CivilBay Crane Load and Crane Runway Beam Design v1.0.0 User Manual

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2.0 QUICK START

2.1 Software Installation

- After downloading the ZIP file the user can unzip the file and save it to user's computer.
- User can double click the two EXE files and open them just as normal Excel files.
- The 14-day trial will start the same date when user tries any of these compiled Excel files.
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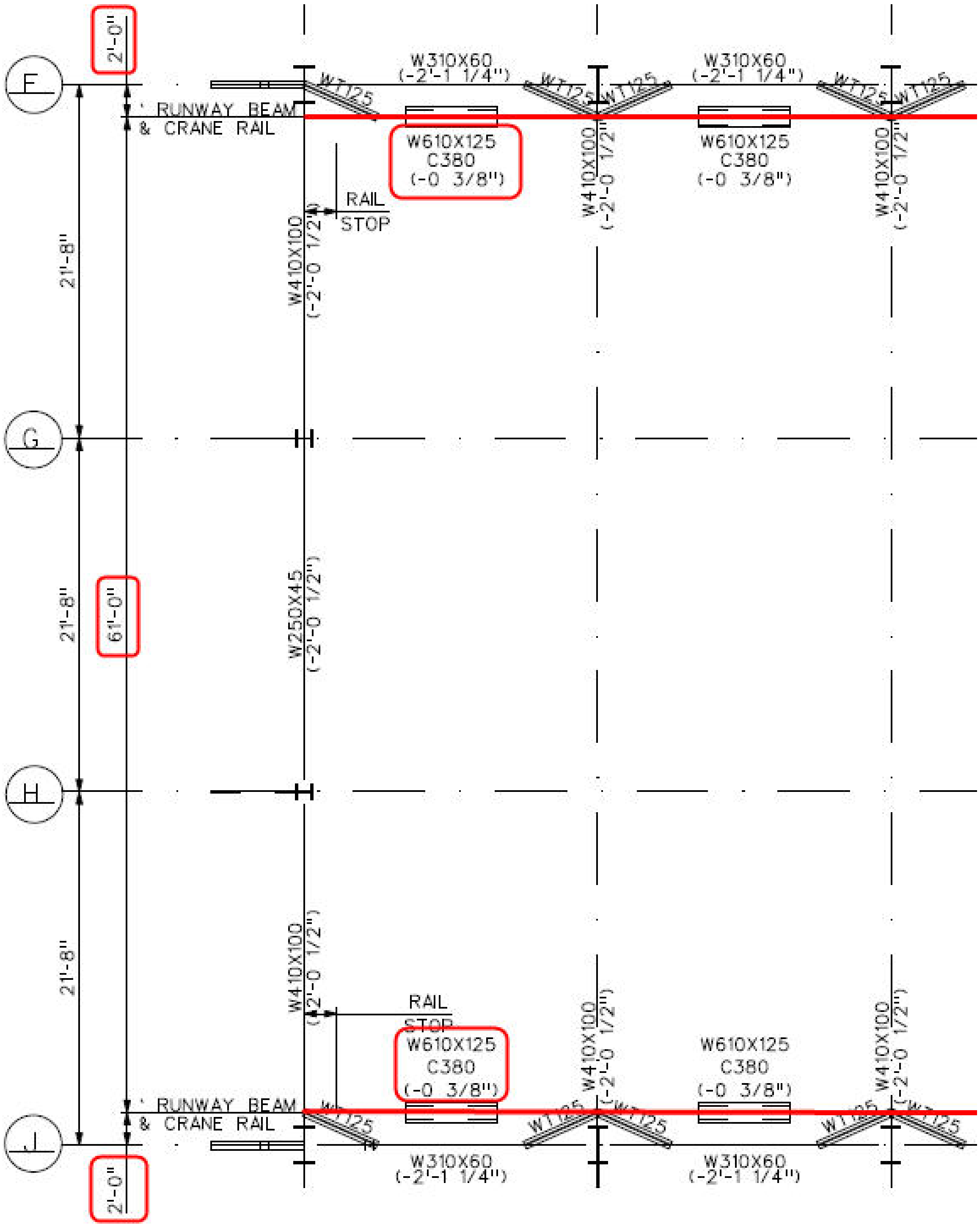
2.3 Crane Load and Crane Runway Beam Design v1.0.0 Modules

03-01-01 Top Running & Underhung Bridge Crane Crane Load & Runway Beam Design.exe
→ Crane load and crane runway beam design as per AISC ASD 9 and LRFD 13

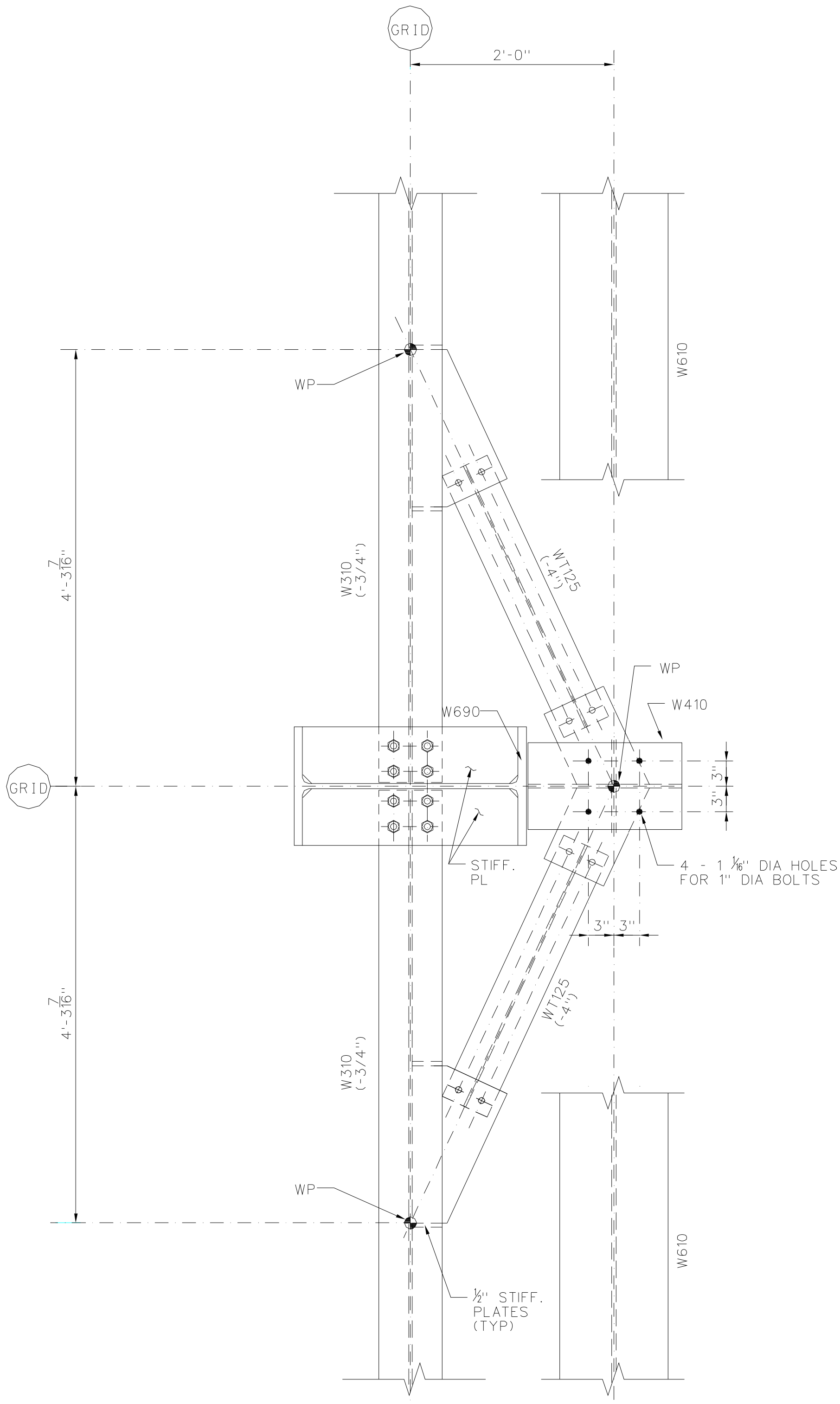
03-02-01 Top Running & Underhung Bridge Crane Crane Load & Runway Beam Design-Metric.exe
→ Crane load and crane runway beam design as per AISC ASD 9 and LRFD 13 using metric unit input

3.0 DESIGN EXAMPLES

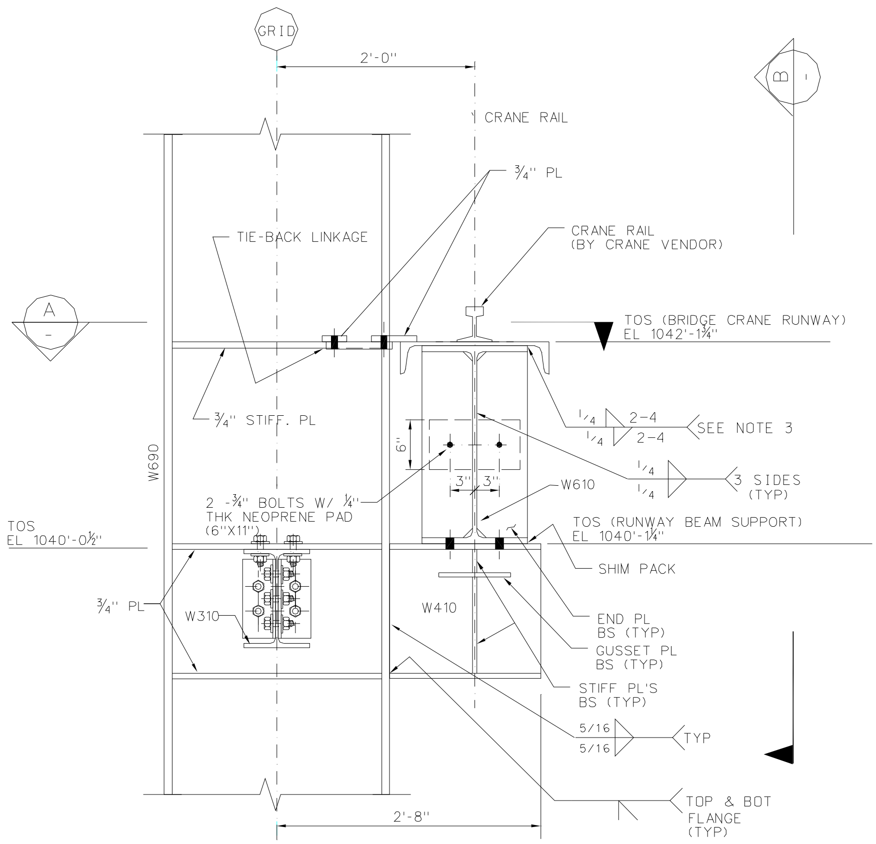
Example 01: Top Running 20 Ton Crane + Runway W Shape with Cap Channel – Imperial Unit



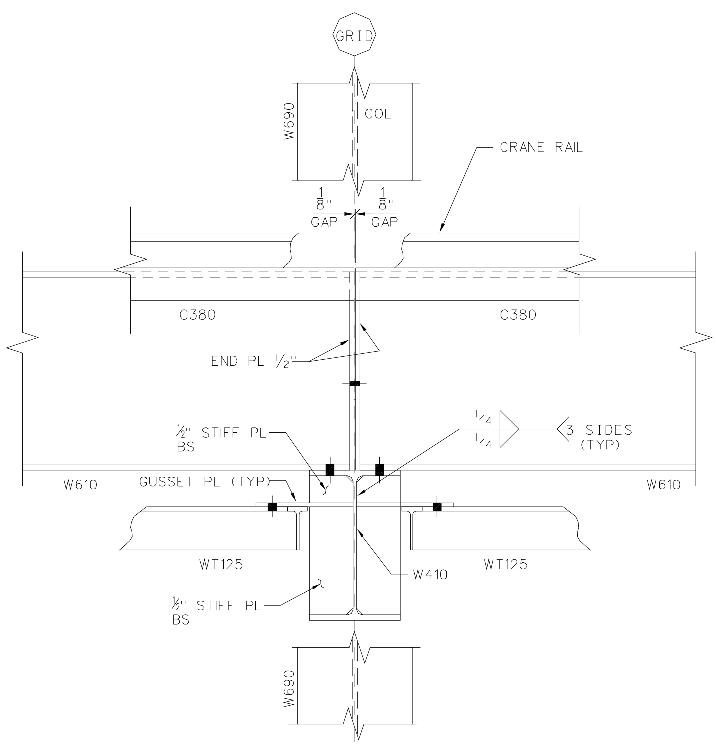
BRIDGE CRANE RUNWAY BEAM PLAN



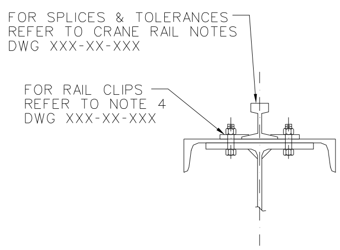
CRANE RUNWAY BEAM CONNECTION –PLAN



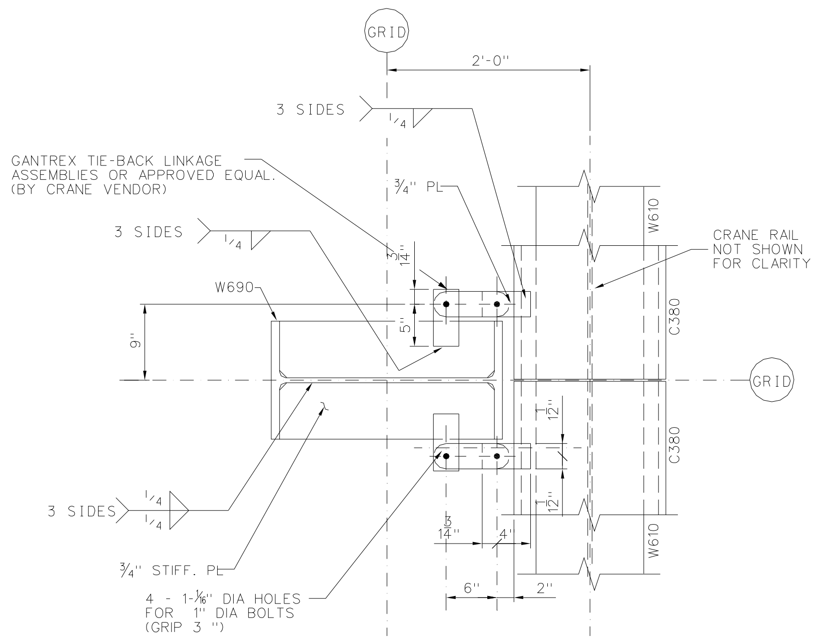
RUNWAY BEAM CONNECTION - SECTION



SECTION B - B



CRANE RAIL FASTENING DETAIL

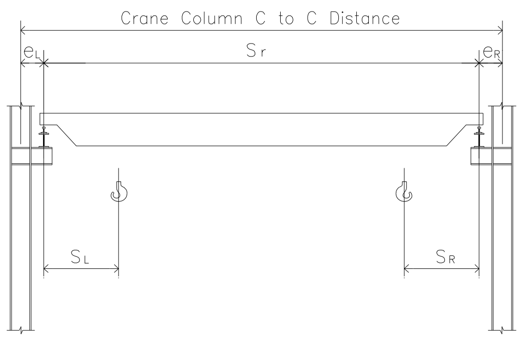


SECTION A - A

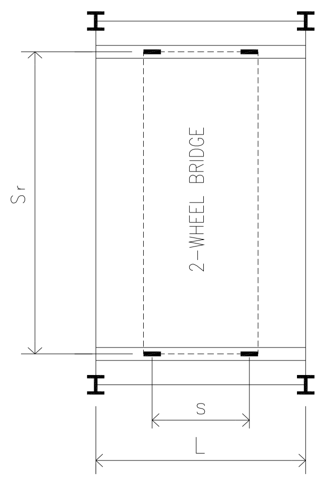
Crane Data	Imperial	Metric
Crane capacity	20 US Tons = 40 kips	18.14 Metric Tons = 177.9 kN
Bridge weight	28.0 kips	12701 kg
Trolley + hoist weight	6.1 kips	2767 kg
Max static wheel load	30.1 kips	133.9 kN
Bridge span S_r	61.0 ft	18.593 m
Left min. hook approach S_L	4.0 ft	1.219 m
Right min. hook approach S_R	3.5 ft	1.067 m
Bridge wheel spacing s	12.5 ft	3.810 m
Crane runway beam span L	20 ft	6.096 m
Left runway CL to column CL dist e_L	2.0 ft	0.610 m
Right runway CL to column CL dist e_R	2.0 ft	0.610 m
Crane rail size	ASCE 85	ASCE 85
CMAA crane service class	Class C	Class C
Vertical impact factor	25%	25%
Crane type	Top Running	Top Running
Crane runway beam size	W24x84 + C15x33.9	W610x125 + C380x50
W shape F_y	50 ksi	345 MPa
Channel cap F_y	36 ksi	248 MPa

BRIDGE CRANE LOAD CALCULATION

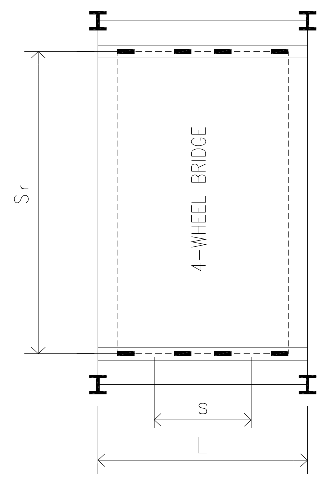
Bridge crane load calc based on	**Code Abbreviation**
CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition	*CISC Crane Guide*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*
CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes	*CMAA 70-04*



SECTION



PLAN – 2 WHEEL



PLAN – 4 WHEEL

Crane Data

				suggested value		
Crane rated capacity	W_{rc} =	20.0	[US Ton]		= 40.0	[kips]
Bridge weight	W_{br} =	28.0	[kips]	26.1	= 12701	[kg]
Trolley + hoist weight	W_{th} =	6.1	[kips]	3.6	= 2767	[kg]
Bridge wheel spacing	s =	12.5	[ft]	9.8		
Max. static wheel load by vendor	P_{max-v} =	30.1	[kips]	input 0 if vendor data is unknown		
Crane bridge span	S_r =	61.0	[ft]	61.7		
Min. hook approach-left	S_L =	4.0	[ft]	3.1		
Min. hook approach-right	S_R =	3.5	[ft]	3.1		
Crane runway beam span	L =	20.0	[ft]			
Runway CL to col CL dist-left	e_L =	2.0	[ft]	1.6		
Runway CL to col CL dist-right	e_R =	2.0	[ft]	1.6		
Crane column C to C distance	$S_r + 2e$ =	65.0	[ft]		suggested section	
Runway beam type	=	W_Shape_Cap_Channel	?			
Runway beam size	=	W24x84 C15x33.9			size <= W21x62 C12x20.7	
Top flange cap plate size	width b_p			thick t_p		not applicable
	suggest	ASCE 60		U_{rb} =	0.118	[kip/ft]
Crane rail size	=	ASCE 85		U_{cr} =	85	[lbs/yd]
				=	0.028	[kip/ft]
Rail base width	B_w =	5.188	[in]	Rail height H_t =	5.188	[in]
W section yield strength	f_{wy} =	50.0	[ksi]	=	345	[MPa]
Cap channel or plate yield strength	f_{cy} =	36.0	[ksi]	=	248	[MPa]
CMAA crane service class	=	Class C	?		Moderate service	
Crane type	=	Top Running		?		

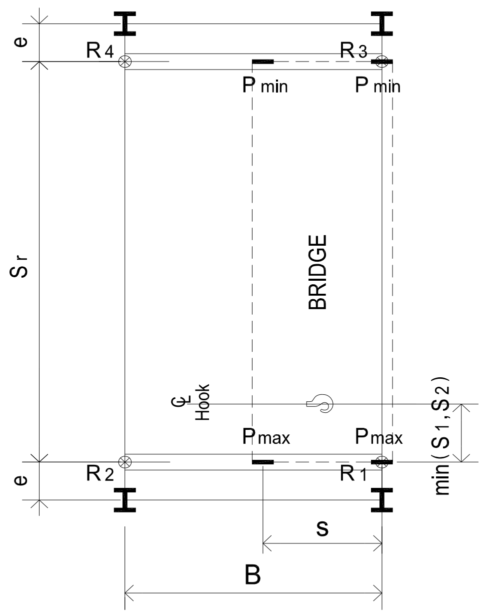
			Code Reference
			CISC Crane Guide
Vertical load impact factor	=	0.25 ?	Table 2.1
Crane side thrust load option	=	Option 1 ?	Table 2.1

Crane side thrust load can be calculated using one of the following 3 options

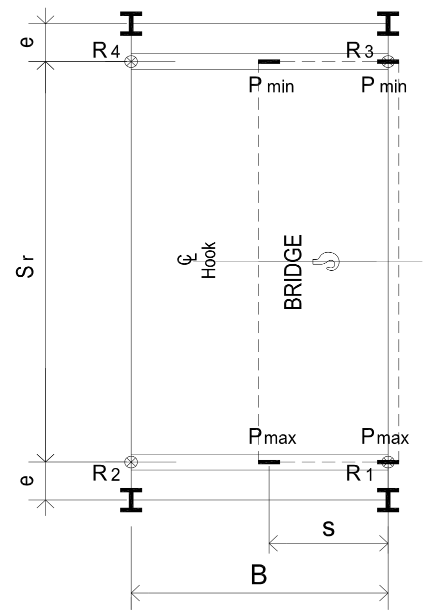
Option 1	H_s =	0.2 (Lifted Load+ Trolley/Hoist Wt)
Option 2	H_s = max of	0.2 (Lifted Load+ Trolley/Hoist Wt)
		0.1 (Lifted Load+ Entire Crane Wt)
Option 3	H_s = max of	0.2 (Lifted Load+ Trolley/Hoist Wt)
		0.1 (Lifted Load+ Entire Crane Wt)
		0.4 Lifted Load

Conclusion

Runway Beam Design Using AISC ASD 9		
Overall	ratio = **0.38**	OK
Local buckling		OK
Bending about X-X Axis	ratio = 0.34	OK
Bending about Y-Y Axis on Top Flange	ratio = 0.10	OK
Biaxial Bending on Top Flange	ratio = 0.38	OK
Shear along Y-Y Axis	ratio = 0.23	OK
Web Sidesway Buckling	ratio = 0.00	OK
Runway Beam Vertical Deflection	ratio = 0.24	OK
Runway Beam Lateral Deflection	ratio = 0.11	OK
Runway Beam Design Using AISC LRFD 13		
Overall	ratio = **0.46**	OK
Local buckling		OK
Biaxial Bending on Top Flange	ratio = 0.46	OK
Shear along Y-Y Axis	ratio = 0.26	OK
Web Sidesway Buckling	ratio = 0.00	OK
Runway Beam Vertical Deflection	ratio = 0.24	OK
Runway Beam Lateral Deflection	ratio = 0.11	OK



CASE 1 HOOK AT ONE SIDE

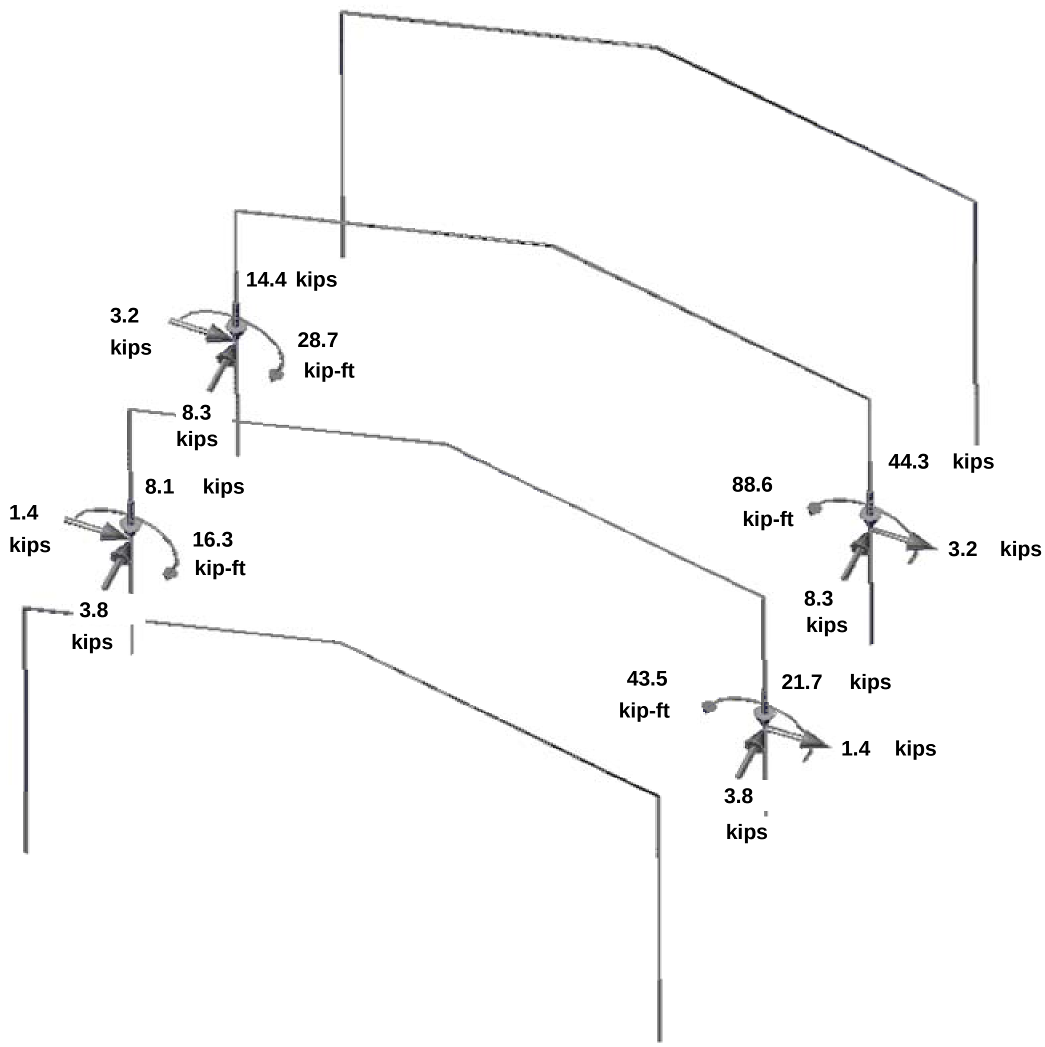


CASE 2 HOOK AT CENTER

Crane Load Calculation					**Code Reference**
Crane runway + rail selfweight	R_{sw} = $(U_{rb} + U_{cr})$ x B		= 2.9	[kips]	
Wheel load by bridge selfwei	P_{br} = W_{br} / 4 wheel		= 7.0	[kip/per wheel]	
Side Thrust Load					
Crane side thrust load calculated by	= Option 1				*CISC Crane Guide*
	H_{s1} = 0.4 Lifted Load		= 16.0	[kips]	Table 2.1
	H_{s2} = 0.2 (Lifted Load+ Trolley/Hoist Wt)		= 9.2	[kips]	
	H_{s3} = 0.1 (Lifted Load+ Entire Crane Wt)		= 7.4	[kips]	
	H_{st} = side thrust load calc using Option 1		= 2.3	[kip/per wheel]	
	H_{st1}=H_{st3} = H_{st} (1 + (B-s) / B)		= **3.2**	[kips]	
	H_{st2}=H_{st4} = H_{st} s / B		= **1.4**	[kips]	
Tractive Load					Table 2.1
	H_{tr} = 0.2 Max wheel load		= 6.0	[kip/per wheel]	
	H_{tr1}=H_{tr3} = H_{tr} (1 + (B-s) / B)		= **8.3**	[kips]	
	H_{tr2}=H_{tr4} = H_{tr} s / B		= **3.8**	[kips]	
Vertical Load					
Case 1 Hook at One Side					
Min. hook aproach	S_{min} = min (S_1, S_2)		= 3.5	[ft]	
Max wheel load by calc	$P_{max\text{-}c}$ = $[(W_{rc}+W_{th})x(S_r-S_{min})/ S_r]/2$ wheel+P_{br}		= 28.7	[kip/per wheel]	
Max. wheel load by vendor	$P_{max\text{-}v}$ =		= 30.1	[kip/per wheel]	
Max static wheel load	P_{max} = max $(P_{max\text{-}v}$, $P_{max\text{-}c})$		= **30.1**	[kip/per wheel]	
Min wheel load	P_{min} = $[(W_{rc}+W_{th})xS_{min}/S_r]/2$ wheel+P_{br}		= **8.3**	[kip/per wheel]	

Reaction on runway support	$R_1 = P_{max} (1 + (B\text{-}s) / B) + R_{sw}$	= **44.3**	[kips]
	$R_2 = P_{max}\, s / B + R_{sw}$	= **21.7**	[kips]
	$R_3 = P_{min} (1 + (B\text{-}s) / B) + R_{sw}$	= **14.4**	[kips]
	$R_4 = P_{min}\, s / B + R_{sw}$	= **8.1**	[kips]
Point moment to column center	$M_1 = R_1 \times e_R$	= **88.6**	[kip-ft]
	$M_2 = R_2 \times e_R$	= **43.5**	[kip-ft]
	$M_3 = R_3 \times e_L$	= **28.7**	[kip-ft]
	$M_4 = R_4 \times e_L$	= **16.3**	[kip-ft]

Case 1 Hook at One Side - Crane Load Summary



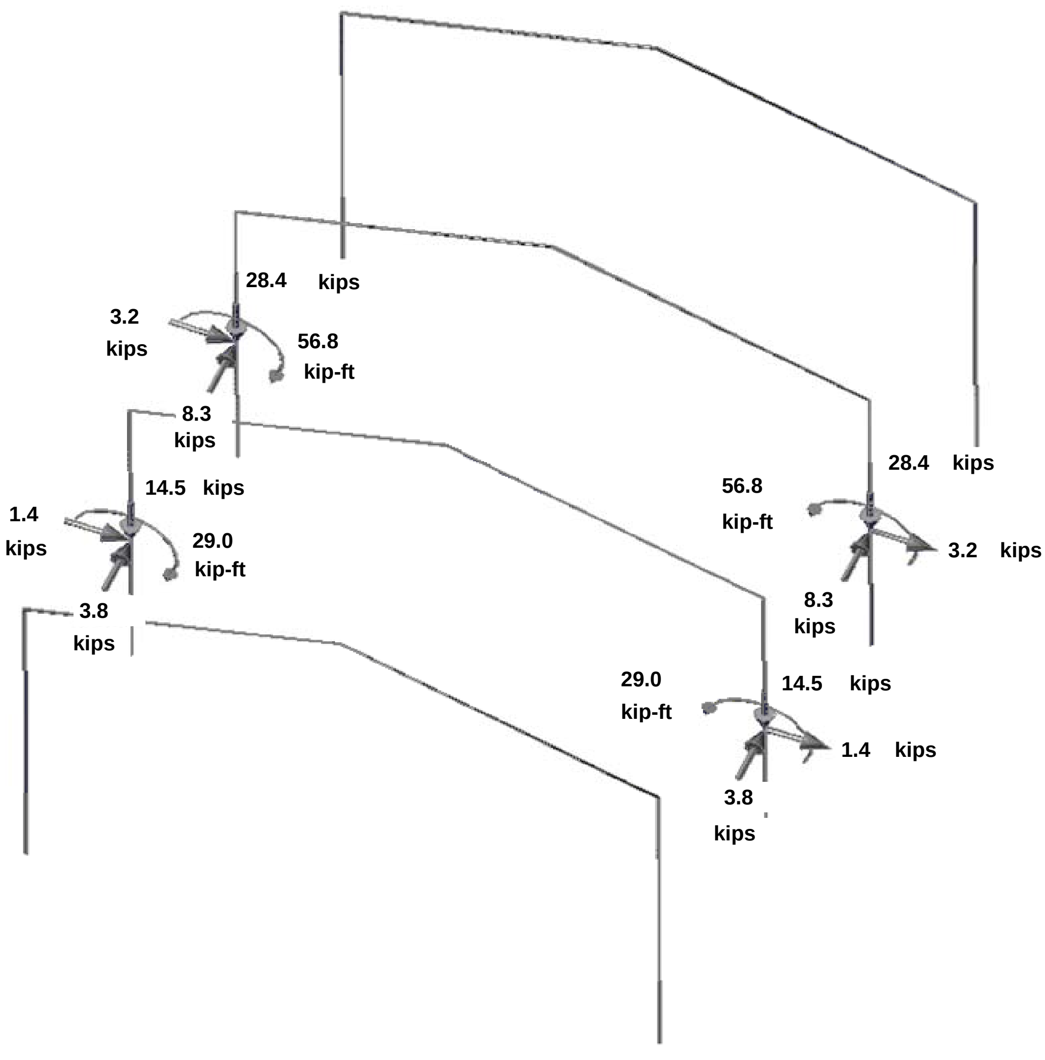
Note:

The crane loads shown above may be reverse if crane hook goes to the other side. When reverse the loads and apply them on building columns, the point moment value may need adjusted if eccentricity e_L <> e_R

Case 2 Hook at Center of Bridge

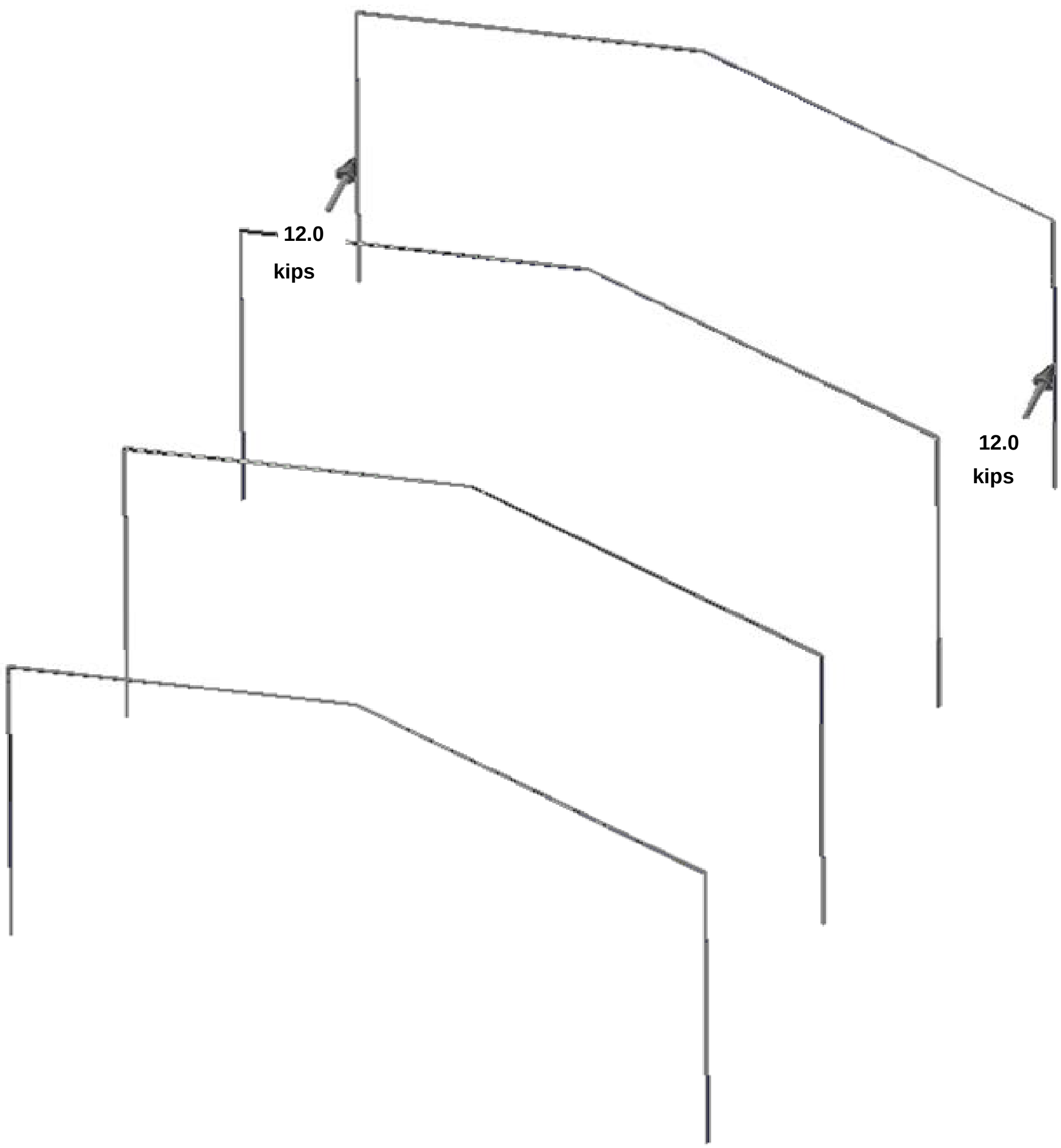
Max wheel load	P_{max} = P_{min} = $(W_{rc}+W_{br}+W_{th})/4$ wheel	= 18.5	[kip/per wheel]
Reaction on runway support	R_1 = R_3 = P_{max} (1 + (B-s) / B) + R_{sw}	= **28.4**	[kips]
	R_2 = R_4 = P_{max} s / B + R_{sw}	= **14.5**	[kips]
Point moment to column center	M_1 = M_3 = R_1 x max (e_L , e_R)	= **56.8**	[kip-ft]
	M_2 = R_2 x max (e_L , e_R)	= **29.0**	[kip-ft]

