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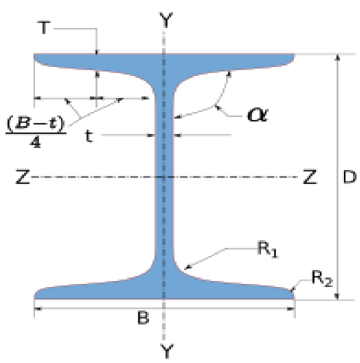
Company Name	IIT Bombay	Project Title	Moment Connection
Group/Team Name	Osdag	Subtitle	Beam-to-Beam End Plate
Designer	Engineer#1	Job Number	1.2.1.2.1.1.1
Date	04 /02 /2021	Client	Prof. Meera Raghunandan, IIT Bombay

1 Input Parameters

Main Module		Moment Connection	
Module		Beam-to-Beam End Plate Connection	
Connectivity		Coplanar Tension-Compression Flange	
End Plate Type		Flushed - Reversible Moment	
Bending Moment (kNm)		250.0	
Shear Force (kN)		120.0	
Axial Force (kN)		35.0	
Beam Section - Mechanical Properties			
Beam Section		WB 500	
Material		E 250 (Fe 410 W)C	
Ultimate Strength, F_u (MPa)		410	
Yield Strength, F_y (MPa)		250	
Mass, m (kg/m)	95.12	I_z (cm^4)	52200.0
Area, A (cm^2)	12100.0	I_y(cm^4)	2980.0
D (mm)	500.0	r_z (cm)	20.7
B (mm)	250.0	r_y (cm)	4.96
t (mm)	9.9	Z_z (cm^3)	2090.0
T (mm)	14.7	Z_y (cm^3)	239.0
Flange Slope	96	Z_{pz} (cm^3)	2350.0
R_1 (mm)	15.0	Z_{py} (cm^3)	406.0
R_2 (mm)	7.5		
Plate Details - Input and Design Preference			
Thickness (mm)		[20, 22, 25, 28, 32]	
Material		E 300 (Fe 440)	
Ultimate Strength, F_u (MPa)		440	
Yield Strength, F_y (MPa)		290	
Bolt Details - Input and Design Preference			
Diameter (mm)		[20, 24, 30]	
Property Class		[6.8, 8.8]	
Type		Bearing Bolt	
Bolt Tension		Non 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)	500.0
Beam Flange to End Plate	Groove Weld
Beam Web to End Plate	Fillet Weld
Stiffener	Fillet Weld
Detailing - Design Preference	
Edge Preparation Method	Rolled, machine-flame cut, sawn and planed
Gap Between Beams (mm)	0.0
Are the Members Exposed to Corrosive Influences?	False

2 Design Checks

Design Status	**Pass**

2.1 Member Capacity

Check	Required	Provided	Remarks
Shear Capacity (kN)		$V_{d_y} = \frac{A_v f_y}{\sqrt{3}\gamma_{m0}}$ $= \frac{0.6 \times 470.6 \times 9.9 \times 250}{\sqrt{3} \times 1.1 \times 1000}$ $= 366.8$ [Ref. IS 800:2007, Cl.10.4.3]	**Restricted to low shear**
Plastic Moment Capacity (kNm)		$M_{d_z} = \frac{\beta_b Z_{p_z} fy}{\gamma_{m0}}$ $= \frac{1 \times 2350000.0 \times 250}{1.1 \times 10^6}$ $= 534.09$ [Ref. IS 800:2007, Cl.8.2.1.2]	**V < 0.6 Vdy**

2.2 Load Consideration

Check	Required	Provided	Remarks
Shear Force (kN)	$V_y = 120.0$	$V_{y_{\min}} = \min(0.15V_{d_y},\ 40.0)$ $= \min(0.15 \times 366.8,\ 40.0)$ $= \min(55.02,\ 40.0)$ $= 40$ $V_u = \max(V_y,\ V_{y_{\min}})$ but, $\leq V_{dy}$ $= \max(120.0,\ 40)$ but, ≤ 366.8 $= 120.0$ [Ref. IS 800:2007, Cl.10.7]	**Pass**

