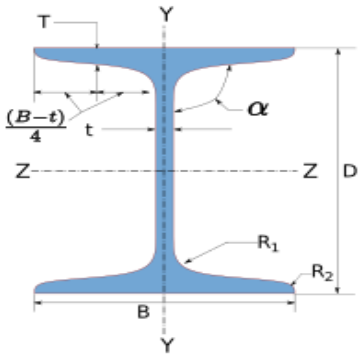
Company Name	IIT Bombay	Project Title	Moment Connection
Group/Team Name	Osdag	Subtitle	Beam-to-Beam End Plate
Designer	Engineer#1	Job Number	1.2.1.2.1.3.2
Date	04 /02 /2021	Client	Dr. Harshvardhan Subbarao, Mumbai

1 Input Parameters

Main Module			Moment Connection	
Module			Beam-to-Beam End Plate Connection	
Connectivity			Coplanar Tension-Compression Flange	
End Plate Type			Extended Both Ways - Reversible Moment	
Bending Moment (kNm)			85.0	
Shear Force (kN)			40.0	
Axial Force (kN)			12.0	
Beam Section - Mechanical Properties				
	Beam Section		UB 406 x 140 x 46	
	Material		E 300 (Fe 440)	
	Ultimate Strength, F_u (MPa)		440	
	Yield Strength, F_y (MPa)		300	
	Mass, m (kg/m)	46.0	I_z (cm^4)	15685.0
	Area, A (cm^2)	5860.0	I_y(cm^4)	538.0
	D (mm)	403.0	r_z (cm)	16.4
	B (mm)	142.2	r_y (cm)	3.0
	t (mm)	6.8	Z_z (cm^3)	778.0
	T (mm)	11.2	Z_y (cm^3)	76.0
	Flange Slope	90	Z_{pz} (cm^3)	888.0
	R_1 (mm)	10.2	Z_{py} (cm^3)	118.0
	R_2 (mm)	0.0		
Plate Details - Input and Design Preference				
Thickness (mm)			[14]	
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)			[16]	
Property Class			[12.9]	
Type			Friction Grip Bolt	
Bolt Tension			Pre-tensioned	
Hole Type			Standard	

Slip Factor, (μ_f)	0.48
Weld Details - Input and Design Preference	
Type of Weld Fabrication	Shop Weld
Material Grade Overwrite, F_u (MPa)	440.0
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)		$V_{d_y} = \frac{A_v f_y}{\sqrt{3}\gamma_{m0}}$ $= \frac{0.6 \times 380.6 \times 6.8 \times 300}{\sqrt{3} \times 1.1 \times 1000}$ $= 244.51$ [Ref. IS 800:2007, Cl.10.4.3]	Restricted to low shear
Plastic Moment Capacity (kNm)		$M_{d_z} = \frac{\beta_b Z_{p_z} fy}{\gamma_{m0}}$ $= \frac{1 \times 888000.0 \times 300}{1.1 \times 10^6}$ $= 242.18$ [Ref. IS 800:2007, Cl.8.2.1.2]	V < 0.6 Vdy

2.2 Load Consideration

Check	Required	Provided	Remarks
Shear Force (kN)	$V_y = 40.0$	$V_{y_{\min}} = \min(0.15V_{d_y},\ 40.0)$ $= \min(0.15 \times 244.51,\ 40.0)$ $= \min(36.68,\ 40.0)$ $= 36.68$ $V_u = \max(V_y,\ V_{y_{\min}})$ but, $\leq V_{dy}$ $= \max(40.0,\ 36.68)$ but, ≤ 244.51 $= 40.0$ [Ref. IS 800:2007, Cl.10.7]	Pass

Check	Required	Provided	Remarks
Axial Force (kN)		$P_x = 12.0$	OK
Bending Moment (kNm)	$M_z = 85.0$	$M_{z\min} = 0.5 M_{dz}$ $= 0.5 \times 242.18$ $= 121.09$ $M_u = \max(M_z,\ M_{z\min})$ but, $\leq M_{dz}$ $= \max(85.0, 121.09)$ ≤ 242.18 $= 121.09$ [Ref. IS 800:2007, Cl.8.2.1.2]	Pass
Effective Bending Moment (kNm)		$M_{ue} = M_u + P_x \times \left(\frac{D}{2} - \frac{T}{2}\right) \times 10^{-3}$ $= 121.09 +$ $12.0 \times \left(\frac{403.0}{2} - \frac{11.2}{2}\right) \times 10^{-3}$ $= 123.44$	OK

