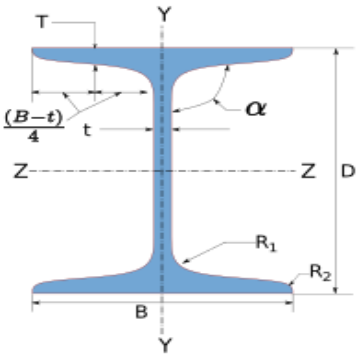
Company Name	IIT Bombay	Project Title	Sample Connection Design
Group/Team Name	Osdag	Subtitle	Beam-Column End Plate
Designer	Engineer #1	Job Number	1.2.2.1.1.2.1
Date	18 /12 /2020	Client	Pratip Bhattacharya, TCE, Kolkata

1 Input Parameters

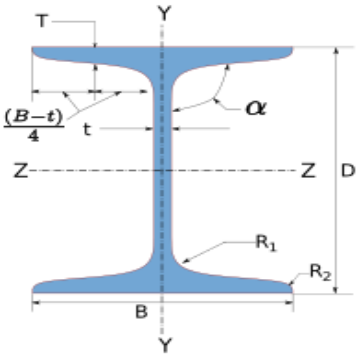
Main Module	Moment Connection
Module	Beam-Column End Plate
Connectivity	Column Flange-Beam Web
End Plate Type	Extended One Way - Irreversible Moment
Bending Moment (kNm)	210.0
Shear Force (kN)	40.0
Axial Force (kN)	15.0

Column Section - Mechanical Properties



Column Section		HB 450	
Material		E 250 (Fe 410 W)A	
Ultimate Strength, Fu (MPa)		410	
Yield Strength, Fy (MPa)		250	
Mass, m (kg/m)	87.22	I_z (cm^4)	39200.0
Area, A (cm^2)	111.0	I_y(cm^4)	2980.0
D (mm)	450.0	r_z (cm)	18.7
B (mm)	250.0	r_y (cm)	5.18
t (mm)	9.8	Z_z (cm^3)	1740.0
T (mm)	13.7	Z_y (cm^3)	238.0
Flange Slope	94	Z_{pz} (cm^3)	1950.0
R_1 (mm)	15.0	Z_{py} (cm^3)	394.0
R_2 (mm)	7.5		

Beam Section - Mechanical Properties



Beam Section		WB 450	
Material		E 250 (Fe 410 W)A	
Ultimate Strength, Fu (MPa)		410	
Yield Strength, Fy (MPa)		250	
Mass, m (kg/m)	79.52	I_z (cm^4)	35100.0
Area, A (cm^2)	101.0	I_y(cm^4)	1700.0
D (mm)	450.0	r_z (cm)	18.6
B (mm)	200.0	r_y (cm)	4.1
t (mm)	9.2	Z_z (cm^3)	1560.0
T (mm)	15.4	Z_y (cm^3)	170.0
Flange Slope	96	Z_{pz} (cm^3)	1760.0

	R_1 (mm)	15.0	Z_{py} (cm^3)	284.0
	R_2 (mm)	7.0		

Plate Details - Input and Design Preference	
Thickness (mm)	[16, 18, 20, 22]
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)	[20, 24, 30]
Property Class	[6.8, 8.8, 9.8]
Type	Bearing Bolt
Bolt Tension	Non pre-tensioned
Hole Type	Standard
Slip Factor, (mu_f)	0.3
Weld Details - Input and Design Preference	
Type of Weld Fabrication	Shop Weld
Material Grade Overwrite, f_u (MPa)	410.0
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	Sheared or hand flame cut
Gap Between Members (mm)	0.0
Are the Members Exposed to Corrosive Influences?	False

2 Design Checks

Design Status	Pass

2.1 Beam to Column - Compatibility Check

Check	Required	Provided	Remarks
Beam Section Compatibility	$B_{req} = B_b + 25$ $= 200.0 + 25$ $= 225.0$	$B_{available} = B_c$ $= 250.0$	**Compatible**

2.2 Member Capacity - Supported Section

Check	Required	Provided	Remarks
Shear Capacity (kN)		$V_{dy} = \frac{A_v\ f_y}{\sqrt{3}\ \gamma_{mo}}$ $= \frac{0.6 \times 419.2 \times 9.2 \times 250}{\sqrt{3} \times 1.1 \times 1000}$ $= 303.63$ $[Ref. IS\ 800 : 2007, Cl. 10.4.3]$	**Restricted to low shear**
Plastic Moment Capacity (kNm)		$M_{dz-z} = \frac{\beta_b Z_{pz} fy}{\gamma_{mo}}$ $= \frac{1.0 \times 1760000.0 \times 250}{1.1 \times 10^6}$ $= 400.0$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 8.2.1.2]$	**V < 0.6 Vdy**

2.3 Member Capacity - Supporting Section

Check	Required	Provided	Remarks

Check	Required	Provided	Remarks
Plastic Moment Capacity (kNm)		$M_{dz-z} = \frac{\beta_b Z_{pz} fy}{\gamma_{mo}}$ $= \frac{0.89 \times 1950000.0 \times 250}{1.1 \times 10^6}$ $= 395.45$ *Note : The capacity of the section is not based on the beam – colum or column design. The actual capacity might vary.* [*Ref. IS* 800 : 2007, *Cl.* 8.2.1.2]	**Semi-compact**
Plastic Moment Capacity (kNm)		$M_{dy-y} = \frac{\beta_b Z_{py} fy}{\gamma_{mo}}$ $= \frac{0.6 \times 394000.0 \times 250}{1.1 \times 10^6}$ $= 54.09$ *Note : The capacity of the section is not based on the beam – colum or column design. The actual capacity might vary.* [*Ref. IS* 800 : 2007, *Cl.* 8.2.1.2]	**Semi-compact**