Check	Required	Provided	Remarks
Axial Force (kN)		$P_x = 35.0$	OK
Bending Moment (kNm)	$M_z = 250.0$	$M_{z\min} = 0.5 M_{dz}$ $= 0.5 \times 534.09$ $= 267.05$ $M_u = \max(M_z,\ M_{z\min})$ but, $\leq M_{dz}$ $= \max(250.0, 267.05)$ ≤ 534.09 $= 267.05$ [Ref. IS 800:2007, Cl.8.2.1.2]	Pass
Effective Bending Moment (kNm)		$M_{ue} = M_u\ +\ P_x \times \left(\frac{D}{2} - \frac{T}{2}\right) \times 10^{-3}$ $= 267.05 +$ $35.0 \times \left(\frac{500.0}{2} - \frac{14.7}{2}\right) \times 10^{-3}$ $= 275.54$	OK

2.3 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		$n_r = 4$	Pass
Total No. of Bolts		$n = n_r X n_c = 8$	Pass

2.4 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)	$p_{\max} = \min(32t,\ 300)$ $= \min(32 \times 28.0,\ 300)$ $= \min(896.0,\ 300)$ $= 300$ Where, $t = \min(28.0, 28.0)$ [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
Max. End Distance (mm)	$e_{\max} = 12t\varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 28.0 \times \sqrt{\frac{250}{290}} = 311.97$ $e_2 = 12 \times 28.0 \times \sqrt{\frac{250}{290}} = 311.97$ $e_{\max} = \min(e_1,\ e_2) = 311.97$ [Ref. IS 800:2007, Cl.10.2.4.3]	40	Pass
Min. Edge 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

Check	Required	Provided	Remarks
Max. Edge Distance (mm)	$e'_{\max} = 12t\varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 28.0 \times \sqrt{\frac{250}{290}} = 311.97$ $e_2 = 12 \times 28.0 \times \sqrt{\frac{250}{290}} = 311.97$ $e'_{\max} = min(e_1,\ e_2) = 311.97$ [Ref. IS 800:2007, Cl.10.2.4.3]	40	**Pass**
Cross-centre Gauge Distance (mm)		106	**Pass**

2.5 Critical Bolt Design

Check	Required	Provided	Remarks
Shear Capacity (kN)		$V_{\text{dsb}} = \frac{f_{ub} n_n A_{nb}}{\sqrt{3}\gamma_{mb}}$ $= \frac{830.0 \times 1 \times 353}{1000 \times \sqrt{3} \ \times \ 1.25}$ $= 135.33$ [Ref. IS 800:2007, Cl.10.3.3]	**OK**
Kb		$k_b = \min\left(\frac{e}{3d_0},\ \frac{p}{3d_0} - 0.25,\ \frac{f_{ub}}{f_u},\ 1.0\right)$ $= \min\left(\frac{40}{3 \times 26.0},\ \frac{80}{3 \times 26.0} - 0.25,\ \frac{830.0}{410},\ 1.0\right)$ $= \min(0.51, 0.78, 2.02, 1.0)$ $= 0.51$ [Ref. IS 800:2007, Cl.10.3.4]	**OK**

Check	Required	Provided	Remarks
Bearing Capacity (kN)		$V_{\text{dpb}} = \frac{2.5 k_b d t f_u}{\gamma_{mb}}$ $= \frac{2.5 \times 0.51 \times 24.0 \times 28.0 \times 440}{1000 \times 1.25}$ $= 301.59$ [Ref. IS 800:2007, Cl.10.3.4]	OK
Bolt Capacity (kN)		$V_{\text{db}} = \min\ (V_{\text{dsb}},\ V_{\text{dpb}})$ $= \min\ (135.33,\ 301.59)$ $= 135.33$ [Ref. IS 800:2007, Cl.10.3.2]	
Large Grip Length Reduction Factor		$l_g = \sum \left(t_p + t_{\text{member}}\right)$ $= \sum \left(28.0 + 28.0\right)$ $= 56.0$ mm $5d = 5 \times 24.0 = 120.0$ $8d = 8 \times 24.0 = 192.0$ Since, $l_g < 5d$ $\beta_{lg} = 1.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.3.2]$	Pass
Bolt Capacity (post reduction factor) (kN)		$V_{\text{db}} = V_{\text{db}} \beta_{lg}$ $= 135.33 \times 1.0$ $= 135.33$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.3.2]$	OK
Shear Demand (kN)	$V_{sb} = \frac{V_u}{n}$ $= \frac{120.0}{8}$ $= 15.0$	Vdb = 135.33	Pass

