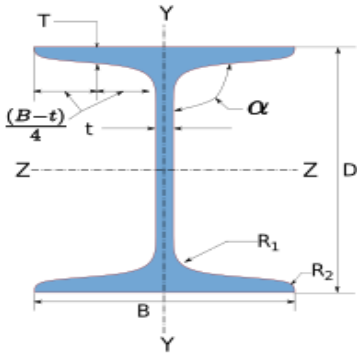
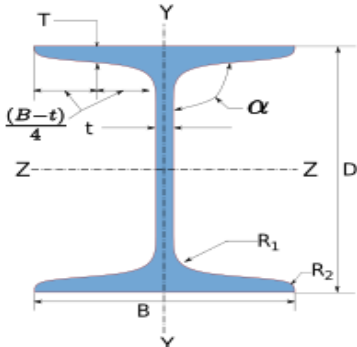




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Designer	Engineer#1	Job Number	1.2.2.1.2.3.1
Date	04 /02 /2021	Client	Dr. Pradyumna M, Bengaluru

1 Input Parameters

Main Module		Moment Connection		
Module		Beam-to-Column End Plate Connection		
Connectivity		Column Web-Beam Web		
End Plate Type		Extended Both Ways - Reversible Moment		
Bending Moment (kNm)		65.0		
Shear Force (kN)		150.0		
Axial Force (kN)		0.0		
Column Section - Mechanical Properties				
	Column Section		UC 356 x 406 x 235	
	Material		E 350 (Fe 490)	
	Ultimate Strength, Fu (MPa)		490	
	Yield Strength, Fy (MPa)		330	
	Mass, m (kg/m)	235.1	Iz (cm4)	79085.0
	Area, A (cm2)	299.4	Iy(cm4)	30992.0
	D (mm)	381.0	rz (cm)	16.3
	B (mm)	394.8	ry (cm)	10.2
	t (mm)	18.4	Zz (cm3)	4151.0
	T (mm)	30.2	Zy (cm3)	1570.0
	Flange Slope	90	Zpz (cm3)	4687.0
	R1 (mm)	15.2	Zpy (cm3)	2383.0
	R2 (mm)	0.0		
	Beam Section - Mechanical Properties			
	Beam Section		UB 305 x 165 x 40	
	Material		E 300 (Fe 440)	
	Ultimate Strength, Fu (MPa)		440	
	Yield Strength, Fy (MPa)		300	
	Mass, m (kg/m)	40.3	Iz (cm4)	8503.0
	Area, A (cm2)	51.3	Iy(cm4)	764.0
	D (mm)	303.0	rz (cm)	12.9
	B (mm)	165.0	ry (cm)	3.9
	t (mm)	6.0	Zz (cm3)	560.0
	T (mm)	10.2	Zy (cm3)	93.0
	Flange Slope	90	Zpz (cm3)	623.0



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	R_1 (mm)	8.9	Z_{py} (cm ³)	142.0
	R_2 (mm)	0.0		
Plate Details - Input and Design Preference				
Thickness (mm)			[16, 18, 20]	
Material			E 250 (Fe 410 W)A	
Ultimate Strength, F_u (MPa)			410	
Yield Strength, F_y (MPa)			250	
Bolt Details - Input and Design Preference				
Diameter (mm)			[24]	
Property Class			[8.8]	
Type			Friction Grip Bolt	
Bolt Tension			Pre-tensioned	
Hole Type			Standard	
Slip Factor, (μ_f)			0.3	
Weld Details - Input and Design Preference				
Type of Weld Fabrication			Shop Weld	
Material Grade Overwrite, F_u (MPa)			450.0	
Beam Flange to End Plate			Groove Weld	
Beam Web to End Plate			Fillet Weld	
Stiffener			Fillet Weld	
Continuity Plate			Fillet Weld	
Detailing - Design Preference				
Edge Preparation Method			Rolled, machine-flame cut, sawn and planed	
Gap Between Members (mm)			0.0	
Are the Members Exposed to Corrosive Influences?			False	



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2 Design Checks

Design Status	Pass
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2.1 Beam to Column - Compatibility Check

Check	Required	Provided	Remarks
Beam Section Compatibility	$B_{req} = B_b + 25$ $= 165.0 + 25$ $= 190.0$	$B_{available} = D_c - (2T_c) - (2R_{1c}) - 10$ $= 381.0 - (2 \times 30.2) - (2 \times 15.2) - 10$ $= 280.2$	Compatible

2.2 Member Capacity - Supported Section

Check	Required	Provided	Remarks
Shear Capacity (kN)		$V_{dy} = \frac{A_v f_y}{\sqrt{3} \gamma_{m0}}$ $= \frac{0.6 \times 282.6 \times 6.0 \times 300}{\sqrt{3} \times 1.1 \times 1000}$ $= 160.19$ [Ref. IS 800:2007, Cl.10.4.3]	Restricted to low shear
Plastic Moment Capacity (kNm)		$M_{dz} = \frac{\beta_b Z_{pz} f_y}{\gamma_{m0}}$ $= \frac{1.0 \times 623000.0 \times 300}{1.1 \times 10^6}$ $= 169.91$ [Ref. IS 800:2007, Cl.8.2.1.2]	$V < 0.6 V_{dy}$