2.4 Load Consideration

Check	Required	Provided	Remarks
Shear Force (kN)	$V_y = 40.0$	$V_{y_{min}} = min(0.15 \times V_{dy}, 40.0)$ $= min(0.15 \times 303.63,\ 40.0)$ $= min(45.54,\ 40.0)$ $= 40.0$ $V_u = max(V_y,\ V_{y_{min}})$ $= max(40.0,\ 40.0)$ $= 40.0$ [*Ref. IS* 800 : 2007, *Cl.* 10.7]	**OK**

Check	Required	Provided	Remarks
Axial Force (kN)		P_x = 15.0	**OK**
Bending Moment (major axis) (kNm)	$M_z = 210.0$	$M_{zmin} = 0.5 * M_{dz-z}$ $= 0.5 \times 400.0$ $= 200.0$ $M_u = max(M_z,\ M_{zmin})$ $but,\ \leq M_{dz-z}\ of\ the\ column\ section$ $= max(210.0, 200.0)$ ≤ 395.45 $= 210.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 8.2.1.2]$	**OK**
Effective Bending Moment (major axis) (kNm)		$M_{ue} = M_u\ +\ P_x \times \left(\frac{D}{2} - \frac{T}{2}\right) \times 10^{-3}$ $= 210.0 +$ $15.0 \times \left(\frac{450.0}{2} - \frac{15.4}{2}\right) \times 10^{-3}$ $= 213.26$	**OK**

2.5 Bolt Optimization

Check	Required	Provided	Remarks
Diameter (mm)	Bolt Diameter Optimization	$d = 20$	**Pass**
Property Class	Bolt Property Class Optimization	6.8	**Pass**
Hole Diameter (mm)		$d_0 = 22.0$	**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**

2.6 Detailing

Check	Required	Provided	Remarks
Min. Pitch Distance (mm)	$p_{min} = 2.5\ d$ $= 2.5 \times 20.0$ $= 50.0$ [$Ref\ IS\ 800:2007,\ Cl.\ 10.2.2$]	70	Pass
Max. Pitch Distance (mm)	$p_{max} = \min(32\ t,\ 300\ mm)$ $= \min(32 \times 16.0,\ 300\ mm)$ $= \min(512.0,\ 300\ mm)$ $= 300$ $Where,\ t = min(16.0, 16.0)$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.2.3$]	70	Pass
Min. End Distance (mm)	$e_{min} = 1.7\ d_0$ $= 1.7 \times 22.0$ $= 37.4$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.2$]	40	Pass
Max. End Distance (mm)	$e_{max} = 12\ t\ \varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 16.0 \times \sqrt{\frac{250}{250}} = 192.0$ $e_2 = 12 \times 16.0 \times \sqrt{\frac{250}{250}} = 192.0$ $e_{max} = min(e_1, e_2) = 192.0$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.3$]	40	Pass
Min. Edge Distance (mm)	$e'_{min} = 1.7\ d_0$ $= 1.7 \times 22.0$ $= 37.4$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.2$]	40	Pass

Check	Required	Provided	Remarks
Max. Edge Distance (mm)	$e'_{max} = 12\ t\ \varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 16.0 \times \sqrt{\frac{250}{250}} = 192.0$ $e_2 = 12 \times 16.0 \times \sqrt{\frac{250}{250}} = 192.0$ $e'_{max} = min(e_1, e_2) = 192.0$ [*Ref. IS* 800 : 2007, *Cl.* 10.2.4.3]	40	**Pass**
Cross-centre Gauge Distance (mm)		106	**Pass**

2.7 Critical Bolt Design

Check	Required	Provided	Remarks
Shear Capacity (kN)		$V_{dsb} = \frac{f_{ub}\ n_n\ A_{nb}}{\sqrt{3}\ \gamma_{mb}}$ $= \frac{600.0 \times 1 \times 245}{1000 \times \sqrt{3}\ \times\ 1.25}$ $= 67.9$ [*Ref. IS* 800 : 2007, *Cl.* 10.3.3]	**OK**
Kb		$k_b = min\left(\frac{e}{3d_0},\ \frac{p}{3d_0} - 0.25,\ \frac{f_{ub}}{f_u},\ 1.0\right)$ $= min\left(\frac{40}{3 \times 22.0},\ \frac{70}{3 \times 22.0} - 0.25,\ \frac{600.0}{410},\ 1.0\right)$ $= min(0.61, 0.81, 1.46, 1.0)$ $= 0.61$ [*Ref. IS* 800 : 2007, *Cl.* 10.3.4]	**OK**