2.3 Bolt Optimization

Check	Required	Provided	Remarks
Diameter (mm)	Bolt Diameter Optimization	$d = 16$	Pass
Property Class	Bolt Property Class Optimization	12.9	Pass
Hole Diameter (mm)		$d_0 = 18.0$	OK
No. of Bolt Columns		$n_c = 2$	Pass
No. of Bolt Rows		$n_r = 6$	Pass
Total No. of Bolts		$n = n_r X n_c = 12$	Pass

2.4 Detailing

Check	Required	Provided	Remarks
Min. Pitch Distance (mm)	$p_{min} = 2.5d$ $= 2.5 \times 16.0$ $= 40.0$ [Ref. IS 800:2007, Cl.10.2.2]	55	Pass
Max. Pitch Distance (mm)	$p_{max} = \min(32t,\ 300)$ $= \min(32 \times 14.0,\ 300)$ $= \min(448.0,\ 300)$ $= 300$ Where, $t = \min(14.0, 14.0)$ [Ref. IS 800:2007, Cl.10.2.3]	55	Pass
Min. End Distance (mm)	$e_{min} = 1.5d_0$ $= 1.5 \times 18.0$ $= 27.0$ [Ref. IS 800:2007, Cl.10.2.4.2]	30	Pass
Max. End Distance (mm)	$e_{max} = 12t\varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 14.0 \times \sqrt{\frac{250}{250}} = 168.0$ $e_2 = 12 \times 14.0 \times \sqrt{\frac{250}{250}} = 168.0$ $e_{max} = \min(e_1,\ e_2) = 168.0$ [Ref. IS 800:2007, Cl.10.2.4.3]	30	Pass
Min. Edge Distance (mm)	$e'_{min} = 1.5d_0$ $= 1.5 \times 18.0$ $= 27.0$ [Ref. IS 800:2007, Cl.10.2.4.2]	30	Pass

Check	Required	Provided	Remarks
Max. Edge Distance (mm)	$e'_{max} = 12t\varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 14.0 \times \sqrt{\frac{250}{250}} = 168.0$ $e_2 = 12 \times 14.0 \times \sqrt{\frac{250}{250}} = 168.0$ $e'_{max} = min(e_1,\ e_2) = 168.0$ [Ref. IS 800:2007, Cl.10.2.4.3]	30	**Pass**
Cross-centre Gauge Distance (mm)		78	**Pass**

2.5 Critical Bolt Design

Check	Required	Provided	Remarks
Slip Resistance (kN)	$V_{sf} = \frac{V_u}{n}$ $= \frac{40.0}{12}$ $= 3.33$	$V_{dsf} = \frac{\mu_f n_e K_h F_o}{\gamma_{mf}}$ Where , $F_o = 0.7 f_{ub} A_{nb}$ $V_{dsf} = \frac{0.48 \times 1 \times 1 \times 0.7 \times 1220.0 \times 157}{1.25 \times 10^3}$ $= 51.49$ [Ref. IS 800:2007, Cl.10.4.3]	**Pass**

Check	Required	Provided	Remarks
Lever Arm (mm)	$r = [391.8, 391.8, 0, 35.6, 301.2, 90.6]$ 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. 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)	$T_1 = \frac{M_{ue}}{2 \times n_c \times \left(r_1 + \sum_{i=4}^{n_r} \frac{r_i^2}{r_1}\right)}$ $= \frac{123.44 \times 10^3}{2 \times 2 \times \left(391.8 + \sum_{i=4}^{6} \frac{r_i^2}{391.8}\right)}$ $= 47.66$ 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)	$Q = \frac{l_v}{2l_e}\left[T_e - \frac{\beta\eta f_o b_e t^4}{27 l_e l_v^2}\right]$ $l_v = e - \frac{R_1}{2}$ $= 30 - \frac{10.2}{2} = 24.9$ mm $f_o = 0.7 f_{ub}$ $= 0.7 \times 1220.0$ $= 854.0$ N/mm^2 $l_e = \min\left(e, 1.1t\sqrt{\frac{\beta f_o}{f_y}}\right)$ $= \min\left(30, 1.1 \times 14 \times \sqrt{\frac{1 \times 854.0}{250}}\right)$ $= \min(30,\ 28.46) = 28.46$ mm $\beta = 1$ (pre-tensioned bolt) $\eta = 1.5$ $b_e = \frac{B}{n_c}$ $= \frac{142.2}{2} = 71.1$ mm $Q = \frac{24.9}{2 \times 28.46} \times$ $\left[47.66 - \left(\frac{1 \times 1.5 \times 854.0 \times 71.1 \times 14^4}{27 \times 28.46 \times 24.9^2}\right) \times 10^{-3}\right]$ $Q = 17.63$ [Ref. IS 800:2007, Cl.10.4.7]		OK

