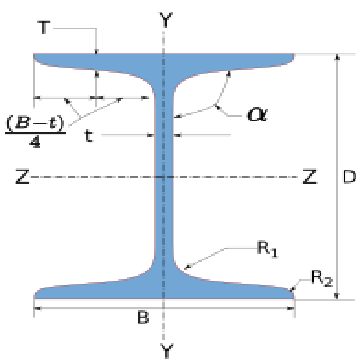
1 Input Parameters

Main Module	Moment Connection
Module	Beam-Beam End Plate Splice
Connectivity	Coplanar Tension-Compression Flange
End Plate Type	Flushed - Reversible Moment
Bending Moment (kNm)	100.0
Shear Force (kN)	40.0
Axial Force (kN)	20.0

Beam Section - Mechanical Properties



Beam Section		MB 400	
Material		E 250 (Fe 410 W)C	
Ultimate Strength, Fu (MPa)		410	
Yield Strength, Fy (MPa)		250	
Mass, m (kg/m)	61.55	I_z (cm^4)	20400.0
Area, A (cm^2)	7840.0	I_y(cm^4)	622.0
D (mm)	400.0	r_z (cm)	16.1
B (mm)	140.0	r_y (cm)	2.81
t (mm)	8.9	Z_z (cm^3)	1020.0
T (mm)	16.0	Z_y (cm^3)	88.8
Flange Slope	98	Z_{pz} (cm^3)	1170.0
R_1 (mm)	14.0	Z_{py} (cm^3)	149.0
R_2 (mm)	7.0		

Plate Details - Input and Design Preference

Thickness (mm)	[22]
Material	E 300 (Fe 440)
Ultimate Strength, Fu (MPa)	440
Yield Strength, Fy (MPa)	290

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)	450.0
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?	True

2 Design Checks

Design Status	Pass

2.1 Member Capacity

Check	Required	Provided	Remarks
Shear Capacity (kN)		$V_{dy} = \frac{A_v\ f_y}{\sqrt{3}\ \gamma_{mo}}$ $= \frac{0.6 \times 368.0 \times 8.9 \times 250}{\sqrt{3} \times 1.1 \times 1000}$ $= 257.86$ $[Ref. IS\ 800:2007, Cl. 10.4.3]$	**Restricted to low shear**
Plastic Moment Capacity (kNm)		$M_{dz-z} = \frac{\beta_b Z_{pz} fy}{\gamma_{mo}}$ $= \frac{1 \times 1170000.0 \times 250}{1.1 \times 10^6}$ $= 265.91$ $[Ref.\ IS\ 800:2007,\ Cl.\ 8.2.1.2]$	**V < 0.6 Vdy**

2.2 Load Consideration

Check	Required	Provided	Remarks
Shear Force (kN)	$V_y = 40.0$	$V_{y_{min}} = min(0.15 \times V_{dy}, 40.0)$ $= min(0.15 \times 257.86,\ 40.0)$ $= min(38.68,\ 40.0)$ $= 38.68$ $V_u = max(V_y,\ V_{y_{min}})$ $= max(40.0,\ 38.68)$ $= 40.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.7]$	**OK**
Axial Force (kN)		P_x = 20.0	**OK**

Check	Required	Provided	Remarks
Bending Moment (kNm)	$M_z = 100.0$	$M_{z min} = 0.5 * M_{d z-z}$ $= 0.5 \times 265.91$ $= 132.96$ $M_u = max(M_z,\ M_{z min})$ $= max(100.0, 132.96)$ $= 132.96$ $[Ref.\ IS\ 800:2007,\ Cl.\ 8.2.1.2]$	**OK**
Effective Bending Moment (kNm)		$M_{ue} = M_u\ +\ P_x \times \left(\frac{D}{2} - \frac{T}{2}\right) \times 10^{-3}$ $= 132.96 +$ $20.0 \times \left(\frac{400.0}{2} - \frac{16.0}{2}\right) \times 10^{-3}$ $= 136.8$	**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		$n_r = 4$	**Pass**
Total No. of Bolts		$n = n_r X n_c = 8$	**Pass**

