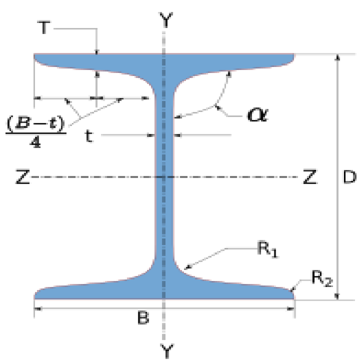
		Created with Osdag®	
Company Name	IIT Bombay	Project Title	Sample Connection Design
Group/Team Name	Osdag	Subtitle	Beam-Beam End Plate Splice
Designer	Engineer #1	Job Number	1.2.1.2.1.3.2
Date	17 /12 /2020	Client	Pradyumna M, Independent Consultant, Bengaluru

1 Input Parameters

Main Module	Moment Connection
Module	Beam-Beam End Plate Splice
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, Fu (MPa)		440	
Yield Strength, Fy (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, Fu (MPa)	410
Yield Strength, Fy (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, (mu_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)		$V_{dy} = \frac{A_v\ f_y}{\sqrt{3}\ \gamma_{mo}}$ $= \frac{0.6 \times 380.6 \times 6.8 \times 300}{\sqrt{3} \times 1.1 \times 1000}$ $= 244.51$ $[Ref. IS\ 800:2007, Cl. 10.4.3]$	**Restricted to low shear**
Plastic Moment Capacity (kNm)		$M_{d_{z-z}} = \frac{\beta_b Z_{pz} fy}{\gamma_{mo}}$ $= \frac{1 \times 888000.0 \times 300}{1.1 \times 10^6}$ $= 242.18$ $[Ref.\ IS\ 800:2007,\ Cl.\ 8.2.1.2]$	**V < 0.6 Vdy**

2.2 Load Consideration

Check	Required	Provided	Remarks
Shear Force (kN)	$V_y = 40.0$	$V_{y_{min}} = min(0.15 \times V_{dy}, 40.0)$ $= min(0.15 \times 244.51,\ 40.0)$ $= min(36.68,\ 40.0)$ $= 36.68$ $V_u = max(V_y,\ V_{y_{min}})$ $= max(40.0,\ 36.68)$ $= 40.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.7]$	**OK**
Axial Force (kN)		P_x = 12.0	**OK**

Check	Required	Provided	Remarks
Bending Moment (kNm)	$M_z = 85.0$	$M_{zmin} = 0.5 * M_{dz-z}$ $= 0.5 \times 242.18$ $= 121.09$ $M_u = max(M_z,\ M_{zmin})$ $= max(85.0, 121.09)$ $= 121.09$ $[Ref.\ IS\ 800:2007,\ Cl.\ 8.2.1.2]$	**OK**
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)	$p_{min} = 2.5\ d$ $= 2.5 \times 16.0$ $= 40.0$ $[Ref\ IS\ 800:2007,\ Cl.\ 10.2.2]$	55	**Pass**
Max. Pitch Distance (mm)	$p_{max} = \min(32\ t,\ 300\ mm)$ $= \min(32 \times 14.0,\ 300\ mm)$ $= \min(448.0,\ 300\ mm)$ $= 300$ $Where,\ t = min(14.0, 14.0)$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.2.3]$	55	**Pass**
Min. End Distance (mm)	$e_{min} = 1.5\ d_0$ $= 1.5 \times 18.0$ $= 27.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.2]$	30	**Pass**
Max. End Distance (mm)	$e_{max} = 12\ t\ \varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 14.0 \times \sqrt{\frac{250}{250}} = 168.0$ $e_2 = 12 \times 14.0 \times \sqrt{\frac{250}{250}} = 168.0$ $e_{max} = min(e_1, e_2) = 168.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.3]$	30	**Pass**
Min. Edge Distance (mm)	$e'_{min} = 1.5\ d_0$ $= 1.5 \times 18.0$ $= 27.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.2]$	30	**Pass**

