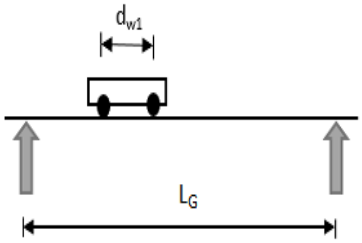
1.0 INPUT

Gantry Girder Span	L_G	=	**7500** mm

1.1 Section Shape

Type	Type	=	**Rolled I Section + Plate**
I Section	I	=	**UB 610x305x179**



1.1.1 Top Plate

Width of Plate	b_p	=	**350** mm
Thickness of Plate	t_p	=	**30** mm

1.2 Wheel Arrangement

No of Wheels Per End Carriage	N_w	=	**2**
Distance of End Carriage Wheel Centers	d_{w1}	=	**4000** mm
Crane Rail Height	h_r	=	**100** mm

1.3 Restraints

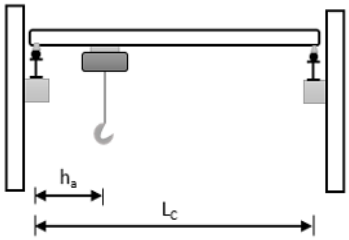
Destabilizing		=	**Yes**
Restraint Condition		=	**Compression Flange Laterally Restrained**
		=	**Both Flanges Fully Restrained**
Span Type		=	**Interior Span**

1.4 Loads (Unfactored)

User Defined Wheel Load		=	**Yes**
Static Wheel Load	W_{stat}	=	**100** kN
Transverse Surge Load Per Wheel	W_{su}	=	**10** %
Dynamic Wheel Load Factor	W_{dy}	=	**1.5**
Unfactored Weight of Crane Rail	W_r	=	**0.5** kN/m

1.5 Weld

Type		=	**Continuous**
Weld Length	S	=	**5** mm



1.6 Deflection

Vertical Deflection Limit	δ_{av}	=	**600**
Horizontal Deflection Limit	δ_{ah}	=	**500**

1.7 Properties

Modulus of Elasticity	E	=	**205000** N/mm^2
Class of Crane	C_c	=	**Q3**
Steel Grade	f_y	=	**460** N/mm^2

2.1 Effective Length

Restraint Condition Factor	L_E	= **0.85**	
Effective Length of Gantry Girder	L_g	= L_E * L_G = **6.38** m	*Table 13*

2.2 Section Properties

2.2.1 I Section [From Section Table]

Section Mass	$Mass_{bm}$	= **179** kg/m
Cross Sectional Area	A_{bm}	= **228** cm^2
Overall Depth of Section	D_{bm}	= **620.2** mm
Breadth of Section	B_{bm}	= **307.1** mm
Web Thickness	t_{bm}	= **14.1** mm
Flange Thickness	T_{bm}	= **23.6** mm
Root Radius	r_{bm}	= **16.5** mm
Depth of Web	d_{bm}	= **540** mm
End Clearance	C_{bm}	= **9.05** mm
Moment of Inertia - Major	I_{xxbm}	= **153000** cm^4
Moment of Inertia - Minor	I_{yybm}	= **11400** cm^4
Radius of Gyration - Major	r_{xxbm}	= **25.9** cm
Radius of Gyration - Minor	r_{yybm}	= **7.07** cm
Elastic Section Modulus - Major	Z_{xxbm}	= **4930** cm^3
Elastic Section Modulus - Minor	Z_{yybm}	= **743** cm^3
Plastic Section Modulus - Major	S_{xxbm}	= **5550** cm^3
Plastic Section Modulus - Minor	S_{yybm}	= **1140** cm^3
Warping Constant	H_{bm}	= **10.2** dm^6
Buckling Parameter	u_{bm}	= **0.886**
Torsional Index	x_{bm}	= **27.7**
Torsion Constant	J_{bm}	= **340** cm^4

2.2.2 Plate

Area of Plate	A_{pl}	= b_p * t_p = **105** cm^2
Mass of Plate	$Mass_{pl}$	= b_p * t_p * 7850 = **82.4** kg/m
Moment of Inertia - Major	I_{xxpl}	= t_p * b_p^3 / 12 = **10718.8** cm^4
Moment of Inertia - Minor	I_{yypl}	= b_p * t_p^3 / 12 = **78.8** cm^4
Torsion Constant	J_{pl}	= b_p * t_p^3 / 3 = **315** cm^4