2.4 Detailing

Check	Required	Provided	Remarks
Min. Pitch Distance (mm)	$p_{min} = 2.5\ d$ $= 2.5 \times 16.0$ $= 40.0$ $[Ref\ IS\ 800:2007,\ Cl.\ 10.2.2]$	55	**Pass**
Max. Pitch Distance (mm)	$p_{max} = \min(32\ t,\ 300\ mm)$ $= \min(32 \times 22.0,\ 300\ mm)$ $= \min(704.0,\ 300\ mm)$ $= 300$ $Where,\ t = min(22.0, 22.0)$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.2.3]$	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)	$e_{max} = 40 + 4t$ $Where, t = min(22.0, 22.0)$ $= 40 + (4 \times 22)$ $e_{max} = 128.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.3]$	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)	$e'_{max} = 40 + 4t$ $Where, t = min(22.0, 22.0)$ $= 40 + (4 \times 22)$ $e'_{max} = 128.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.3]$	30	**Pass**
Cross-centre Gauge Distance (mm)		84	**Pass**

2.5 Critical Bolt Design

Check	Required	Provided	Remarks
Slip Resistance (kN)	$V_{sf} = \frac{V_u}{n}$ $= \frac{40.0}{8}$ $= 5.0$	$V_{dsf} = \frac{\mu_f\ n_e\ K_h\ F_o}{\gamma_{mf}}$ $Where\ , F_o = 0.7 f_{ub} A_{nb}$ $V_{dsf} = \frac{0.48 \times 1 \times 1 \times 0.7 \times 1220.0 \times 157}{1.25 \times 10^3}$ $= 51.49$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.4.3]$	**Pass**
Lever Arm (mm)	$r = [346.0, 38.0, 291.0, 93.0]$ *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 row 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 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**

Check	Required	Provided	Remarks
Tension Due to Moment (kN)	$T_1 = \frac{M_{ue}}{n_c \times \left(r_1 + \sum_{i=2}^{n_r} \frac{r_i^2}{r_1}\right)}$ $= \frac{136.8 \times 10^3}{2 \times \left(346.0 + \sum_{i=2}^{4} \frac{r_i^2}{346.0}\right)}$ $= 110.34$ $Note:$ 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)	$Q = \frac{l_v}{2 \times l_e}\left[T_e - \frac{\beta \times \eta \times f_o \times b_e \times t^4}{27 \times l_e \times l_v^2}\right]$ $l_v = e - \frac{R_1}{2}$ $= 30 - \frac{14.0}{2} = 23.0\ mm$ $f_o = 0.7 \times f_{ub}$ $= 0.7 \times 1220.0$ $= 854.0\ N/mm^2$ $l_e = min\left(e, 1.1\ t\ \sqrt{\frac{\beta\ f_o}{f_y}}\right)$ $= min\left(30, 1.1 \times 22 \times \sqrt{\frac{1 \times 854.0}{290}}\right)$ $= min(30, 41.53) = 30\ mm$ $\beta = 1\ (pre-tensioned\ bolt)$ $\eta = 1.5$ $b_e = \frac{B}{n_c}$ $= \frac{140.0}{2} = 70.0\ mm$ $Q = \frac{23.0}{2 \times 30} \times$ $\left[110.34 - \left(\frac{1 \times 1.5 \times 854.0 \times 70.0 \times 22^4}{27 \times 30 \times 23.0^2}\right) \times 10^{-3}\right]$ $Q = 23.5$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.4.7]$		**OK**

Check	Required	Provided	Remarks
Tension Demand (kN)	$T_f = T_1 + Q$ $= 110.34 + 23.5$ $= 133.84$	$T_f = 0.90\ f_{ub}\ A_n\ /\ \gamma_{mf}$ $<\ f_{yb}\ A_{sb}\ (\gamma_{m1}\ /\ \gamma_{m0})$ $= min\Big(0.90\ \times 1220.0 \times 157\ /\ 1.25,$ $1100.0 \times 201.0 \times (1.25/1.1)\Big)$ $= min(137.91,\ 251.25)$ $= 137.91$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.5]$	**Pass**
Combined Capacity, (I.R)	≤ 1	$\left(\frac{V_{sf}}{V_{df}}\right)^2 + \left(\frac{T_f}{T_{df}}\right)^2 \leq 1.0$ $\left(\frac{5.0}{51.49}\right)^2 + \left(\frac{133.84}{137.91}\right)^2 = 0.95$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.6]$	**Pass**