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2.3 Member Capacity - Supporting Section

Check	Required	Provided	Remarks
Plastic Moment Capacity (kNm)		$M_{dz} = \frac{\beta_b Z_{pz} f_y}{\gamma_{m0}}$ $= \frac{0.89 \times 4687000.0 \times 330}{1.1 \times 10^6}$ $= 1245.3$ <p>Note: The capacity of the section is not based on the beam-column or column design. The actual capacity might vary.</p> <p>[Ref. IS 800:2007, Cl.8.2.1.2]</p>	Semi-compact
Plastic Moment Capacity (kNm)		$M_{dy} = \frac{\beta_b Z_{py} f_y}{\gamma_{m0}}$ $= \frac{0.66 \times 2383000.0 \times 330}{1.1 \times 10^6}$ $= 471.0$ <p>Note: The capacity of the section is not based on the beam-column or column design. The actual capacity might vary.</p> <p>[Ref. IS 800:2007, Cl.8.2.1.2]</p>	Semi-compact

2.4 Load Consideration

Check	Required	Provided	Remarks
Axial Force (kN)		$P_x = 0.0$	OK



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Check	Required	Provided	Remarks
Shear Force (kN)	$V_y = 150.0$	$V_{ymin} = \min(0.15V_{dy}, 40.0)$ $= \min(0.15 \times 160.19, 40.0)$ $= \min(24.03, 40.0)$ $= 24.03$ $V_u = \max(V_y, V_{ymin})$ but, $\leq V_{dy}$ $= \max(150.0, 24.03)$ but, ≤ 160.19 $= 150.0$ [Ref. IS 800:2007, Cl.10.7]	Pass
Bending Moment (major axis) (kNm)	$M = 65.0$	$M_{zmin} = 0.5M_{dz}$ $= 0.5 \times 169.91$ $= 84.95$ $M_u = \max(M_z, M_{zmin})$ but, $\leq M_{dy}$ of the column section $= \max(65.0, 84.95)$ ≤ 471.0 $= 84.95$ [Ref. IS 800:2007, Cl.8.2.1.2]	Pass
Effective Bending Moment (major axis) (kNm)		$M_{ue} = M_u + P_x \times \left(\frac{D}{2} - \frac{T}{2} \right) \times 10^{-3}$ $= 84.95 +$ $0.0 \times \left(\frac{303.0}{2} - \frac{10.2}{2} \right) \times 10^{-3}$ $= 84.95$	OK



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2.5 Bolt Optimization

Check	Required	Provided	Remarks
Diameter (mm)	Bolt Diameter Optimization	$d = 24$	Pass
Property Class	Bolt Property Class Optimization	8.8	Pass
Hole Diameter (mm)		$d_0 = 26.0$	OK
No. of Bolt Columns		$n_c = 2$	Pass
No. of Bolt Rows		$n_r = 6$	Pass
Total No. of Bolts		$n = n_r \times n_c = 12$	Pass

2.6 Detailing

Check	Required	Provided	Remarks
Min. Pitch Distance (mm)	$p_{\min} = 2.5d$ $= 2.5 \times 24.0$ $= 60.0$ [Ref. IS 800:2007, Cl.10.2.2]	80	Pass
Max. Pitch Distance (mm)	$p_{\max} = \min(32t, 300)$ $= \min(32 \times 16.0, 300)$ $= \min(512.0, 300)$ $= 300$ Where, $t = \min(16.0, 16.0)$ [Ref. IS 800:2007, Cl.10.2.3]	80	Pass
Min. End Distance (mm)	$e_{\min} = 1.5d_0$ $= 1.5 \times 26.0$ $= 39.0$ [Ref. IS 800:2007, Cl.10.2.4.2]	40	Pass



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Check	Required	Provided	Remarks
Max. End Distance (mm)	$e_{\max} = 12t\varepsilon; \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 16.0 \times \sqrt{\frac{250}{250}} = 192.0$ $e_2 = 12 \times 16.0 \times \sqrt{\frac{250}{250}} = 192.0$ $e_{\max} = \min(e_1, e_2) = 192.0$ <p>[Ref. IS 800:2007, Cl.10.2.4.3]</p>	40	Pass
Min. Edge Distance (mm)	$e'_{\min} = 1.5d_0$ $= 1.5 \times 26.0$ $= 39.0$ <p>[Ref. IS 800:2007, Cl.10.2.4.2]</p>	40	Pass
Max. Edge Distance (mm)	$e'_{\max} = 12t\varepsilon; \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 16.0 \times \sqrt{\frac{250}{250}} = 192.0$ $e_2 = 12 \times 16.0 \times \sqrt{\frac{250}{250}} = 192.0$ $e'_{\max} = \min(e_1, e_2) = 192.0$ <p>[Ref. IS 800:2007, Cl.10.2.4.3]</p>	40	Pass
Cross-centre Gauge Distance (mm)		96	Pass