2.2.3 Elastic Section Properties (I + Plate)

Position of Neutral Axis Above Bottom Flange	y_{nap}	= ((A_{bm} * D_{bm} / 2) + (A_{pl} * (D_{bm} + 0.5) * t_p)) / (A_{bm} + A_{pl}) = **412.6** mm
Moment of Inertia About Major Axis	I_{xxp}	= I_{xxbm} + (A_{bm} * (y_{nap} - (D_{bm} / 2))^2) + I_{yypl} + (A_{pl} * (D_{bm} + 0.5* t_p - y_{nap})^2) = **229061.3** cm^4
Moment of Inertia About Minor Axis	I_{yyp}	= I_{yybm} + I_{xxpl} = **22118.8** cm^4
Elastic Modulus About Major Axis (Top)	Z_{xxtopp}	= I_{xxp} / (D_{bm} + t_p - y_{nap}) = **9641** cm^3
Elastic Modulus About Major Axis (Bottom)	Z_{xxbtmp}	= I_{xxp} / y_{nap} = **5551.5** cm^3
Elastic Modulus About Minor Axis	Z_{yyp}	= I_{yyp} / (b_p / 2) = **1263.9** cm3
Radius of Gyration	r_{yp}	= (I_{yyp} / (A_{bm} + A_{pl}))$^{0.5}$ = **81.5** mm

Area of Beam Flange	A_{flp}	=	$T_{bm} * B_{bm}$ = **7247.6** mm^2
Position of Equal Area Axis (E.A.A)	y_{eap}	=	$T_{bm} + (((A_{bm} + A_{pl}) / 2) - A_{flp}) / t_{bm}$ = **600.9** mm

2.2.4 Plastic Section Properties (I + Plate)

Plate Component Above E.A.A	S_{xupl}	=	$A_{pl} * (D_{bm} + t_p * 0.5 - y_{eap})$ = **360.1** cm^3
Plate Component Below E.A.A	S_{xlpl}	=	**0** cm^3
Top Flange Component Above E.A.A	S_{xutfl}	=	$B_{bm} * (D_{bm} - y_{eap})^2 / 2$ = **57.1** cm^3
Top Flange Component Below E.A.A	S_{xltfl}	=	$B_{bm} * (y_{eap} - (D_{bm} - T_{bm}))^2 / 2$ = **2.9** cm^3
Beam Web Component Above E.A.A	S_{xuweb}	=	**0** cm^3
Beam Web Component Below E.A.A	S_{xlweb}	=	$t_{bm} * (D_{bm} - (2 * T_{bm})) * (y_{eap} - T_{bm} - (D_{bm} - 2 * T_{bm}) / 2)$ = **2349.5** cm^3
Beam Bottom Flange Component	S_{xbfl}	=	$A_{flp} * (y_{eap} - 0.5 * T_{bm})$ = **4269.6** cm^3
Plastic Section Modulus About Major Axis	S_{xp}	=	$S_{xupl} + S_{xlpl} + S_{xutfl} + S_{xltfl} + S_{xuweb} + S_{xlweb} + S_{xbfl}$ = **7039.2** cm^3

2.2.5 Torsional Index (I + Plate)

Annex. B.2.4.1

Combined Torsional Constant	J_p	=	$J_{bm} + J_{pl}$ = **655** cm^4
Position of Top Shear Center from Top Section	S_{ctp}	=	$((A_{pl} * 0.5 * t_p) + (A_{flp} * (t_p + 0.5 * T_{bm}))) / (A_{pl} + A_{flp})$ = **25.9** mm
Distance Between Flange Shear Centers	h_{sp}	=	$D_{bm} + t_p - 0.5 * T_{bm} - S_{ctp}$ = **612.5** mm
Torsional Index	x_p	=	$0.566 * h_{sp} * ((A_{bm} + A_{pl}) / J_p)^{0.5}$ = **24.7**
Buckling Parameter	u	=	$((4 * S_{xp}^2 * (1 - (I_{yyp} / I_{xxp}))) / ((A_{bm} + A_{pl})^2 * h_{sp}^2))^{0.25}$ = **0.8**

Annex. B.2.3

2.2.6 Flange Ratio / Mono Symmetry Index

Cl. 4.3.6.7

Inertia of Top Flange (Major)	I_{tfp}	=	$I_{xxpl} + (T_{bm} * B_{bm}^3 / 12)$ = **16414.8** cm^4
Inertia of Top Flange (Minor)	I_{bfp}	=	$T_{bm} * B_{bm}^3 / 12$ = **5696** cm^4
Flange Ratio	η_{sagp}	=	$I_{tfp} / (I_{tfp} + I_{bfp})$ = **0.742**
Mono Symmetry Index	ψ_{sagp}	=	$0.8 * ((2 * \eta_{sagp}) - 1)$ = **0.388**