Check	Required	Provided	Remarks
Lever Arm (mm)	$r = [437.95, 47.35, 357.95, 127.35]$ Note: r_1 is the first row inside tension/top flange, r_2 is the first row inside compression/bottom flange. Further row(s) are added in a symmetrical manner with odd rows placed near the tension/top flange and even row placed near the compression/bottom flange respectively. 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.		**Pass**
Tension Due to Moment (kN)	$T_1 = \dfrac{M_{ue}}{n_c \times \left(r_1 + \sum_{i=2}^{n_r} \dfrac{r_i^2}{r_1}\right)}$ $= \dfrac{275.54 \times 10^3}{2 \times \left(437.95 + \sum_{i=2}^{4} \dfrac{r_i^2}{437.95}\right)}$ $= 178.31$ Note: T_1 is the tension in the critical bolt. The critical bolt is the bolt nearest to the tension flange.		**OK**

Check	Required	Provided	Remarks
Prying Force (kN)	$Q = \frac{l_v}{2l_e}\left[T_e - \frac{\beta\eta f_o b_e t^4}{27 l_e l_v^2}\right]$ $l_v = e - \frac{R_1}{2}$ $= 40 - \frac{15.0}{2} = 32.5$ mm $f_o = 0.7 f_{ub}$ $= 0.7 \times 830.0$ $= 581.0\ \mathrm{N/mm^2}$ $l_e = \min\left(e, 1.1t\sqrt{\frac{\beta f_o}{f_y}}\right)$ $= \min\left(40, 1.1 \times 28 \times \sqrt{\frac{2 \times 581.0}{290}}\right)$ $= \min(40,\ 61.65) = 40$ mm $\beta = 2$ (non pre-tensioned bolt) $\eta = 1.5$ $b_e = \frac{B}{n_c}$ $= \frac{250.0}{2} = 125.0$ mm $Q = \frac{32.5}{2 \times 40} \times$ $\left[178.31 - \left(\frac{2 \times 1.5 \times 581.0 \times 125.0 \times 28^4}{27 \times 40 \times 32.5^2}\right) \times 10^{-3}\right]$ $Q = 24.74$ [Ref. IS 800:2007, Cl.10.4.7]		OK

Check	Required	Provided	Remarks
Tension Demand (kN)	$T_b = T_1 + Q$ $= 178.31 + 24.74$ $= 203.05$	$T_{\mathrm{db}} = 0.90 f_{ub} A_n \;/\; \gamma_{mb}$ $< \; f_{yb} A_{sb} (\gamma_{mb} \;/\; \gamma_{m0})$ $= \min\Big(0.90 \times 830.0 \times 353 \;/\; 1.25,$ $660.0 \times 452.0 \times (1.25/1.1)\Big)$ $= \min(210.95,\; 339.0)$ $= 210.95$ [Ref. IS 800:2007, Cl.10.3.5]	**Pass**
Combined Capacity, (I.R)	≤ 1	$\left(\frac{V_{sb}}{V_{\mathrm{db}}}\right)^2 + \left(\frac{T_{\mathrm{b}}}{T_{\mathrm{db}}}\right)^2 \leq 1.0$ $\left(\frac{15.0}{135.33}\right)^2 + \left(\frac{203.05}{210.95}\right)^2 = 0.94$ [Ref. IS 800:2007, Cl.10.3.6]	**Pass**