2.7 Critical Bolt Design

Check	Required	Provided	Remarks
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Check	Required	Provided	Remarks
Slip Resistance (kN)	$V_{sf} = \frac{V_u}{n}$ $= \frac{150.0}{12}$ $= 12.5$	$V_{dsf} = \frac{\mu_f n_e K_h F_o}{\gamma_{mf}}$ <p>Where, $F_o = 0.7 f_{ub} A_{nb}$</p> $V_{dsf} = \frac{0.3 \times 1 \times 1 \times 0.7 \times 830.0 \times 353}{1.25 \times 10^3}$ $= 49.22$ <p>[Ref. IS 800:2007, Cl.10.4.3]</p>	Pass
Lever Arm (mm)	<p>$r = [292.8, 292.8, 0, 45.1, 167.7, 125.1]$</p> <p>Note: r_1 and r_2 are the first rows outside and inside the tension/top flange. r_3 and r_4 are the first rows outside and inside the compression/bottom flange. r_5 is the second row inside tension/top flange, and r_6 is the second row inside the compression/bottom flange. row(s) r_7 and beyond are the rows inside the flange, placed in a symmetrical manner.</p> <p>Note: The lever arm is computed by considering the N.A at the centre of the bottom flange. Rows with identical lever arm values mean they are considered acting as bolt group near the tension or compression flange.</p>		Pass



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Check	Required	Provided	Remarks
Tension Due to Moment (kN)	$T_1 = \frac{M_{ue}}{2 \times n_c \times \left(r_1 + \sum_{i=4}^{n_r} \frac{r_i^2}{r_1} \right)}$ $= \frac{84.95 \times 10^3}{2 \times 2 \times \left(292.8 + \sum_{i=4}^6 \frac{r_i^2}{292.8} \right)}$ $= 47.27$ <p>Note: T_1 is the tension in the critical bolt. The critical bolt is the bolt nearest to the tension flange.</p>		OK



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Check	Required	Provided	Remarks
Prying Force (kN)	$Q = \frac{l_v}{2l_e} \left[T_e - \frac{\beta \eta f_o b_e t^4}{27 l_e l_v^2} \right]$ $l_v = e - \frac{R_1}{2}$ $= 40 - \frac{8.9}{2} = 35.55 \text{ mm}$ $f_o = 0.7 f_{ub}$ $= 0.7 \times 830.0$ $= 581.0 \text{ N/mm}^2$ $l_e = \min \left(e, 1.1 t \sqrt{\frac{\beta f_o}{f_y}} \right)$ $= \min \left(40, 1.1 \times 16 \times \sqrt{\frac{1 \times 581.0}{250}} \right)$ $= \min(40, 26.83) = 26.83 \text{ mm}$ $\beta = 1 \text{ (pre-tensioned bolt)}$ $\eta = 1.5$ $b_e = \frac{B}{n_c}$ $= \frac{165.0}{2} = 82.5 \text{ mm}$ $Q = \frac{35.55}{2 \times 26.83} \times \left[47.27 - \left(\frac{1 \times 1.5 \times 581.0 \times 82.5 \times 16^4}{27 \times 26.83 \times 35.55^2} \right) \times 10^{-3} \right]$ $Q = 27.91$ <p>[Ref. IS 800:2007, Cl.10.4.7]</p>		OK



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Check	Required	Provided	Remarks
Tension Demand (kN)	$T_f = T_1 + Q$ $= 47.27 + 27.91$ $= 75.18$	$T_f = 0.90 f_{ub} A_n / \gamma_{mf}$ $< f_{yb} A_{sb} (\gamma_{m1} / \gamma_{m0})$ $= \min \left(0.90 \times 830.0 \times 353 / 1.25, \right.$ $\left. 660.0 \times 452.0 \times (1.25/1.1) \right)$ $= \min(210.95, 339.0)$ $= 210.95$ [Ref. IS 800:2007, Cl.10.3.5]	Pass
Combined Capacity, (I.R)	≤ 1	$\left(\frac{V_{sf}}{V_{df}} \right)^2 + \left(\frac{T_f}{T_{df}} \right)^2 \leq 1.0$ $\left(\frac{12.5}{49.22} \right)^2 + \left(\frac{75.18}{210.95} \right)^2 = 0.19$ [Ref. IS 800:2007, Cl.10.3.6]	Pass