Case 2 Hook at Center of Bridge - Load Summary



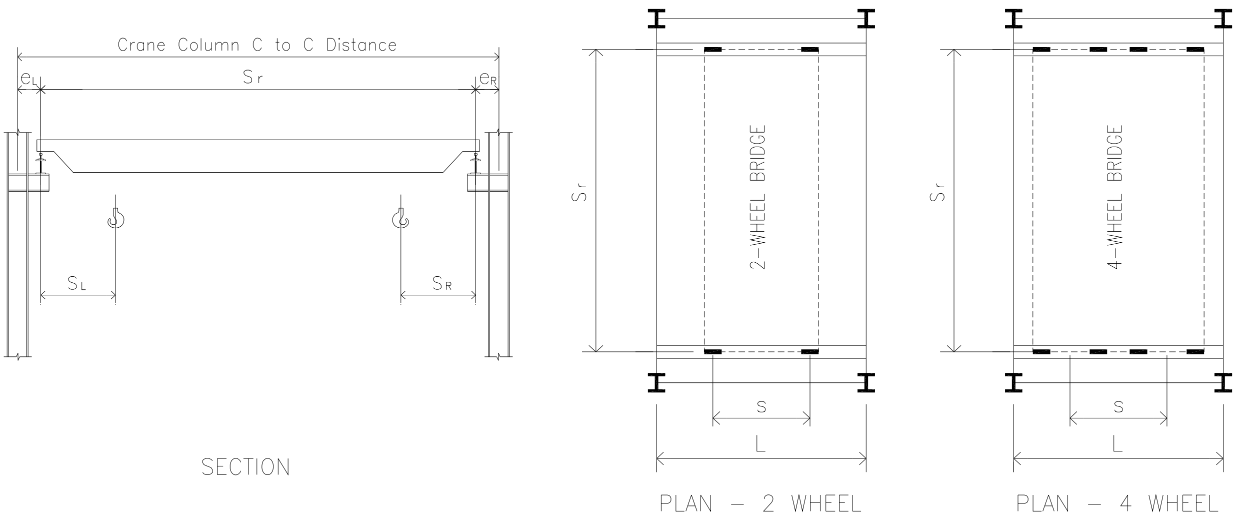
				Code Reference
Bumper Force at End Frame				*AISC Design Guide 7*
Bumper force to be the greater of	1 Twice the tractive force	= 12.0	[kips]	18.6
	2 10% of entire crane weight	= 3.7	[kips]	
Bumper force used for design		**= 12.0**	[kips]	

Apply longitudinal bumper force to both sides of end frame



CRANE RUNWAY BEAM DESIGN

Crane beam design using two codes : AISC LRFD-13 and AISC ASD 9th Edition	**Code Abbreviation**
AISC 360-05 Specification for Structural Steel Buildings	*AISC LRFD-13*
AISC Manual of Steel Construction: Allowable Stress Design 9th Edition	*ASD 9th Edition*
CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition	*CISC Crane Guide*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*



Crane Data

Crane rated capacity	W_{rc} =	20.0	[tonne]	= 44.1	[kips]
Bridge weight	W_{br} =	28.0	[kips]	= 12701	[kg]
Trolley + hoist weight	W_{th} =	6.1	[kips]	= 2767	[kg]
Bridge wheel spacing	s =	12.5	[ft]	= 3.810	[m]

For 4-wheel crane **double** the vendor provided max static wheel load as input

Max <u>static</u> wheel load	P_{max} =	30.1	[kips]	= 133.9	[kN]
Crane bridge span	S_r =	61.0	[ft]	= 18.593	[m]
Left min. hook approach	S_1 =	4.0	[ft]	= 1.219	[m]
Right min. hook approach	S_2 =	3.5	[ft]	= 1.067	[m]
Crane runway beam span	L =	20.0	[ft]	= 6.096	[m]
Runway CL to column CL dist	e =	2.0	[ft]	= 0.610	[m]

Runway beam type W_Shape_Cap_Channel Runway beam size W24x84 C15x33.9

U_{rb} = 0.12 [kip/ft] = 1.7 [kN/m]

Crane rail size ASCE 85

U_{cr} = 0.03 [kip/ft] = 0.4 [kN/m]

Crane Load Calculation *CISC Crane Guide*

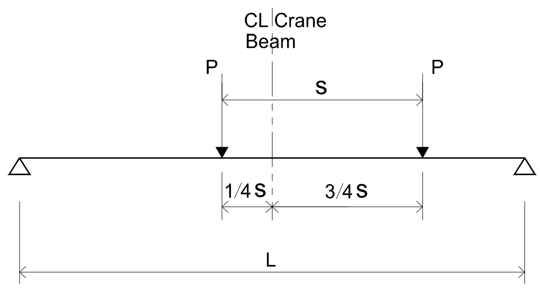
Ver. load impact factor	α = 1.25				Table 2.1
Crane side thrust load	H_s = Option 1		= 9.2	[kips]	
Option 1	H_s =	0.2 (Lifted Load+ Trolley/Hoist Wt)			
Option 2	H_s = max of	0.2 (Lifted Load+ Trolley/Hoist Wt)			
		0.1 (Lifted Load+ Entire Crane Wt)			
Option 3	H_s = max of	0.2 (Lifted Load+ Trolley/Hoist Wt)			
		0.1 (Lifted Load+ Entire Crane Wt)			
		0.4 Lifted Load			

Runway beam span L = 20.0 [ft]

Bridge wheel spacing s = 12.5 [ft]

$$M_{max} = \frac{P}{2\,L}\left(L - \frac{s}{2}\right)^2$$

= 4.73 P



Max Bending Moment Case

Runway beam + rail selfwei	U = $U_{rb} + U_{cr}$	= 0.146	[kip/ft]	

Crane Load for Design per AISC ASD 9th Ed

Max ver. load /wheel (no impact)	P_v =	= 30.1	[kips / per wheel]	
Max hor. load /wheel	$P_h = H_s / 4$	= 2.3	[kips / per wheel]	
Bending moment x-x axis	M_x = 4.73 xP_vx α (impact) + U x L^2 / 8	= **185.2**	[kip-ft]	
Bending moment y-y axis	M_y = 4.73 xP_h	= **10.9**	[kip-ft]	
Shear along y-y axis	V_x = P_v [1+ (L - s) / L]x α (mpact) + UxL/2	= **53.2**	[kips]	

Crane Load for Design per AISC LRFD-13th Ed

Wheel load by bridge selfwei	$P_{br} = W_{br} / 4$	= 7.0	[kips]	as dead load
Wheel load by lift load + trolley	$P_{lt} = P_{max} - P_{br}$	= 23.1	[kips]	as live load
Max factored ver. load /wheel	$P_v = 1.2 \times P_{br} + 1.6 \times P_{lt}$	= 45.4	[kips]	impact not included
Max factored hor. load /wheel	P_h = H x 1.6 / 4	= 3.7	[kips]	
Factor bending moment x-x axis	M_x = 4.73 xP_vx α(impact)+1.2xUxL^2/ 8	= **276.8**	[kip-ft]	
Factor bending moment y-y axis	M_y = 4.73 xP_h	= **17.4**	[kip-ft]	
Factor shear along y-y axis	V_x = P_v [1+ (L - s) /L]xα(mpact)+1.2xUxL/2	= **79.7**	[kips]	

CRANE RUNWAY BEAM DESIGN - ASD 9

Crane runway design based on

	Code Abbreviation
AISC Manual of Steel Construction: Allowable Stress Design 9th Edition	*ASD 9th Edition*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*

Crane runway beam section W24x84 C15x33.9 W24x84 and C15x33.9

Section Properties

Combined Section Overall

A =	34.700	[in^2]	d_{all} =	24.500	[in]
top y_2 =	9.100	[in]	bott. y_1 =	15.400	[in]
I_x =	3340.0	[in^4]	I_y =	409.00	[in^4]
top S_2 =	367.00	[in^3]	bott. S_1 =	217.00	[in^3]
S_y =	54.50	[in^3]			
Z_x =	286.00	[in^3]	Z_y =	83.40	[in^3]
r_x =	9.820	[in]	r_y =	3.430	[in]
J =	4.71	[in^4]	C_w =	0	[in^6]

W Section

d =	24.100	[in]	b_f =	9.020	[in]
t_w =	0.470	[in]	t_f =	0.770	[in]
h =	21.560	[in]			

Top Flange

A_f =	16.895	[in^2]	d_{all} / A_f =	1.450	[in^{-1}]
r_T =	4.468	[in]	r_{yt} =	4.629	[in]
I_t =	362.09	[in^4]			
S_t =	48.28	[in^3]	Z_t =	66.46	[in^3]

W section yield strength	F_{wy} = 50.0	[ksi]	= 345	[MPa]
C section yield strength	F_{cy} = 36.0	[ksi]	= 248	[MPa]
Runway beam unbraced length	L_b = 240.00	[in]		

Design Forces

Bending moment x-x axis	M_x = 185.15	[kip-ft]
Bending moment y-y axis	M_y = 10.89	[kip-ft]
Shear along y-y axis	V_x = 53.20	[kips]

Conclusion

Overall	ratio = **0.38**	OK
Local buckling		OK
Bending about X-X Axis	ratio = 0.34	OK
Bending about Y-Y Axis on Top Flange	ratio = 0.10	OK
Biaxial Bending on Top Flange	ratio = 0.38	OK
Shear along Y-Y Axis	ratio = 0.23	OK
Web Sidesway Buckling	ratio = 0.00	OK
Runway Beam Vertical Deflection	ratio = 0.24	OK
Runway Beam Lateral Deflection	ratio = 0.11	OK

			Code Reference
Design Basis & Assumption			*AISC Design Guide 7*

1. The channel and W section top flange resist the hor. load and the combined section resists the ver. load. This assumption eliminates the need for an analysis of torsional effects on the combined section and simplifies the analysis. — 18.1 on page 56
2. If A36 channel cap is used on A992 W section then lateral torsional buckling and weak axis flexure strength must be calculated based on A36 yield stress. — 18.1.4 on page 57

Check Local Buckling

Flange of W shape				*ASD 9th Edition*
Compact limit	λ_p = 65 / sqrt (F_{wy})		= 9.19	Table B5.1
Noncompact limit	λ_r = 95 / sqrt (F_{wy})		= 13.44	
	$b_f / 2t_f$ = 5.86		Compact	
Web of W shape				
Compact limit	λ_p = 640 / sqrt (F_{wy})		= 90.51	Table B5.1
Noncompact limit	λ_r = 760 / sqrt (0.66F_{wy})		= 132.30	
	d / t_w = 51.28	h / t_w	= 45.87	
			Compact	
W shape classification			**Compact**	
Flange of Channel	This part is applicable			
Compact limit	λ_p = 65 / sqrt (F_{cy})		= 10.83	Table B5.1
Noncompact limit	λ_r = 95 / sqrt (F_{cy})		= 15.83	
	b_f / t_f = 5.23		Compact	
Web of Channel				
Compact limit	λ_p = 640 / sqrt (F_{cy})		= 106.67	Table B5.1
Noncompact limit	λ_r = 760 / sqrt (0.66F_{cy})		= 155.92	
	d / t_w = 37.50	h / t_w	= 34.25	
			Compact	
Channel shape classification			**Compact**	
Combined section classification	**Compact**			**OK**

Check Bending about X-X Axis

Tension

Allowable tension stress	$F_{bx\,t}$ = 0.6 x F_{wy}	= **30.00**	[ksi]	
Actual tension stress	$f_{bx\,t}$ = M_x / S_1	= 10.24	[ksi]	
	ratio = $f_{bx\,t}$ / $F_{bx\,t}$	= **0.34**		**OK**

Compression

Comb sect top flange yield stress	F_y = 36.0	[ksi]	see assumption 2
Comb sect top flange width	b_f = 15.0	[in]	use channel depth if capped with channel

				Code Reference
				ASD 9th Edition
Critical length	$L_c = \min\left(\frac{76 x b_f}{\sqrt{F_y}}, \frac{2x10^4}{(d_{all} / A_f) x F_y}\right)$	= 190.00	[in]	Eq F1-2
	$76\ b_f$ / sqrt(F_y) =	= 190.00	[in]	
When $L_b <= L_c$	This part is NOT applicable			
For compact sect	Not Applicable			
	$F_{bx} = 0.66 \times F_y$	= 0.00	[ksi]	Eq F1-1
For non-compact sect	Not Applicable			
	$b_f / 2t_f$ = Comb Sect max(W $b_f / 2t_f$, C b_f / t_f)	= 5.86		
	W Sect $b_f / 2t_f$			
	$F_{bx} = \left(0.79 - 0.002 \frac{b_f}{2t_f} \sqrt{F_y}\right) F_y$	= 0.00	[ksi]	Eq F1-3
	$F_{bx} = 0.6 \times F_y$	= 0.00	[ksi]	Eq F1-5
When $L_b > L_c$	This part is applicable			
	L_b / r_T =	= 53.71		
Bending coefficient	C_b = 1.0 to be conservative			
	$x = \sqrt{\frac{510 x 10^3 x C_b}{F_y}}$	= 119.02		
For (L_b / r_T) <= x	Applicable			
	$F_{bx} = \left(\frac{2}{3} - \frac{F_y (L_b / r_T)^2}{1530 x 10^3 C_b}\right) F_y \le 0.6 F_y$	= 21.56	[ksi]	Eq F1-6
For (L_b / r_T) > x	Not Applicable			
	$F_{bx} = \frac{170 x 10^3 C_b}{(L_b / r_T)^2} \le 0.6 F_y$	= 0.00	[ksi]	Eq F1-7
For any value of (L_b / r_T)	Applicable			
	$F_{bx} = \frac{12 x 10^3 C_b}{L_b x (d_{all} / A_f)} \le 0.6 F_y$	= 21.60	[ksi]	Eq F1-8
Allowable compression stress	$F_{bx\,c}$ =	= **21.60**	[ksi]	
Actual compression stress	$f_{bx\,c} = M_x / S_2$	= 6.05	[ksi]	
	ratio = $f_{bx\,c} / F_{bx\,c}$	= **0.28**	**OK**	

Check Bending about Y-Y Axis on Top Flange

For compact top flange	Applicable			
	$F_{by} = 0.75 \times F_y$	= 27.00	[ksi]	Eq F2-1

					Code Reference
For non-compact top flange	Not Applicable				*ASD 9th Edition*
	F_{by} = 0.60 x F_y	= 0.00	[ksi]		Eq F2-2
Allowable compression stress	$F_{by\ c}$ =	= **27.00**	[ksi]		
Actual compression stress	$f_{by\ c}$ = M_y / S_t	= 2.71	[ksi]		
	ratio = $f_{bx\ c} / F_{bx\ c}$	= **0.10**	**OK**		

Check Biaxial Bending on Top Flange

Combined bending stress	$f_{bx} / F_{bx} + f_{by} / F_{by}$	= **0.38**	**OK**	Eq H1-3

Check Shear along Y-Y Axis

Clear dist between trans. stiffeners	a = L_b	= 240.00	[in]	
W sect clear dist between flange	h = 21.560 [in]	a / h = 11.13		

k_v = 4.00 + 5.34 / (a / h)^2 if a / h <=1 = 5.37 F4

5.34 + 4.00 / (a / h)^2 if a / h >1

h / t_w = 45.87 C_v = 1.36

For h / t_w <= 380 / sqrt (F_y) Applicable

F_v = 0.40 x F_y = 20.00 [ksi] Eq F4-1

For h / t_w > 380 / sqrt (F_y) Not Applicable

	F_v = (F_y x C_v) / 2.89 <=0.4 F_y	= 0.00	[ksi]	Eq F4-2
Allowable shear stress	F_v =	= **20.00**	[ksi]	
Actual shear stress	f_v = V_x / S_t	= 4.70	[ksi]	
	ratio = f_v / F_v	= **0.23**	**OK**	

Check Web Sidesway Buckling *AISC Design Guide 7*

Use LRFD 13 instead of ASD 9 to increase web sidesway buckling resistance when flexural stress in the web is less than 0.66F_y page 61

$(h / t_w) / (L_b / b_f)$ = 1.72 >1.7 *AISC LRFD-13*

Max actual bending stress f_b = 10.24 [ksi]

When $f_b < (F_y / 1.5) = 0.66 F_y$	Applicable	C_r = 9.6E+05	[ksi]
When $f_b >= (F_y / 1.5) = 0.66 F_y$	Not Applicable	C_r = 0.0E+00	[ksi]

$$R_n = \frac{C_r\, t_w^3\, t_f}{h^2}\left[0.4\left(\frac{h\ /\ t_w}{L_b\ /\ b_f}\right)^3\right]$$ = NA [kips] Eq J10-7

R_a = $R_n / \Omega = R_n / 1.76$	= NA	[kips]	
$P_{v\text{-}impt}$ = P_v x α (impact factor)	= 37.63	[kips]	
ratio = $P_{v\text{-}impt} / R_a$	= **0.00**	**OK**	

Check Runway Beam Deflection — **Code Reference**

Crane serviceability criteria based on	
CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition	Table 4.1 item 14,15
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	page 56
CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes	Cl 1.4.3

CMAA crane service class Class C Moderate service

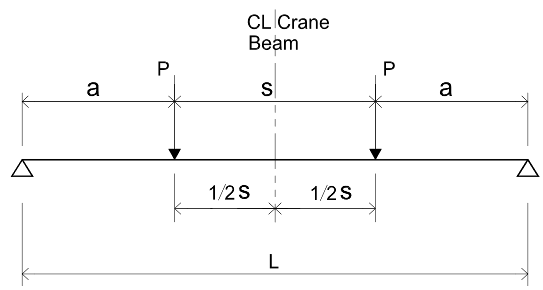
Ver deflection limit (no impact , max wheel load) B_v = L / 600

Hor deflection limit (no impact , 10% max wheel load) B_h = L / 400

Runway beam span L = 240.00 [in]

Bridge wheel spacing s = 150.00 [in]

a = 45.00 [in]



Max Deflection Case

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 10.65 P / I

Vertical Deflection

Unfactored max ver. wheel load P = 30.1 [kips / per wheel] impact factor NOT included

I_x = 3340.0 [in^4]

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 0.096 [in]

Allowable deflection $\Delta_a = L / B_v$ = 0.400 [in]

ratio = Δ_{max} / Δ_a = **0.24** **OK**

Lateral Deflection

Unfactored max hor. wheel load P = 2.3 [kips / per wheel]

I_t = 362.1 [in^4]

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 0.068 [in]

Allowable deflection $\Delta_a = L / B_h$ = 0.600 [in]

ratio = Δ_{max} / Δ_a = **0.11** **OK**

CRANE RUNWAY BEAM DESIGN - LRFD 13

Crane runway design based on		**Code Abbreviation**
AISC 360-05 Specification for Structural Steel Buildings		*AISC LRFD-13*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition		*AISC Design Guide 7*

Crane runway beam section W24x84 C15x33.9 — W24x84 and C15x33.9

Section Properties

Combined Section Overall

A =	34.700	[in^2]	d_{all} =	24.500	[in]
top y_c =	9.100	[in]	bott. y_t =	15.400	[in]
I_x =	3340.0	[in^4]	I_y =	409.00	[in^4]
top S_{xc} =	367.00	[in^3]	bott. S_{xt} =	217.00	[in^3]
S_y =	54.50	[in^3]			
Z_x =	286.00	[in^3]	Z_y =	83.40	[in^3]
r_x =	9.820	[in]	r_y =	3.430	[in]
J =	4.71	[in^4]	C_w =	0	[in^6]

W Section

d =	24.100	[in]	b_f =	9.020	[in]
t_w =	0.470	[in]	t_f =	0.770	[in]
h =	21.560	[in]	$h_c = 2(y_c - k)$ =	15.660	[in]
$h_0 = d - t_f$ =	23.330	[in]			

Top Flange

A_f =	16.895	[in^2]	d_{all} / A_f =	1.450	[in^{-1}]
r_t =	4.468	[in]	r_{yt} =	4.629	[in]
I_t =	362.09	[in^4]			
S_t =	48.28	[in^3]	Z_t =	66.46	[in^3]

W section yield strength	F_{wy} =	50.0	[ksi]	= 345	[MPa]
C section yield strength	F_{cy} =	36.0	[ksi]	= 248	[MPa]
Runway beam unbraced length	L_b =	240.00	[in]		

Design Forces

Bending moment x-x axis	M_x =	276.78	[kip-ft]
Bending moment y-y axis	M_y =	17.43	[kip-ft]
Shear along y-y axis	V_y =	79.72	[kips]

Conclusion

Overall	ratio =	**0.46**	OK
Local buckling			OK
Biaxial Bending on Top Flange	ratio =	0.46	OK
Shear along Y-Y Axis	ratio =	0.26	OK
Web Sidesway Buckling	ratio =	0.00	OK
Runway Beam Vertical Deflection	ratio =	0.24	OK
Runway Beam Lateral Deflection	ratio =	0.11	OK

				Code Reference
Design Basis & Assumption				*AISC Design Guide 7*
1. The channel and W section top flange resist the hor. load and the combined section resists the ver. load. This assumption eliminates the need for an analysis of torsional effects on the combined section and simplifies the analysis.				18.1 on page 56
2. If A36 channel cap is used on A992 W section then lateral torsional buckling and weak axis flexure strength must be calculated based on A36 yield stress.				18.1.4 on page 57
Check Local Buckling				
Flange of W shape				*AISC LRFD-13*
Compact limit	λ_p =	$0.38\ \mathrm{sqrt}\ (E / F_{wy})$	= 9.15	Table B4.1 Case 1
Noncompact limit	λ_r =	$1.0\ \mathrm{sqrt}\ (E / F_{wy})$	= 24.08	
	$b_f / 2t_f$ =	5.86	Compact	
Web of W shape				
Compact limit	λ_p =	$3.76\ \mathrm{sqrt}\ (E / F_{wy})$	= 90.55	Table B4.1 Case 9
Noncompact limit	λ_r =	$5.7\ \mathrm{sqrt}\ (E / F_{wy})$	= 137.27	
	h / t_w =	45.87	Compact	
W shape classification			**Compact**	
Flange of Channel	This part is applicable			
Compact limit	λ_p =	$0.38\ \mathrm{sqrt}\ (E / F_{cy})$	= 10.79	Table B4.1 Case 1
Noncompact limit	λ_r =	$1.0\ \mathrm{sqrt}\ (E / F_{cy})$	= 28.38	
	b_f / t_f =	5.23	Compact	
Web of Channel (flange cover plate between lines of welds)				
Compact limit	λ_p =	$1.12\ \mathrm{sqrt}\ (E / F_{cy})$	= 31.79	Table B4.1 Case 12
Noncompact limit	λ_r =	$1.4\ \mathrm{sqrt}\ (E / F_{cy})$	= 39.74	
	b_f (W shape) / t_w (C channel) =	22.55	Compact	
Channel shape classification			**Compact**	
Combined section classification		**Compact**	ratio = **0.00**	**OK**

Check Bending about X-X Axis

Calculate R_{pc}

	λ_{pw} =	90.55	λ_{rw} = 137.27		
	M_{yc} =	$S_{xc} F_y$	= 1529.2	[kip-ft]	
	M_p =	$\min (Z_x F_y , 1.6 S_{xc} F_y)$	= 1191.7	[kip-ft]	
	λ =	h_c / t_w	= 33.32		
	M_p / M_{yc} =		= 0.78		
For $\lambda \le \lambda_{pw}$	Applicable				
	R_{pc} =	M_p / M_{yc}	= 0.78		Eq F4-9a

				Code Reference
For $\lambda > \lambda_{pw}$	Not Applicable			*AISC LRFD-13*
	$R_{pc} = \left[\frac{M_p}{M_{yc}} - \left(\frac{M_p}{M_{yc}} - 1\right)\left(\frac{\lambda - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}}\right)\right] \le \frac{M_p}{M_{yc}}$	= 0.00		Eq F4-9b
R_{pc} used for design	R_{pc} =	= **0.78**		

Calculate R_{pt}

	$M_{yt} = S_{xt} F_y$	= 904.2	[kip-ft]	
	$M_p = \min(Z_x F_y, 1.6 S_{xt} F_y)$	= 1191.7	[kip-ft]	
	M_p / M_{yt} =	= 1.32		
For $\lambda \le \lambda_{pw}$	Applicable			
	$R_{pt} = M_p / M_{yc}$	= 1.32		Eq F4-15a
For $\lambda > \lambda_{pw}$	Not Applicable			
	$R_{pt} = \left[\frac{M_p}{M_{yt}} - \left(\frac{M_p}{M_{yt}} - 1\right)\left(\frac{\lambda - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}}\right)\right] \le \frac{M_p}{M_{yt}}$	= 0.00		Eq F4-15b
R_{pt} used for design	R_{pt} =	= **1.32**		

Calculate F_L

	$S_{xt} / S_{xc} = 0.59$			
For $S_{xt} / S_{xc} >= 0.7$	Not Applicable			
	$F_L = 0.7 F_y$	= 0.0	[ksi]	Eq F4-6a
For $S_{xt} / S_{xc} < 0.7$	Applicable			
	$F_L = \max(F_y \times (S_{xt} / S_{xc}), 0.5F_y)$	= 21.3	[ksi]	Eq F4-6b
F_L used for design	F_L =	= **21.3**	[ksi]	

M_n - Compression Flange Yielding

	$M_{n1} = R_{pc} F_y S_{xc}$	= **858.0**	[kip-ft]	Eq F4-1

M_n - Lateral Torsional Buckling

Runway beam unbraced length	L_b =	= 240.00	[in]	
Calculate L_p & L_r				
	$L_p = 1.1\, r_t \sqrt{\frac{E}{F_y}}$	= 139.5	[in]	Eq F4-7
	$L_r = 1.95\, r_t \frac{E}{F_L} \sqrt{\frac{J}{S_{xc} h_o}} \sqrt{1 + \sqrt{1 + 6.76\left(\frac{F_L}{E}\frac{S_{xc} h_o}{J}\right)^2}}$			Eq F4-8
		= 597.8	[in]	

				Code Reference
				AISC LRFD-13
For $L_b <= L_p$	Not Applicable			
	M_{n2} =	= NA	[kip-ft]	
For $L_p < L_b <= L_r$	Applicable			
	C_b = 1.0 to be conservative			
	$M_{n2} = C_b \left[R_{pc} M_{yc} - (R_{pc} M_{yc} - F_L S_{xc}) \left(\frac{L_b - L_p}{L_r - L_p} \right) \right] \le R_{pc} M_{yc}$			Eq F4-2
		= 1073.1	[kip-ft]	
For $L_b > L_r$	Not Applicable			
For $I_t / I_y <= 0.23$ J = 0	Not Applicable			
	J = 4.71 [in^4]			
	$F_{cr} = \frac{C_b \pi^2 E}{\left(\frac{L_b}{r_t}\right)^2} \sqrt{1 + 0.078 \frac{J}{S_{xc} h_o} \left(\frac{L_b}{r_t}\right)^2}$	= 0.0	[ksi]	Eq F4-5
	$M_{n2} = F_{cr} S_{xc} <= R_{pc} F_y S_{xc}$	= NA	[kip-ft]	Eq F4-3
M_n - LTB	M_{n2} =	= **1073.1**	[kip-ft]	

<u>M_n - Compression Flange Local Buckling</u>

	λ = 5.86			
	λ_{pf} = 9.15	λ_{rf} = 24.08		
For $\lambda <= \lambda_{pf}$	Applicable			
	M_{n3} =	= NA	[kip-ft]	
For $\lambda_{pf} < \lambda <= \lambda_{rf}$	Not Applicable			
	$M_{n3} = \left[R_{pc} M_{yc} - (R_{pc} M_{yc} - F_L S_{xc}) \left(\frac{\lambda - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}} \right) \right]$	= NA	[kip-ft]	Eq F4-12
	M_{n3} =	= **NA**	[kip-ft]	

<u>M_n - Tension Flange Yielding</u>

	$M_{n4} = R_{pt} F_y S_{xt}$	= **1191.7**	[kip-ft]	Eq F4-14
	$M_{nx} = \min(M_{n1}, M_{n2}, M_{n3}, M_{n4})$	= **858.0**	[kip-ft]	

Check Bending about Y-Y Axis **Code Reference**

Check top flange compactness, for W check W flange only, for W+Cap Channel check both W and Channel flange

Top flange compactness		= Compact			*AISC LRFD-13*
For compact top flange	M_{ny}	= $F_y Z_t$	= 199.4	[kip-ft]	Eq F6-1
For noncompact top flange	M_{ny}	= $F_y S_t$	= 144.8	[kip-ft]	
	M_{ny}	=	= **199.4**	[kip-ft]	

Check Biaxial Bending on Top Flange

Combined bending	$M_x / (\Phi M_{nx}) + M_y / (\Phi M_{ny})$	= **0.46**	**OK**	Eq H1-1b

Check Shear along Y-Y Axis

Clear dist between trans. stiffeners	a	= L_b	= 240.00	[in]	
W sect clear dist between flange	h	= 21.560 [in]	a / h = 11.13		
	h / t_w	= 45.87			
	k_v	= 5 if $h / t_w < 260$	= 5.00		G2.1 (b)
		5 if $a / h > 3.0$ or $a / h > [260/(h / t_w)]^2$			
		$5 + 5 / (a / h)^2$			
	T	= $\text{sqrt}(k_v E / F_y)$	= 53.9		
For $h / t_w <= 1.10\ T$		Applicable			
	C_v	=	1.0		Eq G2-3
For $1.10\ T < h / t_w <= 1.37\ T$		Not Applicable			
	C_v	= $1.10 \times \text{sqrt}(k_v E / F_y) / (h / t_w)$	= NA		Eq G2-4
For $h / t_w > 1.37\ T$		Not Applicable			
	C_v	= $1.51\ E\ k_v / [\ (h / t_w\ )^2\ F_y\ ]$	= NA		Eq G2-5
C_v used for design	C_v	=	= 1.0		
	ΦV_n	= $0.9 \times 0.6\ F_y\ (d\ t_w)\ C_v$	= **305.8**	[kips]	Eq G2-1
	ratio	= $V_y / \Phi V_n$	= **0.26**	**OK**	

Check Web Sidesway Buckling — **Code Reference** *AISC LRFD-13*

$(h / t_w) / (L_b / b_f)$ = 1.72 >1.7

When $M_u < M_y$ — Applicable — C_r = 9.6E+05 [ksi]

When $M_u >= M_y$ — Not Applicable — C_r = 0.0E+00 [ksi]

$$R_n = \frac{C_r t_w^3 t_f}{h^2}\left[0.4\left(\frac{h / t_w}{L_b / b_f}\right)^3\right]$$ = NA [kips] Eq J10-7

Φ = = 0.85

$P_{v\text{-impt}} = P_v \times \alpha$ (impact factor) = 56.70 [kips]

ratio = $P_{v\text{-impt}} / \Phi R_n$ = **0.00** **OK**

Check Runway Beam Deflection

Crane serviceability criteria based on

CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition — Table 4.1 item 14,15

AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition — page 56

CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes — Cl 1.4.3

CMAA crane service class — Class C — Moderate service

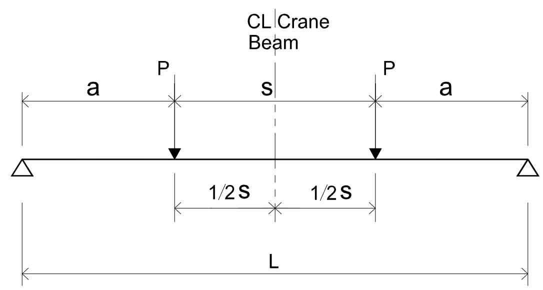
Ver deflection limit (no impact , max wheel load) — B_v = L / 600

Hor deflection limit (no impact , 10% max wheel load) — B_h = L / 400

Runway beam span — L = 240.00 [in]

Bridge wheel spacing — s = 150.00 [in]

a = 45.00 [in]



Max Deflection Case

Max deflection at center $$\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24 E I}$$ = 10.65 P / I

Vertical Deflection

Unfactored max ver. wheel load — P = 30.1 [kips / per wheel] — impact factor NOT included

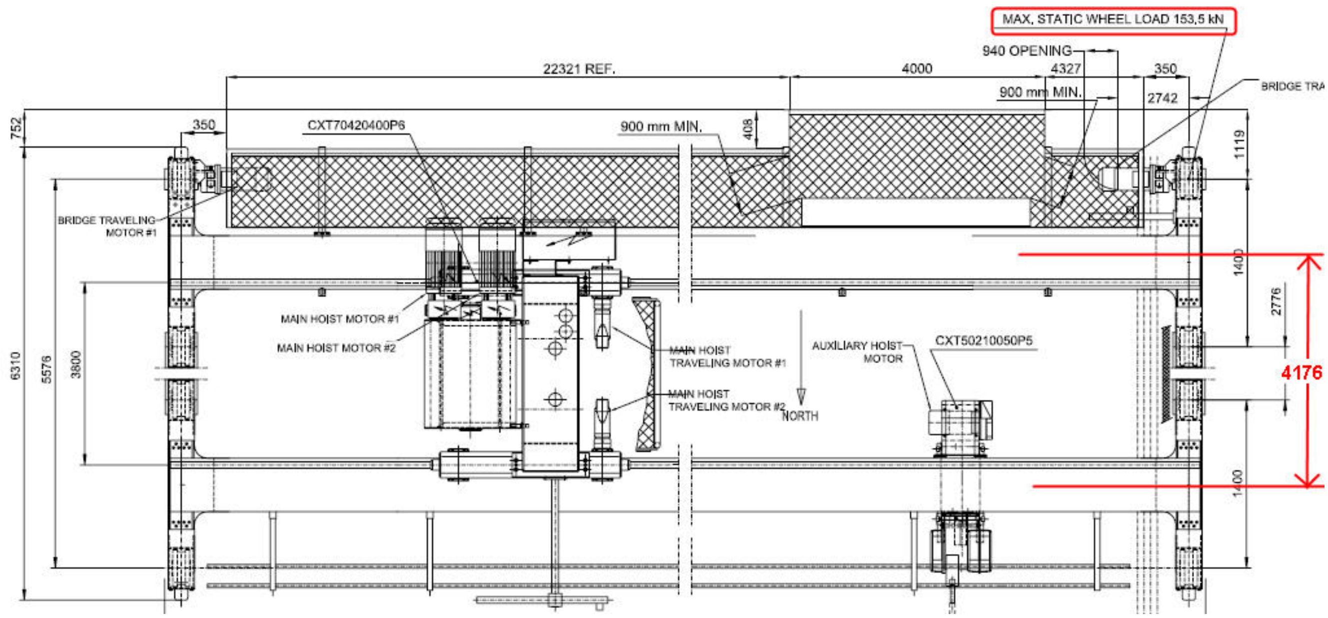
I_x = 3340.0 [in^4]

Max deflection at center $$\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24 E I}$$ = 0.096 [in]

				Code Reference
Allowable deflection	$\Delta_a = L / B_v$	= 0.400	[in]	
	ratio = Δ_{max} / Δ_a	**= 0.24**	**OK**	
Lateral Deflection				
Unfactored max hor. wheel load	P = 2.3 [kips / per wheel]			
	I_t = 362.1 [in^4]			
Max deflection at center	$\Delta_{max} = \dfrac{Pa(3L^2 - 4a^2)}{24\ E\ I}$	= 0.068	[in]	
Allowable deflection	$\Delta_a = L / B_h$	= 0.600	[in]	
	ratio = Δ_{max} / Δ_a	**= 0.11**	**OK**	

Example 02: Top Running 40 Ton Crane + Runway W Shape with Cap Channel – Metric Unit

This is a 35 tonne bridge crane with 5 tonne auxiliary hoist. The bridge has 4 wheels at each side. We need to convert the 4-wheel bridge to equivalent 2-wheel bridge for analysis.



