their maximum loads?
- What allowance should be made for impact?
- What lateral thrusting forces can occur simultaneously?
- How stiff is the roof structure?
- Will facility operate with maximum snow loads present?
- What is the distance from floor to the lowest overhead obstruction?
- What objects (i.e. light fixtures, suspended piping, etc.) will project below the roof structure?

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CMAA Service Classifications

SERVICE CLASS	DUTY SERVICE	DESCRIPTION
A	Standby or Infrequent Service	Slow speeds with long, idle periods between lifts
B	Light Service	Loads vary from no load to occasional full rated loads with 2 to 5 lifts per hour, averaging 10 feet per lift
C	Moderate Service	Loads averaging 50 percent of rated capacity with 5 to 10 lifts per hour, averaging 15 feet, not over 50 percent of the lifts at rated capacity
D	Heavy Service	High speeds with loads approaching 50 percent of the rated capacity handled constantly during the work period. 10 to 20 lifts per hour averaging 15 feet, not over 65 percent of the lifts at rated capacity

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CMAA Service Classifications

- CMAA 74 Load Classes
  - L_1 = Exceptionally loaded at rated capacity, normally very light loads
  - L_2 = Rarely loaded at rated capacity, normally approx. 1/3 of rated load
  - L_3 = Fairly frequently loaded at rated capacity, normally between 1/3 and 2/3 of rated load
  - L_4 = Regularly loaded near rated capacity
- CMAA 74 Load Cycles
  - Loading Condition 1: 20,000 to 100,000 load cycles
  - Loading Condition 2: 100,000 to 500,000 load cycles
  - Loading Condition 3: 500,000 to 2,000,000 load cycles
  - Loading Condition 4: greater than 2,000,000 load cycles

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CMAA Service Classifications

TABLE 2.6-1

DEFINITION OF CMAA CRANE SERVICE CLASS
IN TERMS OF LOAD CLASS AND LOAD CYCLES

LOAD CLASS	LOAD CYCLES				k = MEAN EFFECTIVE LOAD FACTOR
	N_1	N_2	N_3	N_4	
L_1	A	B	C	D	0.35 - 0.53
L_2	B	C	D		0.531 - 0.67
L_3	C	D			0.671 - 0.85
L_4	D				0.851 - 1.00
	Irregular occasional use followed by long idle periods.	Regular use in intermittent operation.	Regular use in continuous operation.	Regular use in severe continuous operation.	

LOAD CLASSES

L_1= Cranes which hoist the rated load exceptionally and normally, very light loads.

L_2= Cranes which rarely hoist the rated load, and normal loads of about 1/3 of the rated load.

L_3= Cranes which hoist the rated load fairly frequently and normally, loads between 1/3 and 2/3 of the rated load.

L_4= Cranes which are regularly loaded close to the rated load.

LOAD CYCLES

N_1= 20,000 to 100,000 cycles

N_2= 100,000 to 500,000 cycles

N_3= 500,000 to 2,000,000 cycles

N_4= Over 2,000,000 cycles

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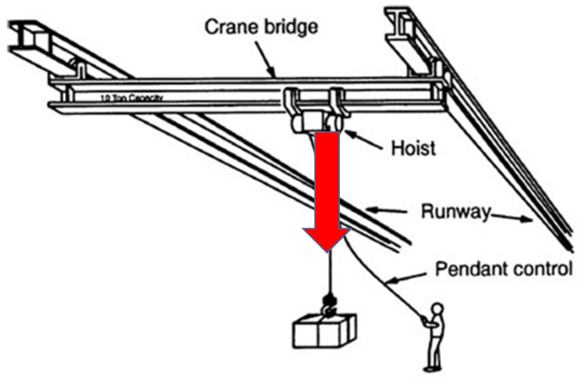
Design Considerations – Loads

- Vertical impact loads – oriented vertically and caused by inertial effect of loaded hoist



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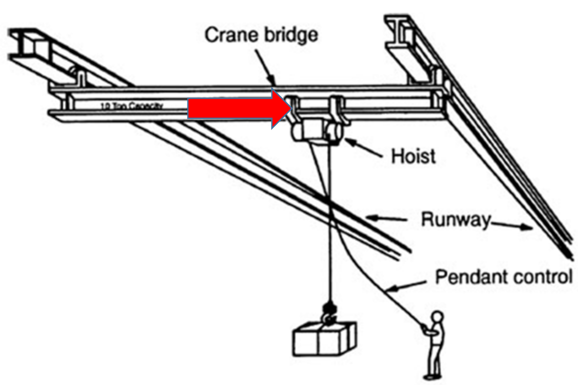
Design Considerations – Loads

- Lateral crane loads – oriented perpendicular to the crane runway and applied at the top of the bottom flange



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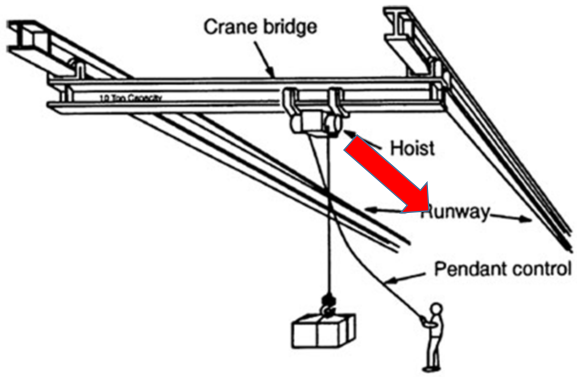
Design Considerations – Loads

- Longitudinal crane loads – oriented parallel to the crane runway and applied at the top of the bottom flange



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Design Considerations – Loads

Information from crane manufacturer is <u>essential</u> in determining the proper design forces

Installation of runways → additional load considerations

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Crane Loads on Runway Beams
(IBC 2015 and ASCE 7-10)

- Maximum Wheel Load
  - Rated capacity + Bridge weight + Trolley/hoist weight
- Vertical Impact = 0%-25% (varies based on usage)
  - Percentage of maximum wheel load
- Lateral Side Thrust = 20% (60% assigned to one side)
  - Percentage of rated capacity + hoist weight + trolley weight
  - Acts horizontally at traction surface of runway beam (top of bottom flange) perpendicular to the beam
- Longitudinal Tractive Force = 10%
  - Percentage of maximum wheel load
  - Acts horizontally at traction surface of runway beam (top of bottom flange) parallel to the beam
- End Stop Force
  - Rigid end stops or buffer end stops

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Load Combinations

- ASCE 7-10: Silent in regards to crane load combos
- IBC 2015: Crane hook loads need not be combined with roof live load or with more than three-fourths of the snow load or one-half of the wind load
- ASD Combinations per AIST Technical Report No. 13
  - For members designed for repeated loads (i.e. fatigue):
    - $D + C_{vs} + 0.5C_{ss} + C_i$
  - For all members:
    - $D + L + (L_r \text{ or } R \text{ or } S) + C_{vs} + C_i + C_{ss} + C_{ls}$ (single crane)
    - $D + L + (L_r \text{ or } R \text{ or } S) + C_{vm} + C_{ss} + C_{ls}$ (multiple cranes)
    - $D + L + (L_r \text{ or } R \text{ or } S) + C_{vs} + C_i + W$ (wind load)
    - $D + L + (L_r \text{ or } R \text{ or } S) + C_{vs} + C_i + C_{ss} + 0.5W$ (wind load)
    - $D + L + (L_r \text{ or } R \text{ or } S) + C_{vs} + C_i + 0.67C_{bs}$ (bumper load)
    - $D + L + (L_r \text{ or } R \text{ or } S) + C_d + E$ (seismic load)

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Load Combinations – Notations

- C_{vs} = vertical loads due to a single crane in one aisle only
- C_{ss} = side thrust due to a single crane in one aisle only
- C_i = vertical impact due to a single crane in one aisle only
- C_{ls} = longitudinal traction due to a single crane in one aisle only
- C_{vm} = vertical loads due to multiple cranes
- C_{bs} = bumper impact due to a single crane in one aisle only at 100% speed
- C_d = dead load of all cranes, parked in each aisle, positioned for maximum seismic effects

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Underhung Runway Design Criteria

- Runway beams shall be straight, parallel and at a constant elevation
- Must meet applicable tolerances given in CMAA 74 Table 1.4.1-1 for crane runways (see next slide)
  - CMAA and OSHA also require crane-to-building tolerances (horizontal and vertical clearances)
- Deflection limitations
  - Vertical Deflection: **L/450** based on maximum wheel without impact
  - Lateral Deflection: **L/400** based on maximum side thrust
  - Angular Twist: Per crane manufacturer recommendations, actual design conditions, etc.