Check	Required	Provided	Remarks
Max. Edge Distance (mm)	$e'_{max} = 12\ t\ \varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 14.0 \times \sqrt{\frac{250}{250}} = 168.0$ $e_2 = 12 \times 14.0 \times \sqrt{\frac{250}{250}} = 168.0$ $e'_{max} = min(e_1, e_2) = 168.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.3]$	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 rows inside the flange, placed in a symmetrical manner.* *Note : The lever arm is computed by considering the NA 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)	$Q = \frac{l_v}{2 \times l_e}\left[T_e - \frac{\beta \times \eta \times f_o \times b_e \times t^4}{27 \times l_e \times l_v^2}\right]$ $l_v = e - \frac{R_1}{2}$ $= 30 - \frac{10.2}{2} = 24.9\ mm$ $f_o = 0.7 \times f_{ub}$ $= 0.7 \times 1220.0$ $= 854.0\ N/mm^2$ $l_e = min\left(e, 1.1\ t\ \sqrt{\frac{\beta\ f_o}{f_y}}\right)$ $= min\left(30, 1.1 \times 14 \times \sqrt{\frac{1 \times 854.0}{250}}\right)$ $= min(30, 28.46) = 28.46\ mm$ $\beta = 1\ (pre - tensioned\ bolt)$ $\eta = 1.5$ $b_e = \frac{B}{n_c}$ $= \frac{142.2}{2} = 71.1\ mm$ $Q = \frac{24.9}{2 \times 28.46} \times \left[47.66 - \left(\frac{1 \times 1.5 \times 854.0 \times 71.1 \times 14^4}{27 \times 28.46 \times 24.9^2}\right) \times 10^{-3}\right]$ $Q = 17.63$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.4.7]$		**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)	$R_c = n_c \sum_{n_r=1}^{n_r} T_{n_r}$ $= 2 \times \sum_{n_r=1}^{6} T_{n_r}$ $= 2 \times 199.29$ $= 398.58$	$F_c = A_g f_y\ /\ \gamma_{m0}$ $= \frac{B \times T \times f_y}{\gamma_{m0}}$ $= \frac{142.2 \times 11.2 \times 300}{1.1 \times 1000}$ $= 434.36$	**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)	$t_p = \sqrt{\frac{4 M_{cr}}{b_e (f_y/\gamma_{m0})}}$ $= \sqrt{\frac{4 \times 0.68 \times 10^6}{71 \times (250/1.1)}}$ $= 13.02$	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)		$H_{st} = \frac{H_p - D}{2}$ $= \frac{523.0 - 403.0}{2}$ $= 60.0$	**Pass**
Length (mm)		$L_{st} = \frac{H_{st}}{tan(30)}$ $= \frac{60.0}{tan(30)}$ $= 104$	**Pass**

Check	Required	Provided	Remarks
Thickness (mm)	$t = 6.8$	$tst = 8$	**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)	$f_{uw} = min(f_w,\ f_u)$ $= min(440.0,\ 410)$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.5.7.1.1]$	$f_{uw} = 410$	**Pass**
Total Weld Length (mm)		$L_w = 2 \times \left[D - (2 \times T) - (2 \times R1) - 20\right]$ $= 2 \times \left[403.0 - (2 \times 11.2) - (2 \times 10.2) - 20\right]$ $= 680.4000000000001$ $Note:\ Weld\ is\ provided\ on\ both\ sides\ of\ the\ web$	
Weld Size (mm)	$t_w = \frac{V_u}{f_{uw} k L_w} \times \sqrt{3}\ \gamma_{mw}$ $= \frac{40.0 \times 10^3}{410 \times 0.7 \times 680.4000000000001} \times \sqrt{3} \times 1.25$ $= 0.44$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.5.7]$	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)		$f_a = \frac{H}{0.7 \times t_w \times L_w}$ $= \frac{12.0 \times 10^3}{0.7 \times 6 \times 680.4000000000001}$ $= 4.2$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.5.9]$	**OK**

Check	Required	Provided	Remarks
Shear Stress (N/mm2)		$q = \frac{V}{0.7 \times t_w \times L_w}$ $= \frac{40.0 \times 10^3}{0.7 \times 6 \times 680.4000000000001}$ $= 14.0$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.5.9$]	**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**