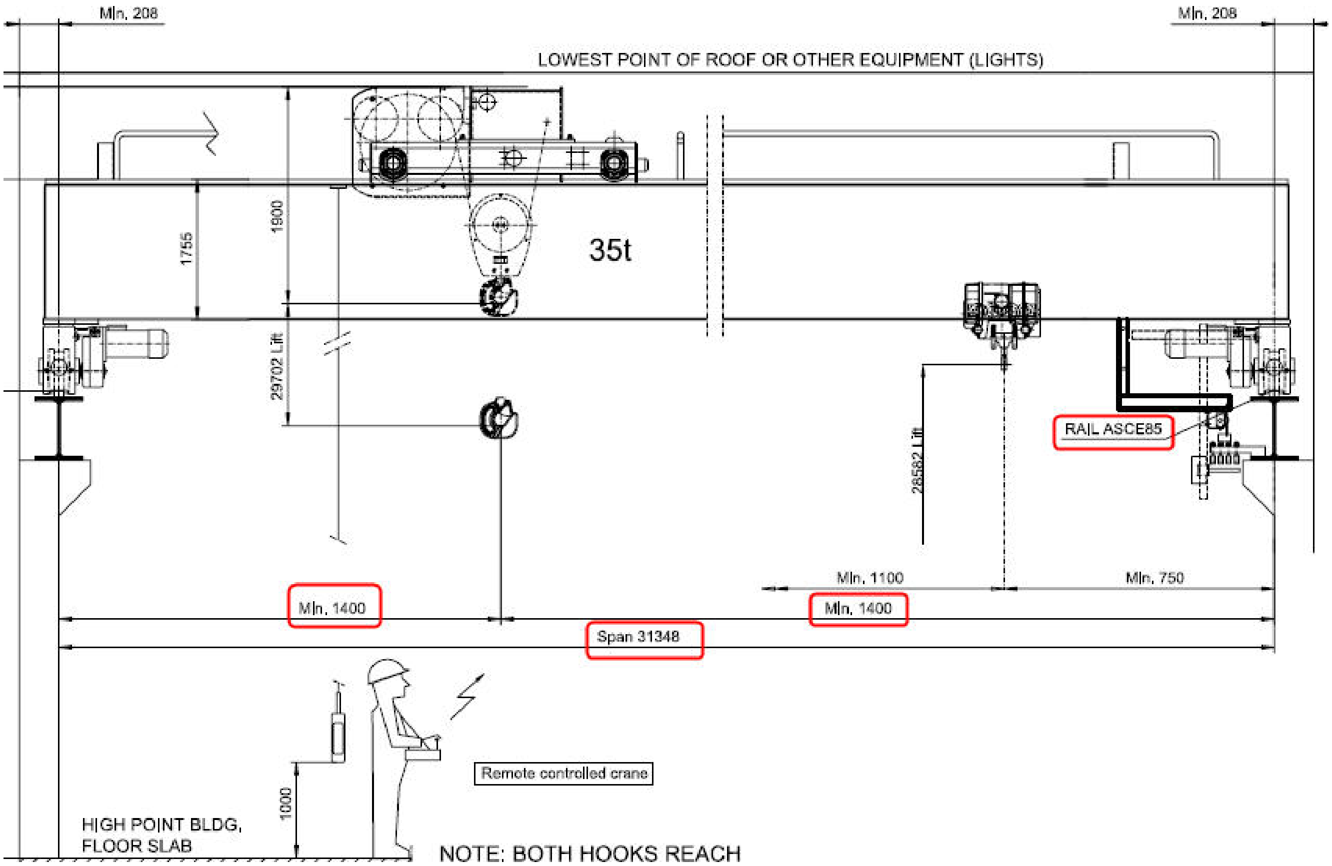
Crane Plan

Convert the 4-wheel bridge to equivalent 2-wheel bridge by consolidating 2-wheel into a single wheel.

For an equivalent 2-wheel bridge

Bridge wheel spacing s = 1400 + 2776 = 4176 mm = 4.176 m

Max static wheel load = 153.5 kN x 2 = 307.0 kN



Crane Elevation

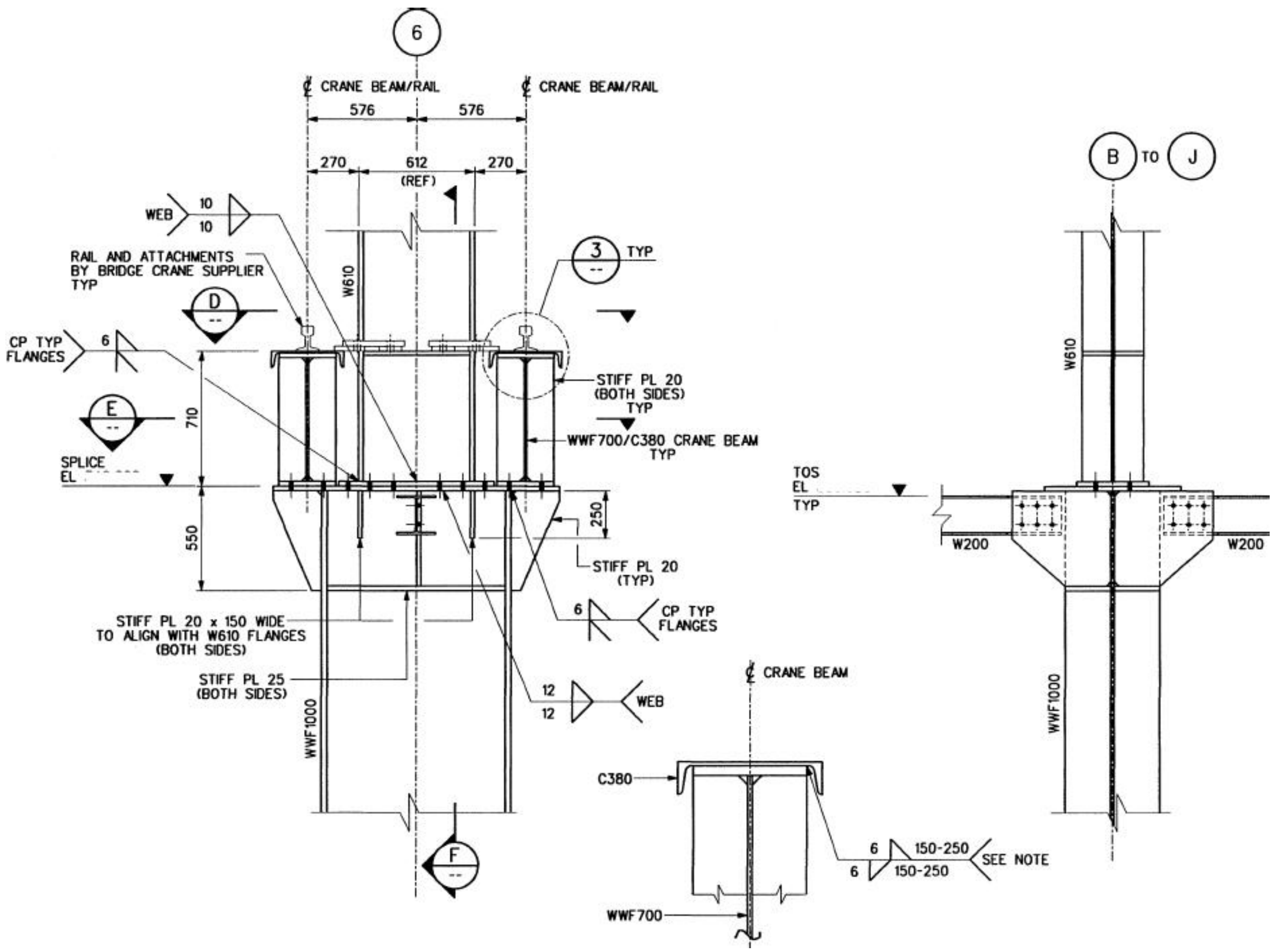
TECHNICAL DATA

LOAD....................................	35 t
SPAN....................................	31.348 m
LIFTING HEIGHT..........................	30 m available on hoist
HOISTING SPEED..........................	4.8/0.8 m/min 2-SPEED
TRAVERSING SPEED........................	20 m/min STEPLESS
TRAVELLING SPEED........................	32 m/min STEPLESS
WEIGHT OF TROLLEY.......................	3.07 t
WEIGHT OF BRIDGE........................	29.13 t
POWER SUPPLY............................	600 V / 3 PH / 60 Hz
CRANE GROUP.............................	CMAA C
HOIST MACHINERY GROUP..	FEM M4 (1Am)
BRIDGE TRAVEL GROUP......	FEM M5 (2m)
POWER, TOTAL............................	54.8 kW
LENGTH OF RUNWAY........................	65 m

AUXILIARY HOIST DATA

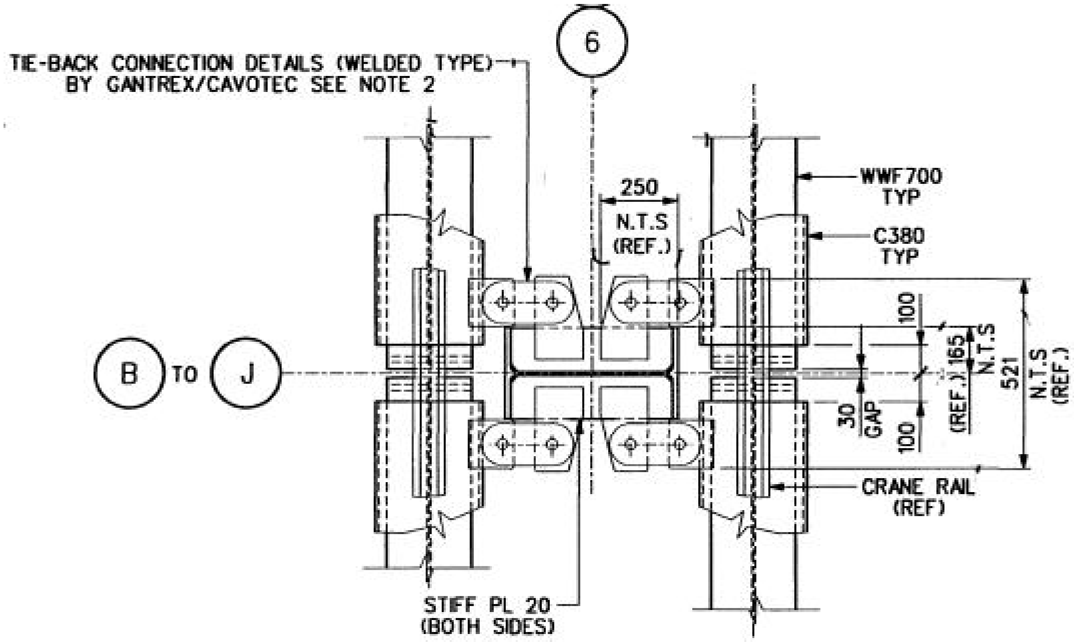
LOAD....................................	5 t
LIFTING HEIGHT..........................	32 m available on hoist
HOISTING SPEED..........................	12/2 m/min 2-SPEED
TRAVERSING SPEED........................	20 m/min STEPLESS
WEIGHT OF TROLLEY.......................	0.71 t
POWER, AUX. HOIST ONLY...	11.6 kW

Crane Data	Imperial	Metric
Crane capacity	44.08 US Tons = 88.2 kips	40 Metric Tons = 392.3 kN
Bridge weight	64.2 kips	29130 kg
Trolley + hoist weight	8.3 kips	3780 kg
Max static wheel load	69.0 kips	307.0 kN
Bridge span S_r	102.9 ft	31.348 m
Left min. hook approach S_L	4.6 ft	1.400 m
Right min. hook approach S_R	4.6 ft	1400 m
Bridge wheel spacing s	13.7 ft	4.176 m
Crane runway beam span L	21.3 ft	6.500 m
Left runway CL to column CL dist e_L	1.9 ft	0.576 m
Right runway CL to column CL dist e_R	1.9 ft	0.576 m
Crane rail size	ASCE 85	ASCE 85
CMAA crane service class	Class C	Class C
Vertical impact factor	25%	25%
Crane type	Top Running	Top Running
Crane runway beam size	W27x84 + C15x33.9	W690x125 + C380x50
W shape F_y	50 ksi	345 MPa
Channel cap F_y	36 ksi	248 MPa



Crane Runway Beam Connection

Runway Beam Size Change to W690x125 + C380x50



PLAN VIEW D
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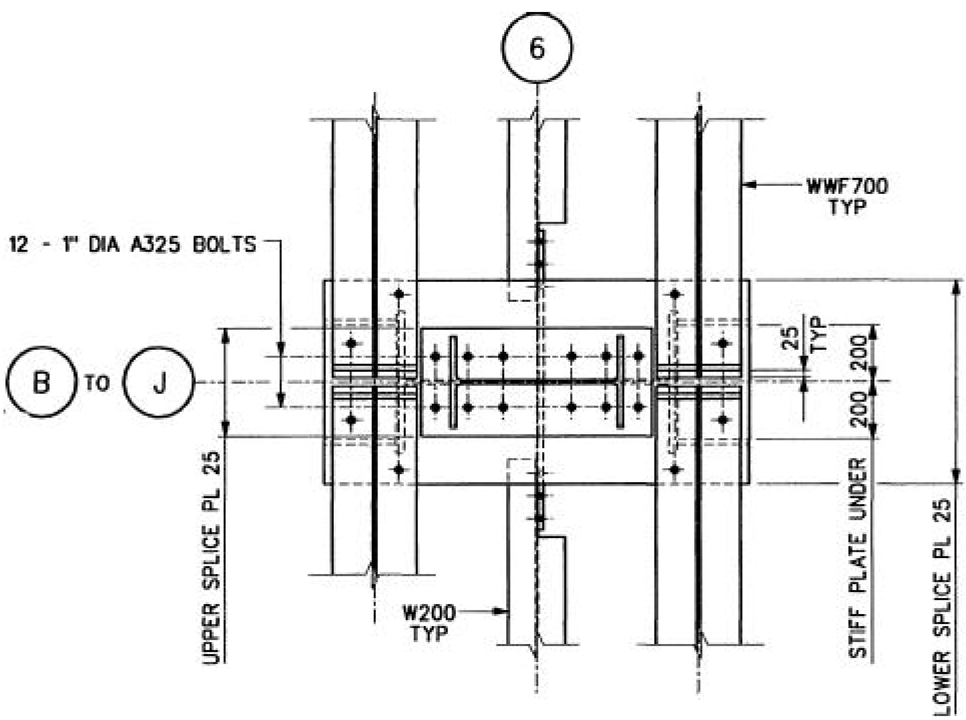

PLAN VIEW E
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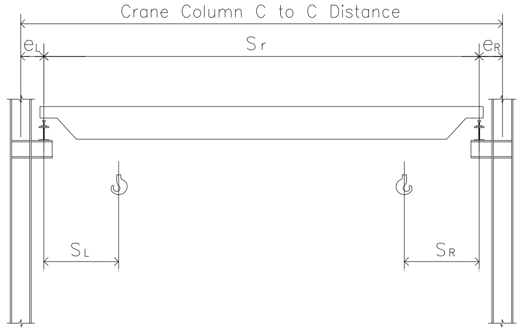
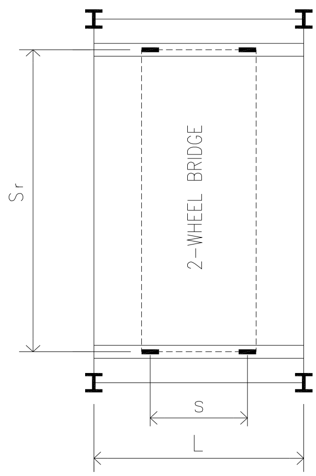
BRIDGE CRANE LOAD CALCULATION

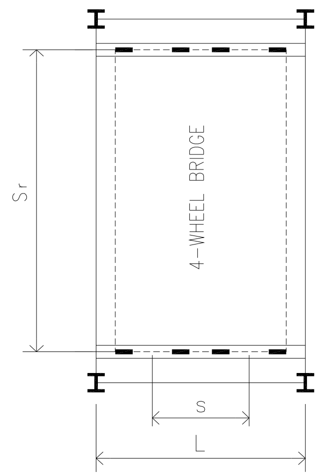
Bridge crane load calc based on	**Code Abbreviation**
CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition	*CISC Crane Guide*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*
CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes	*CMAA 70-04*



SECTION



PLAN – 2 WHEEL



PLAN – 4 WHEEL

Crane Data

					suggested value		
Crane rated capacity	W_{rc}	=	40.0	[Metric Ton]		= 392.3	[kN]
Bridge weight	W_{br}	=	29130	[kg]	32136	= 285.5	[kN]
Trolley + hoist weight	W_{th}	=	3780	[kg]	3300	= 37.0	[kN]
Bridge wheel spacing	s	=	4.176	[m]	4.20		
Max. static wheel load by vendor	P_{max-v}	=	307.0	[kN]	input 0 if vendor data is unknown		
Crane bridge span	S_r	=	31.348	[m]	31.2		
Min. hook approach-left	S_L	=	1.400	[m]	1.40		
Min. hook approach-right	S_R	=	1.400	[m]	1.40		
Crane runway beam span	L	=	6.500	[m]			
Runway CL to col CL dist-left	e_L	=	0.576	[m]	0.65		
Runway CL to col CL dist-right	e_R	=	0.576	[m]	0.65		
Crane column C to C distance	$S_r + 2e$	=	32.500	[m]		suggested section	
Runway beam type		=	W_Shape_Cap_Channel	?			
Runway beam size		=	W690x125 C380x50			size > W610x125 C380x50	
Top flange cap plate size	width b_p				thick t_p	not applicable	
	suggest		ASCE 60		U_{rb}	= 1.72	[kN/m]
Crane rail size		=	ASCE 85		U_{cr}	= 85	[lbs/yd]
						= 0.41	[kN/m]
Rail base width	B_w	=	132	[mm]	Rail height H_t	= 132	[mm]
W section yield strength	f_{wy}	=	345	[MPa]		= 50.0	[ksi]
Cap channel or plate yield strength	f_{cy}	=	248	[MPa]		= 36.0	[ksi]
CMAA crane service class		=	Class C	?		Moderate service	
Crane type		=	Top Running		?		

			Code Reference
			CISC Crane Guide
Vertical load impact factor	= 0.25	?	Table 2.1
Crane side thrust load option	= Option 1	?	Table 2.1

Crane side thrust load can be calculated using one of the following 3 options

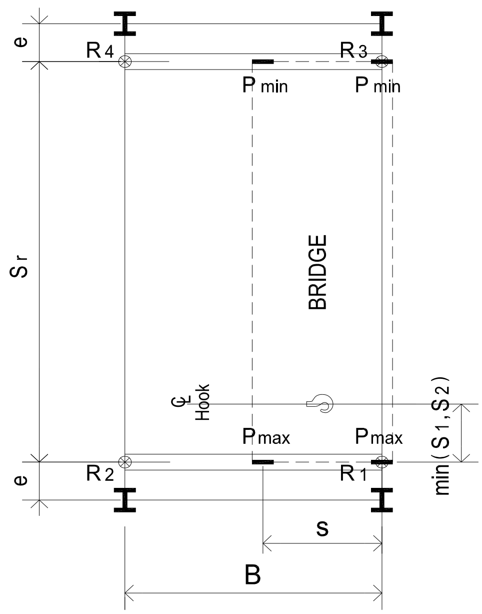
Option 1 H_s = 0.2 (Lifted Load+ Trolley/Hoist Wt)

Option 2 H_s = max of 0.2 (Lifted Load+ Trolley/Hoist Wt)
0.1 (Lifted Load+ Entire Crane Wt)

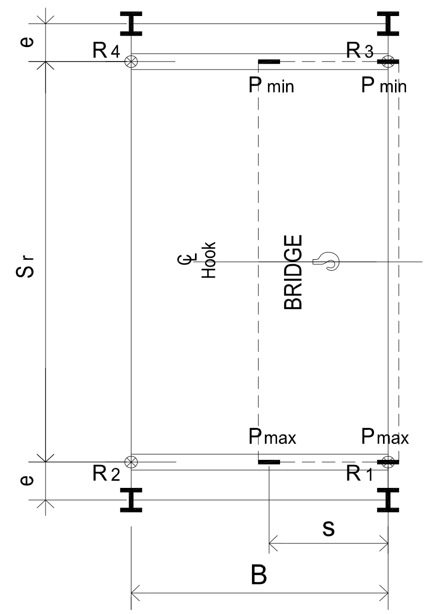
Option 3 H_s = max of 0.2 (Lifted Load+ Trolley/Hoist Wt)
0.1 (Lifted Load+ Entire Crane Wt)
0.4 Lifted Load

Conclusion

Runway Beam Design Using ASD 89		
Overall	ratio = **0.81**	OK
Local buckling		OK
Bending about X-X Axis	ratio = 0.73	OK
Bending about Y-Y Axis on Top Flange	ratio = 0.22	OK
Biaxial Bending on Top Flange	ratio = 0.81	OK
Shear along Y-Y Axis	ratio = 0.48	OK
Web Sidesway Buckling	ratio = 0.00	OK
Runway Beam Vertical Deflection	ratio = 0.49	OK
Runway Beam Lateral Deflection	ratio = 0.25	OK
Runway Beam Design Using LRFD 05		
Overall	ratio = **0.97**	OK
Local buckling		OK
Biaxial Bending on Top Flange	ratio = 0.97	OK
Shear along Y-Y Axis	ratio = 0.54	OK
Web Sidesway Buckling	ratio = 0.00	OK
Runway Beam Vertical Deflection	ratio = 0.49	OK
Runway Beam Lateral Deflection	ratio = 0.25	OK



CASE 1 HOOK AT ONE SIDE

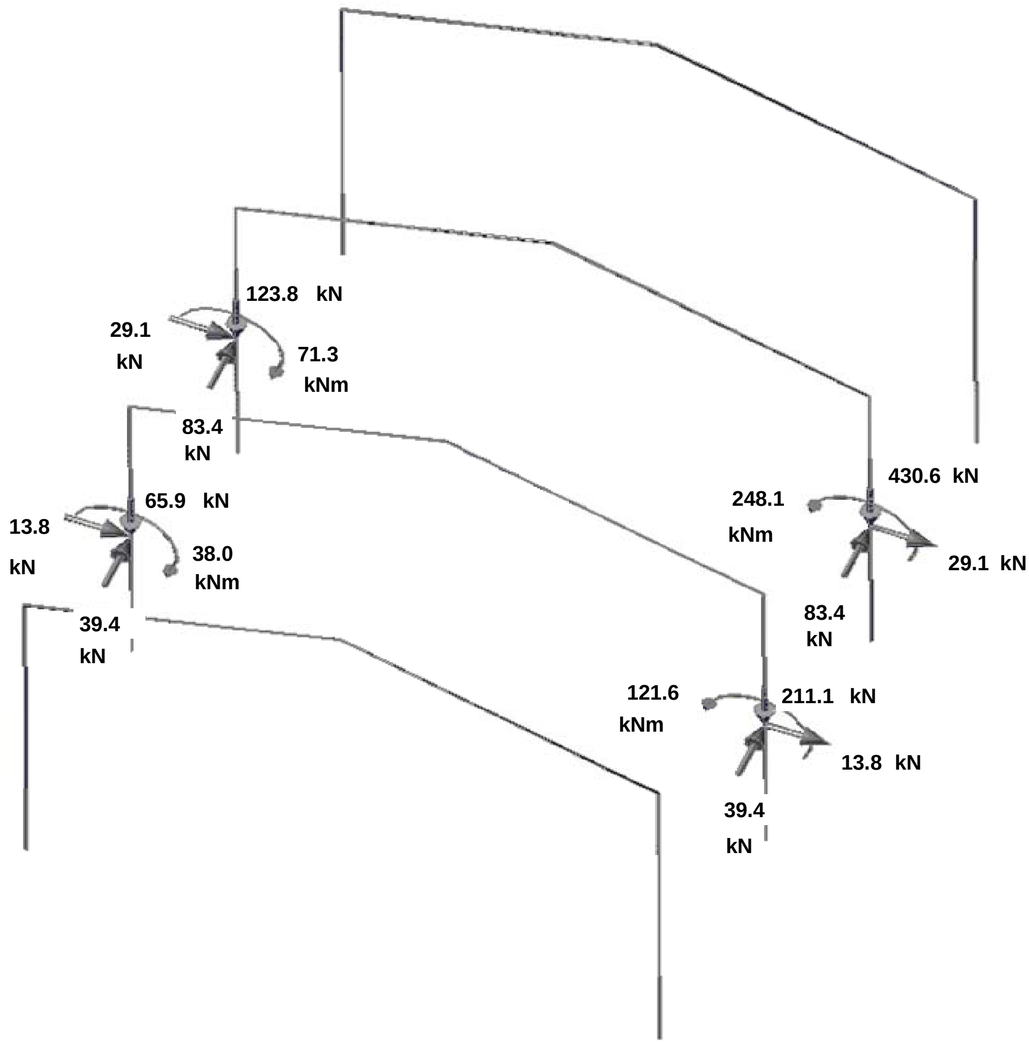


CASE 2 HOOK AT CENTER

Crane Load Calculation					**Code Reference**
Crane runway + rail selfweight	R_{sw}	= $(U_{rb} + U_{cr})$ x B	= 13.9	[kN]	
Wheel load by bridge selfwei	P_{br}	= W_{br} / 4 wheel	= 71.4	[kN/per wheel]	
Side Thrust Load					
Crane side thrust load calculated by		= Option 1			*CISC Crane Guide*
	H_{s1}	= 0.4 Lifted Load	= 156.9	[kN]	Table 2.1
	H_{s2}	= 0.2 (Lifted Load+ Trolley/Hoist Wt)	= 85.9	[kN]	
	H_{s3}	= 0.1 (Lifted Load+ Entire Crane Wt)	= 71.5	[kN]	
	H_{st}	= side thrust load calc using Option 1	= 21.5	[kN/per wheel]	
	H_{st1}=H_{st3}	= H_{st} (1 + (B-s) / B)	= **29.1**	[kN]	
	H_{st2}=H_{st4}	= H_{st} s / B	= **13.8**	[kN]	
Tractive Load					Table 2.1
	H_{tr}	= 0.2 Max wheel load	= 61.4	[kN/per wheel]	
	H_{tr1}=H_{tr3}	= H_{tr} (1 + (B-s) / B)	= **83.4**	[kN]	
	H_{tr2}=H_{tr4}	= H_{tr} s / B	= **39.4**	[kN]	
Vertical Load					
Case 1 Hook at One Side					
Min. hook aproach	S_{min}	= min (S_L, S_R)	= 1.400	[m]	
Max wheel load by calc	P_{max-c}	= $[(W_{rc}+W_{th})x(S_r-S_{min})/ S_r]$/2 wheel+$P_{br}$	= 276.4	[kN/per wheel]	
Max. wheel load by vendor	P_{max-v}	=	= 307.0	[kN/per wheel]	
Max static wheel load	P_{max}	= max (P_{max-v} , P_{max-c})	= **307.0**	[kN/per wheel]	
Min wheel load	P_{min}	= $[(W_{rc}+W_{th})xS_{min}/S_r]$/2 wheel+$P_{br}$	= **81.0**	[kN/per wheel]	

Reaction on runway support	$R_1 = P_{max} (1 + (B\text{-}s) / B) + R_{sw}$	= **430.6**	[kN]
	$R_2 = P_{max}\, s / B + R_{sw}$	= **211.1**	[kN]
	$R_3 = P_{min} (1 + (B\text{-}s) / B) + R_{sw}$	= **123.8**	[kN]
	$R_4 = P_{min}\, s / B + R_{sw}$	= **65.9**	[kN]
Point moment to column center	$M_1 = R_1 \times e_R$	= **248.1**	[kNm]
	$M_2 = R_2 \times e_R$	= **121.6**	[kNm]
	$M_3 = R_3 \times e_L$	= **71.3**	[kNm]
	$M_4 = R_4 \times e_L$	= **38.0**	[kNm]

Case 1 Hook at One Side - Crane Load Summary



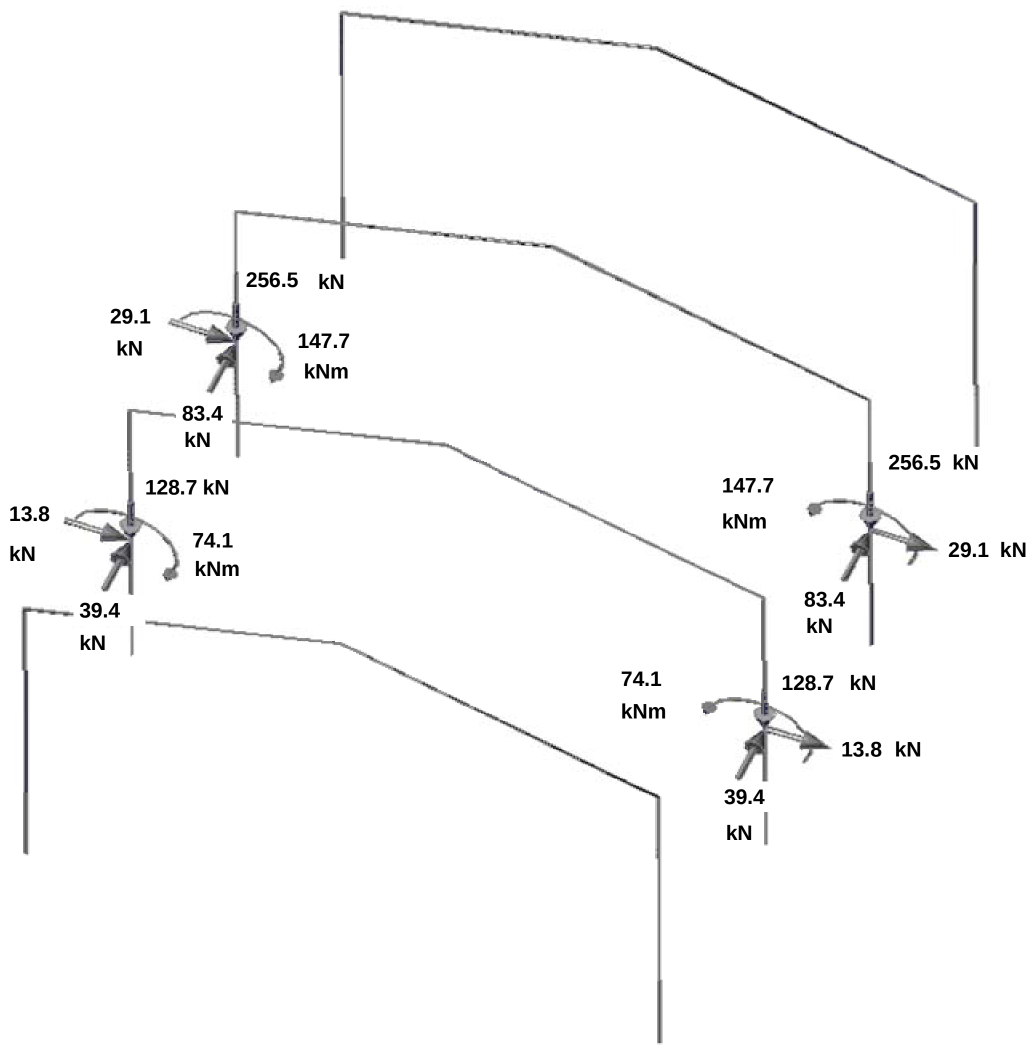
Note:

The crane loads shown above may be reverse if crane hook goes to the other side. When reverse the loads and apply them on building columns, the point moment value may need adjusted if eccentricity e_L <> e_R

Case 2 Hook at Center of Bridge

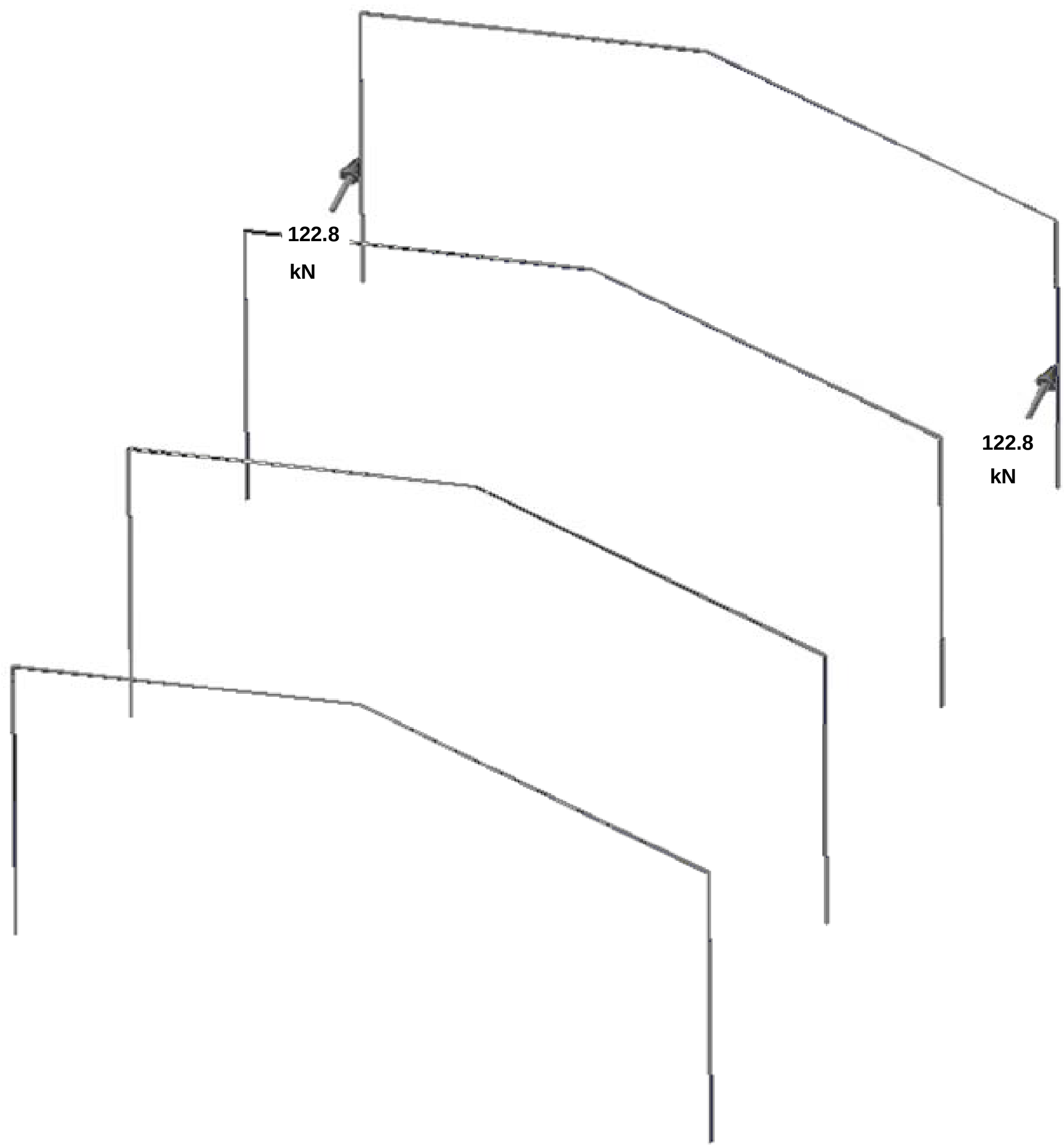
Max wheel load	$P_{max} = P_{min} = (W_{rc}+W_{br}+W_{th})/4$ wheel	= 178.7	[kN/per wheel]
Reaction on runway support	$R_1 = R_3 = P_{max}\,(1 + (B\text{-}s) / B) + R_{sw}$	= **256.5**	[kN]
	$R_2 = R_4 = P_{max}\, s / B + R_{sw}$	= **128.7**	[kN]
Point moment to column center	$M_1 = M_3 = R_1 \times \max(e_L , e_R)$	= **147.7**	[kNm]
	$M_2 = R_2 \times \max(e_L , e_R)$	= **74.1**	[kNm]

Case 2 Hook at Center of Bridge - Load Summary



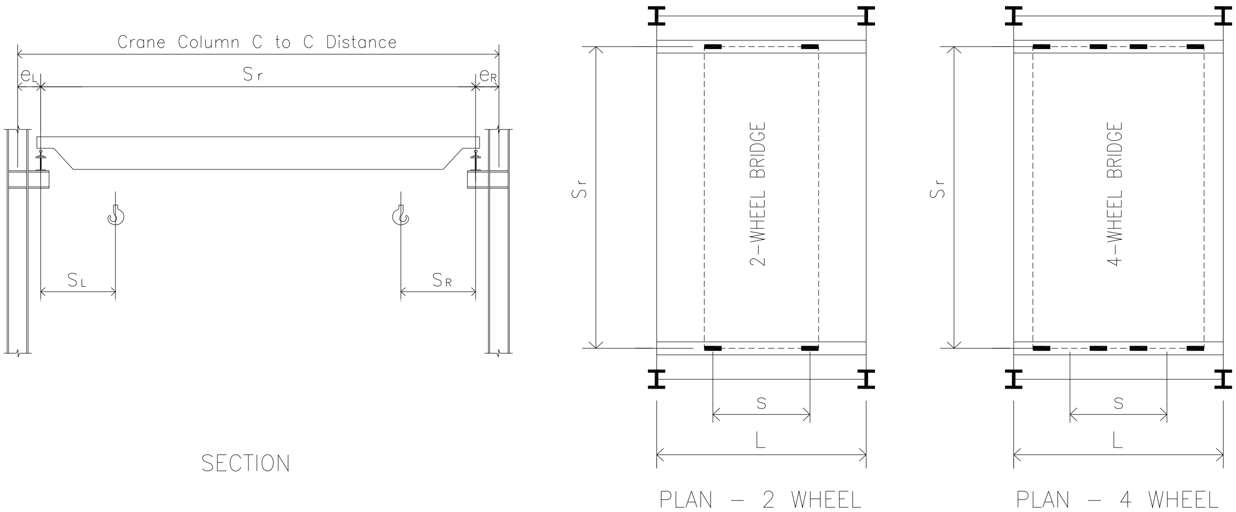
					Code Reference
Bumper Force at End Frame					*AISC Design Guide 7*
Bumper force to be the greater of	1 Twice the tractive force	=	122.8	[kN]	18.6
	2 10% of entire crane weight	=	35.7	[kN]	
Bumper force used for design		=	**122.8**	[kN]	