Check	Required	Provided	Remarks
Tension Demand (kN)	$T_f = T_1 + Q$ $= 47.66 + 17.63$ $= 65.29$	$T_f = 0.90 f_{ub} A_n \ / \ \gamma_{mf}$ $< \ f_{yb} A_{sb} (\gamma_{m1} \ / \ \gamma_{m0})$ $= \min \Big(0.90 \times 1220.0 \times 157 \ / \ 1.25,$ $1100.0 \times 201.0 \times (1.25/1.1) \Big)$ $= \min(137.91, \ 251.25)$ $= 137.91$ [Ref. IS 800:2007, Cl.10.3.5]	**Pass**
Combined Capacity, (I.R.)	≤ 1	$\left(\frac{V_{sf}}{V_{df}}\right)^2 + \left(\frac{T_f}{T_{df}}\right)^2 \leq 1.0$ $\left(\frac{3.33}{51.49}\right)^2 + \left(\frac{65.29}{137.91}\right)^2 = 0.23$ [Ref. IS 800:2007, Cl.10.3.6]	**Pass**

2.6 Compression Flange Check

Check	Required	Provided	Remarks
Tension in Bolt Rows (kN)		$T = [47.66, 47.66, 0, 8.66, 73.27, 22.04]$	**OK**
Reaction at Compression Flange (kN)	$R_c = n_c \sum_{n_r=1}^{n_r} T_{n_r}$ $= 2 \times \sum_{n_r=1}^{6} T_{n_r}$ $= 2 \times 199.29$ $= 398.58$	$F_c = A_g f_y \ / \ \gamma_{m0}$ $= \frac{BTf_y}{\gamma_{m0}}$ $= \frac{142.2 \times 11.2 \times 300}{1.1 \times 1000}$ $= 434.36$	**Pass**

2.7 End Plate Checks

Check	Required	Provided	Remarks
Height (mm)		$H_p = D + (2 \times (2 \times e))$ $= 403.0 + (2 \times (2 \times 30))$ $= 523.0$	**Pass**
Width (mm)		$B_p = B + 25$ $= 142.2 + 25$ $= 167.2$	**Pass**
Moment at Critical Section (kNm)		$M_{cr} = T_1\ l_v - Q\ l_e$ $= (47.66 \times 24.9 - 17.63 \times 28.46) \times 10^{-3}$ $= 0.68$ 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)	$t_p = \sqrt{\frac{4M_{cr}}{b_e(f_y/\gamma_{m0})}}$ $= \sqrt{\frac{4 \times 0.68 \times 10^6}{71 \times (250/1.1)}}$ $= 13.02$	14	**Pass**
Moment Capacity (kNm)	0.68	$M_p = \left(\frac{b_e t_p^2}{4}\right) \times \frac{f_y}{\gamma_{m0}}$ $= \frac{71 \times 14^2}{4} \times \frac{250}{1.1} \times 10^{-6}$ $= 0.79$	**Pass**

2.8 Stiffener Design

Check	Required	Provided	Remarks
Height (mm)		$H_{st} = \frac{H_p - D}{2}$ $= \frac{523.0 - 403.0}{2}$ $= 60$	**Pass**
Length (mm)		$L_{st} = \frac{H_{st}}{\tan 30^\circ}$ $= \frac{60}{\tan 30^\circ}$ $= 104$	**Pass**

Check	Required	Provided	Remarks
Thickness (mm)	$t = 6.8$	$t_{st} = 8$	**Pass**
Weld Size (mm)	5	tw = 6	**Pass**