2.6 Compression Flange Check

Check	Required	Provided	Remarks
Tension in Bolt Rows (kN)		$T = [178.31, 19.28, 145.73, 51.85]$	**OK**
Reaction at Compression Flange (kN)	$R_c = n_c \sum_{n_r=1}^{n_r} T_{n_r}$ $= 2 \times \sum_{n_r=1}^{4} T_{n_r}$ $= 2 \times 395.17$ $= 790.34$	$F_c = A_g f_y \;/\; \gamma_{m0}$ $= \frac{B T f_y}{\gamma_{m0}}$ $= \frac{250.0 \times 14.7 \times 250}{1.1 \times 1000}$ $= 835.23$	**Pass**

2.7 End Plate Checks

Check	Required	Provided	Remarks
Height (mm)		$H_p = D + 25$ $= 500.0 + 25$ $= 525.0$	Pass
Width (mm)		$B_p = B + 25$ $= 250.0 + 25$ $= 275.0$	Pass
Moment at Critical Section (kNm)		$M_{cr} = T_1\ l_v - Q\ l_e$ $= (178.31 \times 32.5 - 24.74 \times 40) \times 10^{-3}$ $= 4.81$ 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)	$t_p = \sqrt{\frac{4M_{cr}}{b_e(f_y/\gamma_{m0})}}$ $= \sqrt{\frac{4 \times 4.81 \times 10^6}{125 \times (290/1.1)}}$ $= 24.15$	28	Pass
Moment Capacity (kNm)	4.81	$M_p = \left(\frac{b_e t_p^2}{4}\right) \times \frac{f_y}{\gamma_{m0}}$ $= \frac{125 \times 28^2}{4} \times \frac{290}{1.1} \times 10^{-6}$ $= 6.46$	Pass

2.8 Longitudinal Stiffener Design

Check	Required	Provided	Remarks
Width (mm)		$W_{st} = B_p - \frac{t}{2}$ $= 275.0 - \frac{9.9}{2}$ $= 132$	Pass
Length (mm)		$L_{st} = 2W_{st}$ $= 2 \times 132$ $= 264$	Pass
Thickness (mm)	$t = 9.9$	$t_{st} = 10$	Pass

Check	Required	Provided	Remarks
Weld Size (mm)	6	tw = 6	**Pass**

2.9 Weld Design - Beam Web to End Plate Connection

Check	Required	Provided	Remarks
Weld Strength (N/mm2)	$f_{u_w} = \min(f_{\mathrm{w}},\ f_u)$ $= \min(500.0,\ 440)$ [Ref. IS 800:2007, Cl.10.5.7.1.1]	$f_{u_w} = 440$	**Pass**
Total Weld Length (mm)		$L_w = 2 \times \left[D - (2 \times T) - (2 \times R1) - 20\right]$ $= 2 \times \left[500.0 - (2 \times 14.7) - (2 \times 15.0) - 20\right]$ $= 840$ Note: Weld is provided on both sides of the web	
Weld Size (mm)	$t_w = \frac{V_u}{f_{uw} k L_w} \times \sqrt{3}\ \gamma_{mw}$ $= \frac{120.0 \times 10^3}{440 \times 0.7 \times 840} \times \sqrt{3} \times 1.25$ $= 1.0$ [Ref. IS 800:2007, Cl.10.5.7]	6	**Pass**

Check	Required	Provided	Remarks
Min. Weld Size (mm)	1) $t_{w\,\text{min}}-$ based on thickness of the thicker part $t_{\text{thicker}} = \max(28.0,\ 9.9)$ $= 28.0$ $t_{w\,\text{min}} = 6$ 2) $t_{w\,\text{min}}-$ based on thickness of the thinner part $t_{\text{thinner}} = \min(28.0,\ 9.9)$ $= 9.9$ $t_{w\,\text{min}} \leq \min(6,\ 9.9)$ [Ref. IS 800:2007, Table 21, Cl 10.5.2.3]	$t_w = \max(t_w,\ t_{w\,\text{min}})$ $= \max(1.0,\ 6)$ $= 6$	**Pass**
Max. Weld Size (mm)	$t_{w\,\text{max}}$ based on thickness of the thinner part $t_{\text{thinner}} = \min(28.0,\ 9.9)$ $= 9.9$ $t_{w\,\text{max}} = 9.9$ [Ref. IS 800:2007, Cl.10.5.3.1]	$t_w \leq t_{w\,\text{max}}$ $6 \leq 9.9$	**Pass**
Normal Stress (N/mm2)		$f_a = \frac{H}{0.7 t_w L_w}$ $= \frac{35.0 \times 10^3}{0.7 \times 6 \times 840}$ $= 9.91$ [Ref. IS 800:2007, Cl.10.5.9]	**OK**