2.2.7 Top Flange Properties (Top Flange of I Section + Plate)

Elastic Modulus	Z_{tfp}	=	$I_{tfp} / (b_p / 2)$ = **938** cm^3
Plastic Modulus	S_{tfp}	=	$t_p * b_p^2 / 4 + (T_{bm} * B_{bm}^2 / 4)$ = **1475.2** cm^3

2.3 Section Classification

Table 11

Maximum Steel Thickness	t_{max}	=	$max(T_{bm}, t_p)$ = **30** mm
Steel Design Strength	p_y	=	**440** N/mm^2
Ratio	ε	=	$(275 / p_y)^{0.5}$ = **0.791**
Plate Outstand (Outstand Element)	R_{atio1}	=	$(0.5 * b_p - 0.5 * B_{bm}) / t_p$ = **0.715**
Inner Plate (Internal Element)	R_{atio2}	=	B_{bm} / t_p = **10.237**
Beam Flange	R_{atio3}	=	$b_p / (2 * T_{bm})$ = **7.415**
Beam Web	R_{atio4}	=	d_{bm} / t_{bm} = **38.298**
Flange Classification		=	**Compact** (9ε < Flange <= 10ε)
Web Classification		=	**Plastic** (Web < 80ε)
Overall Section Classification		=	**Compact**

Table 9

2.4 Section Capacity Calculation

2.4.1 Shear Capacity

Cl. 4.2.3

Vertical Shear Capacity	P_{wp}	=	$0.6 * p_y * t_{bm} * D_{bm}$ = **2308.6** kN
Horizontal Shear Capacity of Beam Flange	P_{vhbmp}	=	$0.6 * p_y * 0.9 * T_{bm} * B_{bm}$ = **1722** kN

Horizontal Shear Capacity of Plate	P_{vhlp}	= $0.6 * p_y * 0.9 * t_p * b_p$ = **2494.8** kN	
Combined Horizontal Shear Capacity	P_{vhp}	= $P_{vhbmp} + P_{vhlp}$ = **4216.8** kN	

2.4.2 Bending Capacity

Cl. 4.2.5

Vertical Bending Capacity	M_{cxp}	= $\min(p_y * S_{xp}, 1.2 * p_y * \min(Z_{xxtopp}, Z_{xxbtmp}))$ = **2931.2** kNm	
Horizontal Moment Capacity Top Flange	M_{ctfp}	= $\min(p_y * S_{tfp}, 1.2 * p_y * Z_{tfp})$ = **495.3** kNm	

2.4.3 Lateral Torsional Buckling Capacity

Slenderness Ratio	λ_p	= L_g / r_{yp} = **78.221**	
Slenderness Factor	v_p	= $1 / (((4 * \eta_{sagp} * (1 - \eta_{sagp})) + (0.05 * (\lambda_p / x_p)^2) + \psi_{sagp}^2)^{0.5} + \psi_{sagp})^{0.5}$ = **0.796**	*Annex. B.2.3*
Factor	β_{wp}	= $\min(Z_{xxtopp}, Z_{xxbtmp}) / S_{xp}$ = **1**	*Cl. 4.3.6.9*
Equivalent Slenderness	λ_{ltp}	= $u * v_p * \lambda_p * \beta_{wp}^{0.5}$ = **50.441**	
Limiting Equivalent Slenderness	λ_{lop}	= $0.4 * (\pi^2 * E / p_y)^{0.5}$ = **27.124**	
Perry Factor	η_{ltp}	= $0.014 * (\lambda_{ltp} - \lambda_{lop})$ = **0.326**	*Annex. B.2.2*
Euler Buckling Stress	p_{ep}	= $(\pi^2 * E) / \lambda_{lt}^2$ = **795.2** N/mm^2	
Factor	ϕ_{Ltp}	= $(p_y + ((\eta_{ltp} + 1) * p_{ep})) / 2$ = **747.4** N/mm^2	*Annex. B.2.1*
Bending Strength	p_{bp}	= $p_{ep} * p_y / (\phi_{Ltp} + (\phi_{Ltp}^2 - (p_{ep} * p_y))^{0.5})$ = **290.6** N/mm^2	
Buckling Moment Resistance	M_{ballow}	= $p_{bp} * S_{xp}$ = **2045.2** kNm	

2.5 Load Calculations

2.5.1 Load Case

W.L - Dynamic Wheel Load
S.W - Self Weight of Gantry
S - Surge Wheel Load
C - Crabbing Wheel Load