2.9 Weld Design - Beam Web to End Plate Connection

Check	Required	Provided	Remarks
Weld Strength (N/mm2)	$f_{u_w} = \min(f_w,\ f_u)$ $= \min(440.0,\ 410)$ [Ref. IS 800:2007, Cl.10.5.7.1.1]	$f_{u_w} = 410$	**Pass**
Total Weld Length (mm)		$L_w = 2 \times \left[D - (2 \times T) - (2 \times R1) - 20\right]$ $= 2 \times \left[403.0 - (2 \times 11.2) - (2 \times 10.2) - 20\right]$ $= 680$ Note: Weld is provided on both sides of the web	
Weld Size (mm)	$t_w = \frac{V_u}{f_{uw} k L_w} \times \sqrt{3}\ \gamma_{mw}$ $= \frac{40.0 \times 10^3}{410 \times 0.7 \times 680} \times \sqrt{3} \times 1.25$ $= 0.44$ [Ref. IS 800:2007, Cl.10.5.7]	6	**Pass**

Check	Required	Provided	Remarks
Min. Weld Size (mm)	1) $t_{w\,min}$ – based on thickness of the thicker part $t_{thicker} = \max(14.0,\ 6.8)$ $= 14.0$ $t_{w\,min} = 5$ 2) $t_{w\,min}$ – based on thickness of the thinner part $t_{thinner} = \min(14.0,\ 6.8)$ $= 6.8$ $t_{w\,min} \leq \min(5,\ 6.8)$ [Ref. IS 800:2007, Table 21, Cl 10.5.2.3]	$t_w = \max(t_w,\ t_{w\,min})$ $= \max(0.44,\ 5)$ $= 6$	**Pass**
Max. Weld Size (mm)	$t_{w\,max}$ based on thickness of the thinner part $t_{thinner} = \min(14.0,\ 6.8)$ $= 6.8$ $t_{w\,max} = 6.8$ [Ref. IS 800:2007, Cl.10.5.3.1]	$t_w \leq t_{w\,max}$ $6 \leq 6.8$	**Pass**
Normal Stress (N/mm2)		$f_a = \frac{H}{0.7 t_w L_w}$ $= \frac{12.0 \times 10^3}{0.7 \times 6 \times 680}$ $= 4.2$ [Ref. IS 800:2007, Cl.10.5.9]	**OK**

Check	Required	Provided	Remarks
Shear Stress (N/mm2)		$q = \frac{V}{0.7 t_w L_w}$ $= \frac{40.0 \times 10^3}{0.7 \times 6 \times 680}$ $= 14.0$ [Ref. IS 800:2007, Cl.10.5.9]	**OK**
Equivalent Stress (N/mm2)	$f_e = \sqrt{f_a^2 + 3q^2}$ $= \sqrt{4.2^2 + (3 \times 14.0^2)}$ $= 24.34$ [Ref. IS 800:2007, Cl.10.5.10.1.1]	$f_w = \frac{f_u}{\sqrt{3}\gamma_{mw}}$ $= \frac{410}{\sqrt{3} \times 1.25}$ $= 189.37$ [Ref. IS 800:2007, Cl.10.5.7.1.1]	**Pass**