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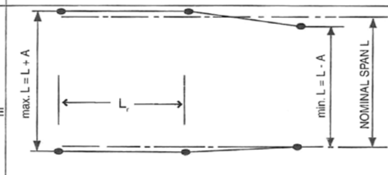
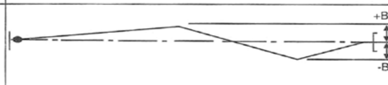
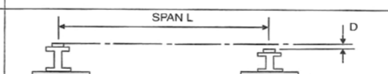
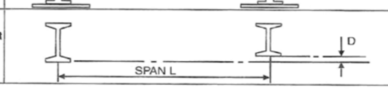
CMAA 74-2015 Runway Tolerances

TABLE 1.4.1-1

ITEM	FIGURE	OVERALL TOLERANCE	MAXIMUM RATE OF CHANGE
CRANE SPAN (L) MEASURED AT CRANE WHEEL CONTACT SURFACE		L ≤ 50′ A = 3/16″ L > 50′ ≤ 100′ A = 1/4″ L > 100′ A = 3/8″	1/4″ IN 20′-0″
STRAIGHTNESS (B)		B = 3/8″	1/4″ IN 20′-0″
ELEVATION (C)		C = 3/8″	1/4″ IN 20′-0″
TOP RUNNING TRANSVERSE RAIL TO RAIL ELEVATION (D)		L ≤ 50′ D = ± 3/16″ L > 50 ≤ 100′ D = ± 1/4″ L > 100′ D = ± 3/8″	N/A
TRANSVERSE GIRDER TO GIRDER ELEVATION UNDER RUNNING (D)			

Design Considerations – Unbraced Flanges

- Unbraced Compression Flange
  - Consider adding a cap channel for longer spans (>25 ft support spacing) and/or heavy bridge cranes
- Unbraced Tension Flange
  - Consider LTB if crane runway beam/girder is continuous
- Important Notes
  - Don’t assume that cap channel is the solution
  - Tradeoffs are extra weight of channel & labor to weld section
  - Recognize that under-running crane runway design is a different problem than top-running crane runway design

Design Considerations – Continuity

- Continuity Issues – Simple or Continuous Spans?
  - Simple Spans
    - Position girder splices carefully to force simple condition
    - Don't introduce unintentional continuity
    - Generally not the most efficient design
  - Continuous Spans
    - More common method of analysis and design
    - Minimizes number of expensive crane girder splices
    - Generally higher C_b values and lower deflection
    - Must consider LTB of girder bottom flange at supports. Treat similar as a cantilevered condition. Must locate inflection point
    - Must consider tensile fatigue stress of girder top flange at structure supports. Use clamped conn's to avoid stress risers

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Design Considerations – Load Height

- Top Flange Loading
  - Top flange loading causes an additional moment about the shear center which is additive to the twist rotations of the beam
  - Buckling resistance is decreased
- Bottom Flange Loading
  - Unbraced crane runway beam loaded on bottom flange has increased resistance to buckling compared to a similar beam loaded on top flange
  - Moment is opposite to the twist rotations of the beam
  - Resists tendency of the beam to buckle
  - Bottom flange loaded condition addressed via adjustment to the bending coefficient C_b

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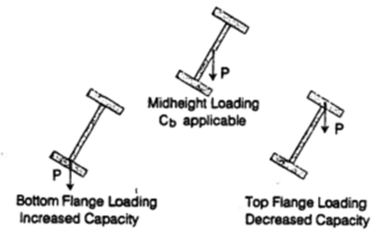
Design Considerations – Load Height



LOAD HEIGHT EFFECTS on M_{cr} (SSRC - 4th Ed.)

A modified version of C_b is used to account for load height effects (C_b^*):

Top Flange Loading: $C_b^* = C_b / B$

Load at Shear Center: $C_b^* = C_b$

Bottom Flange Loading: $C_b^* = C_b B$

B is defined in the following expressions:

Point Load at Midspan: $B = 1 - 0.180\,W^2 + 0.649\,W$

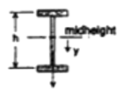
Uniform Distributed Load: $B = 1 - 0.154\,W^2 + 0.535\,W$

W, the "beam parameter," is defined as: $W = \frac{\pi}{L_b}\sqrt{\frac{E\,C_w}{G\,J}}$

Modification to SSRC - 4th Ed. Load Height Equations

Beam	Distributed Load	P @ Midspan
Long Slender Beam - W = 0.5	B = 1.23	B = 1.28
Short Stocky Beam - W = 1.75	B = 1.46	B = 1.58

Use B = 1.4 for load height effects on all beams



For Load height effects with transverse loading applied at any height on the cross-section:

$$C_b^* = (1.4)^{(2y/h)} C_b$$

$$C_b = \frac{12.5M_{max}}{2.5M_{max} + 3M_1 + 4M_2 + 3M_3}$$

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Design Considerations – Cantilevers

- Cantilevered conditions result in special condition
- Unbraced bottom flange of beam needs attention
- Common Problem:
  - Tip of the crane beam extends outside the building such that deliveries can be hoisted up and brought into building
  - Inside the building the beam is over a mechanical space and is supported by roof beams
  - Hoisting device has wheels that run on the bottom flange of the beam so no stiffeners or bracing can be provided to the bottom flange of the cantilever beam without interfering with the operation of the crane device

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Design Considerations – Cantilevers

- <u>Proposed Solution (from Nethercot):</u>
  - Use of K_c and C_b factors
  - Identifies K_c values that were derived assuming C_b = 1
  - C_b = 1 should be used when using the K_c values from Figure shown on next slide
  - Note that Nethercot has published work in which K_c = 1 and the C_b factor is used to adjust for restraint and loading conditions at the cantilever. However, using an effective length factor seems to be more intuitive
  - March 2005 Modern Steel Construction article

https://www.aisc.org/globalassets/modern-steel/steel-interchange/2005/2005v03_si_web.pdf

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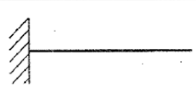
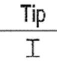
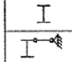
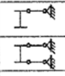
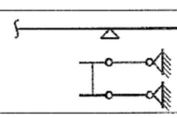
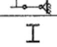
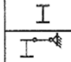
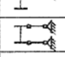
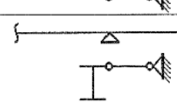
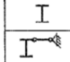
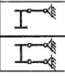
Design Considerations – Cantilevers

Figure 1
K_c Values for Cantilevers

Restraint Continuous		K_c	
Cantilever Support	Tip	Top Flange Loading	All Other Cases
		1.4	0.8
		1.4	0.7
		0.6	0.6
		2.5	1.0
		2.5	0.9
		1.5	0.8
		7.5	3.0
		7.5	2.7
		4.5	2.4

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Design Considerations – Cantilevers

- Sample Problem:
  - Loading that is NOT top flange loading
  - Root of the cantilever beam (cantilever support) is only braced at the top flange
  - Tip is unbraced at the top and bottom
  - K_c value of 3.0 is selected and beam designed accordingly
  - Straight forward way covers most possible restraint conditions and loading conditions and is conservative
- Proposed method lends to expansion to cover other problematic areas such as:
  - Continuous beams
  - Laterally unsupported beams with varying end restraints