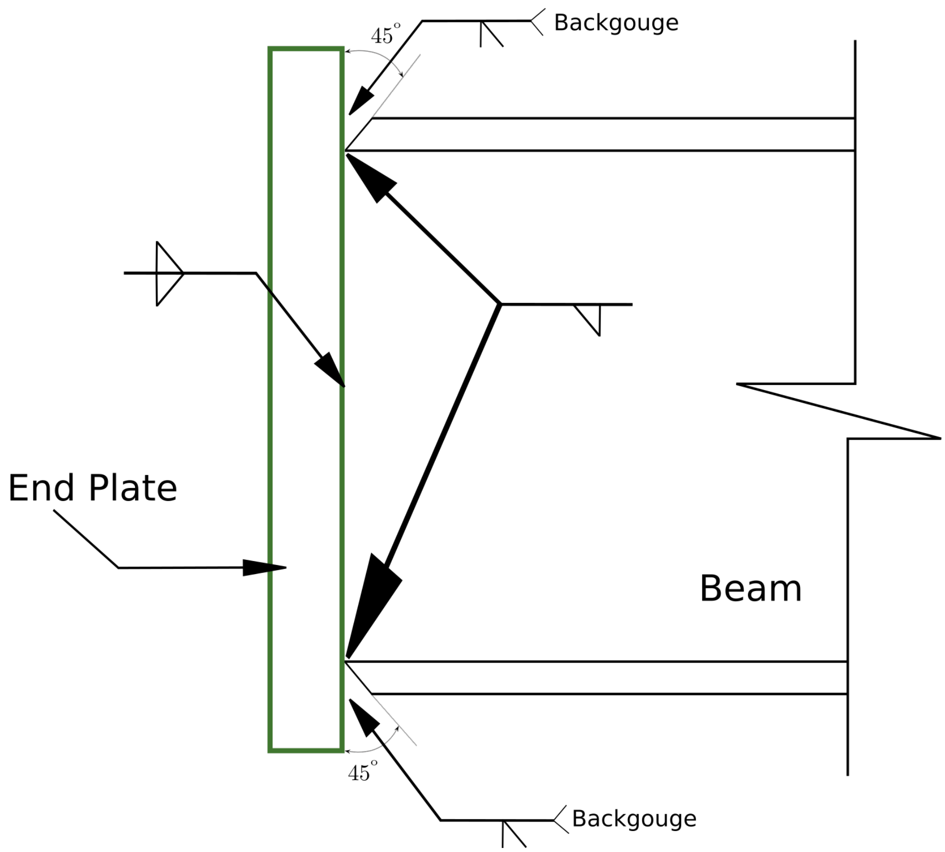


Figure 1: Typical Weld Details - Beam to End Plate Connection

3 2D Drawings (Typical)