Check	Required	Provided	Remarks
Bearing Capacity (kN)		$V_{dpb} = \frac{2.5\ k_b\ d\ t\ f_u}{\gamma_{mb}}$ $= \frac{2.5 \times 0.61 \times 20.0 \times 16.0 \times 410}{1000 \times 1.25}$ $= 160.06$ [*Ref. IS* 800 : 2007, *Cl.* 10.3.4]	**OK**
Bolt Capacity (kN)		$V_{db} = min\ (V_{dsb}, V_{dpb})$ $= min\ (67.9, 160.06)$ $= 67.9$ [*Ref. IS* 800 : 2007, *Cl.* 10.3.2]	
Large Grip Length Reduction Factor		$l_g = \sum \left(t_p + t_{member}\right)$ $= \sum \left(16.0 + 13.7\right)$ $= 29.7\ mm$ $5d = 5 \times 20.0 = 100.0$ $8d = 8 \times 20.0 = 160.0$ *Since*, $l_g < 5d$ $\beta_{lg} = 1.0$ [*Ref. IS* 800 : 2007, *Cl.* 10.3.3.2]	**Pass**
Bolt Capacity (post reduction factor) (kN)		$V_{db} = V_{db}\beta_{lg}$ $= 67.9 \times 1.0$ $= 67.9$ [*Ref. IS* 800 : 2007, *Cl.* 10.3.3.2]	**OK**
Shear Demand (kN)	$V_{sb} = \frac{V_u}{n}$ $= \frac{40.0}{8}$ $= 5.0$	Vdb = 67.9	**Pass**

Check	Required	Provided	Remarks
Lever Arm (mm)	$r = [434.6, 434.6, 47.7, 364.6]$ *Note :* r_1 *is the first row outside tension/top flange* r_2 *is the first row inside tension/top flange* r_3 *is the first row inside compression/bottom flange* r_4 *is the second row inside tension/top flange* *row(s)* r_5 *and beyond are rows inside the flange.* *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)	$T_1 = \frac{M_{ue}}{2 \times n_c \times \left(r_1 + \sum_{i=3}^{n_r} \frac{r_i^2}{r_1}\right)}$ $= \frac{213.26 \times 10^3}{2 \times 2 \times \left(434.6 + \sum_{i=3}^{4} \frac{r_i^2}{434.6}\right)}$ $= 71.5$ *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)	$Q = \frac{l_v}{2 \times l_e}\left[T_e - \frac{\beta \times \eta \times f_o \times b_e \times t^4}{27 \times l_e \times l_v^2}\right]$ $l_v = e - \frac{R_1}{2}$ $= 40 - \frac{15.0}{2} = 32.5\ mm$ $f_o = 0.7 \times f_{ub}$ $= 0.7 \times 600.0$ $= 420.0\ N/mm^2$ $l_e = min\left(e, 1.1\ t\ \sqrt{\frac{\beta\ f_o}{f_y}}\right)$ $= min\left(40, 1.1 \times 16 \times \sqrt{\frac{2 \times 420.0}{250}}\right)$ $= min(40, 32.26) = 32.26\ mm$ $\beta = 2\ (non\ pre-tensioned\ bolt)$ $\eta = 1.5$ $b_e = \frac{B}{n_c}$ $= \frac{200.0}{2} = 100.0\ mm$ $Q = \frac{32.5}{2 \times 32.26} \times$ $\left[71.5 - \left(\frac{2 \times 1.5 \times 420.0 \times 100.0 \times 16^4}{27 \times 32.26 \times 32.5^2}\right) \times 10^{-3}\right]$ $Q = 31.49$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.4.7]$		**OK**

Check	Required	Provided	Remarks
Tension Demand (kN)	$T_b = T_1 + Q$ $= 71.5 + 31.49$ $= 102.99$	$T_{db} = 0.90\ f_{ub}\ A_n\ /\ \gamma_{mb}$ $<\ f_{yb}\ A_{sb}\ (\gamma_{mb}\ /\ \gamma_{m0})$ $= min\Big(0.90\ \times 600.0 \times 245\ /\ 1.25,$ $480.0 \times 314.0 \times (1.25/1.1)\Big)$ $= min(105.84,\ 171.27)$ $= 105.84$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.5]$	**Pass**
Combined Capacity, (I.R)	≤ 1	$\left(\frac{V_{sb}}{V_{db}}\right)^2 + \left(\frac{T_b}{T_{db}}\right)^2 \leq 1.0$ $\left(\frac{5.0}{67.9}\right)^2 + \left(\frac{102.99}{105.84}\right)^2 = 0.95$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.6]$	**Pass**

2.8 Compression Flange Check

Check	Required	Provided	Remarks
Tension in Bolt Rows (kN)		$T = [71.5, 71.5, 15.69, 119.96]$	**OK**
Reaction at Compression Flange (kN)	$R_c = n_c \sum_{n_r=1}^{n_r} T_{n_r}$ $= 2 \times \sum_{n_r=1}^{4} T_{n_r}$ $= 2 \times 278.65$ $= 557.3$	$F_c = A_g f_y\ /\ \gamma_{m0}$ $= \frac{B \times T \times f_y}{\gamma_{m0}}$ $= \frac{200.0 \times 15.4 \times 250}{1.1 \times 1000}$ $= 700.0$	**Pass**