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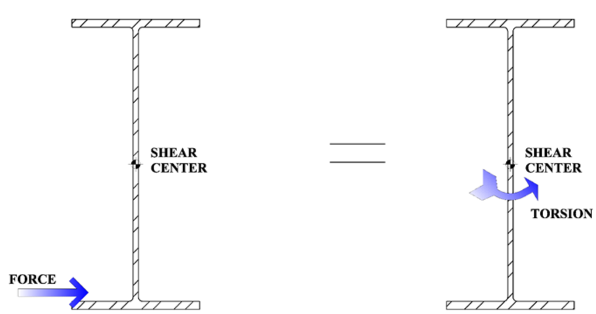
Design Considerations – Torsion

- Lateral side thrust load acting on top of bottom flange induces torsion on section
- Stresses due to torsion additive to all other flexural and shear stresses



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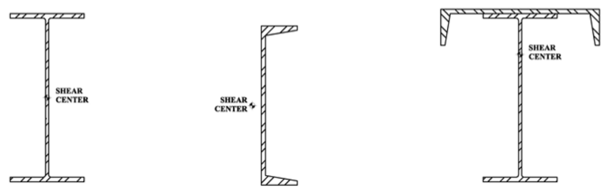
Design Considerations – Torsion

- Shear Center (Center of Twist)
  - A point on a line parallel to the axis of a beam through which any transverse force must be applied to avoid twisting of the section
  - Beam section will rotate when the resultant of the internal shearing forces is not collinear with the externally applied force
  - When beam member is loaded transversely in the plane of the axes it will bend without twisting
  - Coincides with centroid for doubly symmetric sections
  - Does not coincide for singly symmetric sections (W+C)



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Design Considerations – Torsion

- Two principle components of torsion
  - Pure torsion (St. Venant torsion)
  - Warping torsion
- Most critical stresses to consider for W sections are flange normal stresses resulting from warping of the cross section (i.e. warping normal stresses)
- Torsional shear stresses (pure torsion shear and warping shear) usually not a major factor
- Use AISC Specification Chapter H for Combined Loading
- AISC Design Guide 9 – “Torsion Analysis of Steel Structures”

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Design Considerations – Torsion

- Torsional section properties from AISC Manual or calculate for built-up shapes (reference standards, mechanics books, etc.)
- Check fatigue stresses
  - Full vertical load including impact
  - One-half side thrust load
- Should review angular twist of section under side thrust load
  - Computer analysis
  - AISC Design Guide No. 9 - "Torsion Analysis of Steel Structures"
- Use analogy between torsion and flexure
  - Easy way to include torsional effects
  - Intuitive and user friendly
  - Conservative - Overestimates warping normal stresses by 10-30%

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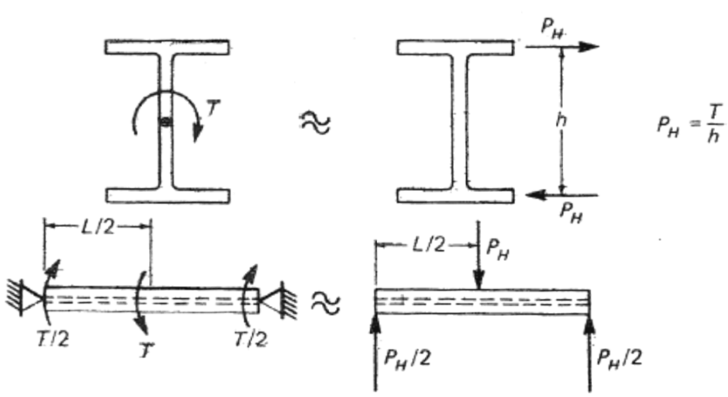
Analogy Between Torsion and Flexure



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Design Considerations – Fatigue

- **ANSI/AISC 360-10 Appendix 3 - Design For Fatigue**
  - "…Applies to members and connections subject to high cycle loading [20,000 cycles] within the elastic range of stresses of frequency and magnitude sufficient to initiate cracking and progressive failure…"
  - Applies to certain components in crane buildings (e.g. runway girders or monorails, bracing, tie-backs, hangers, connections, etc.)
  - Stress range is numerical sum of maximum repeated tensile and compressive stresses or shearing stresses resulting from application of repeated service-level live load
  - Fatigue stresses evaluated at service level

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Design Considerations – Fatigue

- **ANSI/AISC 360-10 Appendix 3 - Design For Fatigue**
  - No evaluation of fatigue resistance required if number of repetitive load cycles less than 20,000 (N=Design Life Stress Range Fluctuations)
  - No evaluation of fatigue resistance required if live load stress range is less than the Threshold Stress Range F_{TH} - maximum stress range for indefinite design life. See AISC Appendix 3 Table A-3.1.
  - No evaluation if stress ranges are completely in compression
  - No evaluation for transient wind loads or seismic loads

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Design Considerations – Fatigue

- Different types of bridge crane system ratings based on expected service
- CMAA 74 Crane Service Classifications (A, B, C, or D)
  - Service classes E and F (severe service) not applicable for underhung cranes
  - Related to Load Classes and Load Cycles

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Design Considerations – Fatigue

- AISC Stress Categories (A, B, B', C, D, E or E')
  - Provided in Appendix 3 Table A-3.1
  - Organized into 8 sections dependent on general conditions for fatigue design including base material & welded/bolted connections
- Determine Design Cyclic Stress Range
- AISC Threshold Fatigue Stress Range F_{TH}
  - Maximum fatigue stress range for indefinite design life
- AISC Allowable Fatigue Stress Range F_{SR}
  - Allowable fatigue stress range
  - Based on number of load cycles (stress range fluctuations) and stress category
  - Greater than or equal to F_{TH}

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Fatigue Design – AISC 14th Edition Spec

**TABLE A-3.1
Fatigue Design Parameters**

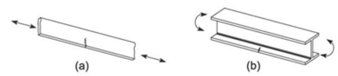
Description	Stress Category	Constant C_f	Threshold F_{TH} ksi (MPa)	Potential Crack Initiation Point
SECTION 1 – PLAIN MATERIAL AWAY FROM ANY WELDING				
1.1 Base metal, except noncoated weathering steel, with rolled or cleaned surface. Flame-cut edges with surface roughness value of 1,000 μin. (25 μm) or less, but without reentrant corners.	A	250×10^8	24 (165)	Away from all welds or structural connections
1.2 Noncoated weathering steel base metal with rolled or cleaned surface. Flame-cut edges with surface roughness value of 1,000 μin. (25 μm) or less, but without reentrant corners.	B	120×10^8	16 (110)	Away from all welds or structural connections

**TABLE A-3.1 (continued)
Fatigue Design Parameters**

Illustrative Typical Examples

SECTION 1 – PLAIN MATERIAL AWAY FROM ANY WELDING

1.1 and 1.2



(a) (b)

Fatigue Design – AISC 14th Edition Spec

3.3. PLAIN MATERIAL AND WELDED JOINTS

In plain material and welded joints the range of *stress* at *service 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:

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

$$F_{SR} = \left(\frac{C_f \times 329}{n_{SR}}\right)^{0.333} \geq F_{TH} \quad \text{(S.I.)} \qquad \text{(A-3-1M)}$$

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
= number of stress range fluctuations per day × 365 × years of design life

Fatigue Design – AISC 14th Edition Spec

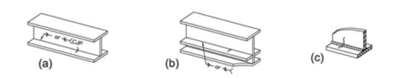
TABLE A-3.1 (continued)
Fatigue Design Parameters

Description	Stress Category	Constant C_f	Threshold F_{TH} ksi (MPa)	Potential Crack Initiation Point
SECTION 3 – WELDED JOINTS JOINING COMPONENTS OF BUILT-UP MEMBERS				
3.1 Base metal and weld metal in members without attachments built up of plates or shapes connected by continuous longitudinal complete-joint-penetration groove welds, back gouged and welded from second side, or by continuous fillet welds.	B	120×10^8	16 (110)	From surface or internal discontinuities in weld away from end of weld
3.2 Base metal and weld metal in members without attachments built up of plates or shapes, connected by continuous longitudinal complete-joint-penetration groove welds with backing bars not removed, or by continuous partial-joint-penetration groove welds.	B′	61×10^8	12 (83)	From surface or internal discontinuities in weld, including weld attaching backing bars