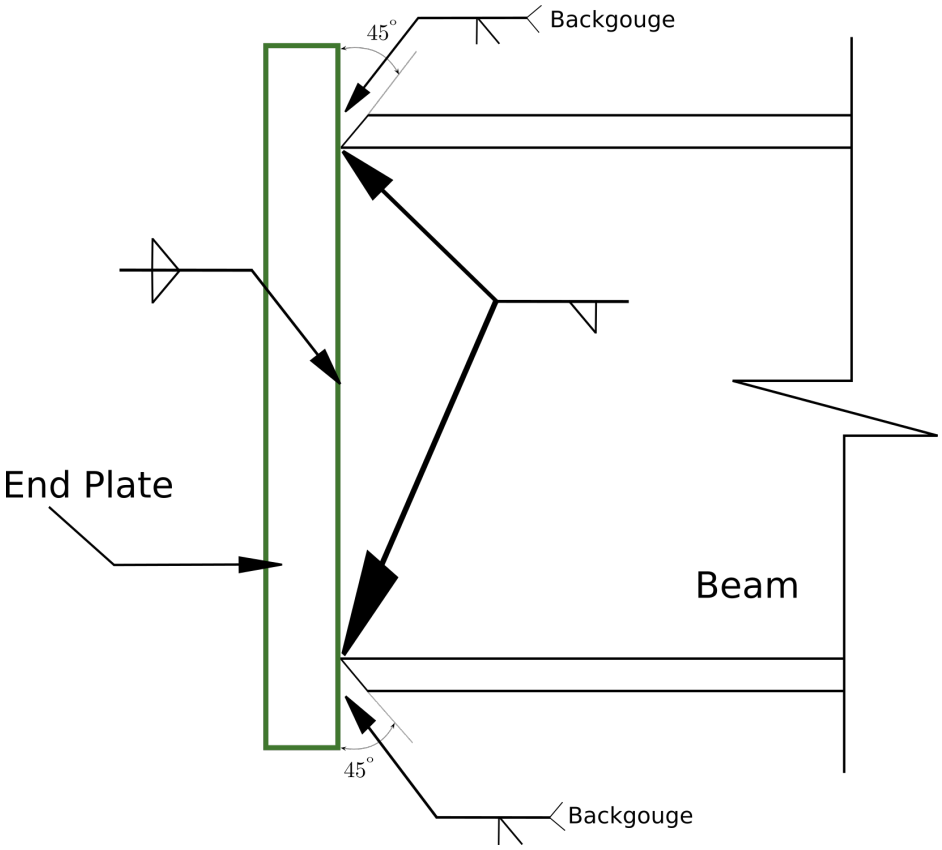


Figure 1: Typical Weld Details -- Beam to End Plate Connection

3 2D Drawings (Typical)