2.8 Compression Flange Check

Check	Required	Provided	Remarks
Tension in Bolt Rows (kN)		$T = [47.27, 47.27, 0, 14.56, 54.15, 40.4]$	OK
Reaction at Compression Flange (kN)	$R_c = n_c \sum_{n_r=1}^{n_r} T_{n_r}$ $= 2 \times \sum_{n_r=1}^6 T_{n_r}$ $= 2 \times 203.65$ $= 407.3$	$F_c = A_g f_y / \gamma_{m0}$ $= \frac{B T f_y}{\gamma_{m0}}$ $= \frac{165.0 \times 10.2 \times 300}{1.1 \times 1000}$ $= 459.0$	Pass



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2.9 End Plate Checks

Check	Required	Provided	Remarks
Height (mm)		$H_p = D + (2 \times (2 \times e))$ $= 303.0 + (2 \times (2 \times 40))$ $= 463.0$	Pass
Width (mm)		$B_p = B + 25$ $= 165.0 + 25$ $= 190.0$	Pass
Moment at Critical Section (kNm)		$M_{cr} = T_1 l_v - Q l_e$ $= (47.27 \times 35.55 - 27.91 \times 26.83) \times 10^{-3}$ $= 0.93$ Note: The critical section is at the toe of the weld or the edge of the flange from bolt center-line	OK
Plate Thickness (mm)	$t_p = \sqrt{\frac{4M_{cr}}{b_e(f_y/\gamma_{m0})}}$ $= \sqrt{\frac{4 \times 0.93 \times 10^6}{82 \times (250/1.1)}}$ $= 14.1$	16	Pass
Moment Capacity (kNm)	0.93	$M_p = \left(\frac{b_e t_p^2}{4}\right) \times \frac{f_y}{\gamma_{m0}}$ $= \frac{82 \times 16^2}{4} \times \frac{250}{1.1} \times 10^{-6}$ $= 1.2$	Pass

2.10 Stiffener Design

Check	Required	Provided	Remarks
Height (mm)		$H_{st} = \frac{H_p - D}{2}$ $= \frac{463.0 - 303.0}{2}$ $= 80.0$	80.0
Length (mm)		$L_{st} = \frac{H_{st}}{\tan 30^\circ}$ $= \frac{80.0}{\tan 30^\circ}$ $= 140$	Pass



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Check	Required	Provided	Remarks
Thickness (mm)	$t = 6.0$	$t_{st} = 6$	Pass
Weld Size (mm)	5	$t_w = 6$	Pass

2.11 Weld Design - Beam Web to End Plate Connection

Check	Required	Provided	Remarks
Weld Strength (N/mm ²)	$f_{uw} = \min(f_w, f_u)$ $= \min(450.0, 410)$ [Ref. IS 800:2007, Cl.10.5.7.1.1]	$f_{uw} = 410$	Pass
Total Weld Length (mm)		$L_w = 2 \times [D - (2 \times T) - (2 \times R1) - 20]$ $= 2 \times [303.0 - (2 \times 10.2) - (2 \times 8.9) - 20]$ $= 483.6$ Note: Weld is provided on both sides of the web	OK
Weld Size (mm)	$t_w = \frac{V_u}{f_{uw} k L_w} \times \sqrt{3} \gamma_{mw}$ $= \frac{150.0 \times 10^3}{410 \times 0.7 \times 483.6} \times \sqrt{3} \times 1.25$ $= 2.34$ [Ref. IS 800:2007, Cl.10.5.7]	6	Pass



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Check	Required	Provided	Remarks
Min. Weld Size (mm)	<p>1) $t_{w\min}$ – based on thickness of the thicker part</p> $t_{\text{thicker}} = \max(16.0, 6.0)$ $= 16.0$ $t_{w\min} = 5$ <p>2) $t_{w\min}$ – based on thickness of the thinner part</p> $t_{\text{thinner}} = \min(16.0, 6.0)$ $= 6.0$ $t_{w\min} \leq \min(5, 6.0)$ <p>[Ref. IS 800:2007, Table 21, Cl 10.5.2.3]</p>	$t_w = \max(t_w, t_{w\min})$ $= \max(2.34, 5)$ $= 6$	Pass
Max. Weld Size (mm)	<p>$t_{w\max}$ based on thickness of the thinner part</p> $t_{\text{thinner}} = \min(16.0, 6.0)$ $= 6.0$ $t_{w\max} = 6.0$ <p>[Ref. IS 800:2007, Cl.10.5.3.1]</p>	$t_w \leq t_{w\max}$ $6 \leq 6.0$	Fail

2.12 Continuity Plate Design

Check	Required	Provided	Remarks
Notch Size (mm)		$n = 24$	OK



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Check	Required	Provided	Remarks
Length (mm)		$l_{cp1} = \text{Outer length}$ $l_{cp1} = D_c - 2T_c$ $= 381.0 - (2 \times 30.2)$ $= 320.6$ $l_{cp2} = \text{Inner length}$ $l_{cp2} = D_c - 2(T_c + n)$ $= 381.0 - [2 \times (30.2 + 24)]$ $= 272.6$	OK
Width (mm)		$w_{cp} = \frac{B_c - T_c - 2n}{2}$ $= \frac{394.8 - 18.4 - 2 \times 24}{2}$ $= 164.0$	OK
Thickness (mm)	tc = 18.4	20	Pass