TABLE A-3.1 (continued)
Fatigue Design Parameters

Illustrative Typical Examples

SECTION 3 – WELDED JOINTS JOINING COMPONENTS OF BUILT-UP MEMBERS

3.1


3.2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Design Considerations – Fatigue

- **Fatigue Design Recommendations**
  - Interview client and understand the expected use and overall service life of crane system
  - Determine load cycles (state on structural drawings)
  - Determine CMAA crane service class (state on structural drawings)
  - Recommend calculating F_{SR} for given stress category and number of repetitive load cycles
  - Can simplify design by limiting stress range to less than F_{TH} but may not result in most efficient design
  - Some educated clients may want stress ranges limited to F_{TH}
- **Avoid the following conditions**
  - Avoid notches and/or holes in tension flange
  - Avoid welded cover plates on tension flange
  - Avoid welded or bolted attachments
  - Avoid transverse fillet welds to tension flange

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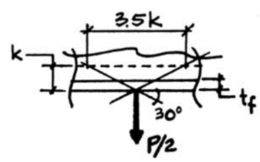
Local Girder Effects

- Additional check required under wheel loads
- Biaxial stress condition results
- Bottom part of the crane runway girder must be checked for:
  - Tension in the web
  - Bending of the bottom flange
- Length of resistance is 3.5k – assuming 30° angle (45° more conservative per AIST)
- A typical underhung crane will be supported by 2 pairs of wheels at each end so each wheel will support $P_{END}/4$ of the load.
- Two wheels cause the web tension, so the load at each point is P/2.



$$f_t = \frac{P_{END}}{2A} = \frac{P_{END}}{(2t_w)(3.5k)} = \frac{P_{END}}{(7k)t_w}$$

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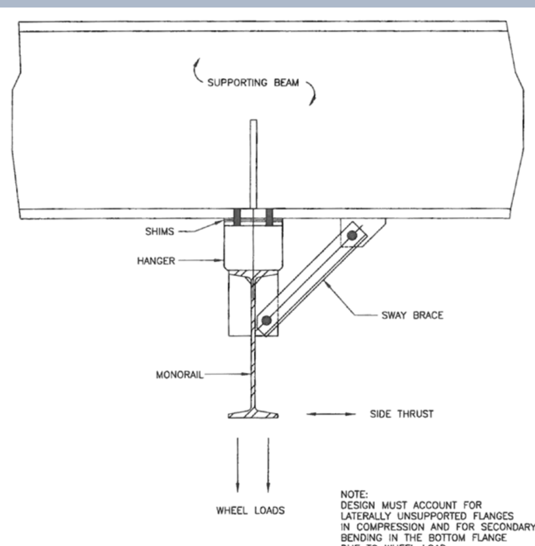
Underhung Crane - Typical Support Detail



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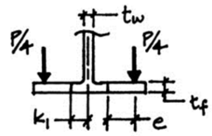
Local Flange Bending

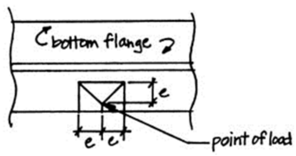
- To determine bending in the bottom flange, the location of the wheels with respect to the web is critical ("e" distance in figure)



$$S = \frac{bd^2}{6} = \frac{et_f^{\,2}}{3}$$

$$M = \frac{eP_{END}}{4}$$

- 2e = length of flange included in the bending resistance



$$f_b = \frac{M}{S} = \frac{3eP_{END}}{4et_f^{\,2}} = \frac{0.75P_{END}}{t_f^{\,2}}$$

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Local Flange Bending

- A similar and more extensive procedure for calculating the local flange bending is available in CMAA 74 – 2015 Section 3.3.2.6
- This procedure is typical for design of a crane runway with an underhung trolley/hoist

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Quiz Question 1

For underhung cranes, how are longitudinal crane loads applied to the runway beam? Choose all that apply.

A. At the top of the bottom flange
B. At the bottom of the bottom flange
C. Perpendicular to crane runway
D. Parallel to crane runway
E. As a % rated capacity + hoist + trolley weights
F. As a % maximum wheel load

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Crane Runway Girder Details

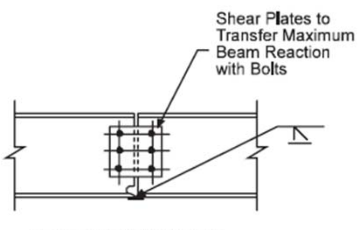

Fig. 22.1 Underhung Crane Beam Splice

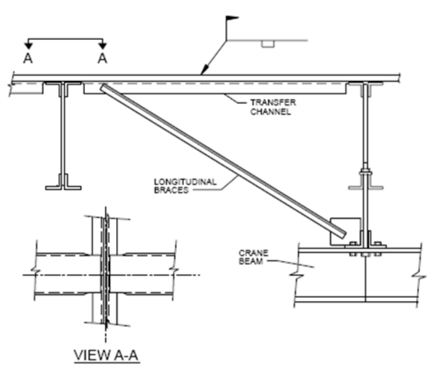

Fig. 5.2.3 Longitudinal Crane Brace

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Crane Runway Girder Details - Splices

- Crane runway beams usually continuous span
- Minimize splices whenever possible
- Introduce splices where required due to material availability, installation, etc.
- Splice near vertical support but not at support
- Smooth running surface required at bottom flange. Usually accomplished with CJP weld ground smooth

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Crane Runway Girder Details

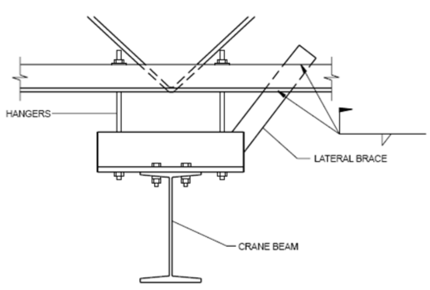

Fig. 5.2.1 Crane Runway Hanger

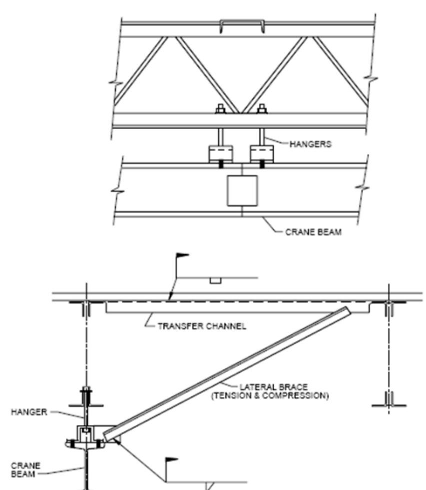

Fig. 5.2.2 Crane Runway Hanger

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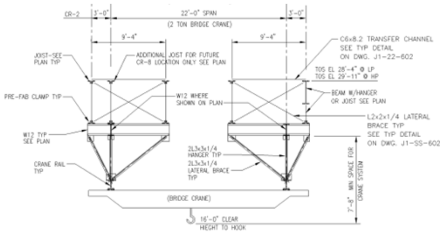
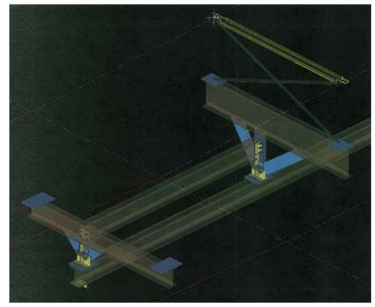
Joist Supported Crane Systems – Details





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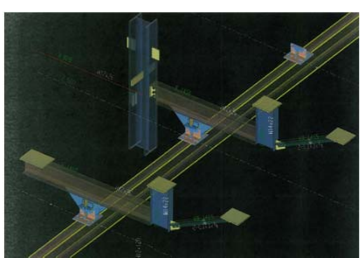
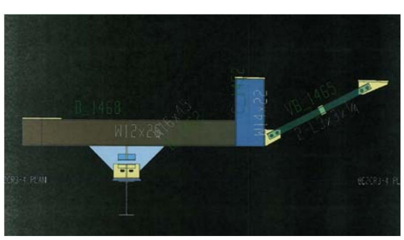
Joist Supported Crane Systems – Details