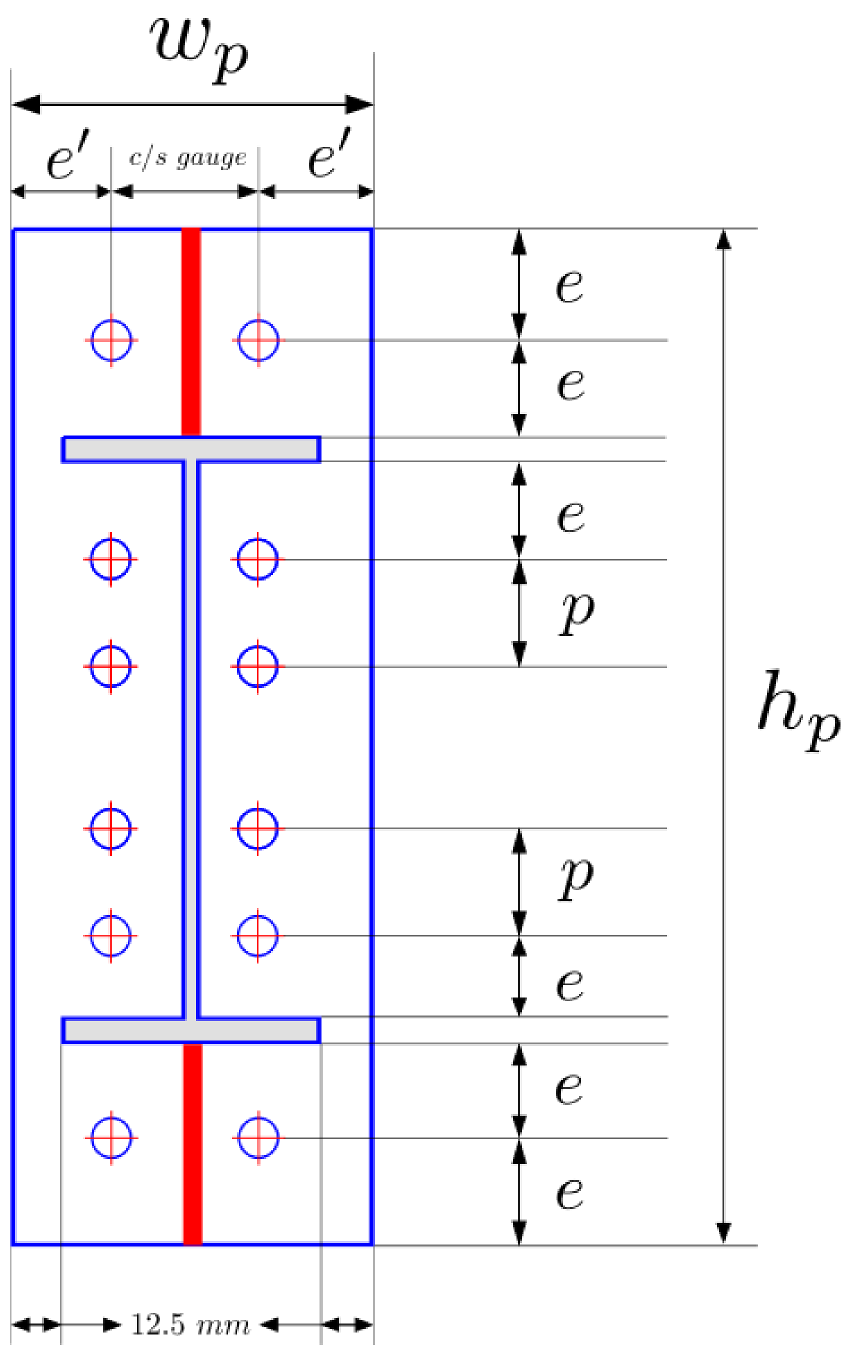


Figure 2: Typical Detailing

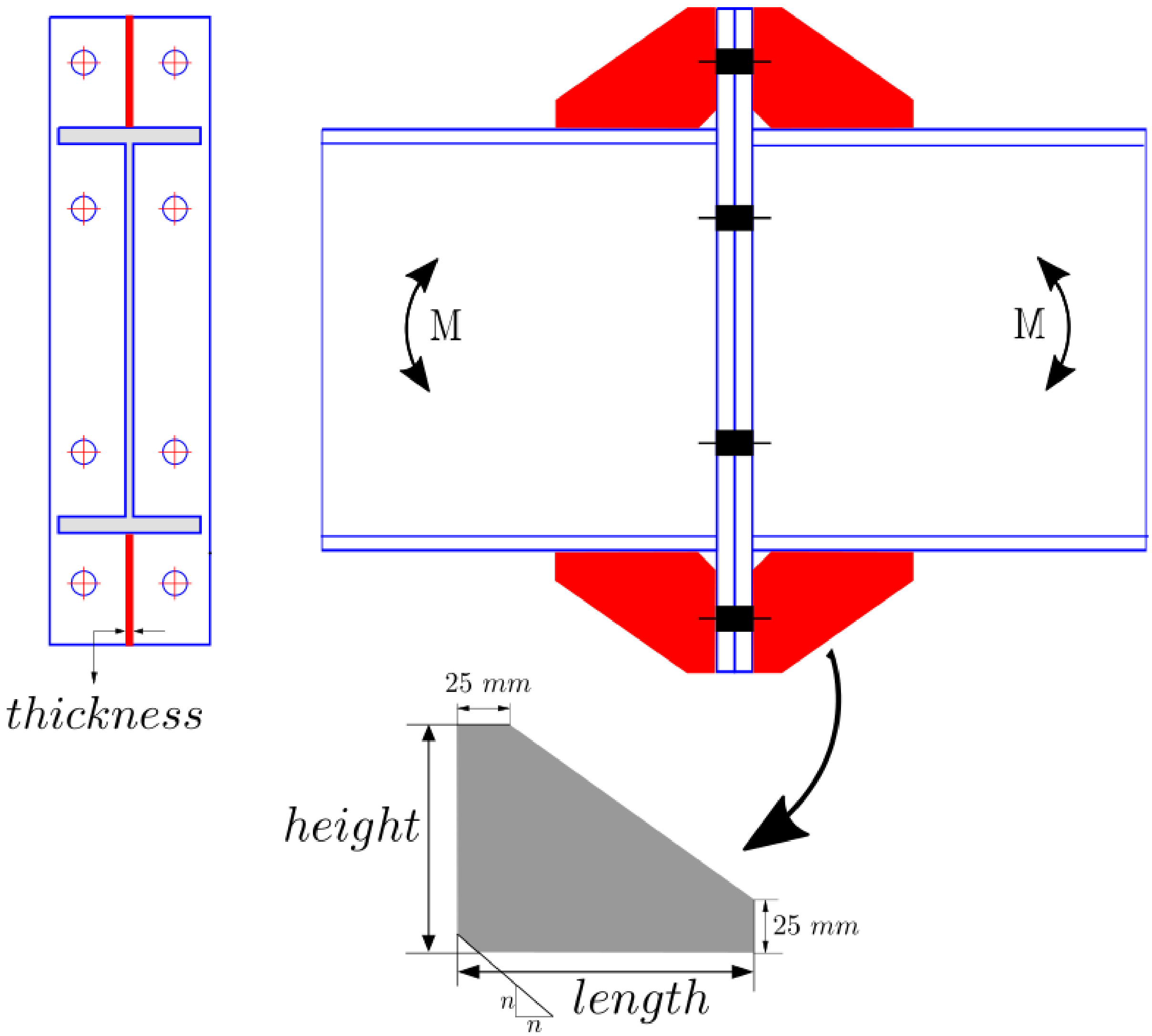
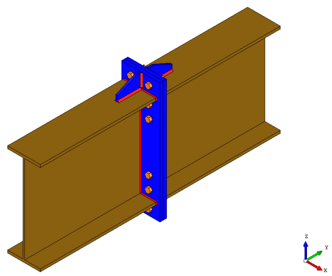
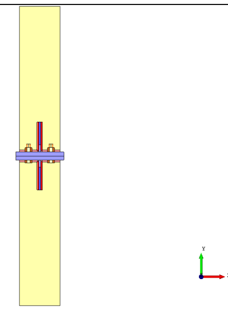