2.6 Compression Flange Check

Check	Required	Provided	Remarks
Tension in Bolt Rows (kN)		$T = [110.34, 12.12, 92.8, 29.66]$	**OK**
Reaction at Compression Flange (kN)	$R_c = n_c \sum_{n_r=1}^{n_r} T_{n_r}$ $= 2 \times \sum_{n_r=1}^{4} T_{n_r}$ $= 2 \times 244.92$ $= 489.84$	$F_c = A_g f_y\ /\ \gamma_{m0}$ $= \frac{B \times T \times f_y}{\gamma_{m0}}$ $= \frac{140.0 \times 16.0 \times 250}{1.1 \times 1000}$ $= 509.09$	**Pass**

2.7 End Plate Checks

Check	Required	Provided	Remarks
Height (mm)		$H_p = D + 25$ $= 400.0 + 25$ $= 425.0$	**Pass**
Width (mm)		$B_p = B + 25$ $= 140.0 + 25$ $= 165.0$	**Pass**
Moment at Critical Section (kNm)		$M_{cr} = T_1\ l_v - Q\ l_e$ $= (110.34 \times 23.0 - 23.5 \times 30) \times 10^{-3}$ $= 1.83$ $Note: The\ critical\ section\ is\ at\ the\ toe\ of\ the\ weld\ or$ $the\ edge\ of\ the\ flange\ from\ bolt\ center-line$	**OK**
Plate Thickness (mm)	$t_p = \sqrt{\frac{4M_{cr}}{b_e(f_y/\gamma_{m0})}}$ $= \sqrt{\frac{4 \times 1.83 \times 10^6}{70 \times (290/1.1)}}$ $= 19.93$	22	**Pass**
Moment Capacity (kNm)	1.83	$M_p = \left(\frac{b_e t_p^2}{4}\right) \times \frac{f_y}{\gamma_{m0}}$ $= \frac{70 \times 22^2}{4} \times \frac{290}{1.1} \times 10^{-6}$ $= 2.23$	**Pass**

2.8 Longitudinal Stiffener Design

Check	Required	Provided	Remarks
Width (mm)		$W_{st} = B_p - \frac{t}{2}$ $= 165.0 - \frac{8.9}{2}$ $= 78.05$	**Pass**
Length (mm)		$L_{st} = 2 * W_{st}$ $= 2 * 78.05$ $= 156.1$	**Pass**
Thickness (mm)	$t = 8.9$	$tst = 10$	**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)	$f_{uw} = min(f_w,\ f_u)$ $= min(450.0,\ 440)$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.5.7.1.1]$	$f_{uw} = 440$	**Pass**
Total Weld Length (mm)		$L_w = 2 \times \left[D - (2 \times T) - (2 \times R1) - 20\right]$ $= 2 \times \left[400.0 - (2 \times 16.0) - (2 \times 14.0) - 20\right]$ $= 640.0$ $Note:\ Weld\ is\ provided\ on\ both\ sides\ of\ the\ web$	
Weld Size (mm)	$t_w = \frac{V_u}{f_{uw} k L_w} \times \sqrt{3}\ \gamma_{mw}$ $= \frac{40.0 \times 10^3}{440 \times 0.7 \times 640.0} \times \sqrt{3} \times 1.25$ $= 0.44$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.5.7]$	6	**Pass**

Check	Required	Provided	Remarks
Min. Weld Size (mm)	1) $t_{w_{min}}-$ *based on thickness of the thicker part* $t_{thicker} = max(22.0,\ 8.9)$ $= 22.0$ $t_{w_{min}} = 6$ 2) $t_{w_{min}}-$ *based on thickness of the thinner part* $t_{thinner} = min(22.0,\ 8.9)$ $= 8.9$ $t_{w_{min}} \leq min(6,\ 8.9)$ $[Ref\ IS\ 800:2007, Table\ 21\ ,\ Cl 10.5.2.3]$	$t_w = max(t_w,\ t_{w_{min}})$ $= max(0.44,\ 6)$ $= 6$	**Pass**
Max. Weld Size (mm)	$t_{w_{max}}$ *based on thickness of the thinner part* $t_{thinner} = min(22.0,\ 8.9)$ $= 8.9$ $t_{w_{max}} = 8.9$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.5.3.1]$	$t_w \leq t_{w_{max}}$ $6 \leq 8.9$	**Pass**
Normal Stress (N/mm2)		$f_a = \frac{H}{0.7 \times t_w \times L_w}$ $= \frac{20.0 \times 10^3}{0.7 \times 6 \times 640.0}$ $= 7.44$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.5.9]$	**OK**