Apply longitudinal bumper force to both sides of end frame



CRANE RUNWAY BEAM DESIGN

Crane beam design using two codes : AISC LRFD 13th Ed and AISC ASD 9th Ed	**Code Abbreviation**
AISC 360-05 Specification for Structural Steel Buildings	*AISC LRFD-13*
AISC Manual of Steel Construction: Allowable Stress Design 9th Edition	*ASD 9th Edition*
CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition	*CISC Crane Guide*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*



Crane Data

Crane rated capacity	W_{rc} =	40.0	[tonne]	= 88.2	[kips]
Bridge weight	W_{br} =	29130	[kg]	= 64.2	[kips]
Trolley + hoist weight	W_{th} =	3780	[kg]	= 8.3	[kips]
Bridge wheel spacing	s =	4.176	[m]	= 13.7	[ft]

For 4-wheel crane **double** the vendor provided max static wheel load as input

Max static wheel load	P_{max} =	307.0	[kN]	= 69.0	[kips]
Crane bridge span	S_r =	31.3	[m]	= 102.8	[ft]
Left min. hook approach	S_1 =	1.400	[m]	= 4.6	[ft]
Right min. hook approach	S_2 =	1.400	[m]	= 4.6	[ft]
Crane runway beam span	L =	6.500	[m]	= 21.3	[ft]
Runway CL to column CL dist	e =	0.576	[m]	= 1.9	[ft]

Runway beam type W_Shape_Cap_Channel   Runway beam size W690x125 C380x50

U_{rb} = 1.72 [kN/m] = 0.119 [kip/ft]

Crane rail size ASCE 85

U_{cr} = 0.41 [kN/m] = 0.029 [kip/ft]

Crane Load Calculation *CISC Crane Guide*

Ver. load impact factor α = 1.25 Table 2.1

Crane side thrust load H_s = Option 1 = 19.3 [kips]

Option 1 H_s = 0.2 (Lifted Load+ Trolley/Hoist Wt)

Option 2 H_s = max of 0.2 (Lifted Load+ Trolley/Hoist Wt)
0.1 (Lifted Load+ Entire Crane Wt)

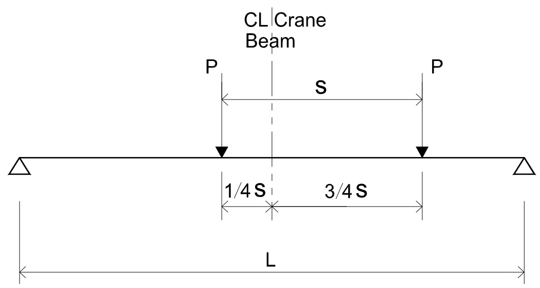
Option 3 H_s = max of 0.2 (Lifted Load+ Trolley/Hoist Wt)
0.1 (Lifted Load+ Entire Crane Wt)
0.4 Lifted Load

Runway beam span L = 21.3 [ft]

Bridge wheel spacing s = 13.7 [ft]

$$M_{max} = \frac{P}{2\,L}\left(L - \frac{s}{2}\right)^2$$

= 4.91 P



Max Bending Moment Case

Runway beam + rail selfwei U = $U_{rb} + U_{cr}$ = 0.147 [kip/ft]

Crane Load for Design per AISC ASD 9th Ed

Max ver. load /wheel (no impact) P_v = = 69.0 [kips / per wheel]

Max hor. load /wheel P_h = H_s / 4 = 4.8 [kips / per wheel]

Bending moment x-x axis M_x = 4.91 xP_vx α (impact) + U x L^2 / 8 = **432.19** [kip-ft]

Bending moment y-y axis M_y = 4.91 xP_h = **23.71** [kip-ft]

Shear along y-y axis V_x = P_v [1+ (L - s) / L]x α (mpact) + UxL/2 = **118.69** [kips]

Crane Load for Design per AISC LRFD 13th Ed

Wheel load by bridge selfwei P_{br} = W_{br} / 4 = 16.1 [kips] as dead load

Wheel load by lift load + trolley P_{lt} = P_{max} - P_{br} = 53.0 [kips] as live load

Max factored ver. load /wheel P_v = 1.2 x P_{br} + 1.6 x P_{lt} = 104.0 [kips] impact not included

Max factored hor. load /wheel P_h = H x 1.6 / 4 = 7.7 [kips]

Factor bending moment x-x axis M_x = 4.91 xP_vx α(impact)+1.2xUxL^2/ 8 = **648.72** [kip-ft]

Factor bending moment y-y axis M_y = 4.91 xP_h = **37.93** [kip-ft]

Factor shear along y-y axis V_x = P_v [1+ (L - s) /L]xα(mpact)+1.2xUxL/2 = **178.37** [kips]

CRANE RUNWAY BEAM DESIGN - ASD 9

Crane runway design based on	**Code Abbreviation**
AISC Manual of Steel Construction: Allowable Stress Design 9th Edition	*ASD 9th Edition*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*

Crane runway beam section W690x125 C380x50 W27x84 and C15x33.9

Section Properties

Combined Section Overall

A =	34.700	[in^2]	d_{all} =	27.100	[in]
top y_2 =	10.000	[in]	bott. y_1 =	17.100	[in]
I_x =	4050.0	[in^4]	I_y =	420.00	[in^4]
top S_2 =	403.00	[in^3]	bott. S_1 =	237.00	[in^3]
S_y =	56.00	[in^3]			
Z_x =	316.00	[in^3]	Z_y =	83.90	[in^3]
r_x =	10.800	[in]	r_y =	3.480	[in]
J =	3.82	[in^4]	C_w =	0	[in^6]

W Section

d =	26.700	[in]	b_f =	9.960	[in]
t_w =	0.460	[in]	t_f =	0.640	[in]
h =	24.220	[in]			

Top Flange

A_f =	16.324	[in^2]	d_{all} / A_f =	1.660	[in^{-1}]
r_T =	4.558	[in]	r_{yt} =	4.746	[in]
I_t =	367.70	[in^4]			
S_t =	49.03	[in^3]	Z_t =	66.67	[in^3]

W section yield strength	F_{wy} =	50.0	[ksi]	= 345	[MPa]
C section yield strength	F_{cy} =	36.0	[ksi]	= 248	[MPa]
Runway beam unbraced length	L_b =	255.91	[in]		

Design Forces

Bending moment x-x axis	M_x =	432.19	[kip-ft]
Bending moment y-y axis	M_y =	23.71	[kip-ft]
Shear along y-y axis	V_x =	118.69	[kips]

Conclusion

Overall	ratio = **0.81**	OK
Local buckling		OK
Bending about X-X Axis	ratio = 0.73	OK
Bending about Y-Y Axis on Top Flange	ratio = 0.22	OK
Biaxial Bending on Top Flange	ratio = 0.81	OK
Shear along Y-Y Axis	ratio = 0.48	OK
Web Sidesway Buckling	ratio = 0.00	OK
Runway Beam Vertical Deflection	ratio = 0.49	OK
Runway Beam Lateral Deflection	ratio = 0.25	OK

			Code Reference
Design Basis & Assumption			*AISC Design Guide 7*
1. The channel and W section top flange resist the hor. load and the combined section resists the ver. load. This assumption eliminates the need for an analysis of torsional effects on the combined section and simplifies the analysis.			18.1 on page 56
2. If A36 channel cap is used on A992 W section then lateral torsional buckling and weak axis flexure strength must be calculated based on A36 yield stress.			18.1.4 on page 57

Check Local Buckling

Flange of W shape				*ASD 9th Edition*
Compact limit	λ_p = 65 / sqrt (F_{wy})		= 9.19	Table B5.1
Noncompact limit	λ_r = 95 / sqrt (F_{wy})		= 13.43	
	$b_f / 2t_f$ = 7.78		Compact	
Web of W shape				
Compact limit	λ_p = 640 / sqrt (F_{wy})		= 90.49	Table B5.1
Noncompact limit	λ_r = 760 / sqrt ($0.66F_{wy}$)		= 132.27	
	d / t_w = 58.04	h / t_w	= 52.65	
			Compact	
W shape classification			**Compact**	
Flange of Channel	This part is applicable			
Compact limit	λ_p = 65 / sqrt (F_{cy})		= 10.84	Table B5.1
Noncompact limit	λ_r = 95 / sqrt (F_{cy})		= 15.84	
	b_f / t_f = 5.23		Compact	
Web of Channel				
Compact limit	λ_p = 640 / sqrt (F_{cy})		= 106.73	Table B5.1
Noncompact limit	λ_r = 760 / sqrt ($0.66F_{cy}$)		= 156.00	
	d / t_w = 37.50	h / t_w	= 34.25	
			Compact	
Channel shape classification			**Compact**	

Combined section classification **Compact** **OK**

Check Bending about X-X Axis

Tension

Allowable tension stress	$F_{bx\,t}$ = 0.6 x F_{wy}	= **30.02**	[ksi]	
Actual tension stress	$f_{bx\,t}$ = M_x / S_1	= 21.88	[ksi]	
	ratio = $f_{bx\,t} / F_{bx\,t}$	= **0.73**		**OK**

Compression

Comb sect top flange yield stress	F_y = 36.0	[ksi]	see assumption 2
Comb sect top flange width	b_f = 15.0	[in]	use channel depth if capped with channel

					Code Reference
					ASD 9th Edition
Critical length	$L_c = \min\left(\frac{76 x b_f}{\sqrt{F_y}}, \frac{2x10^4}{(d_{all} / A_f) x F_y}\right)$		= 190.11	[in]	Eq F1-2
	$76\ b_f$ / sqrt(F_y) =		= 190.11	[in]	
When $L_b <= L_c$	This part is NOT applicable				
For compact sect	Not Applicable				
	$F_{bx} = 0.66 \times F_y$		= 0.00	[ksi]	Eq F1-1
For non-compact sect	Not Applicable				
	$b_f / 2t_f$ = Comb Sect	max(W $b_f / 2t_f$, C b_f / t_f)	= 7.78		
	W Sect	$b_f / 2t_f$			
	$F_{bx} = \left(0.79 - 0.002 \frac{b_f}{2t_f} \sqrt{F_y}\right) F_y$		= 0.00	[ksi]	Eq F1-3
	$F_{bx} = 0.6 \times F_y$		= 0.00	[ksi]	Eq F1-5
When $L_b > L_c$	This part is applicable				
	L_b / r_T =		= 56.14		
Bending coefficient	C_b = 1.0	to be conservative			
	$x = \sqrt{\frac{510 x 10^3 x C_b}{F_y}}$		= 119.09		
For (L_b / r_T) <= x	Applicable				
	$F_{bx} = \left(\frac{2}{3} - \frac{F_y (L_b / r_T)^2}{1530 x 10^3 C_b}\right) F_y \leq 0.6F_y$		= 21.31	[ksi]	Eq F1-6
For (L_b / r_T) > x	Not Applicable				
	$F_{bx} = \frac{170 x 10^3 C_b}{(L_b / r_T)^2} \leq 0.6F_y$		= 0.00	[ksi]	Eq F1-7
For any value of (L_b / r_T)	Applicable				
	$F_{bx} = \frac{12 x 10^3 C_b}{L_b x (d_{all} / A_f)} \leq 0.6F_y$		= 21.58	[ksi]	Eq F1-8
Allowable compression stress	$F_{bx\,c}$ =		= **21.58**	[ksi]	
Actual compression stress	$f_{bx\,c} = M_x / S_2$		= 12.87	[ksi]	
	ratio = $f_{bx\,c} / F_{bx\,c}$		= **0.60**	**OK**	

Check Bending about Y-Y Axis on Top Flange

For compact top flange	Applicable				
	$F_{by} = 0.75 \times F_y$		= 26.97	[ksi]	Eq F2-1

				Code Reference
For non-compact top flange	Not Applicable			*ASD 9th Edition*
	F_{by} = 0.60 x F_y	= 0.00	[ksi]	Eq F2-2
Allowable compression stress	$F_{by\,c}$ =	= **26.97**	[ksi]	
Actual compression stress	$f_{by\,c}$ = M_y / S_t	= 5.80	[ksi]	
	ratio = $f_{bx\,c}$ / $F_{bx\,c}$	= **0.22**	**OK**	

Check Biaxial Bending on Top Flange

Combined bending stress	f_{bx} / F_{bx} + f_{by} / F_{by}	= **0.81**	**OK**	Eq H1-3

Check Shear along Y-Y Axis

Clear dist between trans. stiffeners a = L_b = 255.91 [in]

W sect clear dist between flange h = 24.220 [in] a / h = 10.57

k_v = 4.00 + 5.34 / (a / h)^2 if a / h <=1 = 5.38 F4

5.34 + 4.00 / (a / h)^2 if a / h >1

h / t_w = 52.65 C_v = 1.18

For h / t_w <= 380 / sqrt (F_y) Applicable

F_v = 0.40 x F_y = 20.01 [ksi] Eq F4-1

For h / t_w > 380 / sqrt (F_y) Not Applicable

	F_v = (F_y x C_v) / 2.89 <=0.4 F_y	= 0.00	[ksi]	Eq F4-2
Allowable shear stress	F_v =	= **20.01**	[ksi]	
Actual shear stress	f_v = V_x / S_t	= 9.66	[ksi]	
	ratio = f_v / F_v	= **0.48**	**OK**	

Check Web Sidesway Buckling *AISC Design Guide 7*

Use LRFD 13 instead of ASD 9 to increase web sidesway buckling resistance when flexural stress in the web is less than 0.66F_y page 61

(h / t_w) / (L_b / b_f) = 2.05 >1.7 *AISC LRFD 13*

Max actual bending stress f_b = 21.88 [ksi]

When f_b < (F_y / 1.5) = 0.66 F_y Applicable C_r = 9.6E+05 [ksi]

When f_b >= (F_y / 1.5) = 0.66 F_y Not Applicable C_r = 0.0E+00 [ksi]

$$R_n = \frac{C_r\, t_w^3\, t_f}{h^2}\left[0.4\left(\frac{h\ /\ t_w}{L_b\ /\ b_f}\right)^3\right] \quad = \text{NA} \quad \text{[kips]} \quad \text{Eq J10-7}$$

R_a = R_n / Ω = R_n / 1.76	= NA	[kips]	
$P_{v\text{-}impt}$ = P_v x α (impact factor)	= 86.27	[kips]	
ratio = $P_{v\text{-}impt}$ / R_a	= **0.00**	**OK**	

Check Runway Beam Deflection **Code Reference**

Crane serviceability criteria based on

CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition Table 4.1 item 14,15

AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition page 56

CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes Cl 1.4.3

CMAA crane service class Class C Moderate service

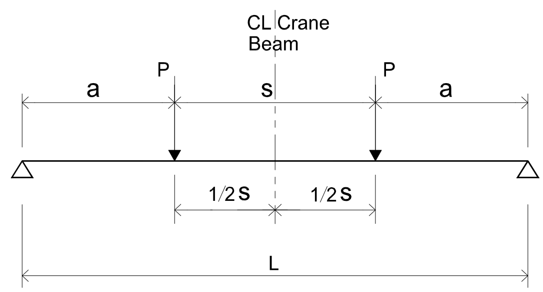
Ver deflection limit (no impact , max wheel load) B_v = L / 600

Hor deflection limit (no impact , 10% max wheel load) B_h = L / 400

Runway beam span L = 255.91 [in]

Bridge wheel spacing s = 164.41 [in]

a = 45.75 [in]



Max Deflection Case

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 12.36 P / I

Vertical Deflection

Unfactored max ver. wheel load P = 69.0 [kips / per wheel] impact factor NOT included

I_x = 4050.0 [in^4]

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 0.211 [in]

Allowable deflection $\Delta_a = L / B_v$ = 0.427 [in]

ratio = Δ_{max} / Δ_a = **0.49** **OK**

Lateral Deflection

Unfactored max hor. wheel load P = 4.8 [kips / per wheel]

I_t = 367.7 [in^4]

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 0.162 [in]

Allowable deflection $\Delta_a = L / B_h$ = 0.640 [in]

ratio = Δ_{max} / Δ_a = **0.25** **OK**

CRANE RUNWAY BEAM DESIGN - LRFD 13

Crane runway design based on	**Code Abbreviation**
AISC 360-05 Specification for Structural Steel Buildings	*AISC LRFD 13*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*

Crane runway beam section W690x125 C380x50 — W27x84 and C15x33.9

Section Properties

Combined Section Overall

A =	34.700	[in^2]	d_{all} =	27.100	[in]
top y_c =	10.000	[in]	bott. y_t =	17.100	[in]
I_x =	4050.0	[in^4]	I_y =	420.00	[in^4]
top S_{xc} =	403.00	[in^3]	bott. S_{xt} =	237.00	[in^3]
S_y =	56.00	[in^3]			
Z_x =	316.00	[in^3]	Z_y =	83.90	[in^3]
r_x =	10.800	[in]	r_y =	3.480	[in]
J =	3.82	[in^4]	C_w =	0	[in^6]

W Section

d =	26.700	[in]	b_f =	9.960	[in]
t_w =	0.460	[in]	t_f =	0.640	[in]
h =	24.220	[in]	$h_c = 2(y_c - k)$ =	17.520	[in]
$h_0 = d - t_f$ =	26.060	[in]			

Top Flange

A_f =	16.324	[in^2]	d_{all} / A_f =	1.660	[in^{-1}]
r_t =	4.558	[in]	r_{yt} =	4.746	[in]
I_t =	367.70	[in^4]			
S_t =	49.03	[in^3]	Z_t =	66.67	[in^3]

W section yield strength	F_{wy} =	50.0	[ksi]	= 345	[MPa]
C section yield strength	F_{cy} =	36.0	[ksi]	= 248	[MPa]
Runway beam unbraced length	L_b =	255.91	[in]		

Design Forces

Bending moment x-x axis	M_x =	648.72	[kip-ft]
Bending moment y-y axis	M_y =	37.93	[kip-ft]
Shear along y-y axis	V_y =	178.37	[kips]

Conclusion

Overall	ratio = **0.97**	OK
Local buckling		OK
Biaxial Bending on Top Flange	ratio = 0.97	OK
Shear along Y-Y Axis	ratio = 0.54	OK
Web Sidesway Buckling	ratio = 0.00	OK
Runway Beam Vertical Deflection	ratio = 0.49	OK
Runway Beam Lateral Deflection	ratio = 0.25	OK

Code Reference

Design Basis & Assumption — *AISC Design Guide 7*

1. The channel and W section top flange resist the hor. load and the combined section resists the ver. load. This assumption eliminates the need for an analysis of torsional effects on the combined section and simplifies the analysis. — 18.1 on page 56
2. If A36 channel cap is used on A992 W section then lateral torsional buckling and weak axis flexure strength must be calculated based on A36 yield stress. — 18.1.4 on page 57

Check Local Buckling

Flange of W shape				*AISC LRFD 13*
Compact limit	λ_p	= 0.38 sqrt (E / F_{wy})	= 9.15	Table B4.1 Case 1
Noncompact limit	λ_r	= 1.0 sqrt (E / F_{wy})	= 24.08	
	b_f / $2t_f$	= 7.78	Compact	
Web of W shape				
Compact limit	λ_p	= 3.76 sqrt (E / F_{wy})	= 90.53	Table B4.1 Case 9
Noncompact limit	λ_r	= 5.7 sqrt (E / F_{wy})	= 137.24	
	h / t_w	= 52.65	Compact	
W shape classification			**Compact**	
Flange of Channel	This part is applicable			
Compact limit	λ_p	= 0.38 sqrt (E / F_{cy})	= 10.79	Table B4.1 Case 1
Noncompact limit	λ_r	= 1.0 sqrt (E / F_{cy})	= 28.40	
	b_f / t_f	= 5.23	Compact	
Web of Channel (flange cover plate between lines of welds)				
Compact limit	λ_p	= 1.12 sqrt (E / F_{cy})	= 31.81	Table B4.1 Case 12
Noncompact limit	λ_r	= 1.4 sqrt (E / F_{cy})	= 39.76	
	b_f (W shape) / t_w (C channel)	= 24.90	Compact	
Channel shape classification			**Compact**	
Combined section classification	**Compact**	ratio = **0.00**	**OK**	

Check Bending about X-X Axis

Calculate R_{pc}

λ_{pw} = 90.53		λ_{rw} = 137.24		
M_{yc}	= S_{xc} F_y	= 1680.0	[kip-ft]	
M_p	= min (Z_x F_y , 1.6 S_{xc} F_y)	= 1317.3	[kip-ft]	
λ	= h_c / t_w	= 38.09		
M_p / M_{yc}	=	= 0.78		

For $\lambda \le \lambda_{pw}$ Applicable

R_{pc} = M_p / M_{yc} = 0.78   Eq F4-9a

				Code Reference
				AISC LRFD 13
For $\lambda > \lambda_{pw}$	Not Applicable			
	$R_{pc} = \left[\frac{M_p}{M_{yc}} - \left(\frac{M_p}{M_{yc}} - 1\right)\left(\frac{\lambda - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}}\right)\right] \le \frac{M_p}{M_{yc}}$	= 0.00		Eq F4-9b
R_{pc} used for design	R_{pc} =	= **0.78**		
<u>Calculate R_{pt}</u>				
	$M_{yt} = S_{xt} F_y$	= 988.0	[kip-ft]	
	$M_p = \min(Z_x F_y, 1.6 S_{xt} F_y)$	= 1317.3	[kip-ft]	
	M_p / M_{yt} =	= 1.33		
For $\lambda <= \lambda_{pw}$	Applicable			
	$R_{pt} = M_p / M_{yc}$	= 1.33		Eq F4-15a
For $\lambda > \lambda_{pw}$	Not Applicable			
	$R_{pt} = \left[\frac{M_p}{M_{yt}} - \left(\frac{M_p}{M_{yt}} - 1\right)\left(\frac{\lambda - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}}\right)\right] \le \frac{M_p}{M_{yt}}$	= 0.00		Eq F4-15b
R_{pt} used for design	R_{pt} =	= **1.33**		
<u>Calculate F_L</u>				
	$S_{xt} / S_{xc} = 0.59$			
For $S_{xt} / S_{xc} >= 0.7$	Not Applicable			
	$F_L = 0.7 F_y$	= 0.0	[ksi]	Eq F4-6a
For $S_{xt} / S_{xc} < 0.7$	Applicable			
	$F_L = \max(F_y \times (S_{xt} / S_{xc}), 0.5F_y)$	= 21.1	[ksi]	Eq F4-6b
F_L used for design	F_L =	= **21.1**	[ksi]	
<u>M_n - Compression Flange Yielding</u>				
	$M_{n1} = R_{pc} F_y S_{xc}$	= **946.9**	[kip-ft]	Eq F4-1
<u>M_n - Lateral Torsional Buckling</u>				
Runway beam unbraced length	L_b =	= 255.91	[in]	
Calculate L_p & L_r				
	$L_p = 1.1\, r_t \sqrt{\frac{E}{F_y}}$	= 142.4	[in]	Eq F4-7
	$L_r = 1.95\, r_t \frac{E}{F_L} \sqrt{\frac{J}{S_{xc} h_o}} \sqrt{1 + \sqrt{1 + 6.76\left(\frac{F_L}{E}\frac{S_{xc} h_o}{J}\right)^2}}$			Eq F4-8
		= 583.8	[in]	

Code Reference

For $L_b \le L_p$ — Not Applicable — *AISC LRFD 13*

M_{n2} = = NA [kip-ft]

For $L_p < L_b \le L_r$ — Applicable

$C_b = 1.0$ to be conservative

$$M_{n2} = C_b\left[R_{pc}M_{yc} - (R_{pc}M_{yc} - F_L S_{xc})\left(\frac{L_b - L_p}{L_r - L_p}\right)\right] \le R_{pc}M_{yc}$$ Eq F4-2

= 1161.2 [kip-ft]

For $L_b > L_r$ — Not Applicable

For $I_t / I_y \le 0.23$ J = 0 — Not Applicable

$J = 3.82$ [in^4]

$$F_{cr} = \frac{C_b \pi^2 E}{\left(\frac{L_b}{r_t}\right)^2}\sqrt{1 + 0.078\frac{J}{S_{xc} h_o}\left(\frac{L_b}{r_t}\right)^2}$$ = 0.0 [ksi] Eq F4-5

$M_{n2} = F_{cr} S_{xc} \le R_{pc} F_y S_{xc}$ = NA [kip-ft] Eq F4-3

M_n - LTB — M_{n2} = **= 1161.2** [kip-ft]

M_n - Compression Flange Local Buckling

$\lambda = 7.78$

$\lambda_{pf} = 9.15$ — $\lambda_{rf} = 24.08$

For $\lambda \le \lambda_{pf}$ — Applicable

M_{n3} = = NA [kip-ft]

For $\lambda_{pf} < \lambda \le \lambda_{rf}$ — Not Applicable

$$M_{n3} = \left[R_{pc}M_{yc} - (R_{pc}M_{yc} - F_L S_{xc})\left(\frac{\lambda - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}\right)\right]$$ = NA [kip-ft] Eq F4-12

M_{n3} = **= NA** [kip-ft]

M_n - Tension Flange Yielding

$M_{n4} = R_{pt} F_y S_{xt}$ **= 1317.3** [kip-ft] Eq F4-14

$M_{nx} = \min(M_{n1}, M_{n2}, M_{n3}, M_{n4})$ **= 946.9** [kip-ft]

Check Bending about Y-Y Axis				**Code Reference**

Check top flange compactness, for W check W flange only, for W+Cap Channel check both W and Channel flange

Top flange compactness		= Compact			*AISC LRFD 13*
For compact top flange	M_{ny}	= $F_y Z_t$	= 199.8	[kip-ft]	Eq F6-1
For noncompact top flange	M_{ny}	= $F_y S_t$	= 146.9	[kip-ft]	
	M_{ny}	=	= **199.8**	[kip-ft]	

Check Biaxial Bending on Top Flange

Combined bending	$M_x / (\Phi M_{nx}) + M_y / (\Phi M_{ny})$	= **0.97**	**OK**	Eq H1-1b

Check Shear along Y-Y Axis

Clear dist between trans. stiffeners	a	= L_b	= 255.91	[in]	
W sect clear dist between flange	h	= 24.220 [in]	a / h = 10.57		
	h / t_w	= 52.65			
	k_v	= 5 if $h / t_w < 260$	= 5.00		G2.1 (b)
		5 if $a / h > 3.0$ or $a / h > [260/(h / t_w)]^2$			
		$5 + 5 / (a / h)^2$			
	T	= $\text{sqrt}(k_v E / F_y)$	= 53.8		
For $h / t_w <= 1.10$ T	Applicable				
	C_v	=	1.0		Eq G2-3
For $1.10 T < h / t_w <= 1.37 T$	Not Applicable				
	C_v	= $1.10 \times \text{sqrt}(k_v E / F_y) / (h / t_w)$	= NA		Eq G2-4
For $h / t_w > 1.37$ T	Not Applicable				
	C_v	= $1.51 E k_v / [(h / t_w)^2 F_y]$	= NA		Eq G2-5
C_v used for design	C_v	=	= 1.0		
	ΦV_n	= $0.9 \times 0.6 F_y (d t_w) C_v$	= **331.8**	[kips]	Eq G2-1
	ratio	= $V_y / \Phi V_n$	= **0.54**	**OK**	

Check Web Sidesway Buckling **Code Reference**

AISC LRFD 13

$(h / t_w) / (L_b / b_f)$ = 2.05 >1.7

When $M_u < M_y$	Applicable	C_r = 9.6E+05	[ksi]
When $M_u >= M_y$	Not Applicable	C_r = 0.0E+00	[ksi]

$$R_n = \frac{C_r\, t_w^3\, t_f}{h^2}\left[0.4\left(\frac{h\ /\ t_w}{L_b\ /\ b_f}\right)^3\right]$$ = NA [kips] Eq J10-7

Φ = = 0.85

$P_{v\text{-}impt}$ = P_v x α (impact factor) = 130.01 [kips]

ratio = $P_{v\text{-}impt} / \Phi R_n$ = **0.00** **OK**

Check Runway Beam Deflection

Crane serviceability criteria based on

CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition Table 4.1 item 14,15

AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition page 56

CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes Cl 1.4.3

CMAA crane service class Class C Moderate service

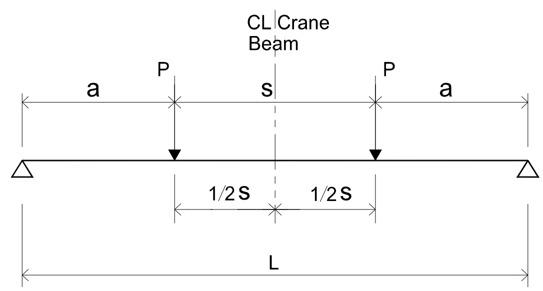
Ver deflection limit (no impact , max wheel load) B_v = L / 600

Hor deflection limit (no impact , 10% max wheel load) B_h = L / 400

Runway beam span L = 255.91 [in]

Bridge wheel spacing s = 164.41 [in]

a = 45.75 [in]



Max Deflection Case

Max deflection at center $\Delta_{max} = \frac{Pa\,(3L^2 - 4a^2)}{24\ E\ I}$ = 12.36 P / I

Vertical Deflection

Unfactored max ver. wheel load P = 69.0 [kips / per wheel] impact factor NOT included

I_x = 4050.0 [in^4]

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 0.211 [in]

Code Reference

Allowable deflection	$\Delta_a = L / B_v$	= 0.427	[in]	
	ratio $= \Delta_{max} / \Delta_a$	= **0.49**		**OK**

Lateral Deflection

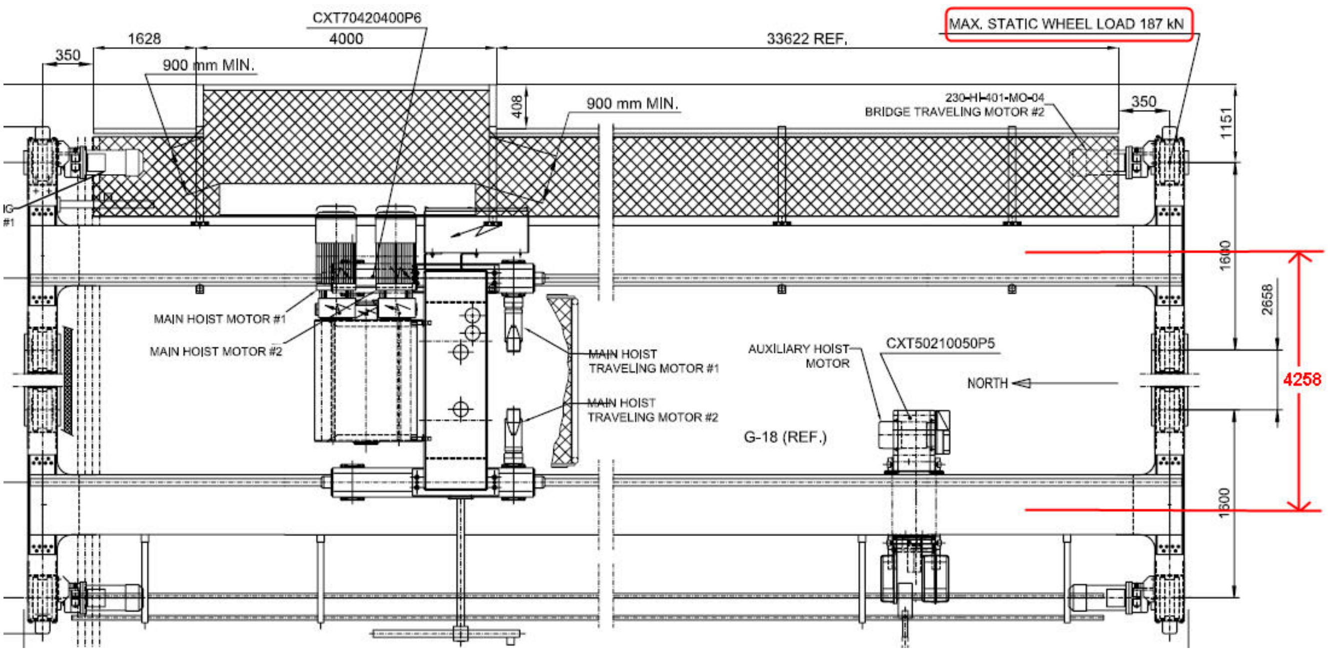
Unfactored max hor. wheel load	P = 4.8	[kips / per wheel]	
	I_t = 367.7	[in^4]	

Max deflection at center $\Delta_{max} = \dfrac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 0.162 [in]

Allowable deflection	$\Delta_a = L / B_h$	= 0.640	[in]	
	ratio $= \Delta_{max} / \Delta_a$	= **0.25**		**OK**

Example 03: Top Running 45 Ton Crane + Runway W Shape with Cap Plate – Imperial Unit

This is a 40 tonne bridge crane with 5 tonne auxiliary hoist. The bridge has 4 wheels at each side. We need to convert the 4-wheel bridge to equivalent 2-wheel bridge for analysis.



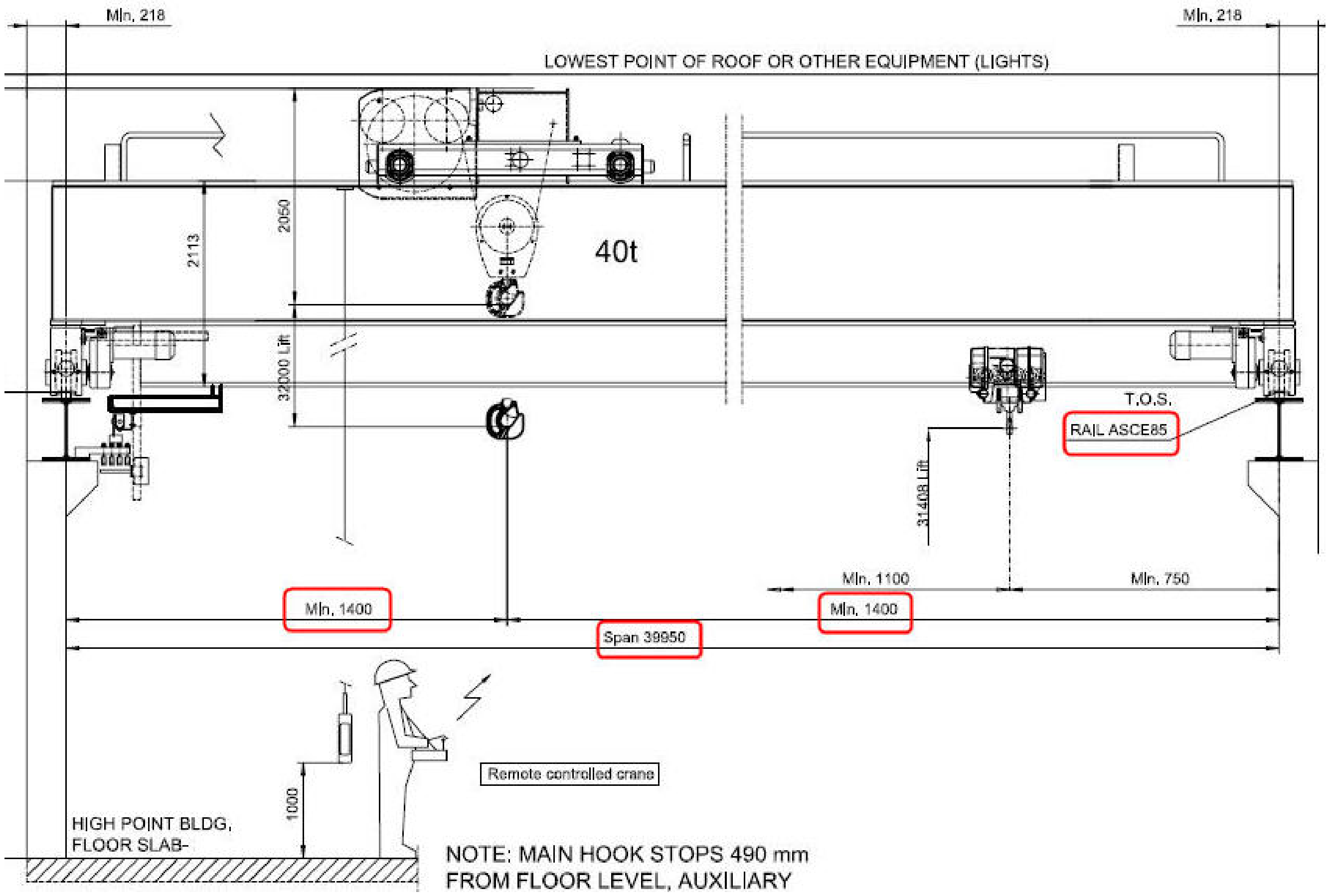
Crane Plan

Convert the 4-wheel bridge to equivalent 2-wheel bridge by consolidating 2-wheel into a single wheel.