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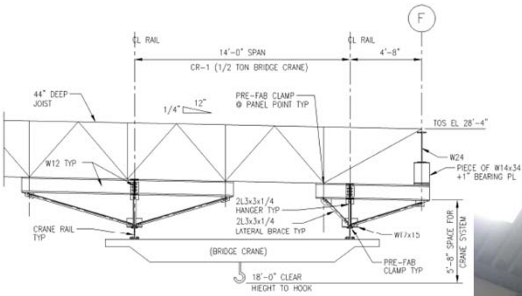
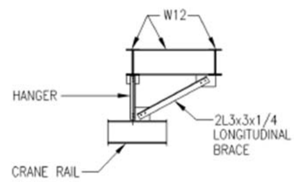
Joist Supported Crane Systems – Details





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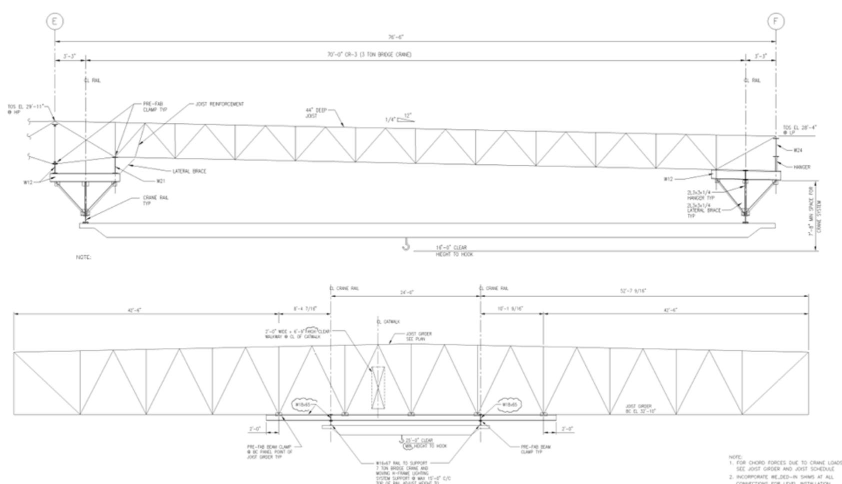
Joist Supported Crane Systems – Details



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Long Span Steel Joists - Lessons Learned

- Supporting joist deflection limits
  - Crane wheel loads without impact: L_r/450 (CMAA 74-2015)
  - Roof snow load: L_r/360 (recommendation)
- Locate crane runway support points so that the differential deflection between successive supports under crane wheel loads without impact is limited to ¼" in 20'-0" (recommendation)
- Crane runways parallel to joists
  - Consider two or more joists to support each runway – load sharing to control deflections
- Locate crane runways symmetrical to supporting joists to avoid differential deflection and rotation of runway beams
- Provide lateral and longitudinal bracing for runways and support system to transfer loads to top chord of joists and roof deck
- Provide for vertical, lateral and longitudinal adjustments in detailing the support systems, for rail alignment

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Long Span Steel Joists - Lessons Learned

- Detail support system for height adjustment from rail to sloping bottom chord. Can incorporate shims for a level installation for smooth crane operation.
- Specify joist design, detailing and fabrication to comply with fatigue loading corresponding to the Class of Service (Class A – Standby or Infrequent Service to Class D – Heavy Service) and number of load cycles
  - There are no SJI design standards for fatigue loading
  - Can use AISC recommendations in the absence of other criteria (ANSI/AISC 360-10 Appendix 3)
- Installation Contractor shall meet required tolerances - vertical, lateral, longitudinal, differential, straightness
- Beneficial to work with the selected Crane Manufacturer & Joist Supplier to agree upon the criteria, develop details and avoid possible issues at a later time

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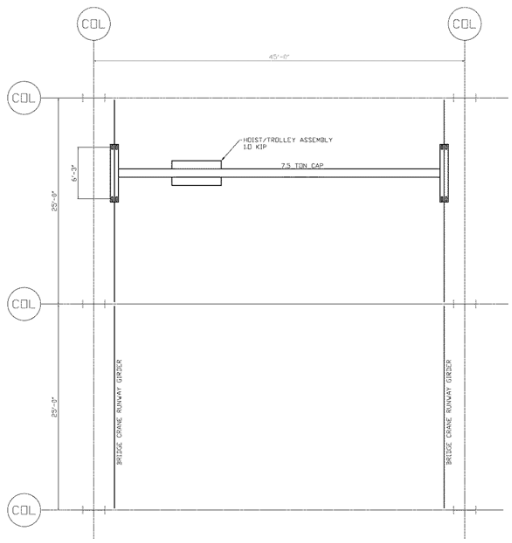
Example Problem



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Example Problem – W Section

- <u>**Example Problem Parameters**</u>

- Crane Runway Girder Design (Allowable Strength Design)
- Rated Crane Capacity = 7.5 Tons - single electric pendant-operated hoist
- Bridge Span = 40 ft
- Runway Girder Span = 25 ft
- Wheel Spacing = 6' - 3"
- Bridge Weight = 6.35 kip
- Trolley + Hoist + Chain + Hook Weight = 1 kip
- Maximum Vertical Wheel Load (without 25% impact) = 10.1 kip (given by supplier)
- Maximum Sidethrust Load (20%) = 0.8 kip (per wheel set)
- Longitudinal Tractive Load (10%) = 1.0 kip (per wheel set)

- Simply supported design for W and W+C crane runway girder
- Use ASTM A992 steel for the beam section and design according to AISC 360-10 (ASD)

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Example Problem – W Section

Critical wheel locations:

Bending moment

$$M_{\max} = \frac{P}{2l}\left(l - \frac{a}{2}\right)^2 = 9.6P\ ft - kip$$

Deflection [AISC Manual Table 3-23, #44]

$$\Delta_{\max} = \frac{Px}{24EI}\left(3l^2 - 4x^2\right) = \frac{35.5P}{I}$$

Maximum vertical deflection = L/450

$$\Delta_{allow} = (25 \times 12)/450 = 0.67\ in$$

$$I_{x-x\ \text{req'd}} = (35.5)(10.1)/0.67 = 538\ in^4$$

Maximum horizontal deflection = L/400

$$\Delta_{allow} = (25 \times 12)/400 = 0.75\ in$$

$$I_{y-y\ \text{req'd}} = (35.5)(0.8)/0.75 = 40\ in^4$$

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Example Problem – W Section

Calculate M_x and M_y

Assumed runway girder weight = 75 lb/ft

$$M_x(w/impact) = 9.6(10.1)(1.25) + \frac{0.075(25^2)}{8} = 127\ ft - kip$$

$$M_y = 9.6(0.8) = 7.7\ ft - kip$$

Choose W16x57

$$I_x = 758\ in^4 : S_x = 92.2\ in^3 : Z_x = 105\ in^3 : J = 2.22\ in^4 : h_o = 15.7\ in$$

$$I_y = 43.1\ in^4 : S_y = 12.1\ in^3 : Z_y = 18.9\ in^3 : r_{ts} = 1.92\ in$$

$$L_r = 18.3\ ft$$

Since L_b = 25 ft > L_r

Lateral Torsional Buckling applies and $M_n = F_{cr}S_x \le M_p$ (Eq. F2-3)

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Example Problem – W Section

Per Specification Section F2.2

$$F_{cr} = \frac{C_b \pi^2 E}{\left(\frac{L_b}{r_{ts}}\right)^2}\sqrt{1+0.078\frac{Jc}{S_x h_o}\left(\frac{L_b}{r_{ts}}\right)^2} = 27.8\,ksi \qquad \text{(Eq.F2-4)}$$

Where: C_b = 1.2 (from analysis)
c = 1 (doubly-symmetric I-shape)

Since load is applied to bottom tension flange, multiply C_b by 1.4 per SSRC recommendations (see previous slides)

F_{cr} = 1.4(27.8) = 38.9 ksi

$M_{nx} = F_{cr}S_x$ = (38.9)(92.2)/12 = 299 ft-kip

M_{nx} / Ω = 299/1.67 = 179 ft-kip > 127 ft-kip (ok)