Check	Required	Provided	Remarks
Shear Stress (N/mm2)		$q = \frac{V}{0.7 t_w L_w}$ $= \frac{120.0 \times 10^3}{0.7 \times 6 \times 840}$ $= 33.97$ [Ref. IS 800:2007, Cl.10.5.9]	**OK**
Equivalent Stress (N/mm2)	$f_e = \sqrt{f_a^2 + 3q^2}$ $= \sqrt{9.91^2 + (3 \times 33.97^2)}$ $= 58.92$ [Ref. IS 800:2007, Cl.10.5.10.1.1]	$f_w = \frac{f_u}{\sqrt{3}\gamma_{mw}}$ $= \frac{440}{\sqrt{3} \times 1.25}$ $= 203.23$ [Ref. IS 800:2007, Cl.10.5.7.1.1]	**Pass**

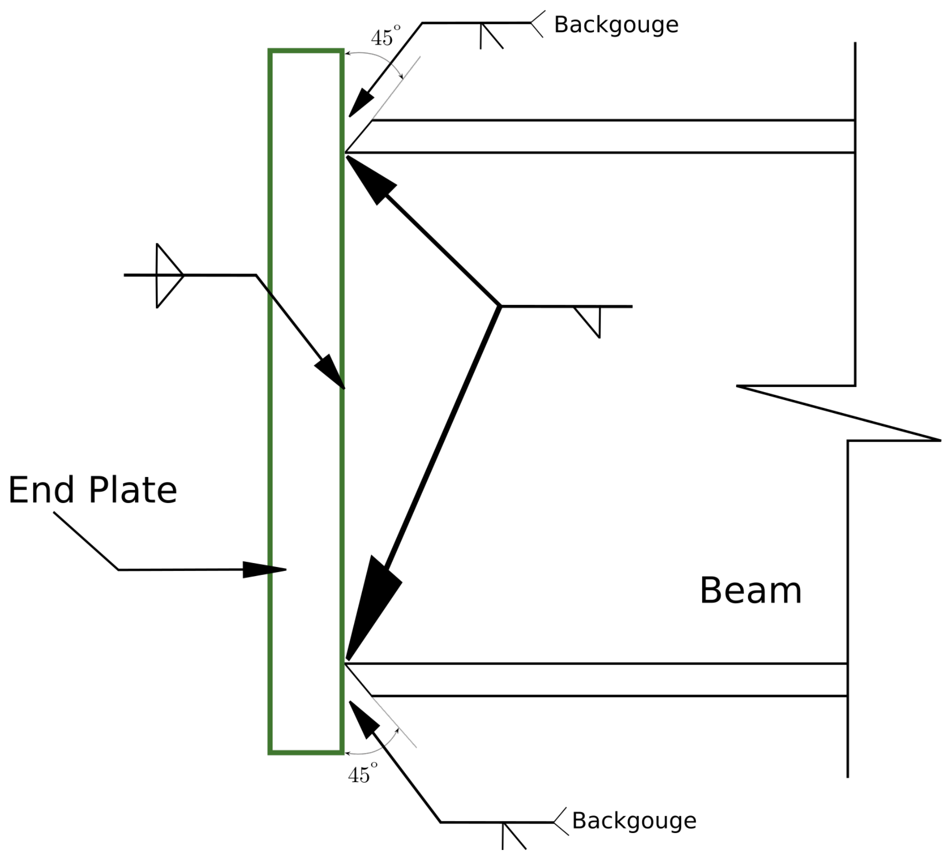


Figure 1: Typical Weld Details -- Beam to End Plate Connection

3 2D Drawings (Typical)