Check	Required	Provided	Remarks
Shear Stress (N/mm2)		$q = \frac{V}{0.7 \times t_w \times L_w}$ $= \frac{40.0 \times 10^3}{0.7 \times 6 \times 640.0}$ $= 14.88$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.5.9$]	**OK**
Equivalent Stress (N/mm2)	$f_e = \sqrt{f_a^2 + 3q^2}$ $= \sqrt{7.44^2 + (3 \times 14.88^2)}$ $= 25.92$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.5.10.1.1$]	$f_w = \frac{f_u}{\sqrt{3}\ \gamma_{mw}}$ $= \frac{440}{\sqrt{3} \times 1.25}$ $= 203.23$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.5.7.1.1$]	**Pass**

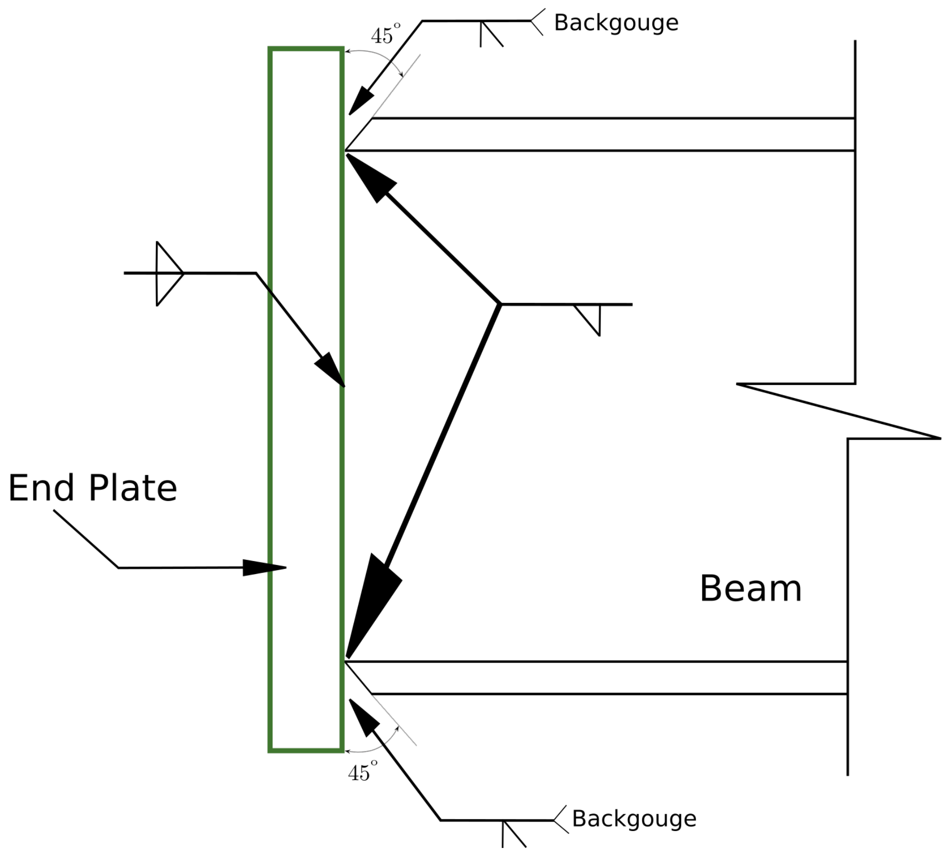


Figure 1: Typical Weld Details - Beam to End Plate Connection

3 2D Drawings (Typical)