For an equivalent 2-wheel bridge

Bridge wheel spacing s = 1600 + 2658 = 4258 mm = 14.0 ft

Max static wheel load = 187 kN x 2 = 374 kN = 84.1 kips



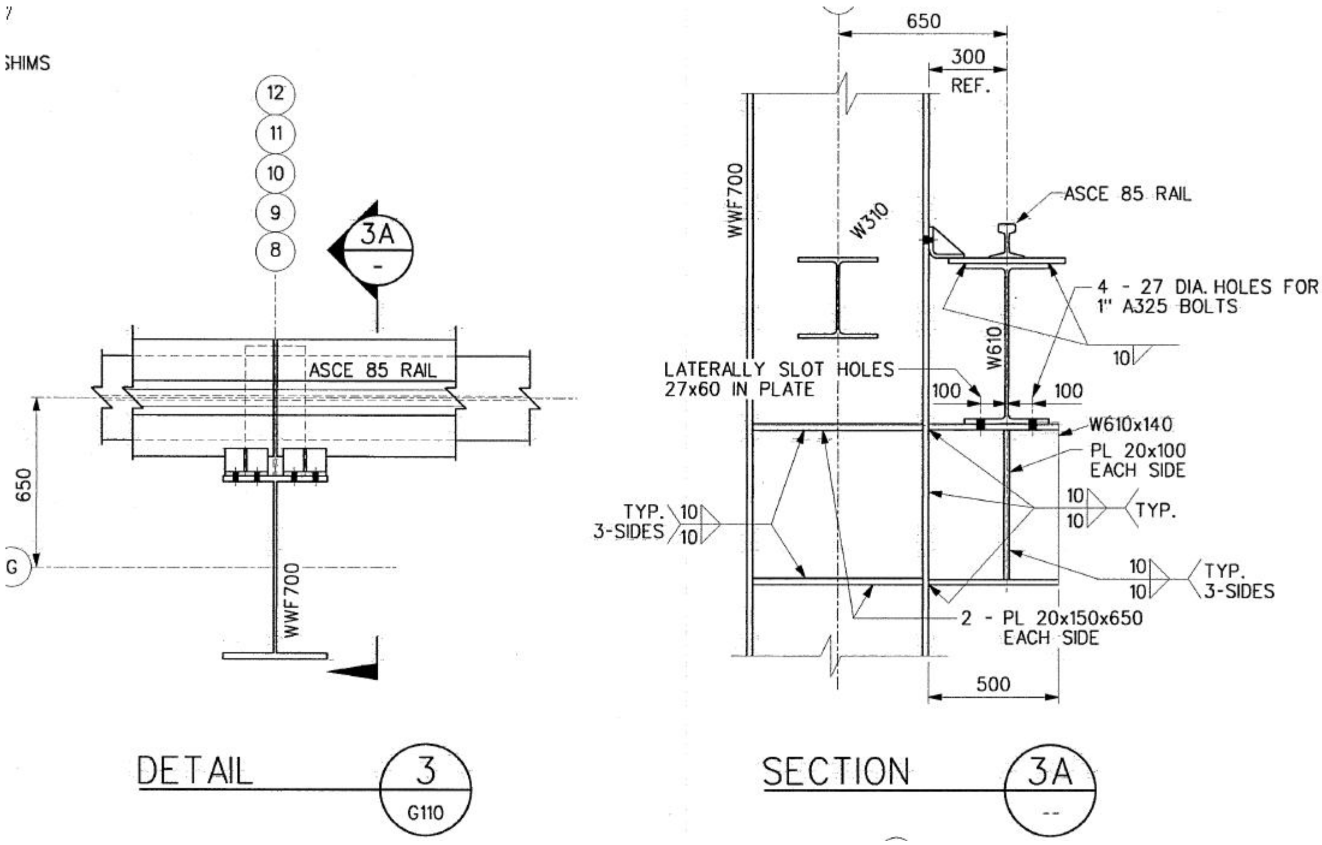
Crane Elevation

TECHNICAL DATA

LOAD.....................................	40 t
SPAN.....................................	39,95 m
LIFTING HEIGHT.....................	32 m available on hoist
HOISTING SPEED..................	4,8/0,8 m/min 2-SPEED
TRAVERSING SPEED............	20 m/min STEPLESS
TRAVELLING SPEED.............	32 m/min STEPLESS
WEIGHT OF TROLLEY...........	3,3 t
WEIGHT OF BRIDGE.............	48,5 t
POWER SUPPLY....................	600 V / 3 PH / 60 Hz
CRANE GROUP......................	CMAA C
HOIST MACHINERY GROUP...	FEM M4 (1Am)
BRIDGE TRAVEL GROUP........	FEM M5 (2m)
POWER (TOTAL)......................	42,88 kW
LENGTH OF RUNWAY............	40 m

AUXILIARY HOIST DATA

LOAD.....................................	5 t
LIFTING HEIGHT.....................	32 m available on hoist
HOISTING SPEED..................	12/2 m/min 2-SPEED
TRAVERSING SPEED............	20 m/min STEPLESS
WEIGHT OF TROLLEY...........	0,71 t



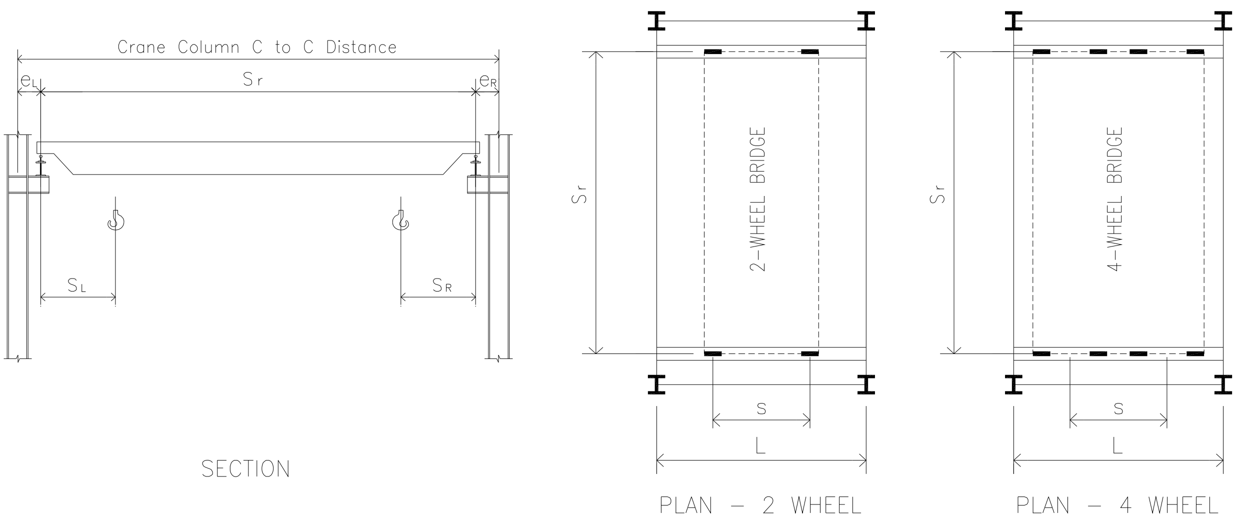
Crane Runway Beam Connection

Runway Beam Size W610x155 + PL457x19

Crane Data	Imperial	Metric
Crane capacity	49.6 US Tons =99.2 kips	45 Metric Tons = 441.3 kN
Bridge weight	106.9 kips	48500 kg
Trolley + hoist weight	8.8 kips	4010 kg
Max static wheel load	84.1 kips	374.0 kN
Bridge span S_r	131.1 ft	39.950 m
Left min. hook approach S_L	4.6 ft	1.400 m
Right min. hook approach S_R	4.6 ft	1.400 m
Bridge wheel spacing s	14.0 ft	4.258 m
Crane runway beam span L	21.3 ft	6.500 m
Left runway CL to column CL dist e_L	2.1 ft	0.650 m
Right runway CL to column CL dist e_R	2.1 ft	0.650 m
Crane rail size	ASCE 85	ASCE 85
CMAA crane service class	Class C	Class C
Vertical impact factor	25%	25%
Crane type	Top Running	Top Running
Crane runway beam size	W24x104 + Plate 18" x 3/4"	W610x155 + Plate 457x19
W shape F_y	50 ksi	345 MPa
Plate cap F_y	50 ksi	345 MPa

BRIDGE CRANE LOAD CALCULATION

Bridge crane load calc based on	**Code Abbreviation**
CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition	*CISC Crane Guide*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*
CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes	*CMAA 70-04*



Crane Data

					suggested value		
Crane rated capacity	W_{rc}	=	49.6	[US Ton]		= 99.2	[kips]
Bridge weight	W_{br}	=	106.9	[kips]	90.7	= 48489	[kg]
Trolley + hoist weight	W_{th}	=	8.8	[kips]	7.3	= 3992	[kg]
Bridge wheel spacing	s	=	14.0	[ft]	13.8		
Max. static wheel load by vendor	P_{max-v}	=	84.1	[kips]	input 0 if vendor data is unknown		
Crane bridge span	S_r	=	131.1	[ft]	131.0		
Min. hook approach-left	S_L	=	4.6	[ft]	4.6		
Min. hook approach-right	S_R	=	4.6	[ft]	4.6		
Crane runway beam span	L	=	21.3	[ft]			
Runway CL to col CL dist-left	e_L	=	2.1	[ft]	2.1		
Runway CL to col CL dist-right	e_R	=	2.1	[ft]	2.1		
Crane column C to C distance	$S_r + 2e$	=	135.3	[ft]		suggested section	
Runway beam type		=	W_Shape_Cap_Plate		?		
Runway beam size		=	W24x104			size > W21x62 C12x20.7	
Top flange cap plate size	width b_p	=	18.000	[in]	thick t_p =	0.750	[in] applicable
	suggest		ASCE 60		U_{rb} =	0.151	[kip/ft]
Crane rail size		=	ASCE 85		U_{cr} =	85	[lbs/yd]
					=	0.028	[kip/ft]
Rail base width	B_w	=	5.188	[in]	Rail height H_t =	5.188	[in]
W section yield strength	f_{wy}	=	50.0	[ksi]	=	345	[MPa]
Cap channel or plate yield strength	f_{cy}	=	50.0	[ksi]	=	345	[MPa]
CMAA crane service class		=	Class C	?		Moderate service	
Crane type		=	Top Running		?		

Code Reference

CISC Crane Guide

Vertical load impact factor = 0.25 ? Table 2.1

Crane side thrust load option = Option 1 ? Table 2.1

Crane side thrust load can be calculated using one of the following 3 options

Option 1 H_s = 0.2 (Lifted Load+ Trolley/Hoist Wt)

Option 2 H_s = max of 0.2 (Lifted Load+ Trolley/Hoist Wt)
0.1 (Lifted Load+ Entire Crane Wt)

Option 3 H_s = max of 0.2 (Lifted Load+ Trolley/Hoist Wt)
0.1 (Lifted Load+ Entire Crane Wt)
0.4 Lifted Load

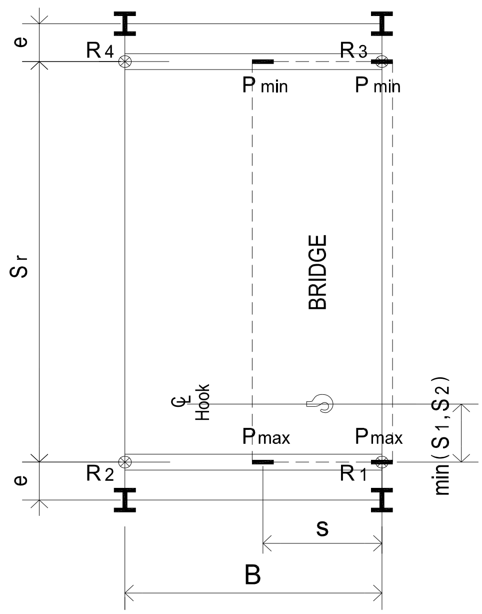
Conclusion

Runway Beam Design Using AISC ASD 9

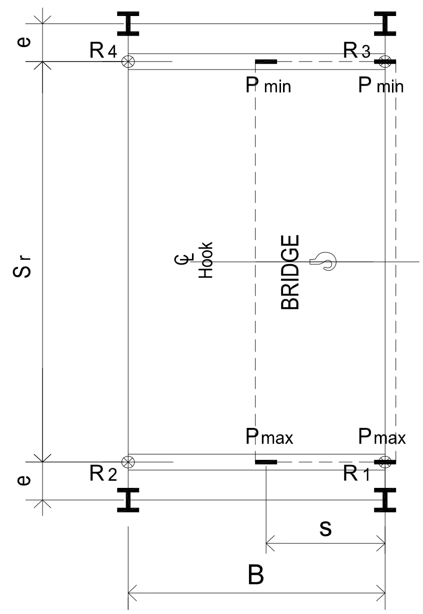
Overall	ratio = **0.72**	OK
Local buckling		OK
Bending about X-X Axis	ratio = 0.72	OK
Bending about Y-Y Axis on Top Flange	ratio = 0.15	OK
Biaxial Bending on Top Flange	ratio = 0.56	OK
Shear along Y-Y Axis	ratio = 0.59	OK
Web Sidesway Buckling	ratio = 0.00	OK
Runway Beam Vertical Deflection	ratio = 0.51	OK
Runway Beam Lateral Deflection	ratio = 0.20	OK

Runway Beam Design Using AISC LRFD 13

Overall	ratio = **0.71**	OK
Local buckling		OK
Biaxial Bending on Top Flange	ratio = 0.71	OK
Shear along Y-Y Axis	ratio = 0.65	OK
Web Sidesway Buckling	ratio = 0.00	OK
Runway Beam Vertical Deflection	ratio = 0.51	OK
Runway Beam Lateral Deflection	ratio = 0.20	OK



CASE 1 HOOK AT ONE SIDE

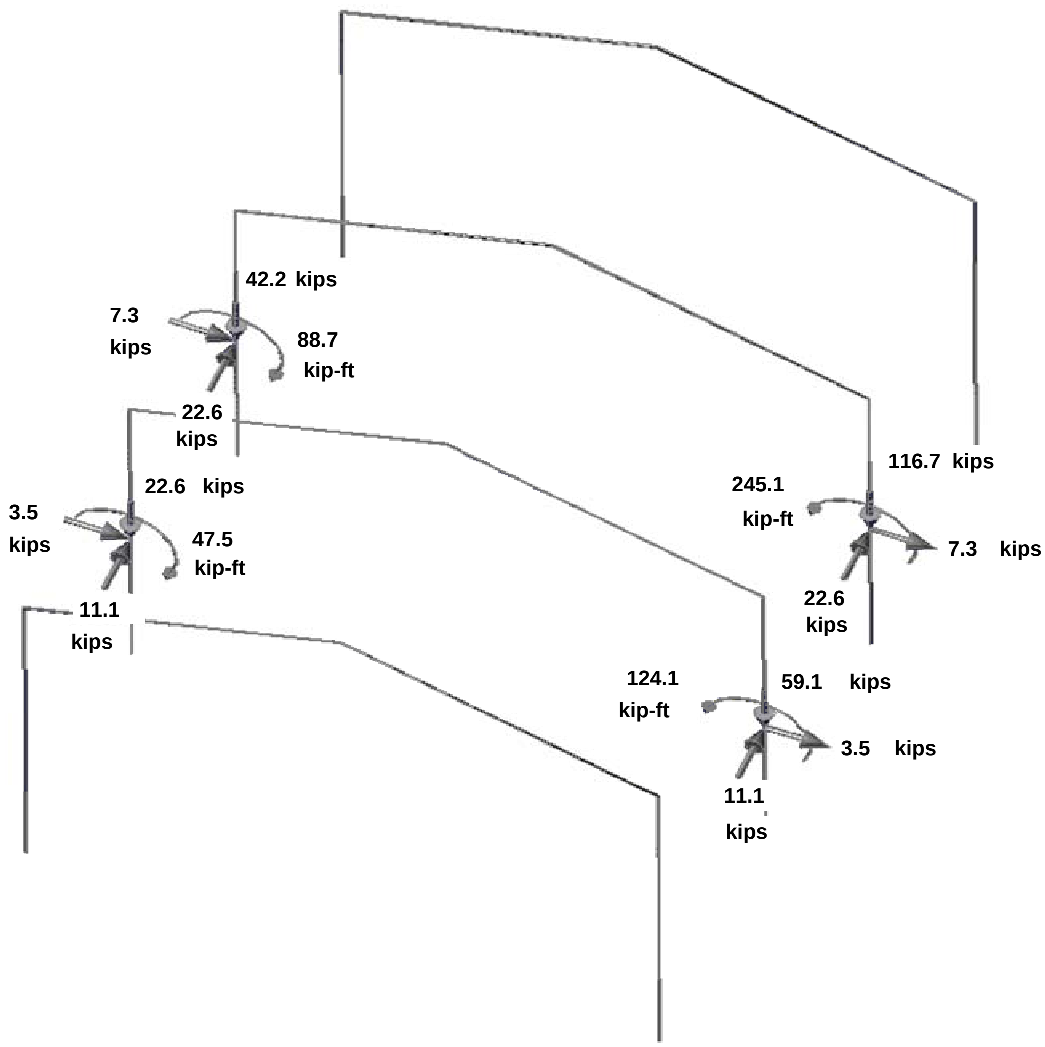


CASE 2 HOOK AT CENTER

Crane Load Calculation					**Code Reference**
Crane runway + rail selfweight	R_{sw} =	$(U_{rb} + U_{cr}) \times B$	= 3.8	[kips]	
Wheel load by bridge selfwei	P_{br} =	W_{br} / 4 wheel	= 26.7	[kip/per wheel]	
Side Thrust Load					
Crane side thrust load calculated by	=	Option 1			*CISC Crane Guide*
	H_{s1} =	0.4 Lifted Load	= 39.7	[kips]	Table 2.1
	H_{s2} =	0.2 (Lifted Load+ Trolley/Hoist Wt)	= 21.6	[kips]	
	H_{s3} =	0.1 (Lifted Load+ Entire Crane Wt)	= 21.5	[kips]	
	H_{st} =	side thrust load calc using Option 1	= 5.4	[kip/per wheel]	
	$H_{st1}=H_{st3}$ =	H_{st} (1 + (B-s) / B)	= **7.3**	[kips]	
	$H_{st2}=H_{st4}$ =	H_{st} s / B	= **3.5**	[kips]	
Tractive Load					Table 2.1
	H_{tr} =	0.2 Max wheel load	= 16.8	[kip/per wheel]	
	$H_{tr1}=H_{tr3}$ =	H_{tr} (1 + (B-s) / B)	= **22.6**	[kips]	
	$H_{tr2}=H_{tr4}$ =	H_{tr} s / B	= **11.1**	[kips]	
Vertical Load					
Case 1 Hook at One Side					
Min. hook aproach	S_{min} =	min (S_1, S_2)	= 4.6	[ft]	
Max wheel load by calc	P_{max-c} =	$[(W_{rc}+W_{th})x(S_r-S_{min})/ S_r]/2$ wheel+P_{br}	= 78.8	[kip/per wheel]	
Max. wheel load by vendor	P_{max-v} =		= 84.1	[kip/per wheel]	
Max static wheel load	P_{max} =	max (P_{max-v} , P_{max-c})	= **84.1**	[kip/per wheel]	
Min wheel load	P_{min} =	$[(W_{rc}+W_{th})xS_{min}/S_r]/2$ wheel+P_{br}	= **28.6**	[kip/per wheel]	

Reaction on runway support	$R_1 = P_{max} (1 + (B\text{-}s) / B) + R_{sw}$	= **116.7**	[kips]
	$R_2 = P_{max}\, s / B + R_{sw}$	= **59.1**	[kips]
	$R_3 = P_{min} (1 + (B\text{-}s) / B) + R_{sw}$	= **42.2**	[kips]
	$R_4 = P_{min}\, s / B + R_{sw}$	= **22.6**	[kips]
Point moment to column center	$M_1 = R_1 \times e_R$	= **245.1**	[kip-ft]
	$M_2 = R_2 \times e_R$	= **124.1**	[kip-ft]
	$M_3 = R_3 \times e_L$	= **88.7**	[kip-ft]
	$M_4 = R_4 \times e_L$	= **47.5**	[kip-ft]

Case 1 Hook at One Side - Crane Load Summary



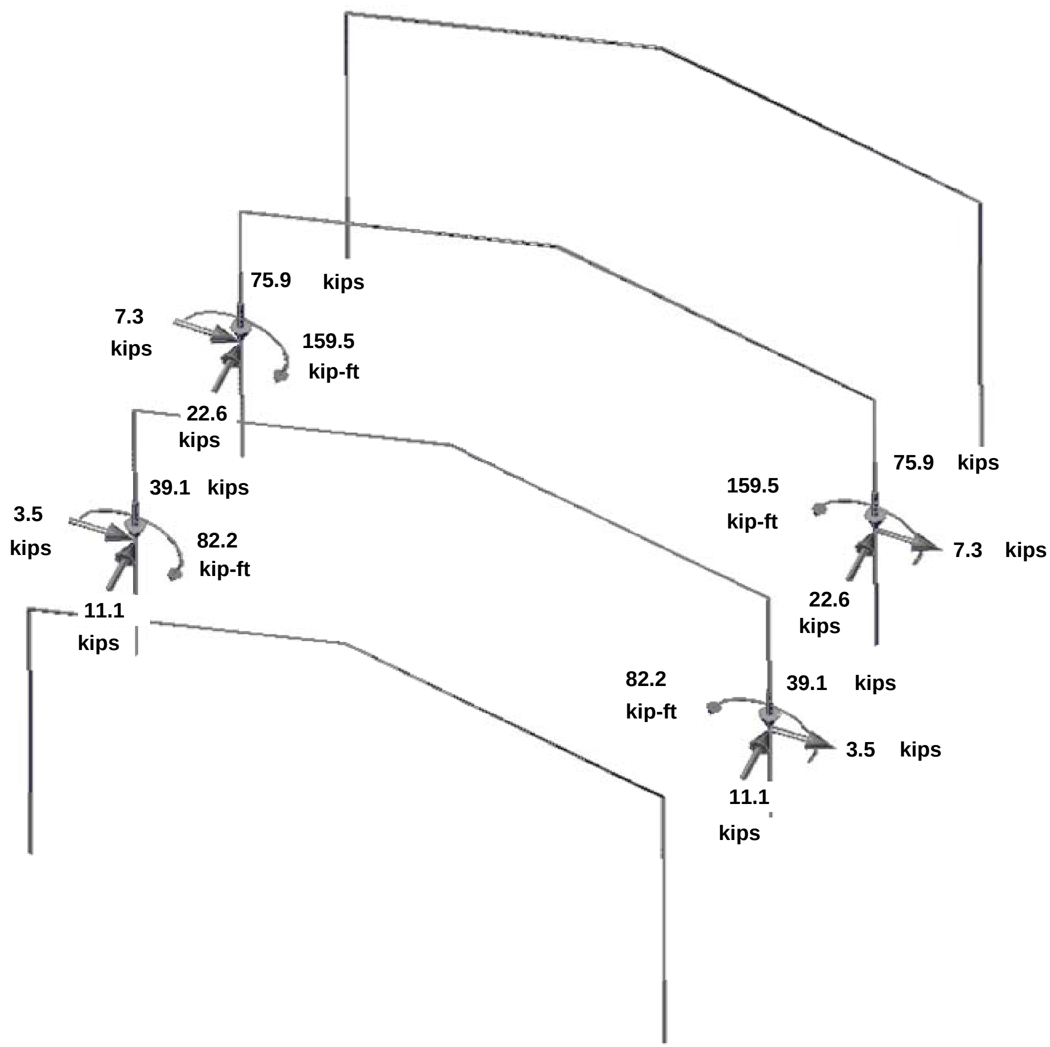
Note:

The crane loads shown above may be reverse if crane hook goes to the other side. When reverse the loads and apply them on building columns, the point moment value may need adjusted if eccentricity $e_L <> e_R$

Case 2 Hook at Center of Bridge

Max wheel load	$P_{max} = P_{min} = (W_{rc}+W_{br}+W_{th})/4$ wheel	= 53.7	[kip/per wheel]
Reaction on runway support	$R_1 = R_3 = P_{max}\,(1 + (B\text{-}s) / B) + R_{sw}$	= **75.9**	[kips]
	$R_2 = R_4 = P_{max}\, s / B + R_{sw}$	= **39.1**	[kips]
Point moment to column center	$M_1 = M_3 = R_1 \times \max(e_L, e_R)$	= **159.5**	[kip-ft]
	$M_2 = R_2 \times \max(e_L, e_R)$	= **82.2**	[kip-ft]

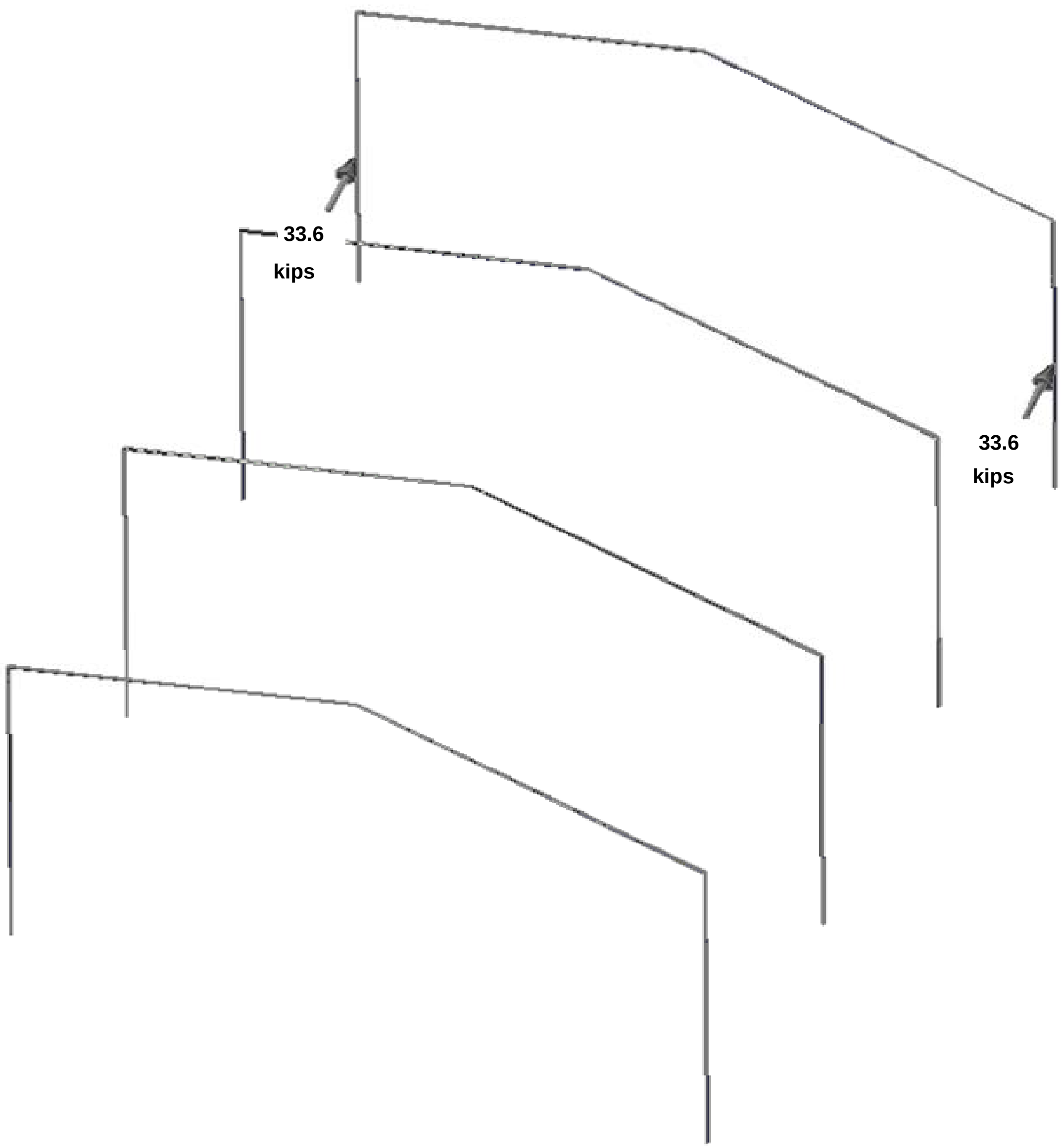
Case 2 Hook at Center of Bridge - Load Summary



Code Reference

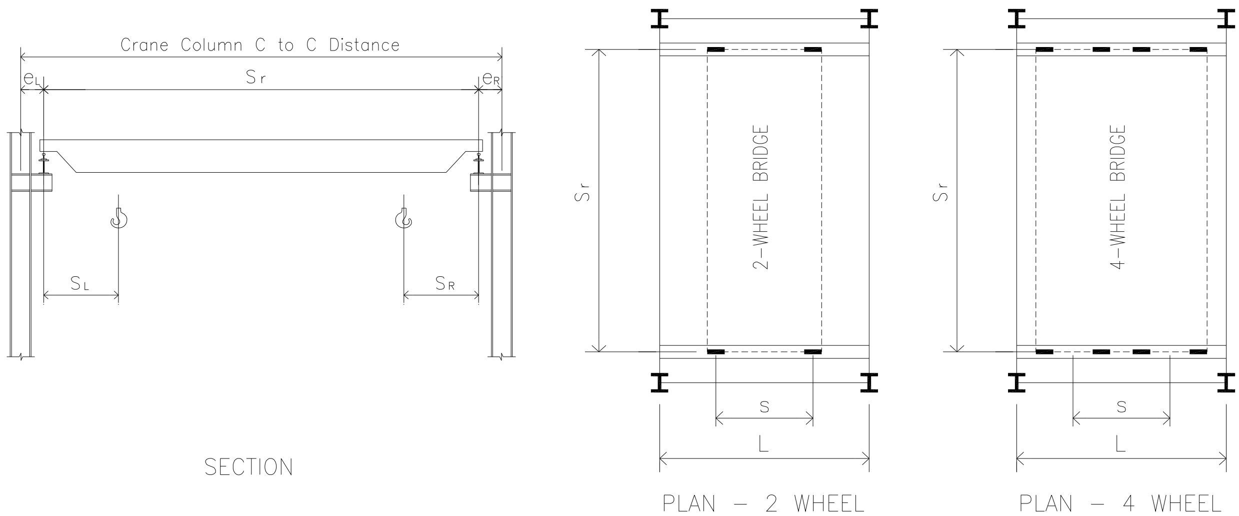
Bumper Force at End Frame					*AISC Design Guide 7*
Bumper force to be the greater of	1 Twice the tractive force	=	33.6	[kips]	18.6
	2 10% of entire crane weight	=	10.7	[kips]	
Bumper force used for design		=	**33.6**	[kips]	

Apply longitudinal bumper force to both sides of end frame



CRANE RUNWAY BEAM DESIGN

Crane beam design using two codes : AISC LRFD-13 and AISC ASD 9th Edition	**Code Abbreviation**
AISC 360-05 Specification for Structural Steel Buildings	*AISC LRFD-13*
AISC Manual of Steel Construction: Allowable Stress Design 9th Edition	*ASD 9th Edition*
CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition	*CISC Crane Guide*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*



Crane Data

Crane rated capacity	W_{rc} =	49.6	[tonne]	= 109.3	[kips]
Bridge weight	W_{br} =	106.9	[kips]	= 48489	[kg]
Trolley + hoist weight	W_{th} =	8.8	[kips]	= 3992	[kg]
Bridge wheel spacing	s =	14.0	[ft]	= 4.267	[m]

For 4-wheel crane **double** the vendor provided max static wheel load as input

Max static wheel load	P_{max} =	84.1	[kips]	= 374.1	[kN]
Crane bridge span	S_r =	131.1	[ft]	= 39.959	[m]
Left min. hook approach	S_1 =	4.6	[ft]	= 1.402	[m]
Right min. hook approach	S_2 =	4.6	[ft]	= 1.402	[m]
Crane runway beam span	L =	21.3	[ft]	= 6.492	[m]
Runway CL to column CL dist	e =	2.1	[ft]	= 0.640	[m]

Runway beam type W_Shape_Cap_Plate Runway beam size W24x104

U_{rb} = 0.15 [kip/ft] = 2.2 [kN/m]

Crane rail size ASCE 85

U_{cr} = 0.03 [kip/ft] = 0.4 [kN/m]

Crane Load Calculation *CISC Crane Guide*

Ver. load impact factor α = 1.25 Table 2.1

Crane side thrust load H_s = Option 1 = 21.6 [kips]

Option 1 H_s = 0.2 (Lifted Load+ Trolley/Hoist Wt)

Option 2 H_s = max of 0.2 (Lifted Load+ Trolley/Hoist Wt)
0.1 (Lifted Load+ Entire Crane Wt)

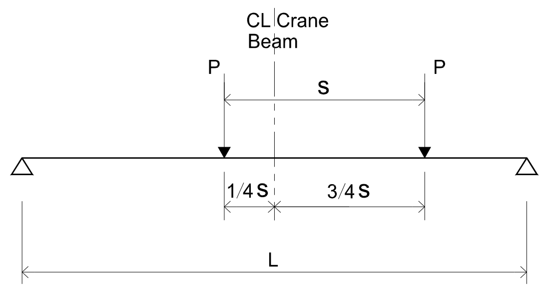
Option 3 H_s = max of 0.2 (Lifted Load+ Trolley/Hoist Wt)
0.1 (Lifted Load+ Entire Crane Wt)
0.4 Lifted Load

Runway beam span L = 21.3 [ft]

Bridge wheel spacing s = 14.0 [ft]

$$M_{max} = \frac{P}{2L}\left(L - \frac{s}{2}\right)^2$$

= 4.80 P



Max Bending Moment Case

Runway beam + rail selfwei U = $U_{rb} + U_{cr}$ = 0.179 [kip/ft]

Crane Load for Design per AISC ASD 9th Ed

Max ver. load /wheel (no impact)	P_v =		= 84.1	[kips / per wheel]
Max hor. load /wheel	P_h =	H_s / 4	= 5.4	[kips / per wheel]
Bending moment x-x axis	M_x =	4.80 xP_vx α (impact) + U x L^2 / 8	= **514.8**	[kip-ft]
Bending moment y-y axis	M_y =	4.80 xP_h	= **25.9**	[kip-ft]
Shear along y-y axis	V_x =	P_v [1+ (L - s) / L]x α (mpact) + UxL/2	= **143.1**	[kips]

Crane Load for Design per AISC LRFD-13th Ed

Wheel load by bridge selfwei	P_{br} =	W_{br} / 4	= 26.7	[kips]	as dead load
Wheel load by lift load + trolley	P_{lt} =	P_{max} - P_{br}	= 57.4	[kips]	as live load
Max factored ver. load /wheel	P_v =	1.2 x P_{br} + 1.6 x P_{lt}	= 123.9	[kips]	impact not included
Max factored hor. load /wheel	P_h =	H x 1.6 / 4	= 8.6	[kips]	
Factor bending moment x-x axis	M_x =	4.80 xP_vx α(impact)+1.2xUxL^2/ 8	= **755.4**	[kip-ft]	
Factor bending moment y-y axis	M_y =	4.80 xP_h	= **41.5**	[kip-ft]	
Factor shear along y-y axis	V_x =	P_v [1+ (L - s) /L]xα(mpact)+1.2xUxL/2	= **210.2**	[kips]	

CRANE RUNWAY BEAM - COMBINED SECTION PROPERTIES CALCULATION

Crane runway beam section W24x104 Top Cap Plate = PL 18 x 0.75

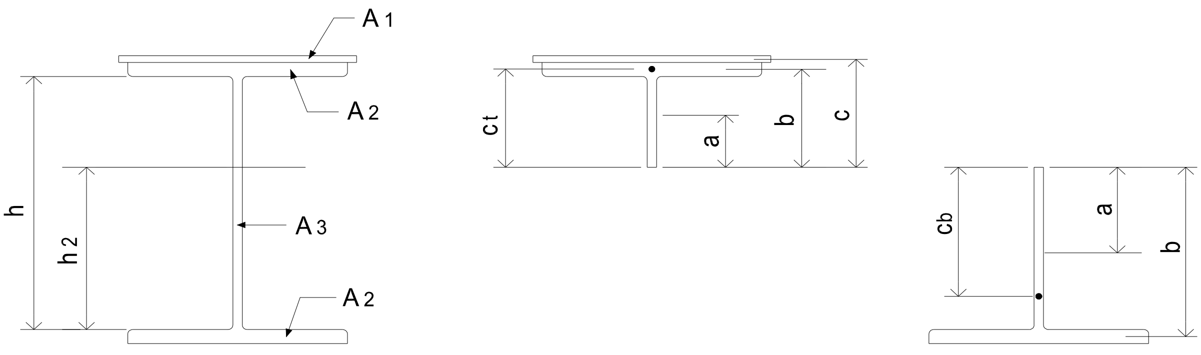
Section Properties

W Section

	d =	24.1	[in]	b_f =	12.8	[in]
	t_f =	0.750	[in]	t_w =	0.500	[in]
	A =	30.6	[in^2]	h =	22.6	[in]
	r_x =	10.10	[in]	r_y =	2.91	[in]
	I_x =	3100.0	[in^4]	S_x =	258.0	[in^3]
	Z_x =	289.0	[in^3]			
	I_y =	259.0	[in^4]	S_y =	40.7	[in^3]
	Z_y =	62.4	[in^3]			
	J =	4.7	[in^4]	C_w =	35200	[in^6]
Top Cap Plate						
Top cap plate size	width b_p =	18.000	[in]	thick t_p =	0.750	[in]