2.13 Weld Design - Continuity Plate

Check	Required	Provided	Remarks
Weld Strength (N/mm ²)	$f_{uw} = \min(f_w, f_{u_{cp}})$ $= \min(450.0, 410)$ [Ref. IS 800 : 2007, Cl. 10.5.7.1.1]	$f_{uw} = 410$	Pass
Total (effective) Weld Length (mm)		$L_{wcp} = 254.20000000000002$ Note: Provide weld on one side of the continuity plate	OK
Weld Size (mm)	5	6	Pass



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Check	Required	Provided	Remarks
Min. Weld Size (mm)	<p>1) $t_{w\min}$ – based on thickness of the thicker part</p> $t_{\text{thicker}} = \max(20, 18.4)$ $= 20$ $t_{w\min} = 5$ <p>2) $t_{w\min}$ – based on thickness of the thinner part</p> $t_{\text{thinner}} = \min(20, 18.4)$ $= 18.4$ $t_{w\min} \leq \min(5, 18.4)$ <p>[Ref. IS 800:2007, Table 21, Cl 10.5.2.3]</p>	$t_w = \max(t_w, t_{w\min})$ $= \max(6, 5)$ $= 6$	Pass
Max. Weld Size (mm)	<p>$t_{w\max}$ based on thickness of the thinner part</p> $t_{\text{thinner}} = \min(20, 18.4)$ $= 18.4$ $t_{w\max} = 18$ <p>[Ref. IS 800:2007, Cl.10.5.3.1]</p>	$t_w \leq t_{w\max}$ $6 \leq 18$	Pass



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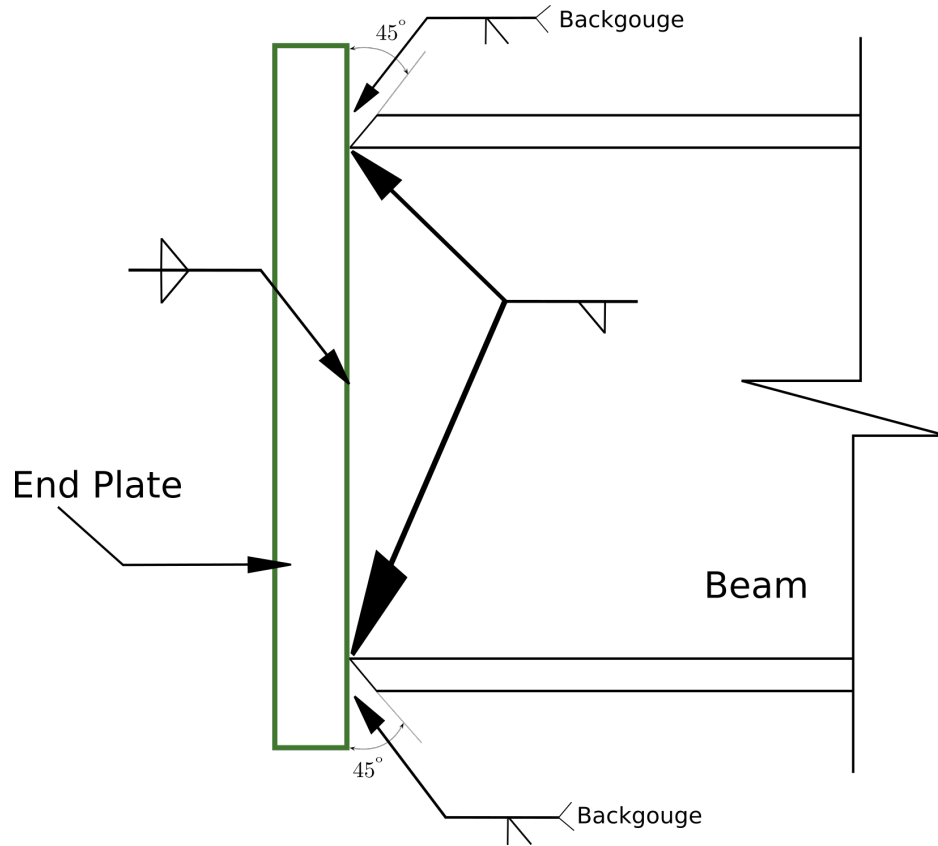


Figure 1: Typical Weld Details -- Beam to End Plate Connection

3 2D Drawings (Typical)