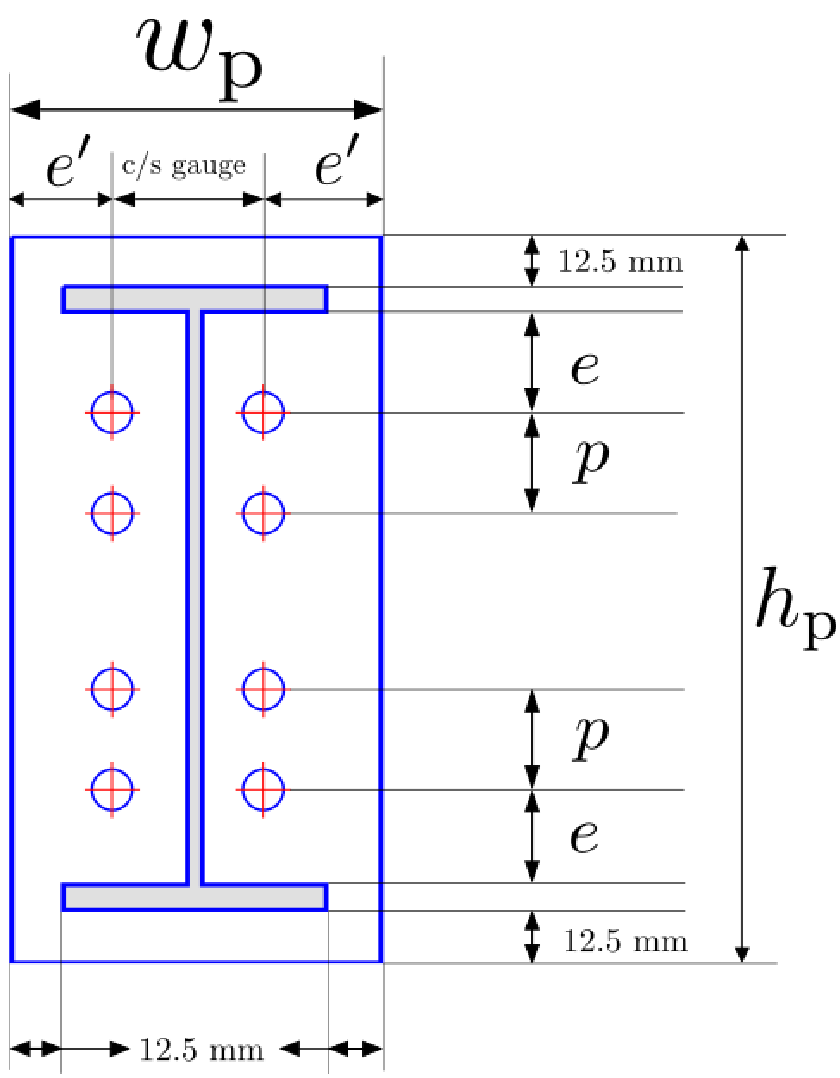


Figure 2: Typical Detailing

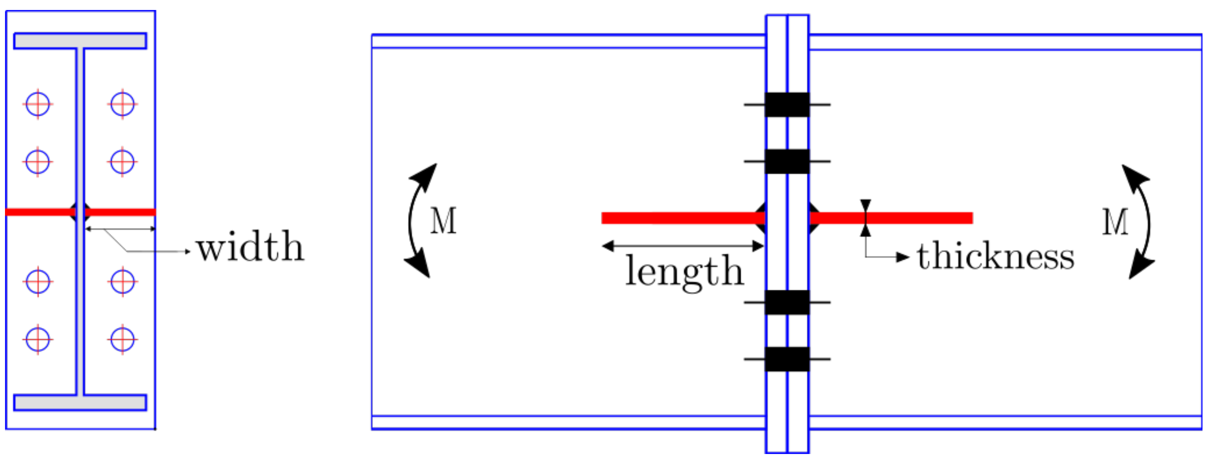
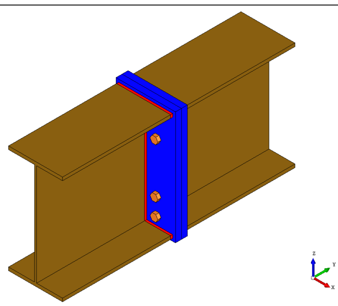
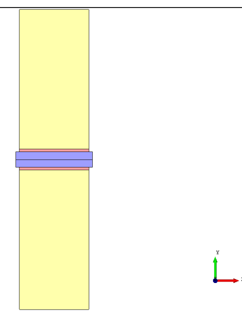