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Example Problem – W Section

Check Bending about Minor Axis (Chap. F6)

For a compact flange, limit state of yielding applies

$M_{ny} = M_p = F_yZ_y \le 1.6F_yS_y$ (Eq. F6-1)

= 79 ft-kip

M_{ny} / Ω = 79/1.67 = 47 ft-kip > 7.7 ft-kip (ok)

Check Biaxial Bending Stress in the T&B flanges (torsion not included)

$$\frac{P_r}{2P_c} + \frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}} \le 1.0 \qquad \text{(Eq. H1-1b)}$$

$$0 + \frac{127}{179} + \frac{7.7}{47} = 0.87 < 1.0 \text{ (ok)}$$

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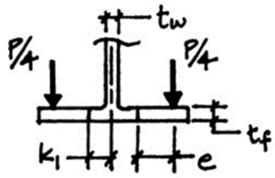
Example Problem – W Section

Check Local Flange Bending



$$f_b = \frac{M}{S} = \frac{3eP}{4et_f^{\,2}} = \frac{0.75P}{t_f^{\,2}}$$

$$f_b = \frac{0.75(10.1 \times 2)}{(0.715)^2} = 29.6\,ksi$$

$$F_b = 0.9F_y = 45\,ksi > 29.6\,ksi \text{ (ok)}$$

This type of local loading could result in biaxial stresses and engineers must design accordingly (CMAA 74-2015)

Based on local flange bending strength and deflection we could reduce the size of beam

However, member would fail in biaxial bending due to crane vertical load and side thrust

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Example Problem – W + Channel

Use loads and moments calculated previously for W Section alone

Choose W16x36 + C12x20.7 (Values from AISC Manual Table 1-19)

$$I_x = 670\,in^4 : S_{xb} = 62.8\,in^3 : S_{xt} = 123\,in^3 : Z_x = 83.2\,in^3$$

$$I_y = 153\,in^4 : S_y = 25.6\,in^3 : r_y = 3.04\,in : Z_y = 36.4\,in^3$$

$$y_t = 5.47\,in : y_b = 10.7\,in : h_o = 15.6\,in : J = 0.91\,in^4$$

Per Specification Section F4, need to determine if LTB applies. Determine L_p and L_r.

Utilize C12 + W16 top flange + 1/3 of the web region in compression to calculate section properties.

$$r_t \sqrt{\frac{I_t}{A_t}}$$

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Example Problem – W + Channel

$I_t = I_{x\_C12} + I_{x\_FLG}$ (neglects influence of web component)

$I_t = 129in^4 + 12.24in^4$

$I_t = 141.24in^4$

$r_t \sqrt{\frac{I_t}{A_t}} = \sqrt{\frac{141.24in^4}{9.55in^4}} = 3.85in$

$$L_p = 1.1r_t\sqrt{\frac{E}{F_y}} = 1.1(3.85)\sqrt{\frac{29000}{50}} = 102in \quad \text{(Eq. F4-7)}$$

$$L_r = 1.95r_t\frac{E}{F_y}\sqrt{\frac{J}{S_{xc}h_0} + \sqrt{\left(\frac{J}{S_{xc}h_0}\right)^2 + 6.76\left(\frac{F_L}{E}\right)^2}} \quad \text{(Eq. F4-8)}$$

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Example Problem – W + Channel

$$\frac{S_{xt}}{S_{xc}} = \frac{62.8in^3}{123in^3} = 0.51 < 0.7$$

$$F_L = F_y\frac{S_{xt}}{S_{xc}} = 50ksi\frac{62.8in^3}{123in^3} = 25.53ksi \quad \text{(Eq. F4-6b)}$$

$$L_r = 1.95r_t\frac{E}{F_L}\sqrt{\frac{J}{S_{xc}h_o} + \sqrt{\left(\frac{J}{S_{xc}h_o}\right)^2 + 6.76\left(\frac{F_L}{E}\right)^2}} = 452in$$

$L_p < L_b$ = 300 in < L_r, therefore Section F4.2(b) applies

$$M_n = C_b\left[R_{pc}M_{yc} - (R_{pc}M_{yc} - F_L S_{xc})\left(\frac{L_b - L_p}{L_r - L_p}\right)\right] \le R_{pc}M_{yc} \quad \text{(Eq. F4-2)}$$

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Example Problem – W + Channel

Lateral Torsional Buckling Strength

$$R_{pc} = \frac{M_p}{M_{yc}} = \frac{F_y Z_x}{F_y S_{xc}} = \frac{83.2 in^3}{123 in^3} = 0.676$$ (Eq. F4-9a)

$$M_{yc} = F_y S_{xc} = 50 ksi \times 123 in^3 = 6150 kip-in$$ (Eq. F4-4)

$$M_n = 1.2\left[(0.676)(6150) - \left((0.676)(6150) - (25.53)(123)\right)\left(\frac{300-102}{452-102}\right)\right]$$

$$M_n = 358k-ft$$

Where: C_b = 1.2 (from analysis)

Since load is applied to bottom tension flange, multiply C_b by 1.4 per SSRC recommendations (see previous slides)

$$M_n = 1.4(358) = 502 kip-ft \le R_{pc} M_{yc} = 0.676 \times \frac{6150}{12} = 346 ft-kip$$

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Example Problem – W + Channel

Lateral Torsional Buckling Strength

$$M_n = 346k-ft$$

$$\frac{M_{nx}}{\Omega} = \frac{346}{1.67} = 207 ft-kip > 127 ft-kip$$ (ok)

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Example Problem – W + Channel

Check Bending about Minor Axis (Chap. F6)

For a compact flange, limit state of yielding applies

$M_{ny} = M_p = F_y Z_y \le 1.6 F_y S_y$ (Eq. F6-1)

$= 152$ ft-kip

$M_{ny} / \Omega = 152/1.67 = 91$ ft-kip > 7.7 ft-kip (ok)

Check Biaxial Bending Stress in the T&B flanges (torsion not included)

$$\frac{P_r}{2P_c} + \frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}} \le 1.0 \qquad \text{(Eq. H1-1b)}$$

$$0 + \frac{127}{207} + \frac{7.7}{91} = 0.70 < 1.0 \text{ (ok)}$$

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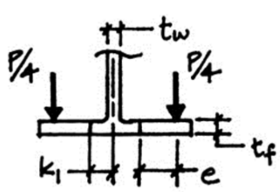
Example Problem – W + Channel

Check Local Flange Bending



$$f_b = \frac{M}{S} = \frac{3eP}{4et_f^{\,2}} = \frac{0.75P}{t_f^{\,2}}$$

$$f_b = \frac{0.75(10.1\times 2)}{(0.43)^2} = 81.9\, ksi$$

$$F_b = 0.9F_y = 45\, ksi < 81.9\, ksi \text{ (NG)}$$

- Based on local flange bending strength, this beam is undersized
- The minimum flange thickness is 0.58 inches
  - W16x50 + C12x20.7
- A cap channel used with an underhung crane runway does not provide any benefit to local flange bending since the wheel loads are concentrated on the unreinforced bottom flange

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Example Problem – Summary

- Additional checks to be made as follows:
  - Check tensile fatigue stresses on bottom flange
  - If continuous, check top flange tensile fatigue stresses at supports
  - If continuous, check bottom flange LTB at supports
  - Check torsional stresses (warping normal stresses)
  - Check angular twist of cross section
  - Check cantilevered conditions
  - Cap channel IS NOT always the solution
    - Lower S_x (bot) so higher bottom flange tensile stresses
    - Shear center shifts up resulting in more torsional moment

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Example Problem – Summary

- <u>W Section Advantages</u>
  - Can provide lighter total section depending on runway span and loads
  - No additional shop fabrication involved in welding multiple rolled shapes together

- <u>W + Channel Section Advantages</u>
  - Higher weak axis moment strength to resist side thrust loads
  - Better torsional properties
  - Rule of thumb: Wide flange + cap channel is economical if it is 20 lb/ft lighter than wide flange alone.
  - See design example in AISC Engineering Journal: “New Fatigue Provisions for the Design of Crane Runway Girders” by Duane S. Ellifritt and Dung-Myau Lue, 2nd Quarter 1998)