2.9 End Plate Checks

Check	Required	Provided	Remarks
Height (mm)		$H_p = D + 12.5 + (2 \times e)$ $= 450.0 + 12.5 + (2 \times 40)$ $= 542.5$	**Pass**
Width (mm)		$B_p = B + 25$ $= 200.0 + 25$ $= 225.0$	**Pass**
Moment at Critical Section (kNm)		$M_{cr} = T_1\ l_v - Q\ l_e$ $= (71.5 \times 32.5 - 31.49 \times 32.26) \times 10^{-3}$ $= 1.31$ *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)	$t_p = \sqrt{\frac{4M_{cr}}{b_e(f_y/\gamma_{m0})}}$ $= \sqrt{\frac{4 \times 1.31 \times 10^6}{100 \times (250/1.1)}}$ $= 15.17$	16	**Pass**
Moment Capacity (kNm)	1.31	$M_p = \left(\frac{b_e t_p^2}{4}\right) \times \frac{f_y}{\gamma_{m0}}$ $= \frac{100 \times 16^2}{4} \times \frac{250}{1.1} \times 10^{-6}$ $= 1.45$	**Pass**

2.10 Stiffener Design

Check	Required	Provided	Remarks
Height (mm)		$H_{st} = H_p - D - 12.5$ $= 542.5 - 450.0 - 12.5$ $= 80.0$	**80.0**
Length (mm)		$L_{st} = \frac{H_{st}}{tan(30)}$ $= \frac{80.0}{tan(30)}$ $= 140$	**Pass**
Thickness (mm)	$t = 9.2$	$tst = 10$	**Pass**

Check	Required	Provided	Remarks
Weld Size (mm)	5	tw = 6	**Pass**

2.11 Weld Design - Beam Web to End Plate Connection

Check	Required	Provided	Remarks
Weld Strength (N/mm2)	$f_{uw} = min(f_w,\ f_u)$ $= min(410.0,\ 410)$ [*Ref. IS* 800 : 2007, *Cl.* 10.5.7.1.1]	$f_{uw} = 410.0$	**Pass**
Total Weld Length (mm)		$L_w = 2 \times \left[D - (2 \times T) - (2 \times R1) - 20\right]$ $= 2 \times \left[450.0 - (2 \times 15.4) - (2 \times 15.0) - 20\right]$ $= 729.2$ *Note : Weld is provided on both sides of the web*	**OK**
Weld Size (mm)	$t_w = \frac{V_u}{f_{uw} k L_w} \times \sqrt{3}\ \gamma_{mw}$ $= \frac{40.0 \times 10^3}{410.0 \times 0.7 \times 729.2} \times \sqrt{3} \times 1.25$ $= 0.41$ [*Ref. IS* 800 : 2007, *Cl.* 10.5.7]	6	**Pass**

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Designer	Engineer #1	Job Number	1.2.2.1.1.2.1
Date	18 /12 /2020	Client	Pratip Bhattacharya, TCE, Kolkata

Check	Required	Provided	Remarks
Min. Weld Size (mm)	1) t_{wmin} – *based on thickness of the thicker part* $t_{thicker} = max(16.0,\ 9.2)$ $= 16.0$ $t_{wmin} = 5$ 2) t_{wmin} – *based on thickness of the thinner part* $t_{thinner} = min(16.0,\ 9.2)$ $= 9.2$ $t_{wmin} \leq min(5,\ 9.2)$ [*Ref IS* 800 : 2007, *Table* 21 , *Cl*10.5.2.3]	$t_w = max(t_w,\ t_{wmin})$ $= max(0.41,\ 5)$ $= 6$	**Pass**
Max. Weld Size (mm)	t_{wmax} *based on thickness of the thinner part* $t_{thinner} = min(16.0,\ 9.2)$ $= 9.2$ $t_{wmax} = 9.2$ [*Ref. IS* 800 : 2007, *Cl.* 10.5.3.1]	$t_w \leq t_{wmax}$ $6 \leq 9.2$	**Pass**
Normal Stress (N/mm2)		$f_a = \frac{H}{0.7 \times t_w \times L_w}$ $= \frac{15.0 \times 10^3}{0.7 \times 6 \times 729.2}$ $= 4.9$ [*Ref. IS* 800 : 2007, *Cl.* 10.5.9]	

Check	Required	Provided	Remarks
Shear Stress (N/mm2)		$q = \frac{V}{0.7 \times t_w \times L_w}$ $= \frac{40.0 \times 10^3}{0.7 \times 6 \times 729.2}$ $= 13.06$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.5.9$]	
Equivalent Stress (N/mm2)	$f_e = \sqrt{f_a^2 + 3q^2}$ $= \sqrt{4.9^2 + (3 \times 13.06^2)}$ $= 22.73$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.5.10.1.1$]	$f_w = \frac{f_u}{\sqrt{3}\ \gamma_{mw}}$ $= \frac{410.0}{\sqrt{3} \times 1.25}$ $= 189.37$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.5.7.1.1$]	**Pass**

2.12 Continuity Plate Check - Compression Flange

Check	Required	Provided	Remarks
Local Web Yielding Capacity (kN)		$P_{cw_1} = \frac{f_{wc}\ (5k + T_b)}{\gamma_{m0}}$ $k = T_c + R_{1c}$ $= 13.7 + 15.0$ $= 28.7$ $f_{wc} = f_{yc} \times t_c$ $= 250.0 \times 9.8$ $= 2450.0$ $P_{cw_1} = \frac{2450.0 \times ((5 \times 28.7) + 15.4)}{1.1 \times 1000}$ $= 353.91$ *Note : subscript c denotes column section, and, subscript b denotes beam section*	**OK**