Figure 3: Typical Stiffener Details

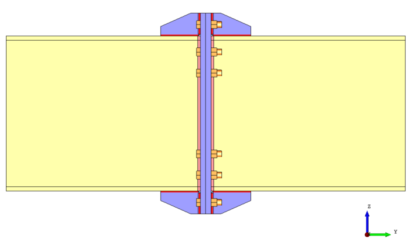
4 3D Views



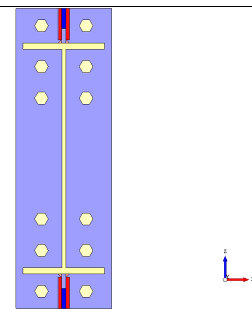
(a) 3D View



(b) Top View



(c) Side View



(d) Front View

5 Design Log

2020-12-17 23:53:12 - Osdag - WARNING - The Load(s) defined is/are less than the minimum recommended value [Ref. IS 800:2007, Cl.10.7].

2020-12-17 23:53:12 - 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)

2020-12-17 23:53:12 - 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)

2020-12-17 23:53:12 - 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

2020-12-17 23:53:12 - Osdag - INFO - Designing the connection for a factored moment of 121.09 kNm

2020-12-17 23:53:12 - Osdag - INFO - [Bolt Design] Bolt diameter and grade combination ready to perform bolt design

2020-12-17 23:53:12 - Osdag - INFO - The solver has selected 1 combinations of bolt diameter and grade to perform optimum bolt design in an iterative manner

2020-12-17 23:53:12 - Osdag - INFO - Checking the design with the following bolt diameter-grade combination [(16.0, 12.9)]

2020-12-17 23:53:12 - Osdag - INFO - [Optimisation] Performing the design by optimising the plate thickness, using the thin plate and large (suitable) bolt diameter approach

2020-12-17 23:53:12 - Osdag - INFO - If you wish to optimise the bolt diameter-grade combination, pass a higher value of plate thickness using the Input Dock

2020-12-17 23:53:12 - Osdag - INFO - The provided beam can accommodate a single column of bolt on either side of the web [Ref. based on the detailing requirement]

2020-12-17 23:53:12 - Osdag - INFO - Performing the design with a single column of bolt on each side

2020-12-17 23:53:12 - Osdag - INFO - [Flange Strength] The reaction at the compression flange of the beam 340.88 kN is less than the flange capacity 434.36 kN. The flange strength requirement is satisfied.

2020-12-17 23:53:12 - Osdag - ERROR - [End Plate] The selected trial end plate of 14.0 mm is insufficient and fails in the moment capacity check

2020-12-17 23:53:12 - Osdag - INFO - The minimum required thickness of end plate is 16.23 mm

2020-12-17 23:53:12 - Osdag - INFO - Re-designing the connection with a plate of available higher thickness

2020-12-17 23:53:12 - Osdag - INFO - [Bolt Design] The bolt of 16.0 mm diameter and 12.9 grade passes the tension check

2020-12-17 23:53:12 - Osdag - INFO - Total tension demand on bolt (due to direct tension + prying action) is 109.07971731795786 kN and the bolt tension capacity is (137.91 kN)

2020-12-17 23:53:12 - Osdag - INFO - [Bolt Design] The bolt of 16.0 mm diameter and 12.9 grade passes the combined shear + tension check

2020-12-17 23:53:12 - Osdag - INFO - The Interaction Ratio (IR) of the critical bolt is 0.635