Combined Section Overall

	A =	44.1	[in^2]	d_{all} =	24.9	[in]
	top y_2 =	9.0	[in]	bott. y_1 =	15.9	[in]
	I_x =	4546.8	[in^4]	I_y =	626.9	[in^4]
	top S_2 =	505.4	[in^3]	bott. S_1 =	286.8	[in^3]
	S_y =	69.7	[in^3]			
	Z_x =	364.6	[in^3]	Z_y =	91.5	[in^3]
	r_x =	10.15	[in]	r_y =	3.77	[in]
	J =	17.2	[in^4]	C_w =	0	[in^6]
Top Flange						
	A_f =	23.1	[in^2]	d_{all} / A_f =	1.076	[in^{-1}]
	r_T =	4.51	[in]	r_{yt} =	4.63	[in]
	I_t =	495.6	[in^4]			
	S_t =	55.1	[in^3]	Z_t =	91.5	[in^3]



Calculate Plastic Z_x and Z_y

Plastic neutral axis — area above neutral axis equals area below neutral axis

A_1	$= b_p \times t_p$	= 13.5	[in^2]
A_2	$= b_f \times t_f$	= 9.6	[in^2]
A_3	$= h \times t_w$	= 11.3	[in^2]
h_2	$= (h \times t_w + A_1) / (2 \times t_w)$	= 24.8	[in]

Plastic modulus x-x axis

Centroid of top

a = -1.1	[in]		b	= -1.8	[in]
c = -1.1	[in]		top web area A_{wt}	= -1.1	[in^2]
c_t = -1.4	[in]				

Centroid of bott

a = 12.4	[in]		b	= 25.2	[in]
			bott web area A_{wb}	= 12.4	[in^2]
c_b = 18.0	[in]				

Total area of bottom part	A_{bott}	$= t_w \times h_2 + A_2$	= 22.0	[in^2]
Plastic modulus x-x axis	Z_x	$= A_{bott} \times (c_b + c_t)$	= 364.6	[in^3]

Plastic modulus y-y axis

only top flange & cap plate are considered

$Z_y = (t_f \times b_f^2 + t_p \times b_p^2) / 4$ = 91.5 [in^3]

Calculate Elastic Properties X-X Axis

	A	y_b	Axy_b	Axy_b^2	I_0
	in^2	in	in^3	in^4	in^4
W24x104	30.6	12.1	368.7	4443.2	3100.0
Plate 18 x 0.75	13.5	24.5	330.4	8086.8	0.6
Sum	44.1		699.1	12530.0	3100.6

Code Reference

$y_B = \Sigma Ay_b / \Sigma A$ = 15.9 [in]

$y_T = d + t_p - y_B$ = 9.0 [in]

$I_x = \Sigma I_0 + \Sigma Ay_b^2 - y_B^2 \Sigma A$ = 4546.8 [in^4]

$S_B = I_x / y_B$ = 286.8 [in^3]

$S_T = I_x / y_T$ = 505.4 [in^3]

Calculate Elastic Properties Y-Y Axis

Top flange + plate	$I_{y1} = (t_f \times b_f^3 + t_p \times b_p^3) / 12$	= 495.6	[in^4]
Web	$I_{y2} = h \times t_w^3 / 12$	= 0.2	[in^4]
Bott. flange	$I_{y3} = t_f \times b_f^3 / 12$	= 131.1	[in^4]
Sum	$I_y =$	= 626.9	[in^4]
	$S_y = I_y / [0.5 \times \max(b_f , b_p)]$	= 69.7	[in^3]

Calculate Torsional Properties

t_{ft} = 1.5 [in] t_{fb} = 0.8 [in]

$d' = d_{all} - (t_{ft} + t_{fb}) / 2$ = 23.7 [in]

$J = (b_f \times t_{ft}^3 + b_f \times t_{fb}^3 + d' \times t_w^3) / 3$ = 17.2 [in^4]

Calculate Top Flange Properties

1/3 compression web depth	$h_{cw} = [y_2 - (t_f + t_p)] / 3$	= 2.5	[in]
	$I_{tw} = (t_f \times b_f^3 + t_p \times b_p^3 + h_{cw} \times t_w^3) / 12$	= 495.6	[in^4]
	$A_{tw} = t_f \times b_f + t_p \times b_p + h_{cw} \times t_w$	= 24.3	[in^2]
	$r_T = \mathrm{sqrt}(I_{tw} / A_{tw})$	= 4.5	[in]
	$I_t = (t_f \times b_f^3 + t_p \times b_p^3) / 12$	= 495.6	[in^4]
	$Z_t = (t_f \times b_f^2 + t_p \times b_p^2) / 4$	= 91.5	[in^3]

CRANE RUNWAY BEAM DESIGN - ASD 9

Crane runway design based on		**Code Abbreviation**
AISC Manual of Steel Construction: Allowable Stress Design 9th Edition		*ASD 9th Edition*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition		*AISC Design Guide 7*

Crane runway beam section W24x104 W24x104 and PL 18 x 0.75

Section Properties

Combined Section Overall

A =	44.10	[in^2]	d_{all} =	24.850	[in]
top y_2 =	8.996	[in]	bott. y_1 =	15.854	[in]
I_x =	4546.8	[in^4]	I_y =	626.9	[in^4]
top S_2 =	505.4	[in^3]	bott. S_1 =	286.8	[in^3]
S_y =	69.7	[in^3]			
Z_x =	364.6	[in^3]	Z_y =	91.5	[in^3]
r_x =	10.154	[in]	r_y =	3.770	[in]
J =	17.2	[in^4]	C_w =	0	[in^6]

W Section

d =	24.100	[in]	b_f =	12.800	[in]
t_w =	0.500	[in]	t_f =	0.750	[in]
h =	21.600	[in]			

Top Flange

A_f =	23.100	[in^2]	d_{all} / A_f =	1.076	[in^{-1}]
r_T =	4.511	[in]	r_{yt} =	4.632	[in]
I_t =	495.57	[in^4]			
S_t =	55.06	[in^3]	Z_t =	91.47	[in^3]

Top cap plate size	width b_p =	18.000	[in]	thick t_p =	0.750	[in]
W section yield strength	F_{wy} =	50.0	[ksi]	=	345	[MPa]
Compression flange yield strength	F_{cy} =	50.0	[ksi]	=	345	[MPa]
Runway beam unbraced length	L_b =	255.60	[in]			

Design Forces

Bending moment x-x axis	M_x =	514.77	[kip-ft]
Bending moment y-y axis	M_y =	25.92	[kip-ft]
Shear along y-y axis	V_x =	143.06	[kips]

Conclusion

Overall	ratio =	**0.72**	OK
Local buckling			OK
Bending about X-X Axis	ratio =	0.72	OK
Bending about Y-Y Axis on Top Flange	ratio =	0.15	OK
Biaxial Bending on Top Flange	ratio =	0.56	OK
Shear along Y-Y Axis	ratio =	0.59	OK
Web Sidesway Buckling	ratio =	0.00	OK
Runway Beam Vertical Deflection	ratio =	0.51	OK
Runway Beam Lateral Deflection	ratio =	0.20	OK

			Code Reference
Design Basis & Assumption			*AISC Design Guide 7*
1. The cap plate and W section top flange resist the hor. load and the combined section resists the ver. load. This assumption eliminates the need for an analysis of torsional effects on the combined section and simplifies the analysis.			18.1 on page 56
2. If A36 cap plate is used on A992 W section then lateral torsional buckling and weak axis flexure strength must be calculated based on A36 yield stress.			18.1.4 on page 57

Check Local Buckling

Flange of W shape				*ASD 9th Edition*
Compact limit	λ_p = 65 / sqrt (F_{wy})		= 9.19	Table B5.1
Noncompact limit	λ_r = 95 / sqrt (F_{wy})		= 13.44	
	b_f / $2t_f$ = 8.53		Compact	
Web of W shape				
Compact limit	λ_p = 640 / sqrt (F_{wy})		= 90.51	Table B5.1
Noncompact limit	λ_r = 760 / sqrt ($0.66F_{wy}$)		= 132.30	
	d / t_w = 48.20	h / t_w =	43.20	
			Compact	
W shape classification			**Compact**	
Flange Cover Plate Between Lines of Welds				*AISC LRFD-13*
Compact limit	λ_p = 1.12 sqrt (E / F_{py})		= 26.97	Table B4.1 Case 12
Noncompact limit	λ_r = 1.40 sqrt (E / F_{py})		= 33.72	
Cap plate classification	b_f / t_p = 17.07		**Compact**	
Combined section classification	**Compact**		= **0.00**	**OK**

Check Bending about X-X Axis

Tension

Allowable tension stress	$F_{bx\,t}$ = 0.6 x F_{wy}	= **30.00**	[ksi]
Actual tension stress	$f_{bx\,t}$ = M_x / S_1	= 21.54	[ksi]
	ratio = $f_{bx\,t}$ / $F_{bx\,t}$	= **0.72**	**OK**

Compression

Comb sect top flange yield stress	F_y = 50.0	[ksi]	see assumption 2
Comb sect top flange width	b_f = 12.8	[in]	

				Code Reference
				ASD 9th Edition
Critical length	$L_c = \min\left(\frac{76 x b_f}{\sqrt{F_y}}, \frac{2x10^4}{(d_{all}/A_f) x F_y}\right)$	= 137.57	[in]	Eq F1-2
	$76\ b_f$ / sqrt(F_y) =	= 137.57	[in]	
When L_b <= L_c	This part is NOT applicable			
For compact sect	Not Applicable			
	$F_{bx} = 0.66 \times F_y$	= 0.00	[ksi]	Eq F1-1
For non-compact sect	Not Applicable			
	$b_f / 2t_f$ =	= 8.53		
	$F_{bx} = \left(0.79 - 0.002 \frac{b_f}{2t_f}\sqrt{F_y}\right) F_y$	= 0.00	[ksi]	Eq F1-3
	$F_{bx} = 0.6 \times F_y$	= 0.00	[ksi]	Eq F1-5
When $L_b > L_c$	This part is applicable			
	L_b / r_T =	= 56.66		
Bending coefficient	$C_b = 1.0$ to be conservative			
	$x = \sqrt{\frac{510 x 10^3 x C_b}{F_y}}$	= 101.00		
For (L_b / r_T) <= x	Applicable			
	$F_{bx} = \left(\frac{2}{3} - \frac{F_y (L_b / r_T)^2}{1530 x 10^3 C_b}\right) F_y \le 0.6 F_y$	= 28.09	[ksi]	Eq F1-6
For (L_b / r_T) > x	Not Applicable			
	$F_{bx} = \frac{170 x 10^3 C_b}{(L_b / r_T)^2} \le 0.6 F_y$	= 0.00	[ksi]	Eq F1-7
For any value of (L_b / r_T)	Applicable			
	$F_{bx} = \frac{12 x 10^3 C_b}{L_b x (d_{all} / A_f)} \le 0.6 F_y$	= 30.00	[ksi]	Eq F1-8
Allowable compression stress	$F_{bx\,c}$ =	= **30.00**	[ksi]	
Actual compression stress	$f_{bx\,c} = M_x / S_2$	= 12.22	[ksi]	
	ratio = $f_{bx\,c} / F_{bx\,c}$	= **0.41**	**OK**	

Check Bending about Y-Y Axis on Top Flange

For compact top flange	Applicable			
	$F_{by} = 0.75 \times F_y$	= 37.50	[ksi]	Eq F2-1

					Code Reference
For non-compact top flange	Not Applicable				*ASD 9th Edition*
	F_{by} = 0.60 x F_y		= 0.00	[ksi]	Eq F2-2
Allowable compression stress	$F_{by\,c}$ =		= **37.50**	[ksi]	
Actual compression stress	$f_{by\,c}$ = M_y / S_t		= 5.65	[ksi]	
	ratio = $f_{bx\,c}$ / $F_{bx\,c}$		= **0.15**	**OK**	

Check Biaxial Bending on Top Flange

Combined bending stress	f_{bx} / F_{bx} + f_{by} / F_{by}	= **0.56**	**OK**	Eq H1-3

Check Shear along Y-Y Axis

Clear dist between trans. stiffeners	a = L_b		= 255.60	[in]	
W sect clear dist between flange	h = 21.600 [in]	a / h	= 11.83		
	k_v = 4.00 + 5.34 / (a / h)^2 if a / h <=1		= 5.37		F4
	5.34 + 4.00 / (a / h)^2 if a / h >1				
	h / t_w = 43.20	C_v	= 1.44		
For h / t_w <= 380 / sqrt (F_y)	Applicable				
	F_v = 0.40 x F_y		= 20.00	[ksi]	Eq F4-1
For h / t_w > 380 / sqrt (F_y)	Not Applicable				
	F_v = (F_y x C_v) / 2.89 <=0.4 F_y		= 0.00	[ksi]	Eq F4-2
Allowable shear stress	F_v =		= **20.00**	[ksi]	
Actual shear stress	f_v = V_x / S_t		= 11.87	[ksi]	
	ratio = f_v / F_v		= **0.59**	**OK**	

Check Web Sidesway Buckling *AISC Design Guide 7*

Use LRFD 13 instead of ASD 9 to increase web sidesway buckling resistance when flexural stress in the web is less than $0.66F_y$ page 61

	(h / t_w) / (L_b / b_f) = 2.16 >1.7				*AISC LRFD-13*
Max actual bending stress	f_b = 21.54 [ksi]				
When f_b < (F_y / 1.5) = 0.66 F_y	Applicable	C_r	= 9.6E+05	[ksi]	
When f_b >= (F_y / 1.5) = 0.66 F_y	Not Applicable	C_r	= 0.0E+00	[ksi]	
	$R_n = \frac{C_r t_w^3 t_f}{h^2}\left[0.4\left(\frac{h / t_w}{L_b / b_f}\right)^3\right]$		= NA	[kips]	Eq J10-7
	R_a = R_n / Ω = R_n / 1.76		= NA	[kips]	
	$P_{v\text{-}impt}$ = P_v x α (impact factor)		= 105.13	[kips]	
	Ratio = $P_{v\text{-}impt}$ / R_a		= **0.00**	**OK**	

Check Runway Beam Deflection — **Code Reference**

Crane serviceability criteria based on

CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition	Table 4.1 item 14,15
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	page 56
CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes	Cl 1.4.3

CMAA crane service class Class C Moderate service

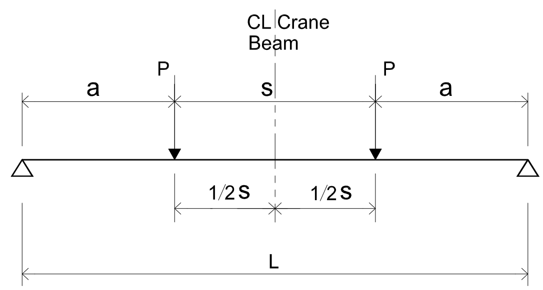
Ver deflection limit (no impact , max wheel load) B_v = L / 600

Hor deflection limit (no impact , 10% max wheel load) B_h = L / 400

Runway beam span L = 255.60 [in]

Bridge wheel spacing s = 168.00 [in]

a = 43.80 [in]



Max Deflection Case

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 11.85 P / I

Vertical Deflection

Unfactored max ver. wheel load P = 84.1 [kips / per wheel] impact factor NOT included

I_x = 4546.8 [in^4]

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 0.219 [in]

Allowable deflection $\Delta_a = L / B_v$ = 0.426 [in]

Ratio = Δ_{max} / Δ_a = **0.51** **OK**

Lateral Deflection

Unfactored max hor. wheel load P = 5.4 [kips / per wheel]

I_t = 495.6 [in^4]

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 0.129 [in]

Allowable deflection $\Delta_a = L / B_h$ = 0.639 [in]

Ratio = Δ_{max} / Δ_a = **0.20** **OK**

CRANE RUNWAY BEAM DESIGN - LRFD 13

Crane runway design based on						**Code Abbreviation**
AISC 360-05 Specification for Structural Steel Buildings						*AISC LRFD-13*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition						*AISC Design Guide 7*
Crane runway beam section	W24x104			W24x104		and PL 18 x 0.75
Section Properties						
Combined Section Overall						
	A =	44.10	[in^2]	d_{all} =	24.850	[in]
	top y_c =	8.996	[in]	bott. y_t =	15.854	[in]
	I_x =	4546.8	[in^4]	I_y =	626.9	[in^4]
	top S_{xc} =	505.4	[in^3]	bott. S_{xt} =	286.8	[in^3]
	S_y =	69.7	[in^3]			
	Z_x =	364.6	[in^3]	Z_y =	91.5	[in^3]
	r_x =	10.154	[in]	r_y =	3.770	[in]
	J =	17.2	[in^4]	C_w =	0	[in^6]
W Section						
	d =	24.100	[in]	b_f =	12.800	[in]
	t_w =	0.500	[in]	t_f =	0.750	[in]
	h =	21.600	[in]	$h_c = 2(y_c - k)$ =	15.493	[in]
	$h_0 = d - t_f$ =	23.350	[in]			
Top Flange						
	A_f =	23.10	[in^2]	d_{all} / A_f =	1.076	[in^{-1}]
	r_t =	4.511	[in]	r_{yt} =	4.632	[in]
	I_t =	495.6	[in^4]			
	S_t =	55.1	[in^3]	Z_t =	91.5	[in^3]
Top cap plate size	width b_p =	18.000	[in]	thick t_p =	0.750	[in]
W section yield strength	F_{wy} =	50.0	[ksi]	=	345	[MPa]
Compression flange yield strength	F_{cy} =	50.0	[ksi]	=	345	[MPa]
Runway beam unbraced length	L_b =	255.60	[in]			
Design Forces						
Bending moment x-x axis	M_x =	755.43	[kip-ft]			
Bending moment y-y axis	M_y =	41.47	[kip-ft]			
Shear along y-y axis	V_y =	210.19	[kips]			

Conclusion

Overall	ratio =	**0.71**	OK
Local buckling			OK
Biaxial Bending on Top Flange	ratio =	0.71	OK
Shear along Y-Y Axis	ratio =	0.65	OK
Web Sidesway Buckling	ratio =	0.00	OK
Runway Beam Vertical Deflection	ratio =	0.51	OK
Runway Beam Lateral Deflection	ratio =	0.20	OK

Code Reference

Design Basis & Assumption — *AISC Design Guide 7*

1. The channel and W section top flange resist the hor. load and the combined section resists the ver. load. This assumption eliminates the need for an analysis of torsional effects on the combined section and simplifies the analysis. — 18.1 on page 56
2. If A36 channel cap is used on A992 W section then lateral torsional buckling and weak axis flexure strength must be calculated based on A36 yield stress. — 18.1.4 on page 57

Check Local Buckling

Flange of W shape				*AISC LRFD-13*
Compact limit	λ_p = 0.38 sqrt (E / F_{wy})	= 9.15		Table B4.1 Case 1
Noncompact limit	λ_r = 1.0 sqrt (E / F_{wy})	= 24.08		
	$b_f / 2t_f$ = 8.53	Compact		
Web of W shape				
Compact limit	λ_p = 3.76 sqrt (E / F_{wy})	= 90.55		Table B4.1 Case 9
Noncompact limit	λ_r = 5.7 sqrt (E / F_{wy})	= 137.27		
	h / t_w = 43.20	Compact		
W shape classification		**Compact**		
Flange Cover Plate Between Lines of Welds				
Compact limit	λ_p = 1.12 sqrt (E / F_{cy})	= 26.97		Table B4.1 Case 12
Noncompact limit	λ_r = 1.4 sqrt (E / F_{cy})	= 33.72		
Cap plate classification	b_f / t_p = 17.07	**Compact**		
Combined section classification	**Compact**	= **0.00**	**OK**	

Check Bending about X-X Axis

Calculate R_{pc}

	λ_{pw} = 90.55	λ_{rw} = 137.27		
	M_{yc} = $S_{xc} F_y$	= 2105.8	[kip-ft]	
	M_p = min ($Z_x F_y$, 1.6 $S_{xc} F_y$)	= 1519.2	[kip-ft]	
	λ = h_c / t_w	= 30.99		
	M_p / M_{yc} =	= 0.72		
For $\lambda <= \lambda_{pw}$	Applicable			
	R_{pc} = M_p / M_{yc}	= 0.72		Eq F4-9a

				Code Reference
				AISC LRFD-13
For $\lambda > \lambda_{pw}$	Not Applicable			
	$R_{pc} = \left[\frac{M_p}{M_{yc}} - \left(\frac{M_p}{M_{yc}} - 1\right)\left(\frac{\lambda - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}}\right)\right] \le \frac{M_p}{M_{yc}}$	= 0.00		Eq F4-9b
R_{pc} used for design	R_{pc} =	= **0.72**		

<u>Calculate R_{pt}</u>

	$M_{yt} = S_{xt} F_y$	= 1195.0	[kip-ft]	
	$M_p = \min(Z_x F_y, 1.6 S_{xt} F_y)$	= 1519.2	[kip-ft]	
	M_p / M_{yt} =	= 1.27		
For $\lambda <= \lambda_{pw}$	Applicable			
	$R_{pt} = M_p / M_{yc}$	= 1.27		Eq F4-15a
For $\lambda > \lambda_{pw}$	Not Applicable			
	$R_{pt} = \left[\frac{M_p}{M_{yt}} - \left(\frac{M_p}{M_{yt}} - 1\right)\left(\frac{\lambda - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}}\right)\right] \le \frac{M_p}{M_{yt}}$	= 0.00		Eq F4-15b
R_{pt} used for design	R_{pt} =	= **1.27**		

<u>Calculate F_L</u>

	S_{xt} / S_{xc} = 0.57			
For S_{xt} / S_{xc} >= 0.7	Not Applicable			
	$F_L = 0.7 F_y$	= 0.0	[ksi]	Eq F4-6a
For S_{xt} / S_{xc} < 0.7	Applicable			
	$F_L = \max(F_y \times (S_{xt} / S_{xc}), 0.5 F_y)$	= 28.4	[ksi]	Eq F4-6b
F_L used for design	F_L =	= **28.4**	[ksi]	

<u>M_n - Compression Flange Yielding</u>

	$M_{n1} = R_{pc} F_y S_{xc}$	= **1519.2**	[kip-ft]	Eq F4-1

<u>M_n - Lateral Torsional Buckling</u>

Runway beam unbraced length	L_b =	= 255.60	[in]	
Calculate L_p & L_r				
	$L_p = 1.1\ r_t \sqrt{\frac{E}{F_y}}$	= 119.5	[in]	Eq F4-7
	$L_r = 1.95\ r_t \frac{E}{F_L} \sqrt{\frac{J}{S_{xc} h_o}} \sqrt{1 + \sqrt{1 + 6.76 \left(\frac{F_L}{E} \frac{S_{xc} h_o}{J}\right)^2}}$			Eq F4-8
		= 595.6	[in]	

				Code Reference
For L_b <= L_p	Not Applicable			*AISC LRFD-13*
	M_{n2} =	= NA	[kip-ft]	
For L_p < L_b <= L_r	Applicable			
	C_b = 1.0 to be conservative			
	$M_{n2} = C_b\left[R_{pc}M_{yc} - \left(R_{pc}M_{yc} - F_L S_{xc}\right)\left(\frac{L_b - L_p}{L_r - L_p}\right)\right] \le R_{pc}M_{yc}$			Eq F4-2
		= 1426.6	[kip-ft]	
For L_b > L_r	Not Applicable			
For I_t / I_y <= 0.23 J = 0	Not Applicable			
	J = 17.19 [in^4]			
	$F_{cr} = \frac{C_b \pi^2 E}{\left(\frac{L_b}{r_t}\right)^2}\sqrt{1 + 0.078\frac{J}{S_{xc}h_o}\left(\frac{L_b}{r_t}\right)^2}$	= 0.0	[ksi]	Eq F4-5
	M_{n2} = F_{cr} S_{xc} <= R_{pc} F_y S_{xc}	= NA	[kip-ft]	Eq F4-3
M_n - LTB	M_{n2} =	= **1426.6**	[kip-ft]	

<u>M_n - Compression Flange Local Buckling</u>

	λ = 8.53			
	λ_{pf} = 9.15	λ_{rf} = 24.08		
For λ <= λ_{pf}	Applicable			
	M_{n3} =	= NA	[kip-ft]	
For λ_{pf} < λ <= λ_{rf}	Not Applicable			
	$M_{n3} = \left[R_{pc}M_{yc} - \left(R_{pc}M_{yc} - F_L S_{xc}\right)\left(\frac{\lambda - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}\right)\right]$	= NA	[kip-ft]	Eq F4-12
	M_{n3} =	= **NA**	[kip-ft]	

<u>M_n - Tension Flange Yielding</u>

	M_{n4} = R_{pt} F_y S_{xt}	= **1519.2**	[kip-ft]	Eq F4-14
	M_{nx} = min(M_{n1} , M_{n2} , M_{n3} , M_{n4})	= **1426.6**	[kip-ft]	

Check Bending about Y-Y Axis					**Code Reference**
Check top flange compactness, for W check W flange only, for W+Cap Plate check both W and Cap Plate					
Top flange compactness		= Compact			*AISC LRFD-13*
For compact top flange	M_{ny}	= $F_y Z_t$	= 381.1	[kip-ft]	Eq F6-1
For noncompact top flange	M_{ny}	= $F_y S_t$	= 229.4	[kip-ft]	
	M_{ny}	=	= **381.1**	[kip-ft]	
Check Biaxial Bending on Top Flange					
Combined bending		$M_x / (\Phi M_{nx}) + M_y / (\Phi M_{ny})$	= **0.71**	**OK**	Eq H1-1b
Check Shear along Y-Y Axis					
Clear dist between trans. stiffeners	a	= L_b	= 255.60	[in]	
W sect clear dist between flange	h	= 21.600 [in]	a / h = 11.83		
	h / t_w	= 43.20			
	k_v	= 5 if $h / t_w < 260$	= 5.00		G2.1 (b)
		5 if $a / h > 3.0$ or $a / h > [260/(h / t_w)]^2$			
		$5 + 5 / (a / h)^2$			
	T	= $\mathrm{sqrt}(k_v E / F_y)$	= 53.9		
For $h / t_w <= 1.10$ T		Applicable			
	C_v	=	1.0		Eq G2-3
For $1.10 T < h / t_w <= 1.37 T$		Not Applicable			
	C_v	= $1.10 \times \mathrm{sqrt}(k_v E / F_y) / (h / t_w)$	= NA		Eq G2-4
For $h / t_w > 1.37$ T		Not Applicable			
	C_v	= $1.51 E k_v / [(h / t_w)^2 F_y]$	= NA		Eq G2-5
C_v used for design	C_v	=	= 1.0		
	ΦV_n	= $0.9 \times 0.6 F_y (d t_w) C_v$	= **325.4**	[kips]	Eq G2-1
	ratio	= $V_y / \Phi V_n$	= **0.65**	**OK**	

Check Web Sidesway Buckling **Code Reference**

AISC LRFD-13

$(h / t_w) / (L_b / b_f)$ = 2.16 >1.7

When $M_u < M_y$ Applicable C_r = 9.6E+05 [ksi]

When $M_u >= M_y$ Not Applicable C_r = 0.0E+00 [ksi]

$$R_n = \frac{C_r t_w^3 t_f}{h^2}\left[0.4\left(\frac{h / t_w}{L_b / b_f}\right)^3\right]$$ = NA [kips] Eq J10-7

Φ = = 0.85

$P_{v\text{-impt}} = P_v \times \alpha$ (impact factor) = 154.84 [kips]

ratio = $P_{v\text{-impt}} / \Phi R_n$ = **0.00** **OK**

Check Runway Beam Deflection

Crane serviceability criteria based on

CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition Table 4.1 item 14,15

AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition page 56

CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes Cl 1.4.3

CMAA crane service class Class C Moderate service

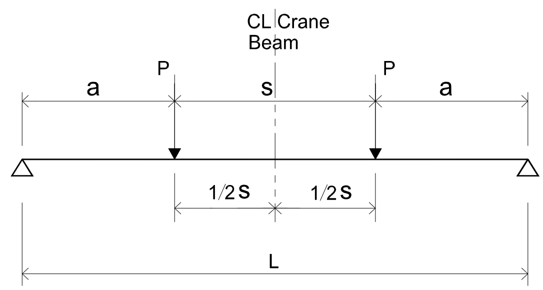
Ver deflection limit (no impact , max wheel load) B_v = L / 600

Hor deflection limit (no impact , 10% max wheel load) B_h = L / 400

Runway beam span L = 255.60 [in]

Bridge wheel spacing s = 168.00 [in]

a = 43.80 [in]



Max Deflection Case

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24 \, E \, I}$ = 11.85 P / I

Vertical Deflection

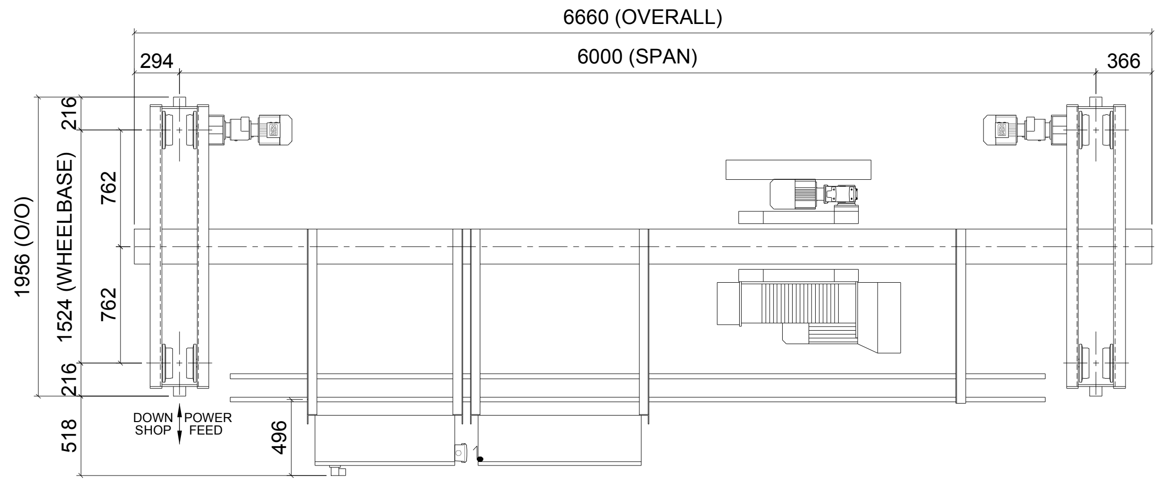
Unfactored max ver. wheel load P = 84.1 [kips / per wheel] impact factor NOT included

I_x = 4546.8 [in^4]

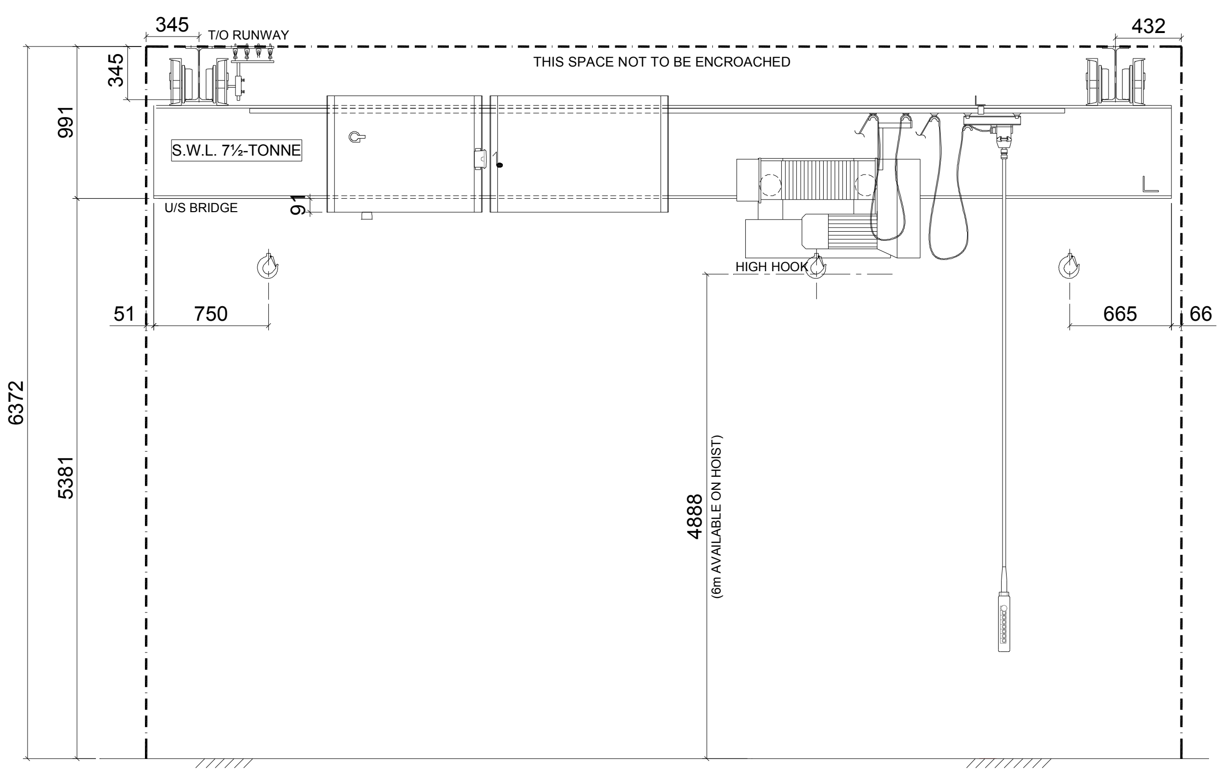
Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24 \, E \, I}$ = 0.219 [in]

					Code Reference
Allowable deflection	$\Delta_a = L / B_v$		= 0.426	[in]	
	ratio = Δ_{max} / Δ_a		**= 0.51**	**OK**	
Lateral Deflection					
Unfactored max hor. wheel load	P = 5.4	[kips / per wheel]			
	I_t = 495.6	[in^4]			
Max deflection at center	$\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$		= 0.129	[in]	
Allowable deflection	$\Delta_a = L / B_h$		= 0.639	[in]	
	ratio = Δ_{max} / Δ_a		**= 0.20**	**OK**	