Check	Required	Provided	Remarks
Web Compression Buckling Capacity (kN)		$P_{cw_2} = 10710 \left(\frac{t_c^3}{h_c}\right) \sqrt{\frac{f_{yc}}{\gamma_{m0}}}$ $h_c = D_c - (2 \times k)$ $= 450.0 - (2 \times 28.7)$ $= 392.6$ $P_{cw_2} = 10710 \times \frac{9.8^3}{392.6} \times \sqrt{\frac{250.0}{1.1}} \times 10^{-3}$ $= 387.07$	**OK**
Web Crippling Capacity (kN)		$P_{cw_3} = \left(\frac{300t_c^2}{\gamma_{m1}}\right)\left[1 + 3\left(T_b/D_c\right)\left(t_c/T_c\right)^{1.5}\right]\sqrt{f_{yc}\left(T_c/t_c\right)}$ $= \left(\frac{300 \times 9.8^2}{1.25}\right) \times \left[1 + 3 \times \left(15.4/450.0\right) \times \left(9.8/13.7\right)^{1.5}\right] \times$ $\sqrt{250.0 \times \left(13.7/9.8\right)} \times 10^{-3}$ $= 457.67$	**OK**
Compression Strength (kN)		$P_{cw} = min(P_{cw_1},\ P_{cw_2},\ P_{cw_3})$ $= min(353.91,\ 387.07,\ 457.67)$ $= 353.91$	**OK**
Continuity Plate Required?	$R_c = 557.3$	$P_{cw} = 353.91$	**Yes**

2.13 Continuity Plate Design - Compression Flange

Check	Required	Provided	Remarks
Area Required (mm2)	$A_{cp} = \frac{R_c - P_{cw}}{f_{y_{cp}}\gamma_{m0}}$ $= \frac{\left(557.3 - 353.91\right) \times 10^3}{250 \times 1.1}$ $= 739.6$		**OK**
Notch Size (mm)		$n = 24$	**OK**

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Designer	Engineer #1	Job Number	1.2.2.1.1.2.1
Date	18 /12 /2020	Client	Pratip Bhattacharya, TCE, Kolkata

Check	Required	Provided	Remarks
Length (mm)		$l_{cp1} = Outer\ length$ $l_{cp1} = D_c - 2 \times T_c$ $= 450.0 - (2 \times 13.7)$ $= 422.6$ $l_{cp2} = Inner\ length$ $l_{cp2} = D_c - 2(T_c + n)$ $= 450.0 - \left[2 \times (13.7 + 24)\right]$ $= 374.6$	**OK**
Width (mm)		$w_{cp} = \frac{B_c - T_c - 2n}{2}$ $= \frac{250.0 - 9.8 - 2 \times 24}{2}$ $= 96.0$	**OK**

Check	Required	Provided	Remarks
Thickness (mm)	$t_{cp1} = Minimum\ area\ criteria$ $t_{cp1} = \frac{A_{cp}/2}{w_{cp}}$ $= \frac{739.6/2}{96.0}$ $= 3.85$ $t_{cp2} = Limiting\ b/t\ ratio\ criteria$ $t_{cp2} = \frac{l_{cp1}}{29.3\ \epsilon_{cp}}$ $\epsilon_{cp} = \sqrt{\frac{250}{f_{y_{cp}}}}$ $= \sqrt{\frac{250}{250}}$ $= 1.0$ $= \frac{422.6}{29.3 \times 1.0}$ $= 14.42$ $t_{cp3} = Minimum\ thickness\ criteria$ $t_{cp3} = T_b$ $= 15.4$ $t_{cp} = max(t_{cp1},\ t_{cp2},\ t_{cp3})$ $= max(3.85, 14.42, 15.4)$ $= 15.4$	16	**Pass**

2.14 Continuity Plate Check - Tension Flange

Check	Required	Provided	Remarks
Continuity Plate Required?	$= 0.4\sqrt{\frac{B_b T_b}{\gamma_{m0}}}$ $= 0.4\sqrt{\frac{200.0 \times 15.4}{1.1}}$ $= 21.17$	$T_c = 13.7$	**Yes**

2.15 Continuity Plate Design - Tension Flange

Check	Required	Provided	Remarks
Notch Size (mm)		$n = 24$	**OK**
Length (mm)		$l_{cp1} = Outer\ length$ $l_{cp1} = D_c - 2 \times T_c$ $= 450.0 - (2 \times 13.7)$ $= 422.6$ $l_{cp2} = Inner\ length$ $l_{cp2} = D_c - 2(T_c + n)$ $= 450.0 - \left[2 \times (13.7 + 24)\right]$ $= 374.6$	**OK**
Width (mm)		$w_{cp} = \frac{B_c - T_c - 2n}{2}$ $= \frac{250.0 - 9.8 - 2 \times 24}{2}$ $= 96.0$	**OK**

Check	Required	Provided	Remarks
Thickness (mm)	$t_{st1} = Minimum\ area\ criteria$ $t_{st1} = \frac{A_{cp}/2}{w_{cp}}$ $= \frac{739.6/2}{96.0}$ $= 3.85$ $t_{st2} = Minimum\ thickness\ criteria$ $t_{st2} = T_b$ $= 15.4$ $t_{st} = max(t_{st1},\ t_{st2})$ $= max(3.85,\ 15.4)$ $= 15.4$	16	**Pass**