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Related Issues

- Curved runways and monorails
- Clamp connections
  - Custom fabricated
  - Pre-fabricated
- Other Issues

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Curved Monorails

- Curved Members
  - Curved members usually not used for bridge crane runways
  - Curved members sometimes used for monorails
- Wide-flanges or S-beams don't make good curved members for vertical loads due to low torsional section properties
- Box sections make much better single curved girders than I-sections do
- Torsional stability in curved runways achieved through the interaction of girders and diaphragms

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Curved Monorails

Must Consider:

- Additional torsion due to curved geometry
- Additional side thrust and resulting torsion due to centrifugal forces
- Pure torsion (St. Venant torsion) and warping torsion must be considered

Recommendations:

- Rationally apply appropriate AASHTO and/or AISC specification provisions
- Space supports very close (less than 5 feet on center)
- Computer analysis required

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Fabricated vs. Pre-Engineered Clamps

Three main factors to consider:

1. Structural design and performance

   Three main components: Bolt, Clamp & Supporting Steel
2. QA/QC in manufacturing
3. Economic cost of the connection

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Fabricated vs. Pre-Engineered Clamps

Structural Design and Performance

- Bolt Design
- Clamp Design
- Support Design

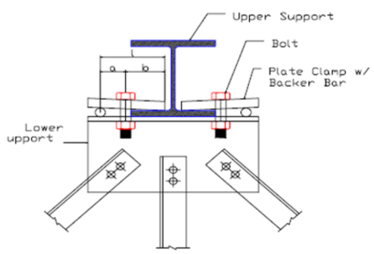

FIGURE 1 – Typical Fabricated Clamp

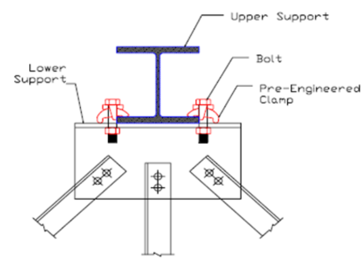

FIGURE 2 – Typical Pre-engineered Lindapter Clamp

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Fabricated vs. Pre-Engineered Clamps

Quality Control and Quality Assurance

- Fabricated clamps
  - No standardized testing for finished product
  - Performance dependent on workmanship of fabricator and proper installation.
- Pre-engineered clamps
  - Manufacturers perform internal quality control
  - Random product testing: Dimensional tolerances, impact tests, material ductility, finish uniformity

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Fabricated vs. Pre-Engineered Clamps

Economic Cost of the Connection

- Must consider design, material, fabrication and installation costs
- Cost comparisons show up to 17% savings by using pre-engineered clamps vs. fabricated clamps
- Self-adjusting clamps allow a universal design and eliminates the potential for installing the wrong clamp at a given location
- Less waste since excess clamps can be used on future jobs, even with different beam sizes

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Fabricated vs. Pre-Engineered Clamps

Advantages of Pre-Engineered Clamps	
Pre-Engineered Clamps	Fabricated Clamps
Bolts act in pure tension with factor of safety of 5 to 1 (machine specs). Also tested for fatigue resistance	Bolts are subjected to prying action with undetermined load capability and reduced factor of safety
Published load capacities verified by physical tests	No accurate design methodology and no published testing on performance
Can accommodate both frictional and tensile loads	Can only handle tensile loads
Easy to install. Fully pre-tensioned high strength bolts (ASTM or SAE) used	Installation subject to interpretation of the installer
Clamp selector software makes evaluation of connection simple	Each clamp must be individually designed

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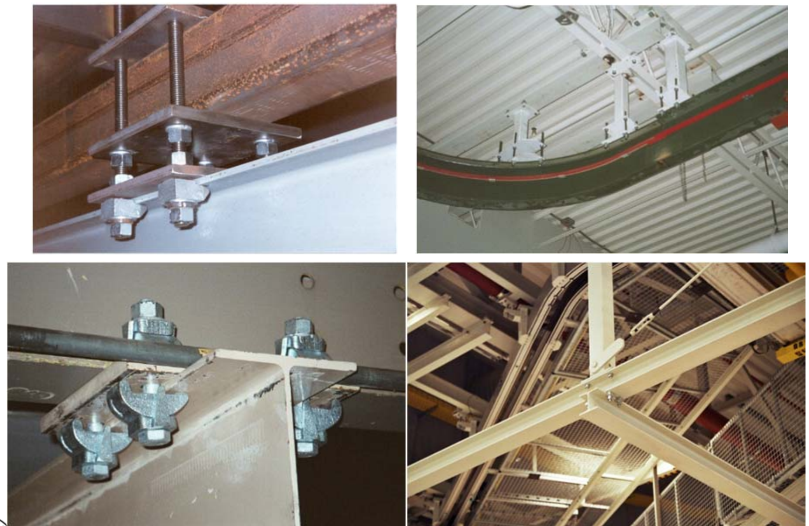
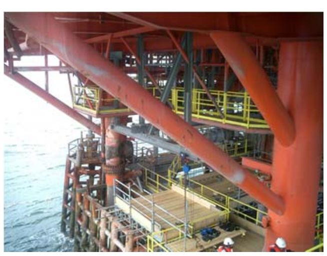
Pre-Engineered Clamps



Pre-Engineered Clamps

Unique Applications



Types of Runway Members

- W Beam
- W Beam + Cap Channel
- S Beam
- S Beam + Cap Channel
- **Enclosed Track**
- **Patented Track**

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Enclosed Track Systems

ANSI MH27.2 – 2009 Specifications for Enclosed Track Underhung Cranes and Monorail Systems

- Specification applies to underhung cranes whose end trucks operate on the internal flange of a runway using enclosed track sections and to trolleys operating on single-track monorail systems
- Specification considers crane and monorail equipment only
- Does not consider design of the building, supporting structure or erection
- Duty Service Classifications
  - Infrequent Usage (Light Service)
  - Frequent Usage (Heavy Service)
  - Severe Usage (Continuous Service)

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Enclosed Track Systems

DUTY SERVICE CLASSIFICATION	
DUTY SERVICE	**DESCRIPTION**
Infrequent Usage (Light Service)	Operation time does not exceed 20% of the work period
Frequent Usage (Heavy Service)	Either: A. Operation time is up to 100% of work period and lifted load is 50% or below of rated capacity. B. Operation time is less than 50% of work period and lifted load is greater than 50% of rated capacity.
Severe Usage (Continuous Service)	Operation time is consistently greater than 50% of the work period and lifted load is consistently greater than 50% of rated capacity. Note: Applications involving vacuums, magnets or other high impact lifting devices fall within this classification category.

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Enclosed Track Systems

ANSI MH27.2 – 2009 Specifications for Enclosed Track Underhung Cranes and Monorail Systems

- Runway and Monorail Track
  - Specially rolled, extruded or fabricated section
  - Tread of load carrying flange shall be compatible with the trolley wheel
  - Maximum vertical deflection of 1-1/4" or per manufacturer, whichever is less
  - Straightness, center-to-center distance, elevation shall be within tolerances per this specification
  - Specific provisions for curved tracks, transfer cranes, track switches

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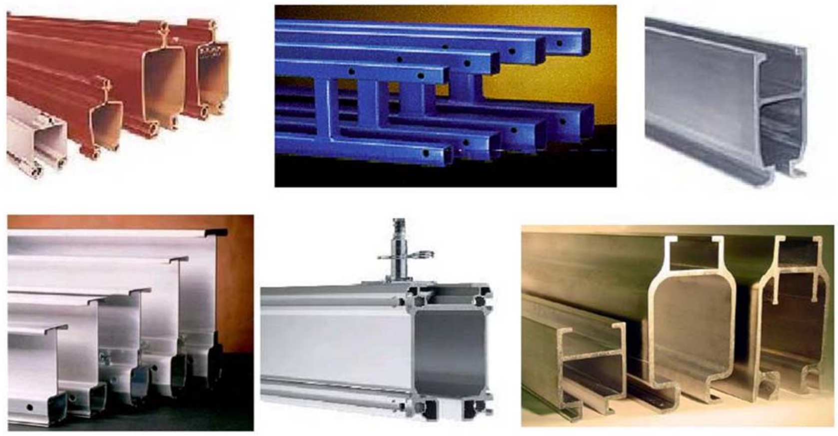
Enclosed Track Systems



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Enclosed Track Manufacturers

CM LodeRail™

DEMAG Cranes & Components

GORBEL A CLASS ABOVE

IR Ingersoll Rand. Productivity Solutions

SPANCO Inc.