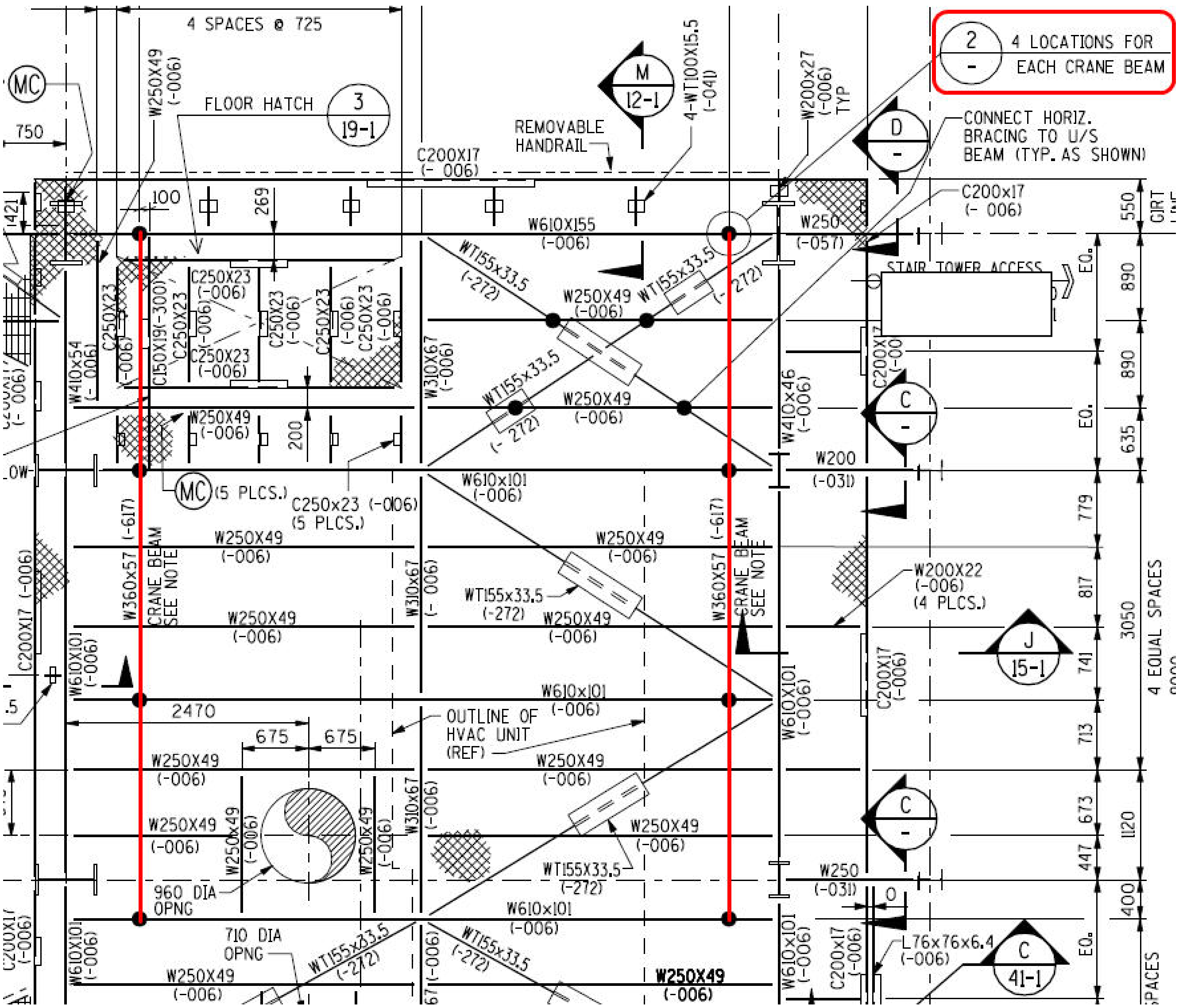
Example 04: Underhung 7.5 Ton Crane + Runway W Shape – Metric Unit



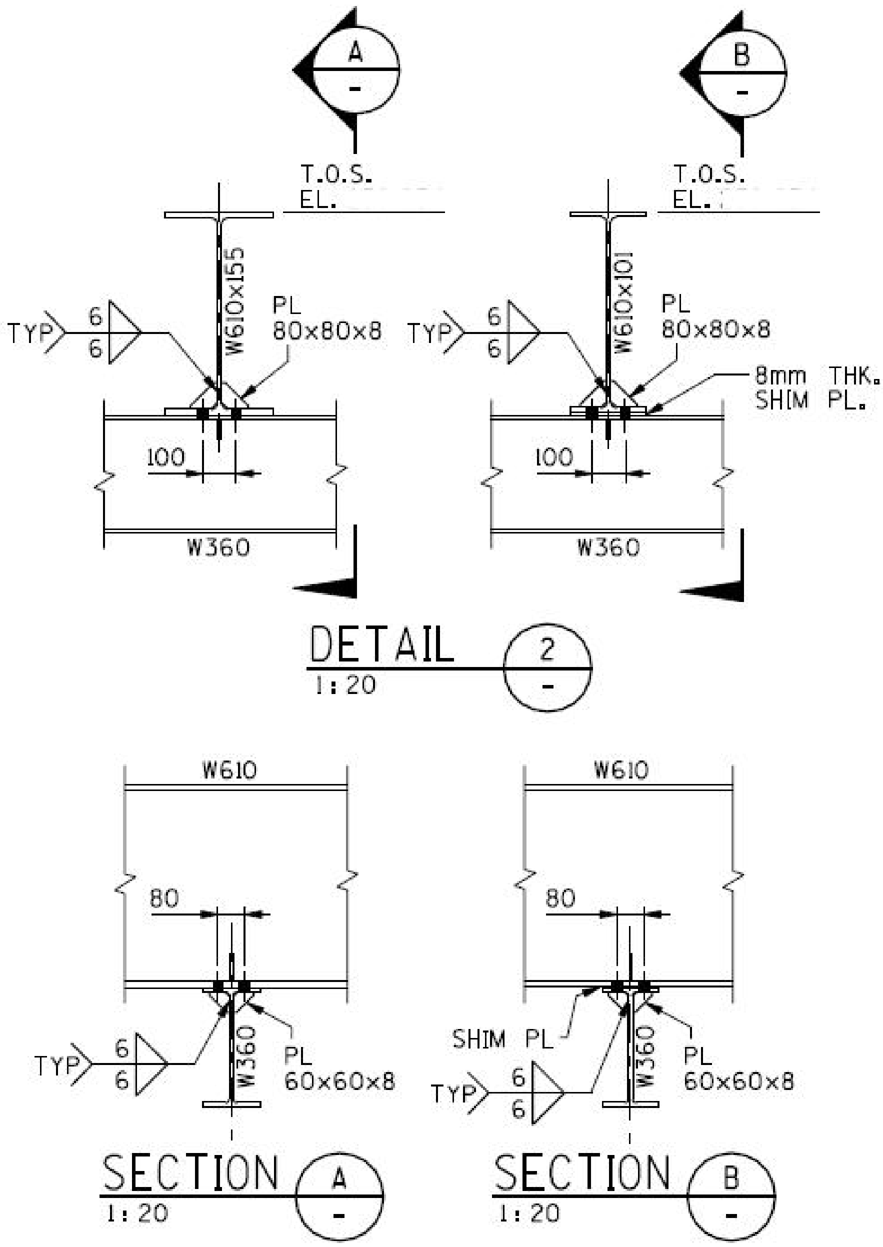
PLAN VIEW



ELEVATION VIEW



7.5 Tonne Underhung Crane Runway Beam Plan

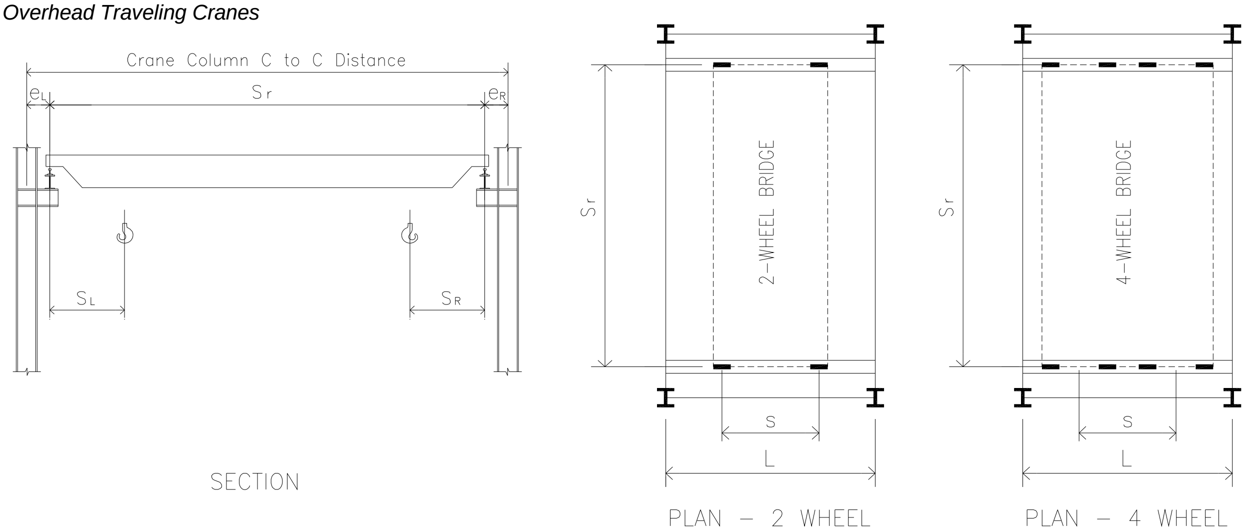


7.5 Tonne Underhung Crane W360x57 Runway Beam Support Point to Floor Beam Connection

Crane Data	Imperial	Metric
Crane capacity	8.3 US Tons =16.6 kips	7.5 Metric Tons = 73.5 kN
Bridge weight	5.8 kips	2630 kg
Trolley + hoist weight	1.6 kips	725 kg
Max static wheel load	10.9 kips	48.5 kN
Bridge span S_r	19.7 ft	6.000 m
Left min. hook approach S_L	1.5 ft	0.456 m
Right min. hook approach S_R	1.0 ft	0.299 m
Bridge wheel spacing s	5.0 ft	1.524 m
Crane runway beam span L	7.9 ft	2.415 m
Left runway CL to column CL dist e_L	0.0 ft	0.000 m
Right runway CL to column CL dist e_R	0.0 ft	0.000 m
Crane rail size	No Rail	No Rail
CMAA crane service class	Class C	Class C
Vertical impact factor	25%	25%
Crane type	Underhung	Underhung
Crane runway beam size	W14x38	W360x57
W shape F_y	50 ksi	345 MPa
Plate cap F_y	NA	NA

BRIDGE CRANE LOAD CALCULATION

Bridge crane load calc based on	**Code Abbreviation**
CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition	*CISC Crane Guide*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*
CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes	*CMAA 70-04*



Crane Data

					suggested value		
Crane rated capacity	W_{rc}	=	7.5	[Metric Ton]		= 73.5	[kN]
Bridge weight	W_{br}	=	2630	[kg]	1454	= 25.8	[kN]
Trolley + hoist weight	W_{th}	=	725	[kg]	1500	= 7.1	[kN]
Bridge wheel spacing	s	=	1.524	[m]	2.20		
Max. static wheel load by vendor	P_{max-v}	=	48.5	[kN]	input 0 if vendor data is unknown		
Crane bridge span	S_r	=	6.000	[m]	5.1		
Min. hook approach-left	S_L	=	0.456	[m]	0.95		
Min. hook approach-right	S_R	=	0.299	[m]	0.95		
Crane runway beam span	L	=	2.415	[m]			
Runway CL to col CL dist-left	e_L	=	0.000	[m]	0.45		
Runway CL to col CL dist-right	e_R	=	0.000	[m]	0.45		
Crane column C to C distance	$S_r + 2e$	=	6.000	[m]		suggested section	
Runway beam type		=	W_Shape		?		
Runway beam size		=	W360x57			size <= W530x92 C310x31	
Top flange cap plate size	width b_p				thick t_p		not applicable
	suggest		ASCE 60		U_{rb}	= 0.57	[kN/m]
Crane rail size		=	No Rail		U_{cr}	= 0	[lbs/yd]
						= 0.00	[kN/m]
Rail base width	B_w	=	0	[mm]	Rail height H_t	= 0	[mm]
W section yield strength	f_{wy}	=	345	[MPa]		= 50.0	[ksi]
Cap channel or plate yield strength	f_{cy}	=	345	[MPa]		= 50.0	[ksi]
CMAA crane service class		=	Class C	?		Moderate service	
Crane type		=	Underhung		?		

Code Reference

CISC Crane Guide

Vertical load impact factor = 0.25 ? Table 2.1

Crane side thrust load option = Option 1 ? Table 2.1

Crane side thrust load can be calculated using one of the following 3 options

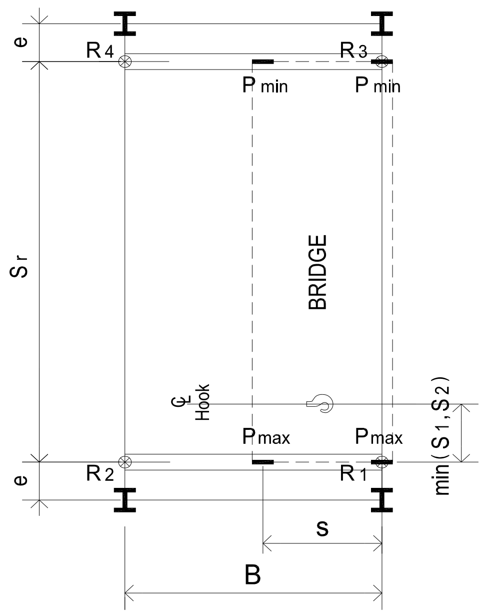
Option 1 H_s = 0.2 (Lifted Load+ Trolley/Hoist Wt)

Option 2 H_s = max of 0.2 (Lifted Load+ Trolley/Hoist Wt)
0.1 (Lifted Load+ Entire Crane Wt)

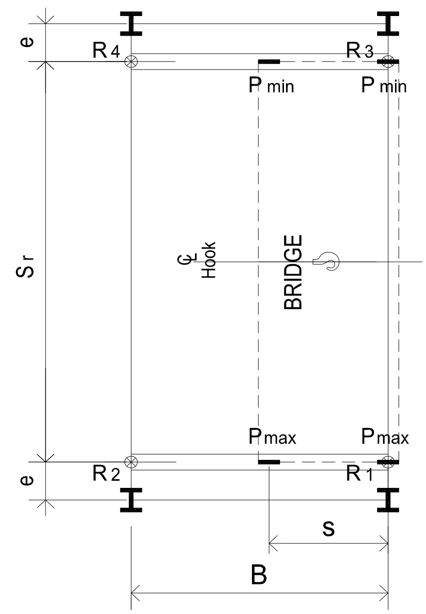
Option 3 H_s = max of 0.2 (Lifted Load+ Trolley/Hoist Wt)
0.1 (Lifted Load+ Entire Crane Wt)
0.4 Lifted Load

Conclusion

Runway Beam Design Using ASD 89		
Overall	ratio = **0.32**	OK
Local buckling		OK
Bending about X-X Axis	ratio = 0.19	OK
Bending about Y-Y Axis on Top Flange	ratio = 0.14	OK
Biaxial Bending on Top Flange	ratio = 0.32	OK
Shear along Y-Y Axis	ratio = 0.22	OK
Web Sidesway Buckling	ratio = 0.00	OK
Runway Beam Vertical Deflection	ratio = 0.12	OK
Runway Beam Lateral Deflection	ratio = 0.19	OK
Runway Beam Design Using LRFD 05		
Overall	ratio = **0.31**	OK
Local buckling		OK
Biaxial Bending on Top Flange	ratio = 0.31	OK
Shear along Y-Y Axis	ratio = 0.25	OK
Web Sidesway Buckling	ratio = 0.00	OK
Runway Beam Vertical Deflection	ratio = 0.12	OK
Runway Beam Lateral Deflection	ratio = 0.19	OK
Runway Beam Bottom Flange Local Bending	ratio = **1.72**	NG



CASE 1 HOOK AT ONE SIDE

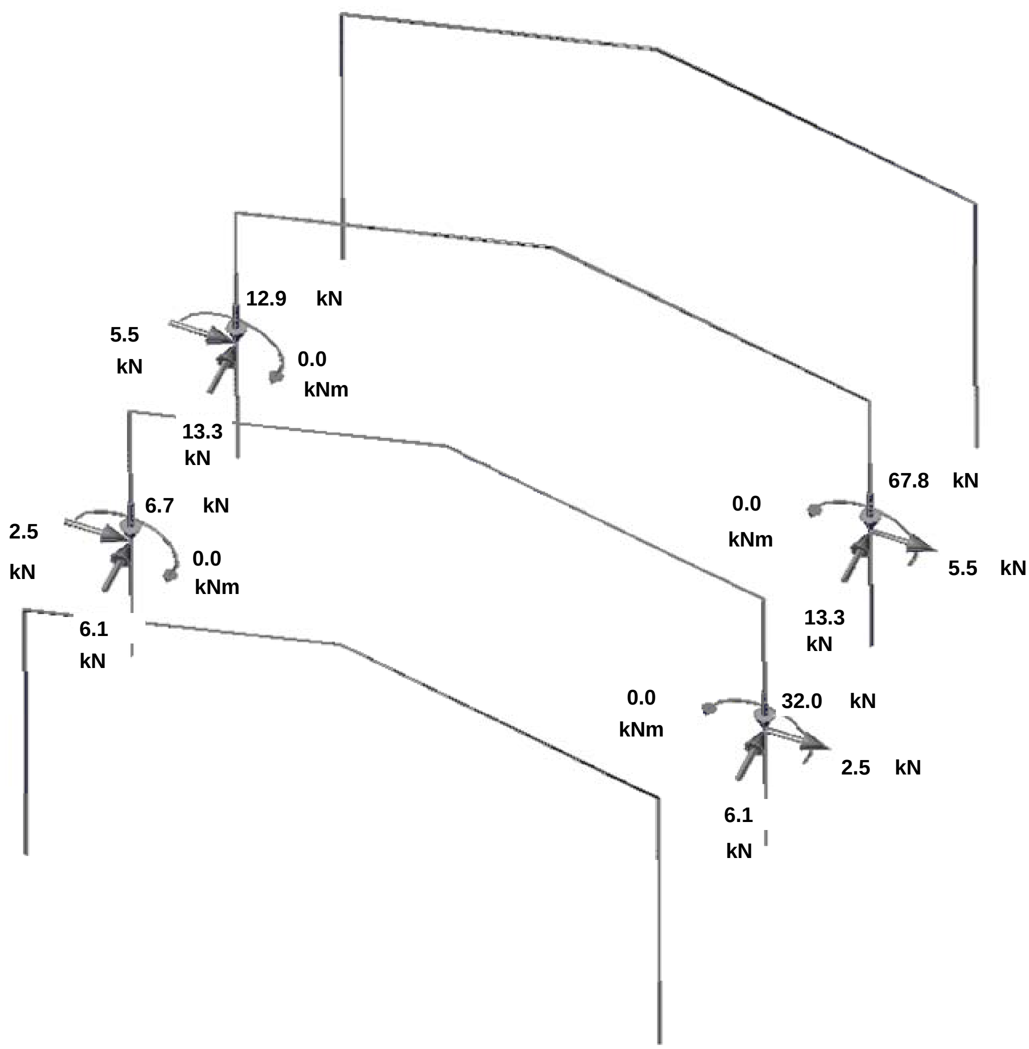


CASE 2 HOOK AT CENTER

Crane Load Calculation					**Code Reference**
Crane runway + rail selfweight	R_{sw} =	$(U_{rb} + U_{cr})$ x B	= 1.4	[kN]	
Wheel load by bridge selfwei	P_{br} =	W_{br} / 4 wheel	= 6.4	[kN/per wheel]	
Side Thrust Load					
Crane side thrust load calculated by	=	Option 1			*CISC Crane Guide*
	H_{s1} =	0.4 Lifted Load	= 29.4	[kN]	Table 2.1
	H_{s2} =	0.2 (Lifted Load+ Trolley/Hoist Wt)	= 16.1	[kN]	
	H_{s3} =	0.1 (Lifted Load+ Entire Crane Wt)	= 10.6	[kN]	
	H_{st} =	side thrust load calc using Option 1	= 4.0	[kN/per wheel]	
	$H_{st1}=H_{st3}$ =	H_{st} (1 + (B-s) / B)	= **5.5**	[kN]	
	$H_{st2}=H_{st4}$ =	H_{st} s / B	= **2.5**	[kN]	
Tractive Load					Table 2.1
	H_{tr} =	0.2 Max wheel load	= 9.7	[kN/per wheel]	
	$H_{tr1}=H_{tr3}$ =	H_{tr} (1 + (B-s) / B)	= **13.3**	[kN]	
	$H_{tr2}=H_{tr4}$ =	H_{tr} s / B	= **6.1**	[kN]	
Vertical Load					
Case 1 Hook at One Side					
Min. hook aproach	S_{min} =	min (S_L, S_R)	= 0.299	[m]	
Max wheel load by calc	P_{max-c} =	$[(W_{rc}+W_{th})x(S_r-S_{min})/ S_r]/2$ wheel+P_{br}	= 44.8	[kN/per wheel]	
Max. wheel load by vendor	P_{max-v} =		= 48.5	[kN/per wheel]	
Max static wheel load	P_{max} =	max (P_{max-v}, P_{max-c})	= **48.5**	[kN/per wheel]	
Min wheel load	P_{min} =	$[(W_{rc}+W_{th})xS_{min}/S_r]/2$ wheel+P_{br}	= **8.5**	[kN/per wheel]	

Reaction on runway support	$R_1 = P_{max} (1 + (B\text{-}s) / B) + R_{sw}$	= **67.8**	[kN]
	$R_2 = P_{max}\, s / B + R_{sw}$	= **32.0**	[kN]
	$R_3 = P_{min} (1 + (B\text{-}s) / B) + R_{sw}$	= **12.9**	[kN]
	$R_4 = P_{min}\, s / B + R_{sw}$	= **6.7**	[kN]
Point moment to column center	$M_1 = R_1 \times e_R$	= **0.0**	[kNm]
	$M_2 = R_2 \times e_R$	= **0.0**	[kNm]
	$M_3 = R_3 \times e_L$	= **0.0**	[kNm]
	$M_4 = R_4 \times e_L$	= **0.0**	[kNm]

Case 1 Hook at One Side - Crane Load Summary



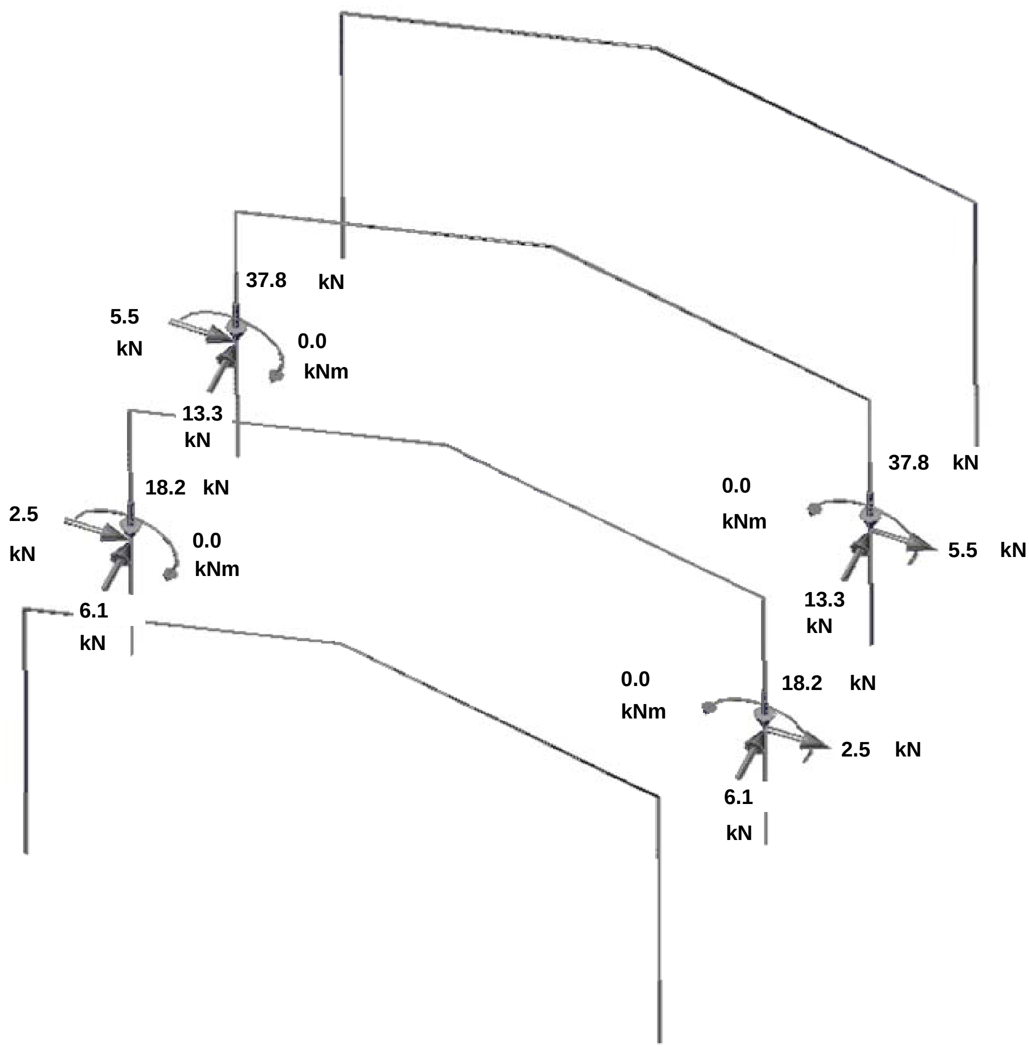
Note:

The crane loads shown above may be reverse if crane hook goes to the other side. When reverse the loads and apply them on building columns, the point moment value may need adjusted if eccentricity $e_L <> e_R$

Case 2 Hook at Center of Bridge

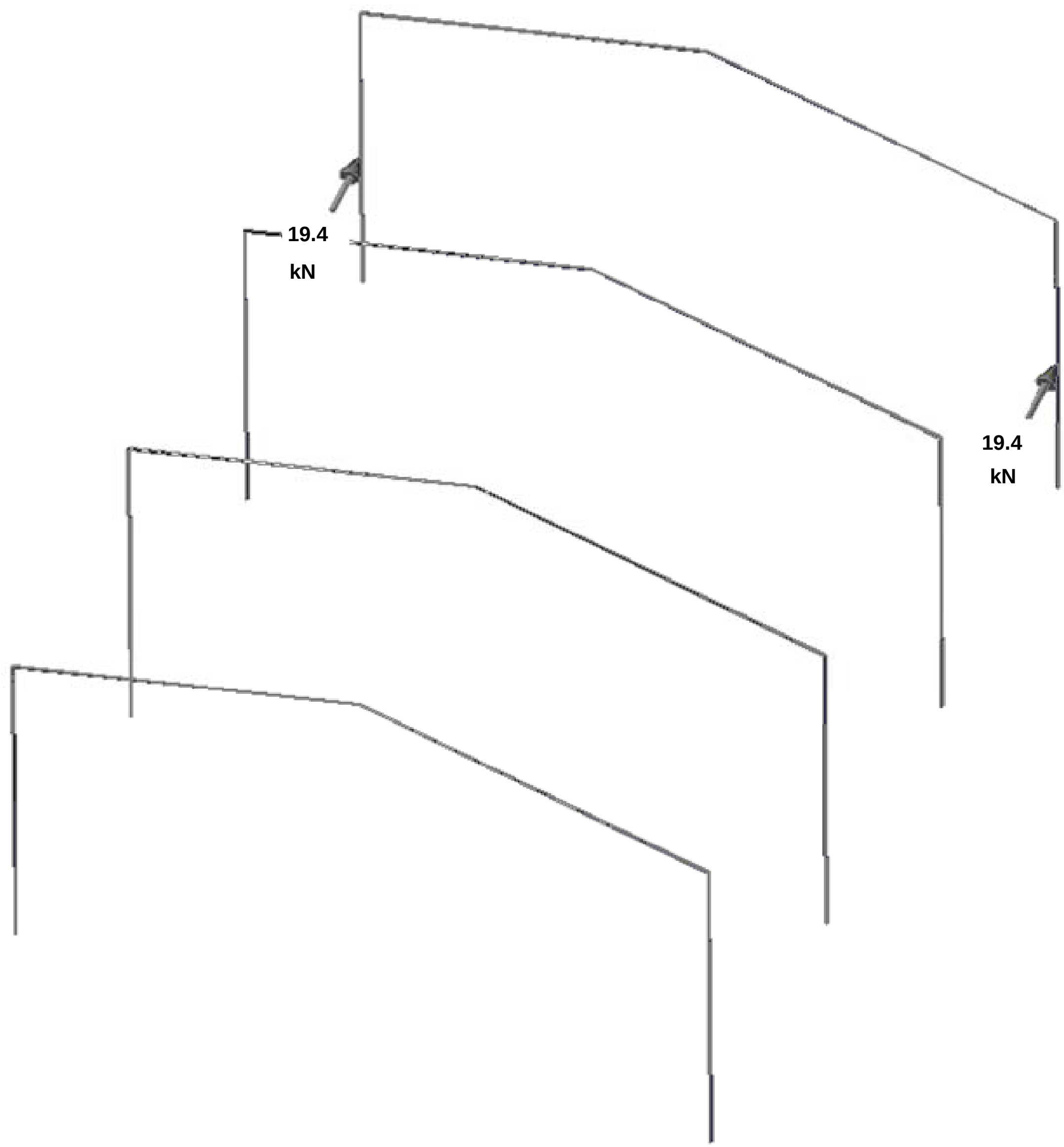
Max wheel load	P_{max} = P_{min} = $(W_{rc}+W_{br}+W_{th})/4$ wheel	= 26.6	[kN/per wheel]
Reaction on runway support	R_1 = R_3 = P_{max} (1 + (B-s) / B) + R_{sw}	= **37.8**	[kN]
	R_2 = R_4 = P_{max} s / B + R_{sw}	= **18.2**	[kN]
Point moment to column center	M_1 = M_3 = R_1 x max (e_L , e_R)	= **0.0**	[kNm]
	M_2 = R_2 x max (e_L , e_R)	= **0.0**	[kNm]

Case 2 Hook at Center of Bridge - Load Summary



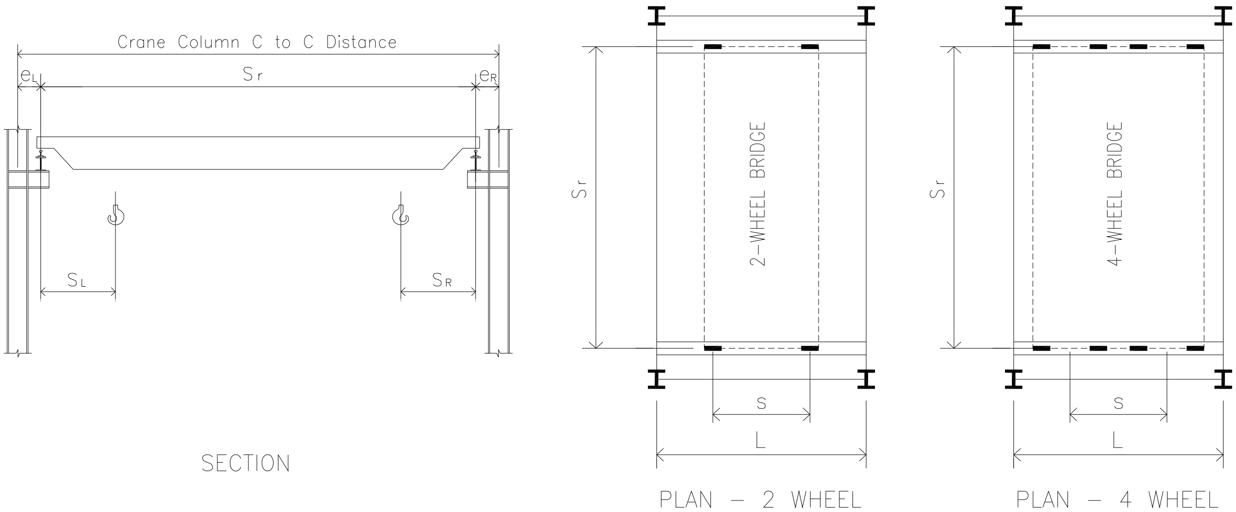
					Code Reference
Bumper Force at End Frame					*AISC Design Guide 7*
Bumper force to be the greater of	1 Twice the tractive force	=	19.4	[kN]	18.6
	2 10% of entire crane weight	=	5.3	[kN]	
Bumper force used for design		=	**19.4**	[kN]	

Apply longitudinal bumper force to both sides of end frame



CRANE RUNWAY BEAM DESIGN

Crane beam design using two codes : AISC LRFD 13th Ed and AISC ASD 9th Ed	**Code Abbreviation**
AISC 360-05 Specification for Structural Steel Buildings	*AISC LRFD-13*
AISC Manual of Steel Construction: Allowable Stress Design 9th Edition	*ASD 9th Edition*
CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition	*CISC Crane Guide*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*



Crane Data

Crane rated capacity	W_{rc} =	7.5	[tonne]	= 16.5	[kips]
Bridge weight	W_{br} =	2630	[kg]	= 5.8	[kips]
Trolley + hoist weight	W_{th} =	725	[kg]	= 1.6	[kips]
Bridge wheel spacing	s =	1.524	[m]	= 5.0	[ft]

For 4-wheel crane **double** the vendor provided max static wheel load as input

Max static wheel load	P_{max} =	48.5	[kN]	= 10.9	[kips]
Crane bridge span	S_r =	6.0	[m]	= 19.7	[ft]
Left min. hook approach	S_1 =	0.456	[m]	= 1.5	[ft]
Right min. hook approach	S_2 =	0.299	[m]	= 1.0	[ft]
Crane runway beam span	L =	2.415	[m]	= 7.9	[ft]
Runway CL to column CL dist	e =	0.000	[m]	= 0.0	[ft]

Runway beam type	W_Shape		Runway beam size	W360x57	
	U_{rb} = 0.57	[kN/m]		= 0.039	[kip/ft]
Crane rail size	No Rail				
	U_{cr} = 0.00	[kN/m]		= 0.000	[kip/ft]

Crane Load Calculation *CISC Crane Guide*

Ver. load impact factor α = 1.25 Table 2.1

Crane side thrust load H_s = Option 1 = 3.6 [kips]

Option 1 H_s = 0.2 (Lifted Load+ Trolley/Hoist Wt)

Option 2 H_s = max of 0.2 (Lifted Load+ Trolley/Hoist Wt)
0.1 (Lifted Load+ Entire Crane Wt)

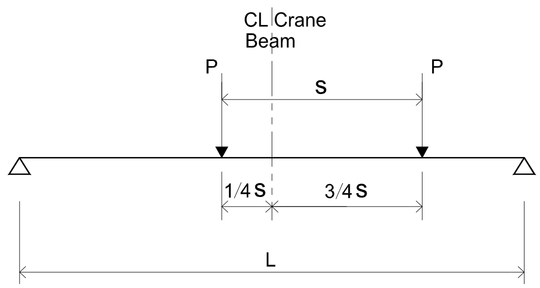
Option 3 H_s = max of 0.2 (Lifted Load+ Trolley/Hoist Wt)
0.1 (Lifted Load+ Entire Crane Wt)
0.4 Lifted Load

Runway beam span L = 7.9 [ft]

Bridge wheel spacing s = 5.0 [ft]

$$M_{max} = \frac{P}{2\,L}\left(L - \frac{s}{2}\right)^2$$

= 1.86 P



Max Bending Moment Case

Runway beam + rail selfwei U = $U_{rb} + U_{cr}$ = 0.039 [kip/ft]

Crane Load for Design per AISC ASD 9th Ed

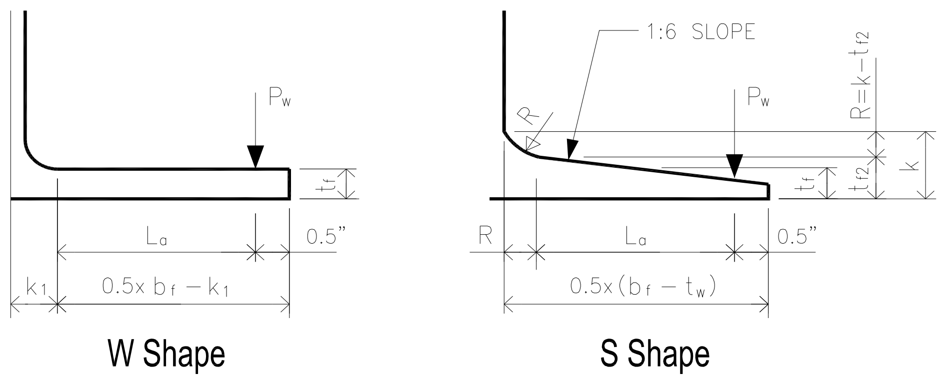
Max ver. load /wheel (no impact)	P_v =		= 10.9	[kips / per wheel]
Max hor. load /wheel	P_h =	H_s / 4	= 0.9	[kips / per wheel]
Bending moment x-x axis	M_x =	1.86 xP_vx α (impact) + U x L^2 / 8	= **25.60**	[kip-ft]
Bending moment y-y axis	M_y =	1.86 xP_h	= **1.68**	[kip-ft]
Shear along y-y axis	V_x =	P_v [1+ (L - s) / L]x α (mpact) + UxL/2	= **18.81**	[kips]

Crane Load for Design per AISC LRFD 13th Ed

Wheel load by bridge selfwei	P_{br} =	W_{br} / 4	= 1.4	[kips]	as dead load
Wheel load by lift load + trolley	P_{lt} =	P_{max} - P_{br}	= 9.5	[kips]	as live load
Max factored ver. load /wheel	P_v =	1.2 x P_{br} + 1.6 x P_{lt}	= 16.9	[kips]	impact not included
Max factored hor. load /wheel	P_h =	H x 1.6 / 4	= 1.5	[kips]	
Factor bending moment x-x axis	M_x =	1.86 xP_vx α(impact)+1.2xUxL^2/ 8	= **39.50**	[kip-ft]	
Factor bending moment y-y axis	M_y =	1.86 xP_h	= **2.69**	[kip-ft]	
Factor shear along y-y axis	V_x =	P_v [1+ (L - s) /L]xα(mpact)+1.2xUxL/2	= **29.05**	[kips]	