2.16 Weld Design - Continuity Plate

Check	Required	Provided	Remarks
Weld Strength (N/mm2)	$f_{uw} = min(f_w,\ f_{ucp})$ $= min(410.0,\ 410)$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.5.7.1.1]$	$f_{uw} = 410.0$	**Pass**
Total (effective) Weld Length (mm)		$L_{wcp} = 364.8$ $Note: Provide\ weld\ on\ one\ side\ of\ the\ continuity\ plate$	**OK**
Weld Size (mm)	$t_{wcp} = \frac{V_{cp}/2}{f_{uw}\ k\ L_{wcp}} \times \sqrt{3}\ \gamma_{mw}$ $= \frac{R_c - P_{cw}}{2 \times f_{uw}\ k\ L_{wcp}} \times \sqrt{3}\ \gamma_{mw}$ $= \frac{(557.3 - 353.91) \times 10^3}{2 \times 410.0 \times 0.7 \times 364.8} \times \sqrt{3} \times 1.25$ $= 2.1$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.5.7]$	5	**Pass**

Check	Required	Provided	Remarks
Min. Weld Size (mm)	1) t_{wmin} – *based on thickness of the thicker part* $t_{thicker} = max(16,\ 9.8)$ $= 16$ $t_{wmin} = 5$ 2) t_{wmin} – *based on thickness of the thinner part* $t_{thinner} = min(16,\ 9.8)$ $= 9.8$ $t_{wmin} \leq min(5,\ 9.8)$ [$Ref\ IS\ 800:2007, Table\ 21\ ,\ Cl 10.5.2.3$]	$t_w = max(t_w,\ t_{wmin})$ $= max(2.1,\ 5)$ $= 5$	**Pass**
Max. Weld Size (mm)	t_{wmax} *based on thickness of the thinner part* $t_{thinner} = min(16,\ 9.8)$ $= 9.8$ $t_{wmax} = 10$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.5.3.1$]	$t_w \leq t_{wmax}$ $5 \leq 10$	**Pass**

2.17 Column Web Shear Check

Check	Required	Provided	Remarks
Web Stiffener Plate Required ?	$t_{wc} = \frac{1.9 M_{ue}}{D_c\ D_b\ f_{yc}}$ $= \frac{1.9 \times 213.26}{450.0 \times 450.0 \times 250.0}$ $= 8.0$	$t_c = 9.8$	**No**

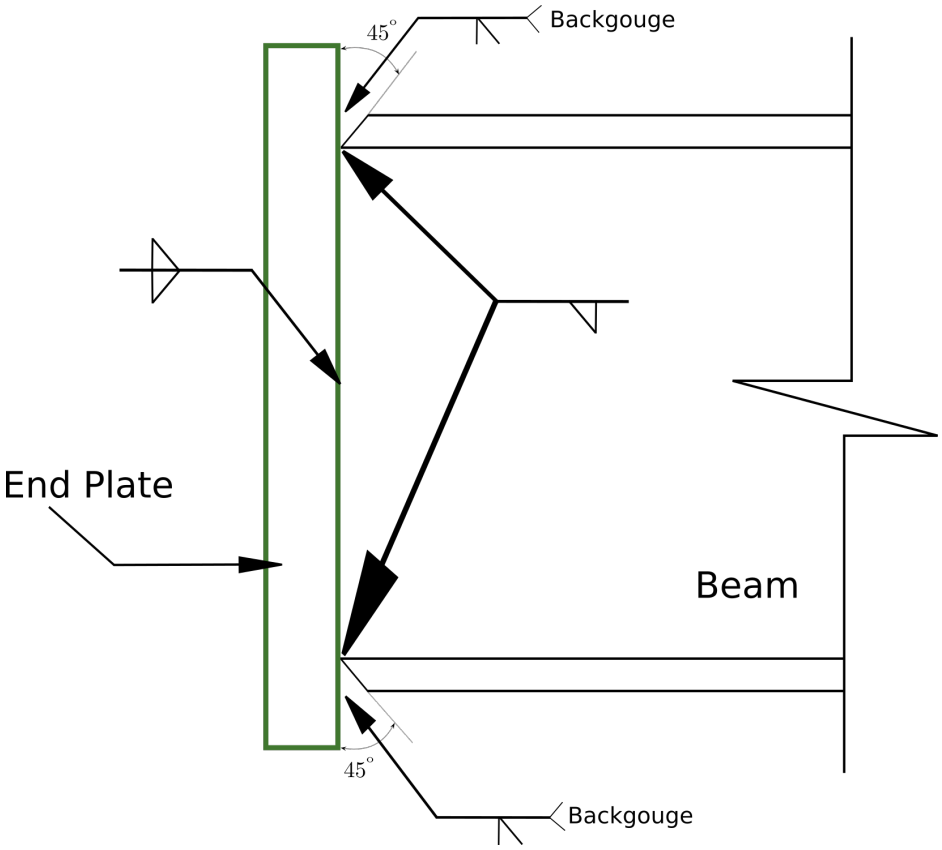


Figure 1: Typical Weld Details - Beam to End Plate Connection

3 2D Drawings (Typical)