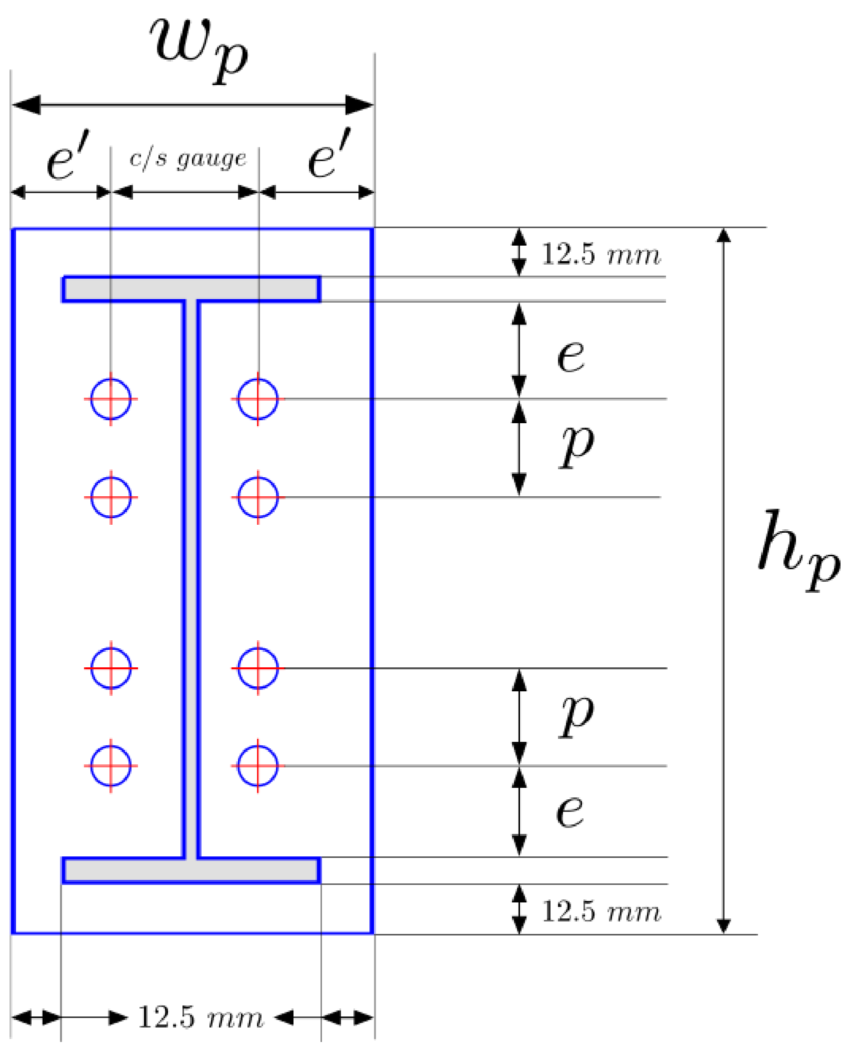


Figure 2: Typical Detailing

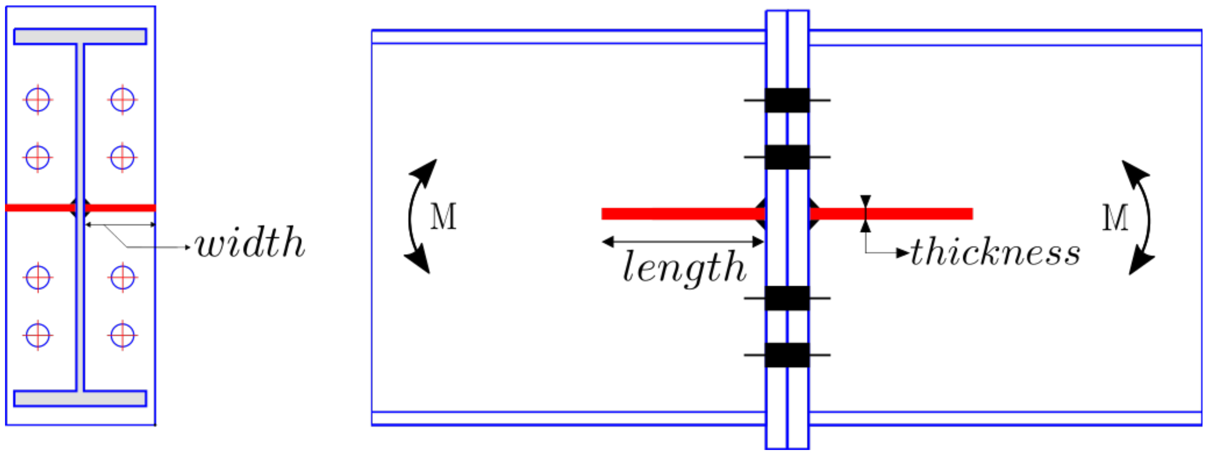
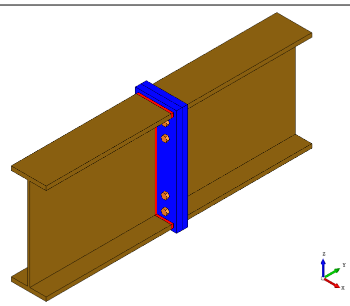
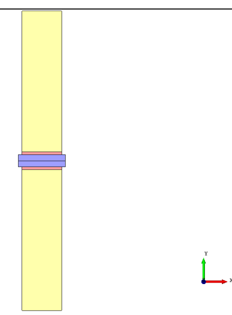