2.5.2 Weight of Girder

Beam and Crane Rail Self Weight (S.W)	W_{sw}	= $(Mass_{bm} + Mass_{pl}) * g + W_r$ = **3.06** kN/m	

2.5.3 Dynamic Loads Per Wheel

Unfactored Transverse Surge Wheel Load (S)	W_{sur}	= $W_{su} * W_{stat}$ = **10** kN	
Max. Unfactored Dynamic Vertical Load (W.L)	W_{dyn}	= $W_{dy} * W_{stat}$ = **150** kN	
Unfactored Transverse Crabbing Load (C)	W_{cra}	= $W_{dyn} / 20$ = **7.5** kN	

2.5.4 Load Combination

L.C. 01 - 1.6 x W.L + 1.4 x S.W
L.C. 02 - 1.4 x W.L + 1.4 x S.W + 1.4 x S + 1.4 x C

2.6 Analysis and Design

2.6.1 Shear

Load Combination	Applied Shear (kN)		Capacity (kN)		Shear Capacity Ratio	
	Vertical (V_v)	**Horizontal** (V_h)	**Vertical** (V_{cv})	**Horizontal** (V_{ch})	**Vertical** (V_v / V_{cv})	**Horizontal** (V_h / V_{ch})
L.C.01	367	-	2308.6	-	0.16	-
L.C.02	367	20.5	2308.6	4216.8	0.16	0.0049

2.6.2 Moment

Load Combination	Applied Moment (kNm)		Capacity (kNm)		Interaction Ratio
	Vertical (M_v)	**Horizontal** (M_h)	**Buckling** (M_{cv})	**Horizontal** (M_{ch})	(M_v / M_{cv}) + (M_h / M_{ch})
L.C.01	510.1	-	2045.2	495.3	0.25
L.C.02	449.6	28.2	2045.2	495.3	0.28

2.6.3 Web Bearing

Cl. 4.5.2.1

Stiff Bearing Length Dispersed Through Rail b_{1p} = $2 * (h_r + t_p)$ = **260** mm

Bearing Capacity of Unstiffened Web P_{bw} = $(b_{1p} + (5 * (T_{bm} + r_{bm}))) * t_{bm} * p_y$ = **2856.9** kN

2.6.4 Web Buckling

Cl. 4.5.3.1

Effective Length of Web L_{ewebp} = $1.2 * d_{bm}$ = **648** mm

Buckling Capacity of Unstiffened Web P_{xr} = $25 * \varepsilon * t_{bm} / (b_{1p} + (5 * (T_{bm} + r_{bm}) * d_{bm}))^{0.5}$ $* P_{bw}$ = **1596.6** kN

2.6.5 Check Plate to Beam Flange Weld

Design Weld Strength P_{ww} = **280** N/mm^2 *Table 37*

Shear Stress on Weld V_w = $V_v * A_{pl} * (D_{bm} + 0.5 * t_p - y_{nap}) / (2 * 0.7 * S * I_{xxp})$

= **53.5** N/mm^2

2.6.6 Deflection Check

2.6.6.1 Allowable Deflection

Allowable Vertical Deflection δ_{av} = L_G / 600 = **12.5** mm

Allowable Horizontal Deflection δ_{ah} = L_G / 500 = **15** mm

2.6.6.2 Actual Deflection

Vertical Deflection δ_v = **2.7** mm

Horizontal Deflection - due to Surge δ_{hs} = **3.4** mm

Horizontal Deflection - due to Crab δ_{hc} = **2.5** mm

Horizontal Deflection δ_h = $\max(\delta_{hs}, \delta_{hc})$ = **3.4** mm

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3.0 SUMMARY

3.1 Shear Capacity (kN)

Description	Required	Actual	Status
Vertical	367	2308.6	**PASS**
Horizontal	20.5	4216.8	**PASS**

3.2 Bending Capacity (kNm)

Description	Required	Actual	Status
Vertical (Buckling)	449.6	2045.2	**PASS**
Horizontal	28.2	495.3	**PASS**
Interaction Ratio	1	0.28	**PASS**

3.3 Web Capacity (kN)

Description	Required	Actual	Status
Bearing	240	2856.9	**PASS**
Buckling	240	1596.6	**PASS**

Weld Capacity (N/mm^2)	53.5	280	**PASS**

3.4 Deflection (mm)

Description	Required	Actual	Status
Vertical	12.5	2.7	**PASS**
Horizontal	15	3.4	**PASS**