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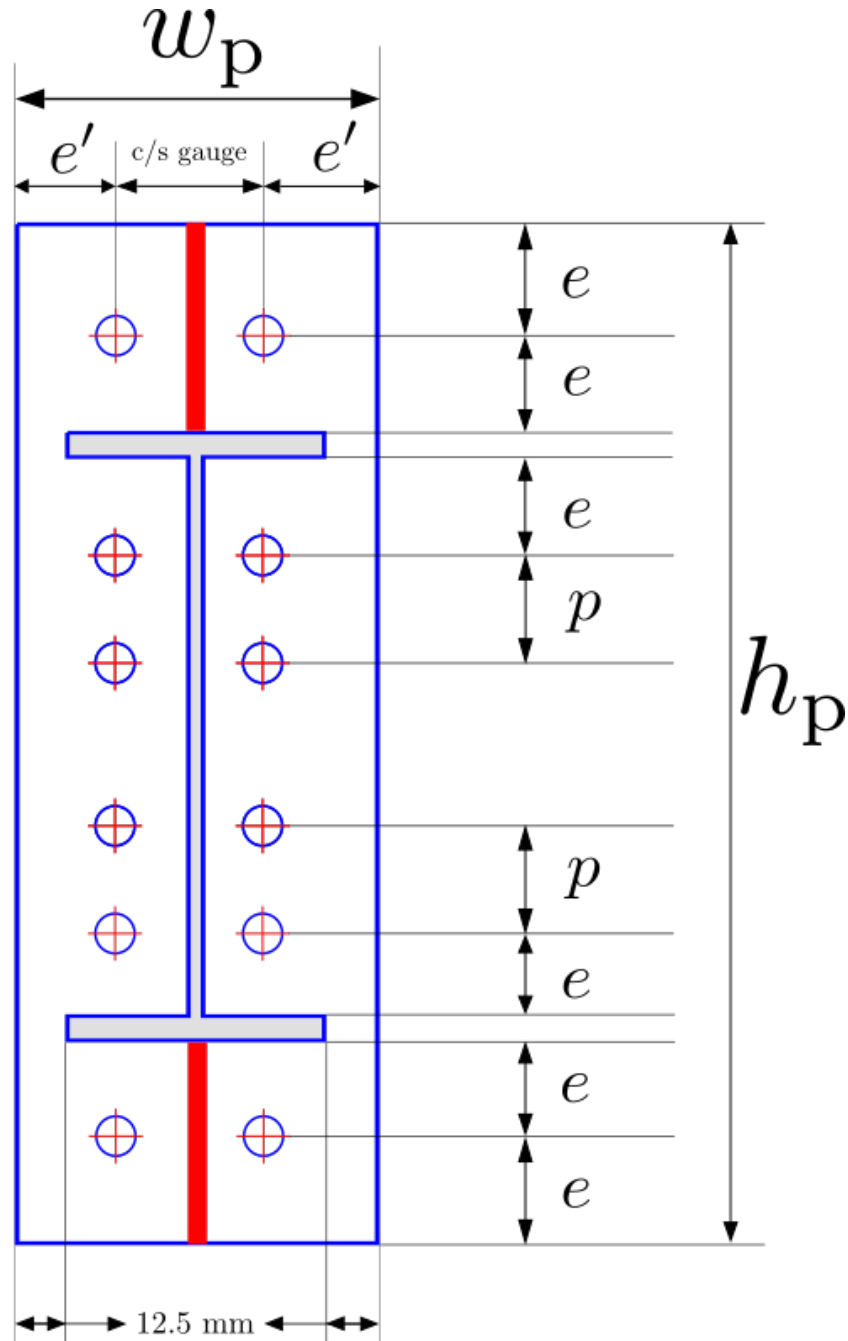


Figure 2: Typical Detailing



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Designer	Engineer#1	Job Number	1.2.2.1.2.3.1
Date	04 /02 /2021	Client	Dr. Pradyumna M, Bengaluru