Figure 3: Typical Stiffener Details

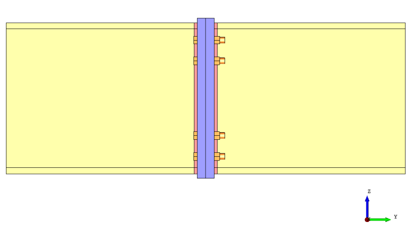
4 3D Views



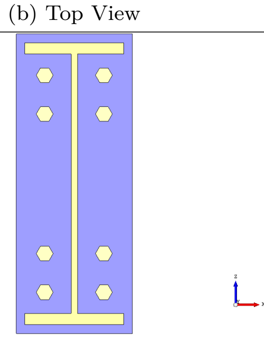
(a) 3D View



(b) Top View



(c) Side View



(d) Front View

5 Design Log

2020-12-17 23:48:34 - Osdag - WARNING - The Load(s) defined is/are less than the minimum recommended value [Ref. IS 800:2007, Cl.10.7].

2020-12-17 23:48:34 - Osdag - WARNING - [Minimum Factored Load] The external factored bending moment (100.0 kNm) is less than 0.5 times the plastic moment capacity of the beam (265.91 kNm)

2020-12-17 23:48:34 - 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 23:48:34 - 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 23:48:34 - Osdag - INFO - Designing the connection for a factored moment of 132.96 kNm

2020-12-17 23:48:34 - Osdag - INFO - [Bolt Design] Bolt diameter and grade combination ready to perform bolt design

2020-12-17 23:48:34 - 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 23:48:34 - Osdag - INFO - Checking the design with the following bolt diameter-grade combination [(16.0, 12.9)]

2020-12-17 23:48:34 - Osdag - INFO - [Optimisation] Performing the design by optimising the plate thickness, using the thin plate and large (suitable) bolt diameter approach

2020-12-17 23:48:34 - 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 23:48:34 - 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 23:48:34 - Osdag - INFO - Performing the design with a single column of bolt on each side

2020-12-17 23:48:35 - Osdag - INFO - [Flange Strength] The reaction at the compression flange of the beam 433.56 kN is less than the flange capacity 509.09 kN. The flange strength requirement is satisfied.

2020-12-17 23:48:35 - Osdag - ERROR - [End Plate] The selected trial end plate of 22.0 mm is insufficient and fails in the moment capacity check

2020-12-17 23:48:35 - Osdag - INFO - The minimum required thickness of end plate is 24.68 mm

2020-12-17 23:48:35 - Osdag - INFO - Re-designing the connection with a plate of available higher thickness

2020-12-17 23:48:35 - Osdag - ERROR - [Bolt Design] The bolt of 16.0 mm diameter and 12.9 grade fails the tension check

2020-12-17 23:48:35 - Osdag - ERROR - Total tension demand on bolt (due to direct tension + prying action) is 251.42179267084845 kN and exceeds the bolt tension capacity (137.91 kN)

2020-12-17 23:48:35 - Osdag - INFO - Re-designing the connection with a bolt of higher grade and/or diameter

2020-12-17 23:48:35 - Osdag - ERROR - [Bolt Design] The bolt of 16.0 mm diameter and 12.9 grade fails the combined shear + tension check

2020-12-17 23:48:35 - Osdag - ERROR - The Interaction Ratio (IR) of the critical bolt is 3.361

2020-12-17 23:48:35 - Osdag - INFO - Re-designing the connection with a bolt of higher grade and/or diameter