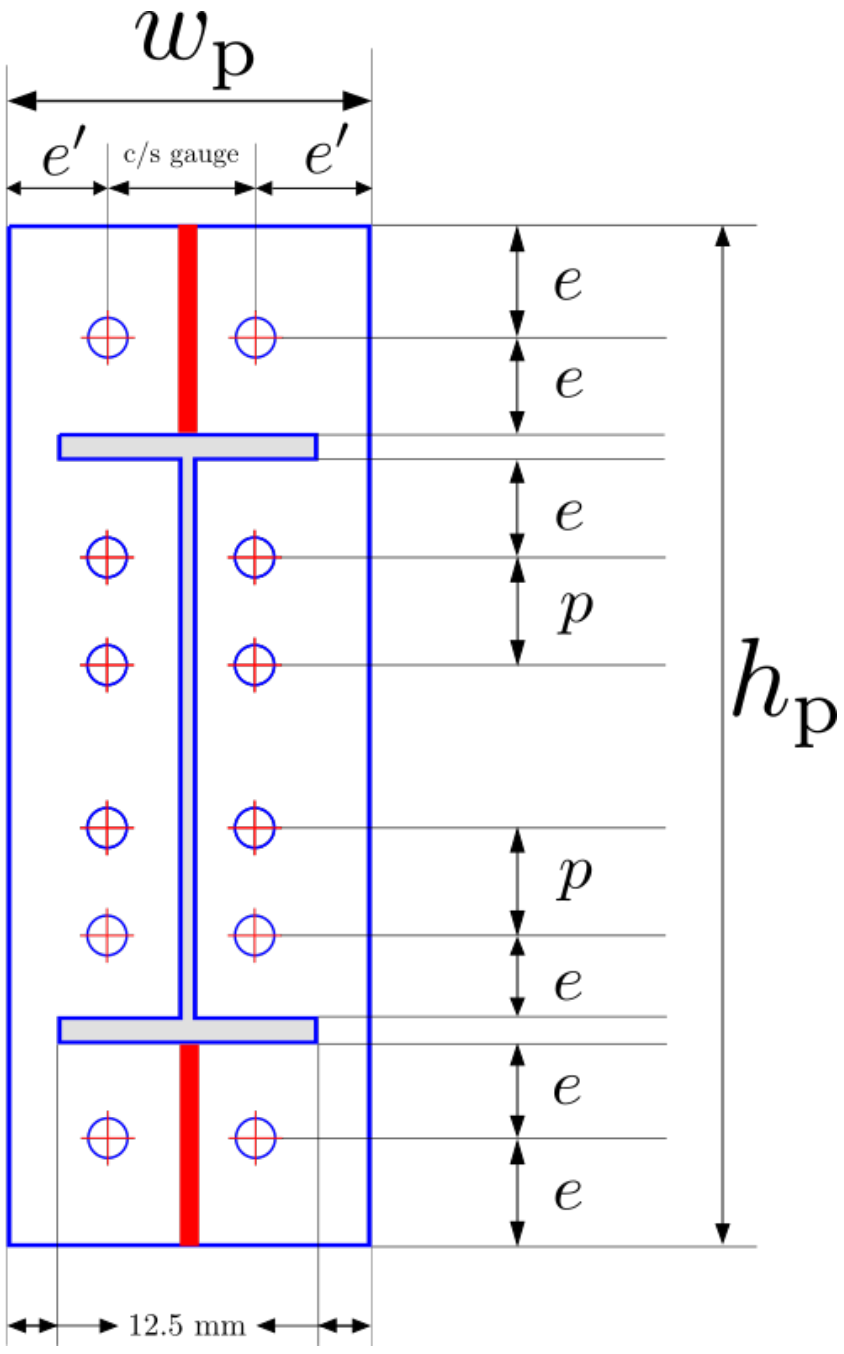


Figure 2: Typical Detailing

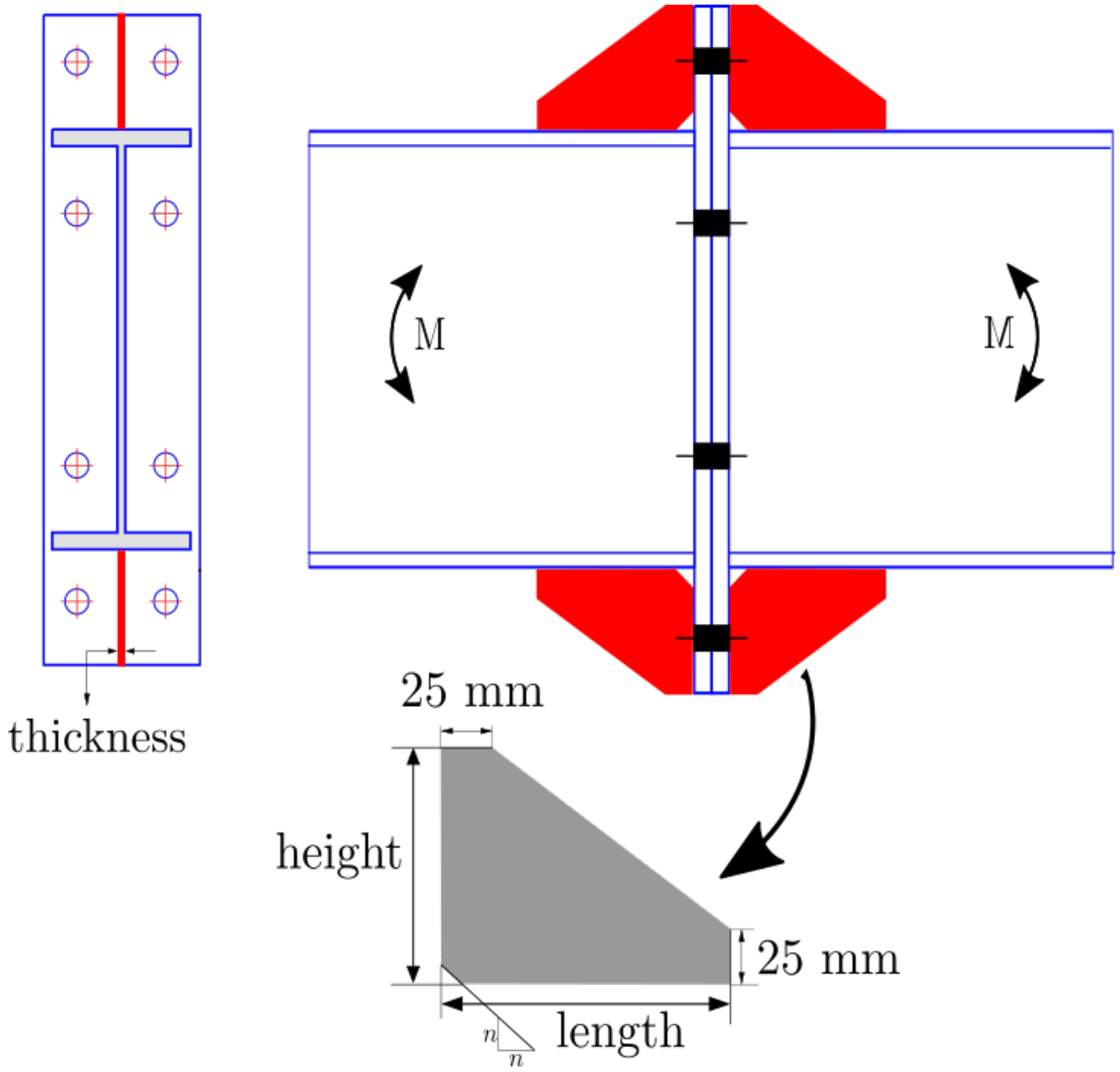
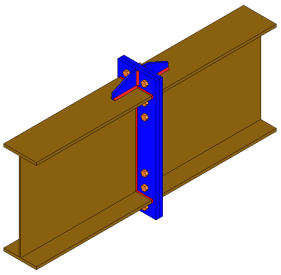
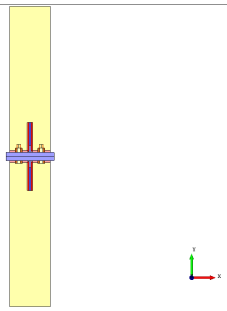