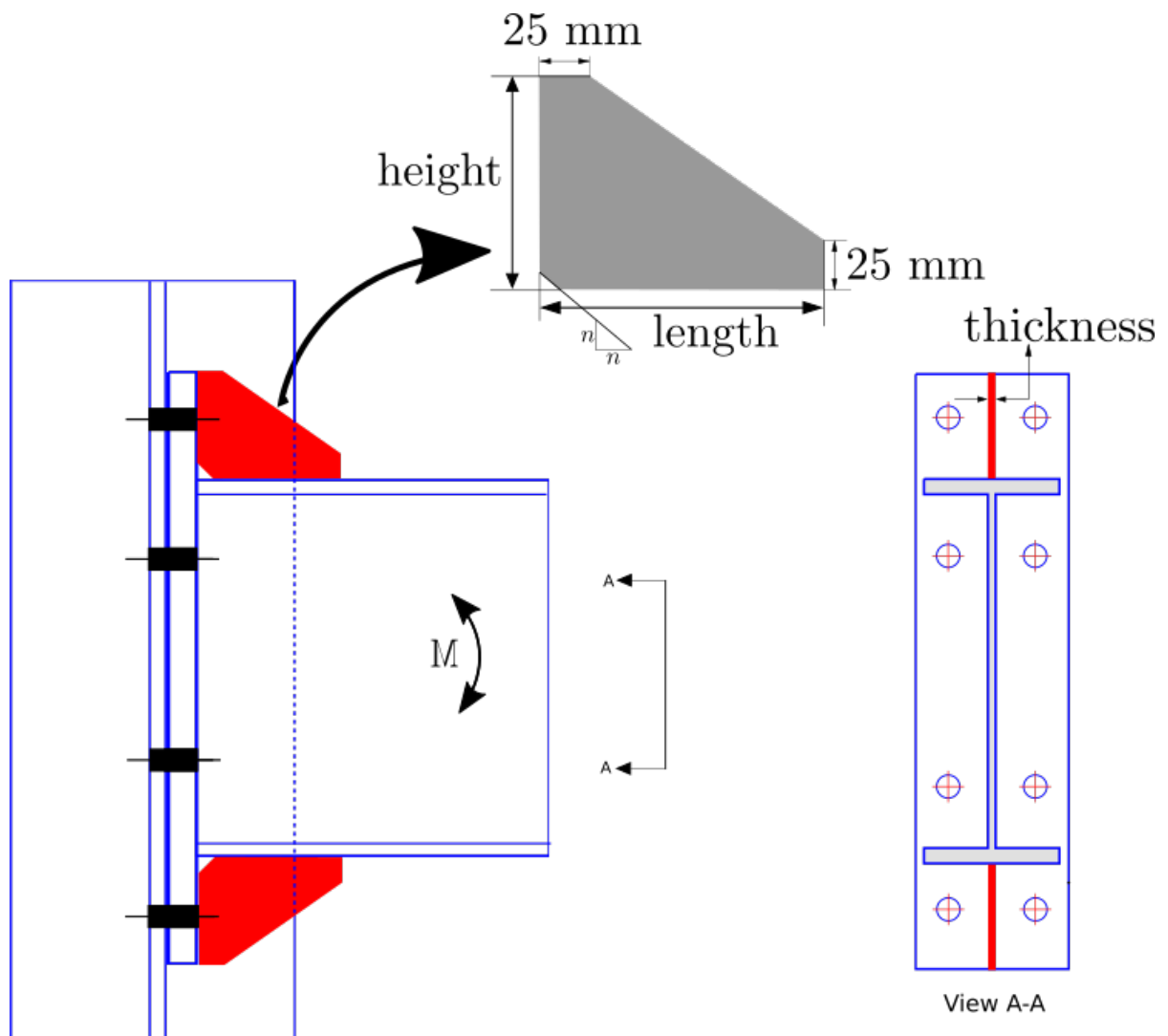
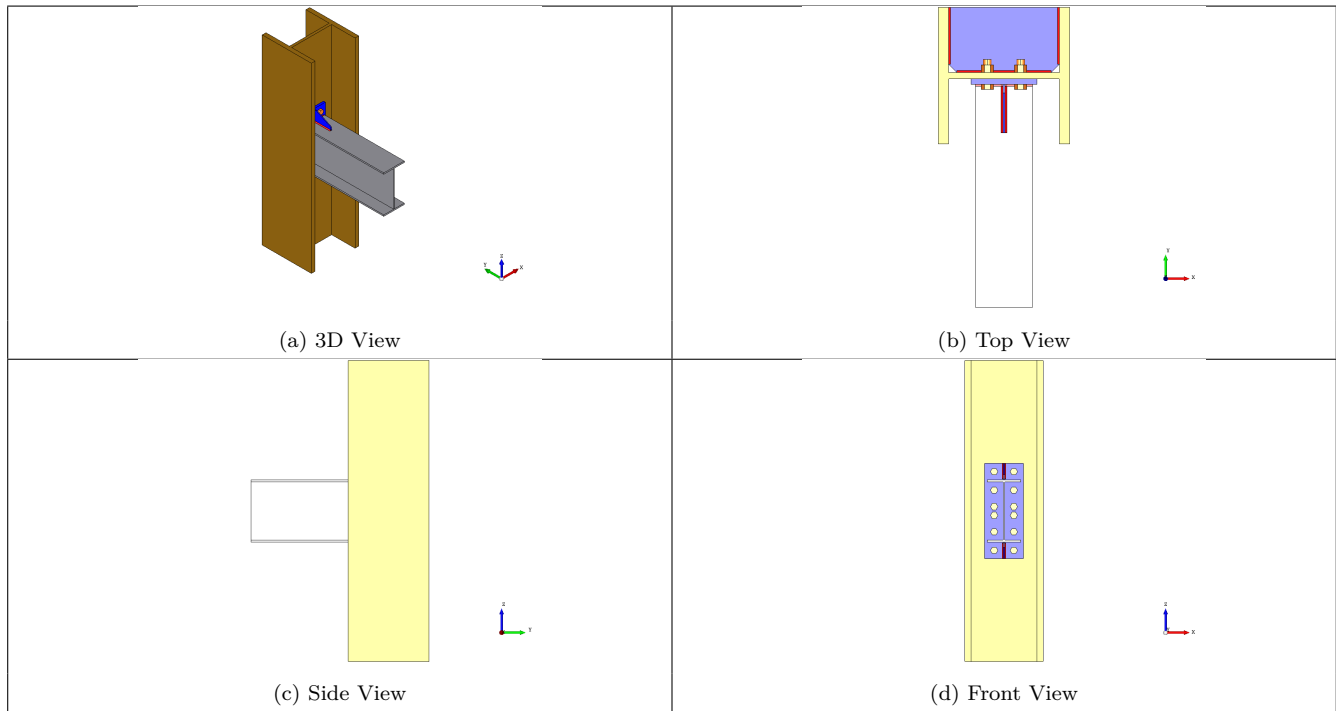