Figure 3: Typical Stiffener Details

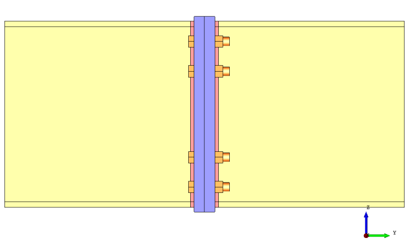
4 3D Views



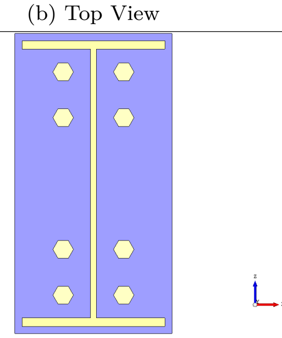
(a) 3D View



(b) Top View



(c) Side View



(d) Front View

5 Design Log

2021-02-04 13:22:28 - Osdag - WARNING - The Load(s) defined is/are less than the minimum recommended value [Ref. IS 800:2007, Cl.10.7].

2021-02-04 13:22:28 - Osdag - WARNING - [Minimum Factored Load] The external factored bending moment (250.0 kNm) is less than 0.5 times the plastic moment capacity of the beam (534.09 kNm)

2021-02-04 13:22:28 - 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 13:22:28 - 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 13:22:28 - Osdag - INFO - Designing the connection for a factored moment of 267.05 kNm

2021-02-04 13:22:28 - Osdag - INFO - [Bolt Design] Bolt diameter and grade combination ready to perform bolt design

2021-02-04 13:22:28 - Osdag - INFO - The solver has selected 6 combinations of bolt diameter and grade to perform optimum bolt design in an iterative manner

2021-02-04 13:22:28 - 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 13:22:28 - 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 13:22:28 - Osdag - INFO - [Flange Strength] The reaction at the compression flange of the beam 790.34 kN is less than the flange capacity 835.23 kN. The flange strength requirement is satisfied.

2021-02-04 13:22:28 - Osdag - INFO - [End Plate] The end plate of 28.0 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 13:22:28 - Osdag - INFO - [Bolt Design] The bolt of 24.0 mm diameter and 8.8 grade passes the tension check

2021-02-04 13:22:28 - Osdag - INFO - Total tension demand on bolt (due to direct tension + prying action) is 203.05 kN and the bolt tension capacity is (210.95 kN)

2021-02-04 13:22:28 - Osdag - INFO - [Bolt Design] The bolt of 24.0 mm diameter and 8.8 grade passes the combined shear + tension check

2021-02-04 13:22:28 - Osdag - INFO - The Interaction Ratio (IR) of the critical bolt is 0.939

2021-02-04 13:22:28 - Osdag - INFO - : ========== Design Status ============

2021-02-04 13:22:28 - Osdag - INFO - : Overall beam to beam end plate splice connection design is SAFE

2021-02-04 13:22:28 - Osdag - INFO - : ========== End Of Design ============