Bottom Flange Local Bending This section is applicable for underhung crane

Crane runway beam section	W360x57		W14x38
Section Properties			
	d = 14.100 [in]		b_f = 6.770 [in]
	t_w = 0.310 [in]		t_f = 0.515 [in]
	k = 1.250 [in]		k_1 = 0.813 [in]
W section yield strength	f_{wy} = 50.0 [ksi]		



Effective Cantilever Length

Assume wheel width = 1" and point load P_w acting at 0.5" offset from flange tip

For W shape	$L_a = b_f/2 - k_1 - 0.5"$	= **2.073**	[in]
For S shape			
Flange thickness at toe	$t_{f2} = t_f + \frac{0.5(b_f - t_w)}{2} \times \frac{1}{6}$	= 0.000	[in]
Radius of fillet	$R = k - t_{f2}$	= 0.000	[in]
	$L_a = 0.5 \times (b_f - t_w) - R - 0.5"$	= 0.000	[in]

Effective Bottom Flange Bending Width

Effective flange bending width	$b_e = 12 \times t_f$	= 6.180	[in]

Falnge Thickness at Web Toe

For W shape	$t = t_f$	= **0.515**	[in]
For S shape	$t = t_{f2}$	= 0.000	[in]
Wheel load one side of flange	$P_w = P_{max} / 2 \times \alpha$ (impact factor)	= 6.8	[kips]
Factored bending moment	$M_f = 1.5 \times P_w \times L_a$	= 1.77	[kip-ft]
	$S = b_e \times t^2 / 6$	= 0.273	[in^3]
	$M_r = 0.9 \times S \times F_y$	= 1.02	[kip-ft]
	ratio = M_f / M_r	= **1.72**	**NG**

CRANE RUNWAY BEAM DESIGN - ASD 9

Crane runway design based on	**Code Abbreviation**
AISC Manual of Steel Construction: Allowable Stress Design 9th Edition	*ASD 9th Edition*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*

Crane runway beam section W360x57 W14x38

Section Properties

Combined Section Overall

A = 11.200	[in^2]		d_{all} = 14.100	[in]
top y_2 = 7.050	[in]		bott. y_1 = 7.050	[in]
I_x = 385.0	[in^4]		I_y = 26.70	[in^4]
top S_2 = 54.60	[in^3]		bott. S_1 = 54.60	[in^3]
S_y = 7.88	[in^3]			
Z_x = 61.50	[in^3]		Z_y = 12.10	[in^3]
r_x = 5.870	[in]		r_y = 1.550	[in]
J = 0.80	[in^4]		C_w = 1230	[in^6]

W Section

d = 14.100	[in]		b_f = 6.770	[in]
t_w = 0.310	[in]		t_f = 0.515	[in]
h = 12.270	[in]			

Top Flange

A_f = 3.487	[in^2]		d_{all} / A_f = 4.044	[in^{-1}]
r_T = 1.789	[in]		r_{yt} = 1.954	[in]
I_t = 13.32	[in^4]			
S_t = 3.93	[in^3]		Z_t = 5.90	[in^3]

W section yield strength	F_{wy} = 50.0	[ksi]	= 345	[MPa]
C section yield strength	F_{cy} = 50.0	[ksi]	= 345	[MPa]
Runway beam unbraced length	L_b = 95.08	[in]		

Design Forces

Bending moment x-x axis	M_x = 25.60	[kip-ft]
Bending moment y-y axis	M_y = 1.68	[kip-ft]
Shear along y-y axis	V_x = 18.81	[kips]

Conclusion

Overall	ratio = **0.32**	OK
Local buckling		OK
Bending about X-X Axis	ratio = 0.19	OK
Bending about Y-Y Axis on Top Flange	ratio = 0.14	OK
Biaxial Bending on Top Flange	ratio = 0.32	OK
Shear along Y-Y Axis	ratio = 0.22	OK
Web Sidesway Buckling	ratio = 0.00	OK
Runway Beam Vertical Deflection	ratio = 0.12	OK
Runway Beam Lateral Deflection	ratio = 0.19	OK

				Code Reference
Design Basis & Assumption				*AISC Design Guide 7*

1. The channel and W section top flange resist the hor. load and the combined section resists the ver. load. This assumption eliminates the need for an analysis of torsional effects on the combined section and simplifies the analysis. (18.1 on page 56)
2. If A36 channel cap is used on A992 W section then lateral torsional buckling and weak axis flexure strength must be calculated based on A36 yield stress. (18.1.4 on page 57)

Check Local Buckling

Flange of W shape				*ASD 9th Edition*
Compact limit	λ_p = 65 / sqrt (F_{wy})		= 9.19	Table B5.1
Noncompact limit	λ_r = 95 / sqrt (F_{wy})		= 13.43	
	$b_f / 2t_f$ = 6.57		Compact	
Web of W shape				
Compact limit	λ_p = 640 / sqrt (F_{wy})		= 90.49	Table B5.1
Noncompact limit	λ_r = 760 / sqrt ($0.66F_{wy}$)		= 132.27	
	d / t_w = 45.48	h / t_w =	39.58	
			Compact	
W shape classification			**Compact**	
Flange of Channel	This part is NOT applicable			
Compact limit	λ_p = 65 / sqrt (F_{cy})		= 0.00	Table B5.1
Noncompact limit	λ_r = 95 / sqrt (F_{cy})		= 0.00	
	b_f / t_f = 0.00		NA	
Web of Channel				
Compact limit	λ_p = 640 / sqrt (F_{cy})		= 0.00	Table B5.1
Noncompact limit	λ_r = 760 / sqrt ($0.66F_{cy}$)		= 0.00	
	d / t_w = 0.00	h / t_w =	0.00	
			NA	
Channel shape classification			**NA**	
Combined section classification	**Compact**			**OK**

Check Bending about X-X Axis

Tension

Allowable tension stress	$F_{bx\,t}$ = 0.6 x F_{wy}	= **30.02**	[ksi]	
Actual tension stress	$f_{bx\,t}$ = M_x / S_1	= 5.63	[ksi]	
	ratio = $f_{bx\,t} / F_{bx\,t}$	= **0.19**		**OK**

Compression

Comb sect top flange yield stress	F_y = 50.0	[ksi]	see assumption 2
Comb sect top flange width	b_f = 6.8	[in]	use channel depth if capped with channel

				Code Reference
				ASD 9th Edition
Critical length	$L_c = \min\left(\frac{76 x b_f}{\sqrt{F_y}}, \frac{2x10^4}{(d_{all} / A_f) x F_y}\right)$	= 72.75	[in]	Eq F1-2
	76 b_f / sqrt(F_y) =	= 72.75	[in]	
When L_b <= L_c	This part is NOT applicable			
For compact sect	Not Applicable			
	$F_{bx} = 0.66 \times F_y$	= 0.00	[ksi]	Eq F1-1
For non-compact sect	Not Applicable			
	$b_f / 2t_f$ = Comb Sect max(W $b_f / 2t_f$, C b_f / t_f)	= 6.57		
	W Sect $b_f / 2t_f$			
	$F_{bx} = \left(0.79 - 0.002 \frac{b_f}{2t_f} \sqrt{F_y}\right) F_y$	= 0.00	[ksi]	Eq F1-3
	$F_{bx} = 0.6 \times F_y$	= 0.00	[ksi]	Eq F1-5
When L_b > L_c	This part is applicable			
	L_b / r_T =	= 53.14		
Bending coefficient	C_b = 1.0 to be conservative			
	$x = \sqrt{\frac{510 x 10^3 x C_b}{F_y}}$	= 100.97		
For (L_b / r_T) <= x	Applicable			
	$F_{bx} = \left(\frac{2}{3} - \frac{F_y (L_b / r_T)^2}{1530 x 10^3 C_b}\right) F_y \le 0.6 F_y$	= 28.73	[ksi]	Eq F1-6
For (L_b / r_T) > x	Not Applicable			
	$F_{bx} = \frac{170 x 10^3 C_b}{(L_b / r_T)^2} \le 0.6 F_y$	= 0.00	[ksi]	Eq F1-7
For any value of (L_b / r_T)	Applicable			
	$F_{bx} = \frac{12 x 10^3 C_b}{L_b x (d_{all} / A_f)} \le 0.6 F_y$	= 30.02	[ksi]	Eq F1-8
Allowable compression stress	$F_{bx\,c}$ =	= **30.02**	[ksi]	
Actual compression stress	$f_{bx\,c} = M_x / S_2$	= 5.63	[ksi]	
	ratio = $f_{bx\,c} / F_{bx\,c}$	= **0.19**	**OK**	

Check Bending about Y-Y Axis on Top Flange

For compact top flange	Applicable			
	$F_{by} = 0.75 \times F_y$	= 37.52	[ksi]	Eq F2-1

				Code Reference
For non-compact top flange	Not Applicable			*ASD 9th Edition*
	F_{by} = 0.60 x F_y	= 0.00	[ksi]	Eq F2-2
Allowable compression stress	$F_{by\ c}$ =	= **37.52**	[ksi]	
Actual compression stress	$f_{by\ c}$ = M_y / S_t	= 5.13	[ksi]	
	ratio = $f_{bx\ c} / F_{bx\ c}$	= **0.14**	**OK**	

Check Biaxial Bending on Top Flange

Combined bending stress	$f_{bx} / F_{bx} + f_{by} / F_{by}$	= **0.32**	**OK**	Eq H1-3

Check Shear along Y-Y Axis

Clear dist between trans. stiffeners	a = L_b	= 95.08	[in]	
W sect clear dist between flange	h = 12.270 [in]	a / h = 7.75		

k_v = 4.00 + 5.34 / (a / h)^2 if a / h <=1 = 5.41 F4

5.34 + 4.00 / (a / h)^2 if a / h >1

h / t_w = 39.58 C_v = 1.58

For h / t_w <= 380 / sqrt (F_y)	Applicable			
	F_v = 0.40 x F_y	= 20.01	[ksi]	Eq F4-1
For h / t_w > 380 / sqrt (F_y)	Not Applicable			
	F_v = (F_y x C_v) / 2.89 <=0.4 F_y	= 0.00	[ksi]	Eq F4-2
Allowable shear stress	F_v =	= **20.01**	[ksi]	
Actual shear stress	f_v = V_x / S_t	= 4.30	[ksi]	
	ratio = f_v / F_v	= **0.22**	**OK**	

Check Web Sidesway Buckling *AISC Design Guide 7*

Use LRFD 13 instead of ASD 9 to increase web sidesway buckling resistance when flexural stress in the web is less than 0.66F_y page 61

(h / t_w) / (L_b / b_f) = 2.82 >1.7 *AISC LRFD 13*

Max actual bending stress f_b = 10.76 [ksi]

When f_b < (F_y / 1.5) = 0.66 F_y	Applicable	C_r = 9.6E+05	[ksi]
When f_b >= (F_y / 1.5) = 0.66 F_y	Not Applicable	C_r = 0.0E+00	[ksi]

$$R_n = \frac{C_r t_w^3 t_f}{h^2}\left[0.4\left(\frac{h / t_w}{L_b / b_f}\right)^3\right] = \text{NA} \quad \text{[kips]} \quad \text{Eq J10-7}$$

R_a = $R_n / \Omega = R_n / 1.76$	= NA	[kips]	
$P_{v\text{-}impt}$ = P_v x α (impact factor)	= 13.63	[kips]	
ratio = $P_{v\text{-}impt} / R_a$	= **0.00**	**OK**	

Check Runway Beam Deflection **Code Reference**

Crane serviceability criteria based on

CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition — Table 4.1 item 14,15

AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition — page 56

CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes — Cl 1.4.3

CMAA crane service class Class C Moderate service

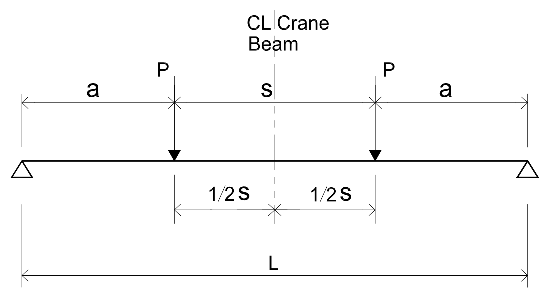
Ver deflection limit (no impact , max wheel load) B_v = L / 600

Hor deflection limit (no impact , 10% max wheel load) B_h = L / 400

Runway beam span L = 95.08 [in]

Bridge wheel spacing s = 60.00 [in]

a = 17.54 [in]



Max Deflection Case

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 0.65 P / I

Vertical Deflection

Unfactored max ver. wheel load P = 10.9 [kips / per wheel] impact factor NOT included

I_x = 385.0 [in^4]

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 0.018 [in]

Allowable deflection $\Delta_a = L / B_v$ = 0.158 [in]

ratio = Δ_{max} / Δ_a = **0.12** **OK**

Lateral Deflection

Unfactored max hor. wheel load P = 0.9 [kips / per wheel]

I_t = 13.3 [in^4]

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 0.044 [in]

Allowable deflection $\Delta_a = L / B_h$ = 0.238 [in]

ratio = Δ_{max} / Δ_a = **0.19** **OK**

CRANE RUNWAY BEAM DESIGN - LRFD 13

Crane runway design based on	**Code Abbreviation**
AISC 360-05 Specification for Structural Steel Buildings	*AISC LRFD 13*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*

Crane runway beam section W360x57 W14x38

Section Properties

Combined Section Overall

A	= 11.200	[in^2]	d_{all}	= 14.100	[in]
top y_c	= 7.050	[in]	bott. y_t	= 7.050	[in]
I_x	= 385.0	[in^4]	I_y	= 26.70	[in^4]
top S_{xc}	= 54.60	[in^3]	bott. S_{xt}	= 54.60	[in^3]
S_y	= 7.88	[in^3]			
Z_x	= 61.50	[in^3]	Z_y	= 12.10	[in^3]
r_x	= 5.870	[in]	r_y	= 1.550	[in]
J	= 0.80	[in^4]	C_w	= 1230	[in^6]

W Section

d	= 14.100	[in]	b_f	= 6.770	[in]
t_w	= 0.310	[in]	t_f	= 0.515	[in]
h	= 12.270	[in]	$h_c = 2(y_c - k)$	= 12.270	[in]
$h_0 = d - t_f$	= 13.585	[in]			

Top Flange

A_f	= 3.487	[in^2]	d_{all} / A_f	= 4.044	[in^{-1}]
r_t	= 1.789	[in]	r_{yt}	= 1.954	[in]
I_t	= 13.32	[in^4]			
S_t	= 3.93	[in^3]	Z_t	= 5.90	[in^3]

W section yield strength	F_{wy}	= 50.0	[ksi]	= 345	[MPa]
C section yield strength	F_{cy}	= 50.0	[ksi]	= 345	[MPa]
Runway beam unbraced length	L_b	= 95.08	[in]		

Design Forces

Bending moment x-x axis	M_x	= 39.50	[kip-ft]
Bending moment y-y axis	M_y	= 2.69	[kip-ft]
Shear along y-y axis	V_y	= 29.05	[kips]

Conclusion

Overall	ratio = **0.31**	OK
Local buckling		OK
Biaxial Bending on Top Flange	ratio = 0.31	OK
Shear along Y-Y Axis	ratio = 0.25	OK
Web Sidesway Buckling	ratio = 0.00	OK
Runway Beam Vertical Deflection	ratio = 0.12	OK
Runway Beam Lateral Deflection	ratio = 0.19	OK

Code Reference

Design Basis & Assumption — *AISC Design Guide 7*

1. The channel and W section top flange resist the hor. load and the combined section resists the ver. load. This assumption eliminates the need for an analysis of torsional effects on the combined section and simplifies the analysis. — 18.1 on page 56
2. If A36 channel cap is used on A992 W section then lateral torsional buckling and weak axis flexure strength must be calculated based on A36 yield stress. — 18.1.4 on page 57

Check Local Buckling

Flange of W shape				*AISC LRFD 13*
Compact limit	λ_p = 0.38 sqrt (E / F_{wy})	= 9.15		Table B4.1 Case 1
Noncompact limit	λ_r = 1.0 sqrt (E / F_{wy})	= 24.08		
	$b_f / 2t_f$ = 6.57	Compact		
Web of W shape				
Compact limit	λ_p = 3.76 sqrt (E / F_{wy})	= 90.53		Table B4.1 Case 9
Noncompact limit	λ_r = 5.7 sqrt (E / F_{wy})	= 137.24		
	h / t_w = 39.58	Compact		
W shape classification		**Compact**		
Flange of Channel	This part is NOT applicable			
Compact limit	λ_p = 0.38 sqrt (E / F_{cy})	= 9.15		Table B4.1 Case 1
Noncompact limit	λ_r = 1.0 sqrt (E / F_{cy})	= 24.08		
	b_f / t_f = 0.00	NA		
Web of Channel (flange cover plate between lines of welds)				
Compact limit	λ_p = 1.12 sqrt (E / F_{cy})	= 26.97		Table B4.1 Case 12
Noncompact limit	λ_r = 1.4 sqrt (E / F_{cy})	= 33.71		
	b_f (W shape) / t_w (C channel) = 0.00	NA		
Channel shape classification		**NA**		
Combined section classification	**Compact**	ratio = **0.00**	**OK**	

Check Bending about X-X Axis

Calculate R_{pc}

	λ_{pw} = 90.53	λ_{rw} = 137.24		
	M_{yc} = $S_{xc} F_y$	= 227.6	[kip-ft]	
	M_p = min ($Z_x F_y$, 1.6 $S_{xc} F_y$)	= 256.4	[kip-ft]	
	λ = h_c / t_w	= 39.58		
	M_p / M_{yc} =	= 1.13		
For $\lambda <= \lambda_{pw}$	Applicable			
	R_{pc} = M_p / M_{yc}	= 1.13		Eq F4-9a

				Code Reference
For $\lambda > \lambda_{pw}$	Not Applicable			*AISC LRFD 13*
	$R_{pc} = \left[\frac{M_p}{M_{yc}} - \left(\frac{M_p}{M_{yc}} - 1\right)\left(\frac{\lambda - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}}\right)\right] \le \frac{M_p}{M_{yc}}$	= 0.00		Eq F4-9b
R_{pc} used for design	R_{pc} =	= **1.13**		
<u>Calculate R_{pt}</u>				
	$M_{yt} = S_{xt} F_y$	= 227.6	[kip-ft]	
	$M_p = \min(Z_x F_y, 1.6 S_{xt} F_y)$	= 256.4	[kip-ft]	
	M_p / M_{yt} =	= 1.13		
For $\lambda <= \lambda_{pw}$	Applicable			
	$R_{pt} = M_p / M_{yc}$	= 1.13		Eq F4-15a
For $\lambda > \lambda_{pw}$	Not Applicable			
	$R_{pt} = \left[\frac{M_p}{M_{yt}} - \left(\frac{M_p}{M_{yt}} - 1\right)\left(\frac{\lambda - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}}\right)\right] \le \frac{M_p}{M_{yt}}$	= 0.00		Eq F4-15b
R_{pt} used for design	R_{pt} =	= **1.13**		
<u>Calculate F_L</u>				
	S_{xt} / S_{xc} = 1.00			
For $S_{xt} / S_{xc} >= 0.7$	Applicable			
	$F_L = 0.7 F_y$	= 35.0	[ksi]	Eq F4-6a
For $S_{xt} / S_{xc} < 0.7$	Not Applicable			
	$F_L = \max(F_y \times (S_{xt} / S_{xc}), 0.5F_y)$	= 0.0	[ksi]	Eq F4-6b
F_L used for design	F_L =	= **35.0**	[ksi]	
<u>M_n - Compression Flange Yielding</u>				
	$M_{n1} = R_{pc} F_y S_{xc}$	= **256.4**	[kip-ft]	Eq F4-1
<u>M_n - Lateral Torsional Buckling</u>				
Runway beam unbraced length	L_b =	= 95.08	[in]	
Calculate L_p & L_r				
	$L_p = 1.1\, r_t \sqrt{\frac{E}{F_y}}$	= 65.7	[in]	Eq F4-7
	$L_r = 1.95\, r_t \frac{E}{F_L} \sqrt{\frac{J}{S_{xc} h_o}} \sqrt{1 + \sqrt{1 + 6.76 \left(\frac{F_L}{E}\frac{S_{xc} h_o}{J}\right)^2}}$			Eq F4-8
		= 191.5	[in]	

Code Reference

For $L_b <= L_p$ Not Applicable *AISC LRFD 13*

M_{n2} = = NA [kip-ft]

For $L_p < L_b <= L_r$ Applicable

C_b = 1.0 to be conservative

$$M_{n2} = C_b\left[R_{pc}M_{yc} - \left(R_{pc}M_{yc} - F_L S_{xc}\right)\left(\frac{L_b - L_p}{L_r - L_p}\right)\right] \le R_{pc}M_{yc}$$ Eq F4-2

= 233.7 [kip-ft]

For $L_b > L_r$ Not Applicable

For $I_t / I_y <= 0.23$ J = 0 Not Applicable

J = 0.80 [in^4]

$$F_{cr} = \frac{C_b \pi^2 E}{\left(\frac{L_b}{r_t}\right)^2}\sqrt{1 + 0.078\frac{J}{S_{xc}h_o}\left(\frac{L_b}{r_t}\right)^2}$$ = 0.0 [ksi] Eq F4-5

$M_{n2} = F_{cr} S_{xc} <= R_{pc} F_y S_{xc}$ = NA [kip-ft] Eq F4-3

M_n - LTB M_{n2} = = **233.7** [kip-ft]

<u>M_n - Compression Flange Local Buckling</u>

λ = 6.57

λ_{pf} = 9.15 λ_{rf} = 24.08

For $\lambda <= \lambda_{pf}$ Applicable

M_{n3} = = NA [kip-ft]

For $\lambda_{pf} < \lambda <= \lambda_{rf}$ Not Applicable

$$M_{n3} = \left[R_{pc}M_{yc} - \left(R_{pc}M_{yc} - F_L S_{xc}\right)\left(\frac{\lambda - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}\right)\right]$$ = NA [kip-ft] Eq F4-12

M_{n3} = = **NA** [kip-ft]

<u>M_n - Tension Flange Yielding</u>

$M_{n4} = R_{pt} F_y S_{xt}$ = **256.4** [kip-ft] Eq F4-14

M_{nx} = min(M_{n1} , M_{n2} , M_{n3} , M_{n4}) = **233.7** [kip-ft]

Check Bending about Y-Y Axis					**Code Reference**
Check top flange compactness, for W check W flange only, for W+Cap Channel check both W and Channel flange					
Top flange compactness		= Compact			*AISC LRFD 13*
For compact top flange	M_{ny}	= $F_y Z_t$	= 24.6	[kip-ft]	Eq F6-1
For noncompact top flange	M_{ny}	= $F_y S_t$	= 16.4	[kip-ft]	
	M_{ny}	=	= **24.6**	[kip-ft]	
Check Biaxial Bending on Top Flange					
Combined bending		$M_x / (\Phi M_{nx}) + M_y / (\Phi M_{ny})$	= **0.31**	**OK**	Eq H1-1b
Check Shear along Y-Y Axis					
Clear dist between trans. stiffeners	a	= L_b	= 95.08	[in]	
W sect clear dist between flange	h	= 12.270 [in]	a / h = 7.75		
	h / t_w	= 39.58			
	k_v	= 5 if $h / t_w < 260$	= 5.00		G2.1 (b)
		5 if $a / h > 3.0$ or $a / h > [260/(h / t_w)]^2$			
		$5 + 5 / (a / h)^2$			
	T	= $\text{sqrt}(k_v E / F_y)$	= 53.8		
For $h / t_w <= 1.10$ T		Applicable			
	C_v	=	1.0		Eq G2-3
For $1.10 T < h / t_w <= 1.37$ T		Not Applicable			
	C_v	= $1.10 \times \text{sqrt}(k_v E / F_y) / (h / t_w)$	= NA		Eq G2-4
For $h / t_w > 1.37$ T		Not Applicable			
	C_v	= $1.51 E k_v / [(h / t_w)^2 F_y]$	= NA		Eq G2-5
C_v used for design	C_v	=	= 1.0		
	ΦV_n	= $0.9 \times 0.6 F_y (d t_w) C_v$	= **118.1**	[kips]	Eq G2-1
	ratio	= $V_y / \Phi V_n$	= **0.25**	**OK**	

Check Web Sidesway Buckling **Code Reference**

AISC LRFD 13

$(h / t_w) / (L_b / b_f)$ = 2.82 >1.7

When $M_u < M_y$ Applicable C_r = 9.6E+05 [ksi]

When $M_u >= M_y$ Not Applicable C_r = 0.0E+00 [ksi]

$$R_n = \frac{C_r\, t_w^3\, t_f}{h^2}\left[0.4\left(\frac{h\ /\ t_w}{L_b\ /\ b_f}\right)^3\right]$$ = NA [kips] Eq J10-7

Φ = = 0.85

$P_{v\text{-}impt}$ = P_v x α (impact factor) = 21.08 [kips]

ratio = $P_{v\text{-}impt} / \Phi R_n$ = **0.00** **OK**

Check Runway Beam Deflection

Crane serviceability criteria based on

CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition Table 4.1 item 14,15

AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition page 56

CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes Cl 1.4.3

CMAA crane service class Class C Moderate service

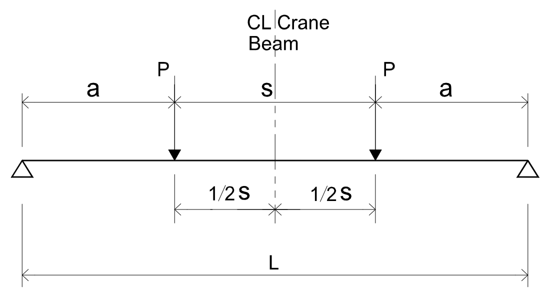
Ver deflection limit (no impact , max wheel load) B_v = L / 600

Hor deflection limit (no impact , 10% max wheel load) B_h = L / 400

Runway beam span L = 95.08 [in]

Bridge wheel spacing s = 60.00 [in]

a = 17.54 [in]



Max Deflection Case

Max deflection at center $\Delta_{max} = \frac{Pa\,(3L^2 - 4a^2)}{24\ E\ I}$ = 0.65 P / I

Vertical Deflection

Unfactored max ver. wheel load P = 10.9 [kips / per wheel] impact factor NOT included

I_x = 385.0 [in^4]

Max deflection at center $\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$ = 0.018 [in]

Code Reference

Allowable deflection	$\Delta_a = L / B_v$	= 0.158	[in]	
	ratio = Δ_{max} / Δ_a	= **0.12**	**OK**	

Lateral Deflection

Unfactored max hor. wheel load	P = 0.9	[kips / per wheel]		
	I_t = 13.3	[in^4]		
Max deflection at center	$\Delta_{max} = \frac{Pa(3L^2 - 4a^2)}{24\ E\ I}$	= 0.044	[in]	
Allowable deflection	$\Delta_a = L / B_h$	= 0.238	[in]	
	ratio = Δ_{max} / Δ_a	= **0.19**	**OK**	

Example 05: Underhung 7.5 Ton Crane + Runway S Shape – Metric Unit

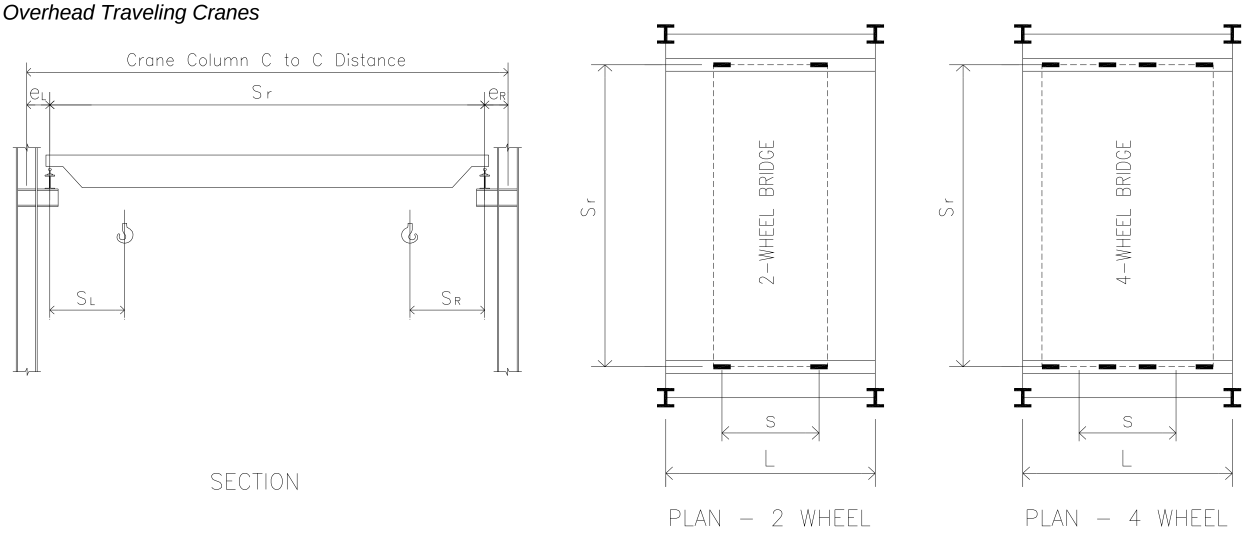
In this example all data are the same as Example 04 except the runway size changing from W360x57 to S310X60.7
This example shows the advantage of using S shape over W shape as underhung crane runway beam due to the bottom flange local bending check requirement.

Crane Data	**Imperial**	**Metric**
Crane capacity	8.3 US Tons =16.6 kips	7.5 Metric Tons = 73.5 kN
Bridge weight	5.8 kips	2630 kg
Trolley + hoist weight	1.6 kips	725 kg
Max static wheel load	10.9 kips	48.5 kN
Bridge span S_r	19.7 ft	6.000 m
Left min. hook approach S_L	1.5 ft	0.456 m
Right min. hook approach S_R	1.0 ft	0.299 m
Bridge wheel spacing s	5.0 ft	1.524 m
Crane runway beam span L	7.9 ft	2.415 m
Left runway CL to column CL dist e_L	0.0 ft	0.000 m
Right runway CL to column CL dist e_R	0.0 ft	0.000 m
Crane rail size	No Rail	No Rail
CMAA crane service class	Class C	Class C
Vertical impact factor	25%	25%
Crane type	Underhung	Underhung
Crane runway beam size	S12x40.8	S310x60.7
W shape F_y	36 ksi	248 MPa
Plate cap F_y	NA	NA

BRIDGE CRANE LOAD CALCULATION

Bridge crane load calc based on

	Code Abbreviation
CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition	*CISC Crane Guide*
AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition	*AISC Design Guide 7*
CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes	*CMAA 70-04*



Crane Data

				suggested value		
Crane rated capacity	W_{rc} =	7.5	[Metric Ton]		= 73.5	[kN]
Bridge weight	W_{br} =	2630	[kg]	1454	= 25.8	[kN]
Trolley + hoist weight	W_{th} =	725	[kg]	1500	= 7.1	[kN]
Bridge wheel spacing	s =	1.524	[m]	2.20		
Max. static wheel load by vendor	P_{max-v} =	48.5	[kN]	input 0 if vendor data is unknown		
Crane bridge span	S_r =	6.000	[m]	5.1		
Min. hook approach-left	S_L =	0.456	[m]	0.95		
Min. hook approach-right	S_R =	0.299	[m]	0.95		
Crane runway beam span	L =	2.415	[m]			
Runway CL to col CL dist-left	e_L =	0.000	[m]	0.45		
Runway CL to col CL dist-right	e_R =	0.000	[m]	0.45		
Crane column C to C distance	$S_r + 2e$ =	6.000	[m]		suggested section	
Runway beam type	=	S_Shape		?		
Runway beam size	=	S310X60.7			size <= W530x92 C310x31	
Top flange cap plate size	width b_p			thick t_p	not applicable	
	suggest	ASCE 60		U_{rb} =	0.61	[kN/m]
Crane rail size	=	No Rail		U_{cr} =	0	[lbs/yd]
				=	0.00	[kN/m]
Rail base width	B_w =	0	[mm]	Rail height H_t =	0	[mm]
W section yield strength	f_{wy} =	248	[MPa]		= 36.0	[ksi]
Cap channel or plate yield strength	f_{cy} =	248	[MPa]		= 36.0	[ksi]
CMAA crane service class	=	Class C	?		Moderate service	
Crane type	=	Underhung		?		

Code Reference

CISC Crane Guide

Vertical load impact factor	= 0.25 ?		Table 2.1
Crane side thrust load option	= Option 1 ?		Table 2.1

Crane side thrust load can be calculated using one of the following 3 options

Option 1	H_s =	0.2 (Lifted Load+ Trolley/Hoist Wt)
Option 2	H_s = max of	0.2 (Lifted Load+ Trolley/Hoist Wt)
		0.1 (Lifted Load+ Entire Crane Wt)
Option 3	H_s = max of	0.2 (Lifted Load+ Trolley/Hoist Wt)
		0.1 (Lifted Load+ Entire Crane Wt)
		0.4 Lifted Load

Conclusion

Runway Beam Design Using ASD 89

Overall	ratio = **0.56**	OK
Local buckling		OK
Bending about X-X Axis	ratio = 0.32	OK
Bending about Y-Y Axis on Top Flange	ratio = 0.25	OK
Biaxial Bending on Top Flange	ratio = 0.56	OK
Shear along Y-Y Axis	ratio = 0.24	OK
Web Sidesway Buckling	ratio = 0.06	OK
Runway Beam Vertical Deflection	ratio = 0.17	OK
Runway Beam Lateral Deflection	ratio = 0.31	OK

Runway Beam Design Using LRFD 05

Overall	ratio = **0.52**	OK
Local buckling		OK
Biaxial Bending on Top Flange	ratio = 0.52	OK
Shear along Y-Y Axis	ratio = 0.27	OK
Web Sidesway Buckling	ratio = 0.06	OK
Runway Beam Vertical Deflection	ratio = 0.17	OK
Runway Beam Lateral Deflection	ratio = 0.31	OK

Runway Beam Bottom Flange Local Bending	ratio = **0.43**	OK

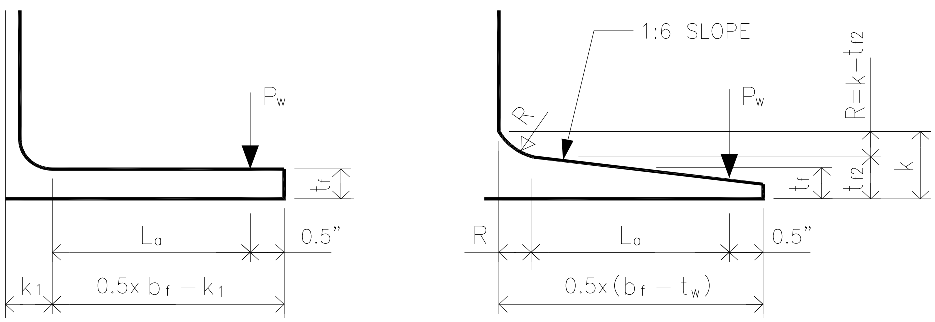
Bottom Flange Local Bending This section is applicable for underhung crane

Crane runway beam section S310X60.7 S12X40.8

Section Properties

d =	12.000	[in]	b_f =	5.250	[in]
t_w =	0.462	[in]	t_f =	0.659	[in]
k =	1.438	[in]	k_1 =	0.000	[in]

W section yield strength f_{wy} = 36.0 [ksi]



W Shape S Shape

Effective Cantilever Length

Assume wheel width = 1" and point load P_w acting at 0.5" offset from flange tip

For W shape	$L_a = b_f/2 - k_1 - 0.5''$	= 0.000	[in]
For S shape			
Flange thickness at toe	$t_{f2} = t_f + \frac{0.5(b_f - t_w)}{2} \times \frac{1}{6}$	= 0.859	[in]
Radius of fillet	$R = k - t_{f2}$	= 0.579	[in]
	$L_a = 0.5 \times (b_f - t_w) - R - 0.5''$	= **1.315**	[in]

Effective Bottom Flange Bending Width

Effective flange bending width	$b_e = 12 \times t_f$	= 7.908	[in]

Falnge Thickness at Web Toe

For W shape	$t = t_f$	= 0.000	[in]
For S shape	$t = t_{f2}$	= **0.859**	[in]
Wheel load one side of flange	$P_w = P_{max} / 2 \times \alpha$ (impact factor)	= 6.8	[kips]
Factored bending moment	$M_f = 1.5 \times P_w \times L_a$	= 1.12	[kip-ft]
	$S = b_e \times t^2 / 6$	= 0.971	[in^3]
	$M_r = 0.9 \times S \times F_y$	= 2.62	[kip-ft]
	ratio = M_f / M_r	= **0.43**	**OK**

4.0 REFERENCES

1. AISC Design Guide 7: Industrial Buildings-Roofs to Anchor Rods 2nd Edition
2. AISC SteelTool Excel Spreadsheet Crane Beam v1.1 created by James M. Fisher
3. CISC Guide for the Design of Crane-Supporting Steel Structures 2nd Edition
4. CMAA 70-04 Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes
5. AISC Manual of Steel Construction Allowable Stress Design 9th Edition
6. AISC Steel Construction Manual 13th Edition