Figure 3: Typical Stiffener Details



Company Name	IIT Bombay	Project Title	Moment Connection
Group/Team Name	Osdag	Subtitle	Beam-to-Column End Plate
Designer	Engineer#1	Job Number	1.2.2.1.2.3.1
Date	04 /02 /2021	Client	Dr. Pradyumna M, Bengaluru

4 3D Views



5 Design Log

2021-02-04 14:08:09 - Osdag - WARNING - The Load(s) defined is/are less than the minimum recommended value [Ref. IS 800:2007, Cl.10.7].

2021-02-04 14:08:09 - Osdag - WARNING - [Minimum Factored Load] The external factored bending moment (65.0 kNm) is less than 0.5 times the plastic moment capacity of the beam (169.91 kNm)

2021-02-04 14:08:09 - Osdag - INFO - The minimum factored bending moment should be at least 0.5 times the plastic moment capacity of the beam to qualify the connection as rigid connection (Annex. F-4.3.1, IS 800:2007)

2021-02-04 14:08:09 - Osdag - INFO - The value of load(s) is/are set at minimum recommended value as per Cl.10.7 and Annex. F, IS 800:2007



2021-02-04 14:08:09 - Osdag - INFO - Designing the connection for a factored moment of 84.95 kNm

2021-02-04 14:08:09 - Osdag - WARNING - [End Plate] The end plate of 16.0 mm is thinner than the thickest of the elements being connected

2021-02-04 14:08:09 - Osdag - INFO - Selecting a plate of higher thickness which is at least 18 mm thick

2021-02-04 14:08:09 - Osdag - WARNING - [End Plate] The end plate of 18.0 mm is thinner than the thickest of the elements being connected

2021-02-04 14:08:09 - Osdag - INFO - Selecting a plate of higher thickness which is at least 18 mm thick

		Created with  Osdag®	
Company Name	IIT Bombay	Project Title	Moment Connection
Group/Team Name	Osdag	Subtitle	Beam-to-Column End Plate
Designer	Engineer#1	Job Number	1.2.2.1.2.3.1
Date	04 /02 /2021	Client	Dr. Pradyumna M, Bengaluru

2021-02-04 14:08:09 - Osdag - INFO - [Bolt Design] Bolt diameter and grade combination ready to perform bolt design

2021-02-04 14:08:09 - Osdag - INFO - The solver has selected 1.0 combinations of bolt diameter and grade to perform optimum bolt design in an iterative manner

2021-02-04 14:08:09 - Osdag - INFO - [Optimisation] Performing the design by optimising the plate thickness, using the most optimum plate and a suitable bolt diameter approach

2021-02-04 14:08:09 - Osdag - INFO - If you wish to optimise the bolt diameter-grade combination, pass a higher value of plate thickness using the Input Dock

2021-02-04 14:08:09 - Osdag - INFO - [Flange Strength] The reaction at the compression flange of the beam 407.3 kN is less than the flange capacity 459.0 kN. The flange strength requirement is satisfied.

2021-02-04 14:08:09 - Osdag - INFO - [End Plate] The end plate of 16.0 mm passes the moment capacity check. The end plate is checked for yielding due tension caused by bending moment and prying force

2021-02-04 14:08:09 - Osdag - INFO - [Bolt Design] The bolt of 24.0 mm diameter and 8.8 grade passes the tension check

2021-02-04 14:08:09 - Osdag - INFO - Total tension demand on bolt (due to direct tension + prying action) is 75.1836823979781 kN and the bolt tension capacity is (210.95 kN)

2021-02-04 14:08:09 - Osdag - INFO - [Bolt Design] The bolt of 24.0 mm diameter and 8.8 grade passes the combined shear + tension check

2021-02-04 14:08:09 - Osdag - INFO - The Interaction Ratio (IR) of the critical bolt is 0.192

2021-02-04 14:08:09 - Osdag - INFO - : ===== Design Status =====

2021-02-04 14:08:09 - Osdag - INFO - : Overall beam to column end plate connection design is SAFE

2021-02-04 14:08:09 - Osdag - INFO - : ===== End Of Design =====