TC/AMERICAN

UNIFIED INDUSTRIES, INC.

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Patented Track Systems

ANSI MH27.1 – 2009 Specifications for Patented Track Underhung Cranes and Monorail Systems

- Specification applies to underhung cranes whose end trucks operate on the internal flange of a runway using patented track sections and to trolleys operating on single-track patented-track monorail systems
- Specification considers crane and monorail equipment only
- Does not consider design of the building, supporting structure or erection
- Duty Service Classifications
  - Range from Class A (Infrequent Handling) to Class E (Continuous Handling)

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Patented Track Systems

ANSI MH27.1 – 2009 Specifications for Patented Track Underhung Cranes and Monorail Systems

- Runway and Monorail Track
  - Specially rolled or fabricated section
  - The minimum hardness of the lower load carrying (tension) flange shall be 195 Brinell
  - High-carbon steel lower flange (rail) for longer track life
  - The tread of the load carrying (tension) flange shall be flat
  - Maximum vertical deflection limited to 1/450 times the crane span or unsupported length, or 1-1/4”
  - Straightness, center-to-center distance, elevation shall be within tolerances per this specification
  - Specific provisions for curved tracks, transfer cranes, track switches

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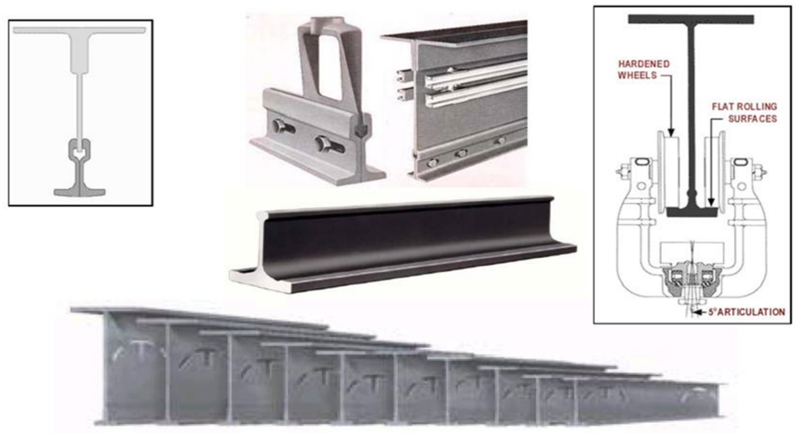
Patented Track Systems



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Patented Track Systems

ACCO® Louden and Trambeam

CLEVELAND TRAMRAIL By Gorbel Inc.

TC/AMERICAN

United States MONORAIL

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Underhung Bridge Cranes – Summary

- Design of underhung crane runways is often overlooked by the Design Team
- Detailed info from Client or Owner regarding cranes is sometimes not known during design phase of project
- Structural Engineers are busy with primary superstructure design, foundation design, process equipment foundation design, etc.

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Underhung Bridge Cranes – Summary

- Crane runways have generally performed successfully when the following items considered:
  - Understand crane parameters (i.e. the intended use, life cycle, etc.)
  - Limit applied stress range to acceptable levels
  - Avoid stress concentrations at critical locations
  - Perform initial survey of runway system to ensure installation tolerances are met
  - Perform periodic maintenance on runway systems to ensure rails and runways are aligned and level

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Underhung Bridge Cranes – Summary

Top 10 Take Aways:

1. Recognize that the design of an under-running crane system is NOT the same problem as a top-running crane system and little documentation is available
2. Understand intended crane use, lifespan, load cycles, number and spacing of cranes within aisle, etc.
3. Coordinate with bridge crane manufacturer to verify stack-up dimensions, available hook heights, type of end stop, etc.
4. Communicate design basis and CMAA runway install tolerances on Structural CD's
5. Allow for vertical impact, side thrust and tractive forces and apply appropriate load combinations per AIST TR 13

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Underhung Bridge Cranes – Summary

Top 10 Take Aways (continued):

6. Recognize that strength and deflection limitations may not govern design – consider torsion, fatigue per ANSI/AISC 360 Appendix 3, local effects, stress risers due to connections, etc.
7. Remember – built-up shapes may not be the most efficient solution for compression flange bracing
8. Allow for adjustability in the runway to primary superstructure connections
9. Use pre-fabricated clamp connections with fully pre-tensioned bolts where possible
10. Recommend using a design checklist

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Reference Documents and Resources

- AISC Design Guide 7: Industrial Buildings: Roofs to Anchor Rods, Second Edition
- AISC Design Guide 9: Torsional Analysis of Steel Members, Second Edition
- CMAA Specification No. 74 – 2015: Specifications for Top Running and Under Running Single Girder Electric Overhead Cranes Utilizing Under Running Trolley Hoist
- AIST Technical Report No. 6: Specification for Electric Overhead Traveling Cranes for Steel Mill Service
- AIST Technical Report No. 13: Guide for the Design and Construction of Mill Buildings
- ASME B30.11-2010: Monorails and Underhung Cranes Safety Standard
- ANSI MH27.1 – 2009 Specifications for Patented Track Underhung Cranes and Monorail Systems
- ANSI MH27.2 – 2009 Specifications for Enclosed Track Underhung Cranes and Monorail Systems

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Reference Documents and Resources

- "Avoiding the Pitfalls of Crane Installation in a New Building," Larry Dunville, The Fabricator, February 2001.
- Engineering Journal Articles
  - Tips for Avoiding Crane Runway Problems, David T. Ricker, Fourth Quarter, 1982
  - New Fatigue Provisions for the Design of Crane Runway Girders, James M. Fisher and Julius P. Van De Pas, Second Quarter, 2002
  - Lessons from Crane Runways, John E. Mueller, January, 1965
  - Design of Crane Runway Beam with Channel Cap, Duane S. Ellifritt and Dung-Myau Lue, Second Quarter, 1998
- Designing with Vulcraft: Steel Joists, Joist Girders and Steel Deck, 2nd Edition, James M. Fisher, Michael A. West and Julius P. Van de Pas, Nucor Corporation, 2002.
- Guide for the Design of Crane-Supporting Steel Structures, 2nd Edition, R.A. MacCrimmon, Canadian Institute of Steel Construction, 2010

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Reference Documents and Resources

- Technical Note: Fabricated Clamps verses Lindapter pre-engineered clamps, Patrick Collings, Lindapter North America
- Bracing for Stability Short Course Notes, AISC & SSRC, Joseph Yura and Todd Helwig, February 2001
- Steel Structures – Design and Behavior, 4th Edition, Charles Salmon and John Johnson

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Additional Technical Resources

AISC Publications:

- http://www.aisc.org/publications

AISC Frequently Asked Questions:

- http://www.aisc.org/faq

AISC Steel Interchange:

- http://www.aisc.org/modernsteel/resources/steel-interchange/

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Quiz Question 2

Adding a cap channel to an I-shape underhung crane runway will improve which of the following characteristics of the beam? Choose all that apply.

A. Flange local bending
B. Weak axis bending strength
C. Torsional resistance
D. Economy of the beam

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PDH Certificates

Within 2 business days…

- You will receive an email on how to report attendance from: registration@aisc.org.
- Be on the lookout: Check your spam filter! Check your junk folder!
- Completely fill out online form. Don't forget to check the boxes next to each attendee's name!

PDH Certificates

Within 2 business days…

- Reporting site (URL will be provided in the forthcoming email).
- Username: Same as AISC website username.
- Password: Same as AISC website password.

There's always a solution in steel.

Thank You

Please give us your feedback!
Survey at conclusion of webinar.