Figure 3: Typical Stiffener Details

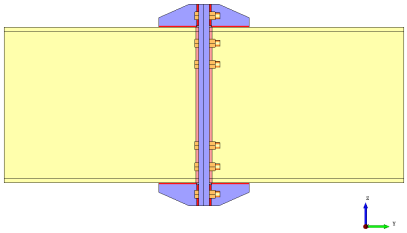
4 3D Views



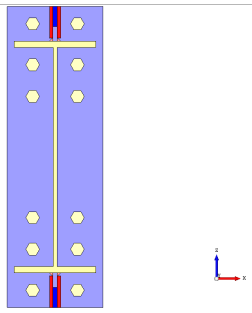
(a) 3D View



(b) Top View



(c) Side View



(d) Front View

5 Design Log

2021-02-04 13:33:15 - Osdag - WARNING - The Load(s) defined is/are less than the minimum recommended value [Ref. IS 800:2007, Cl.10.7].

2021-02-04 13:33:15 - Osdag - WARNING - [Minimum Factored Load] The external factored bending moment (85.0 kNm) is less than 0.5 times the plastic moment capacity of the beam (242.18 kNm)

2021-02-04 13:33:15 - 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 13:33:15 - 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 13:33:15 - Osdag - INFO - Designing the connection for a factored moment of 121.09 kNm

2021-02-04 13:33:15 - Osdag - INFO - [Bolt Design] Bolt diameter and grade combination ready to perform bolt design

2021-02-04 13:33:15 - Osdag - INFO - The solver has selected 1 combinations of bolt diameter and grade to perform optimum bolt design in an iterative manner

2021-02-04 13:33:15 - 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 13:33:15 - 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 13:33:15 - Osdag - INFO - [Flange Strength] The reaction at the compression flange of the beam 398.58 kN is less than the flange capacity 434.36 kN. The flange strength requirement is satisfied.

2021-02-04 13:33:15 - Osdag - INFO - [End Plate] The end plate of 14.0 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 13:33:15 - Osdag - INFO - [Bolt Design] The bolt of 16.0 mm diameter and 12.9 grade passes the tension check

2021-02-04 13:33:15 - Osdag - INFO - Total tension demand on bolt (due to direct tension + prying action) is 65.29 kN and the bolt tension capacity is (137.91 kN)

2021-02-04 13:33:15 - Osdag - INFO - [Bolt Design] The bolt of 16.0 mm diameter and 12.9 grade passes the combined shear + tension check

2021-02-04 13:33:15 - Osdag - INFO - The Interaction Ratio (IR) of the critical bolt is 0.228

2021-02-04 13:33:15 - Osdag - INFO - : ========== Design Status ==========

2021-02-04 13:33:15 - Osdag - INFO - : Overall beam to beam end plate splice connection design is SAFE

2021-02-04 13:33:15 - Osdag - INFO - : ========== End Of Design ==========