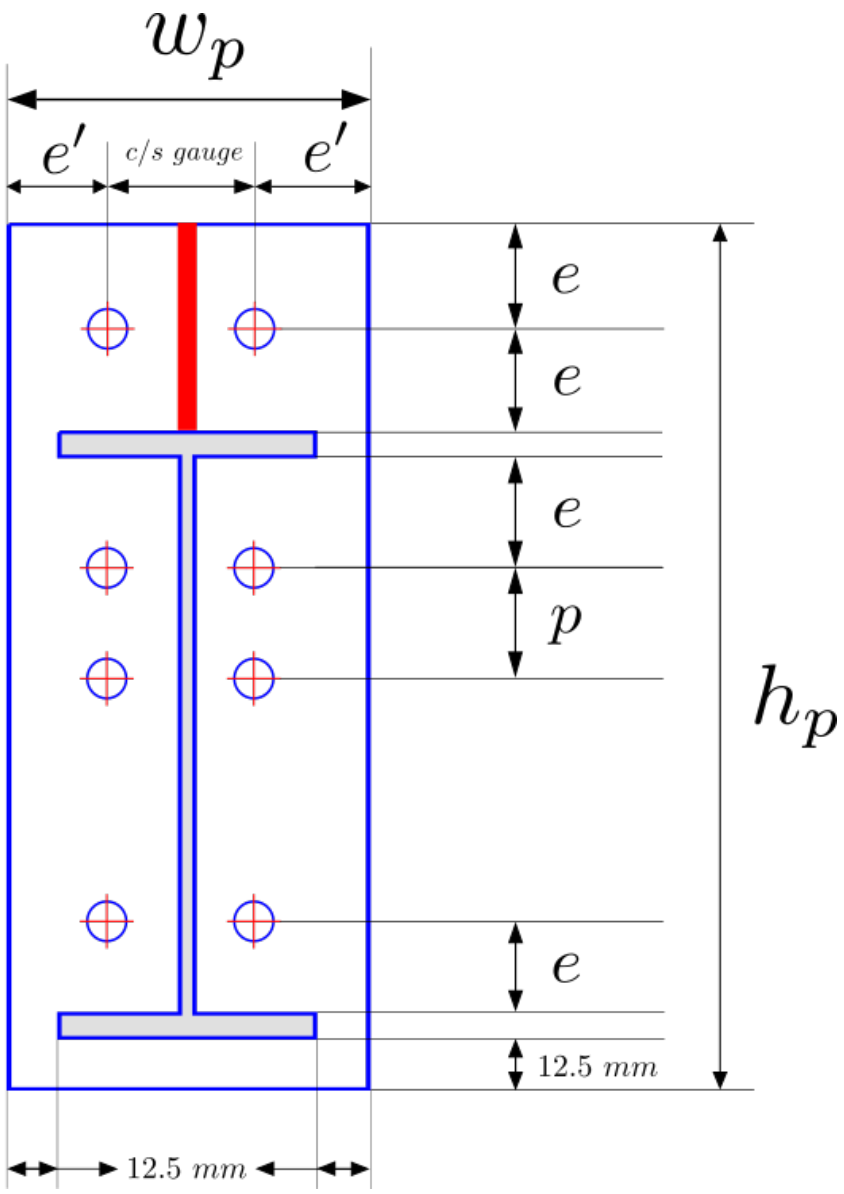


Figure 2: Typical Detailing

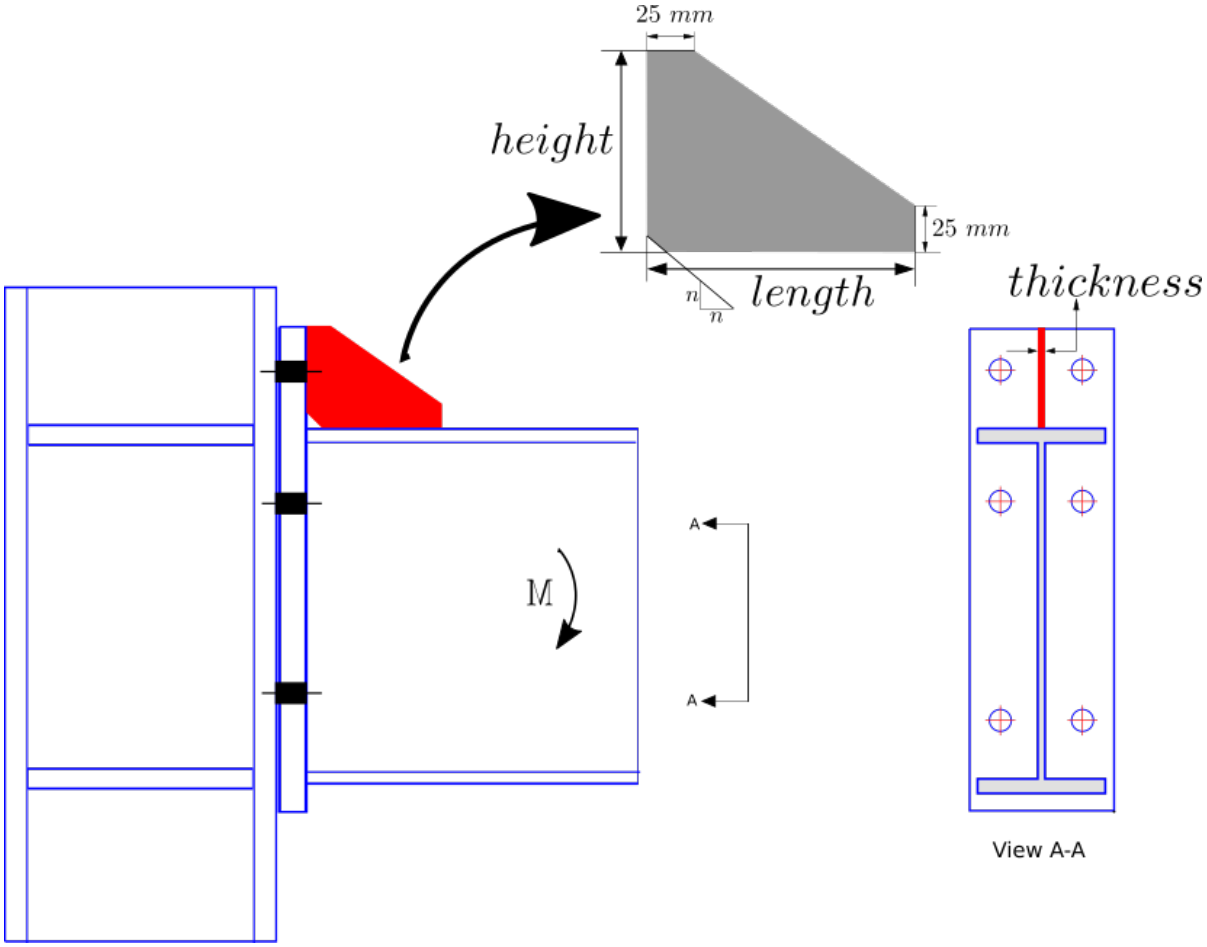
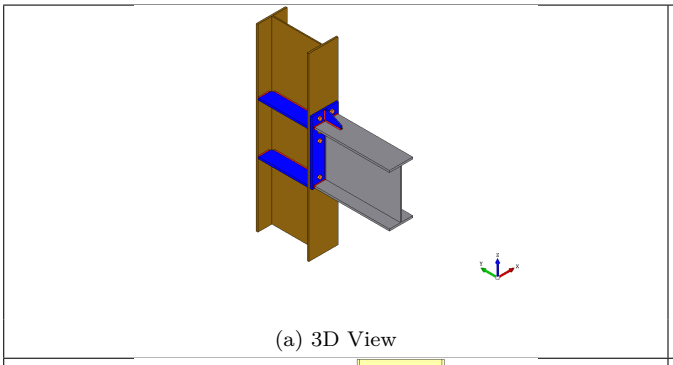
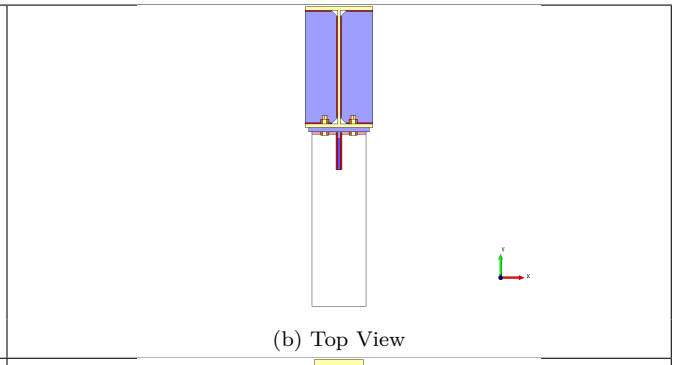


Figure 3: Typical Stiffener Details

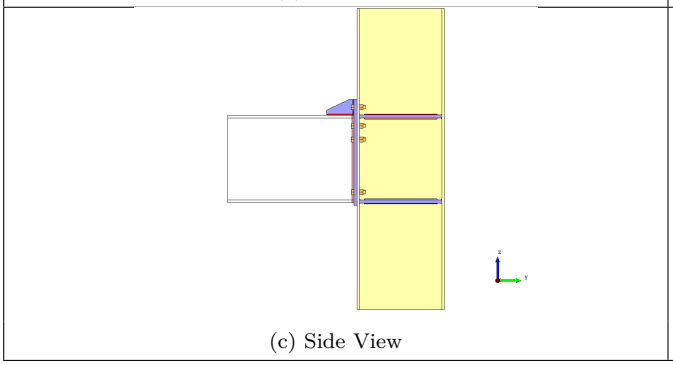
4 3D Views



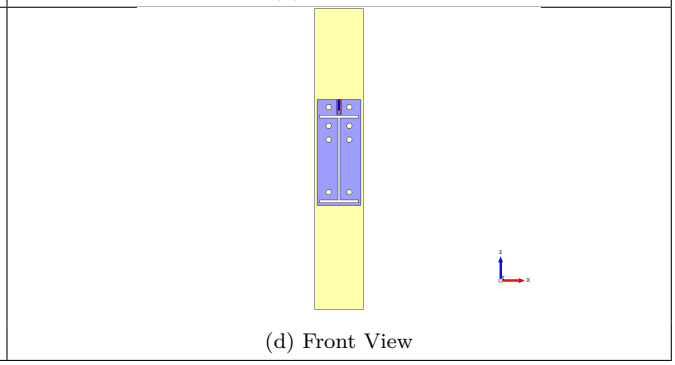
(a) 3D View



(b) Top View



(c) Side View



(d) Front View

5 Design Log

2020-12-18 00:13:14 - Osdag - INFO - [Bolt Design] Bolt diameter and grade combination ready to perform bolt design
2020-12-18 00:13:14 - Osdag - INFO - The solver has selected 9.0 combinations of bolt diameter and grade to perform optimum bolt design in an iterative manner
2020-12-18 00:13:14 - Osdag - INFO - Checking the design with the following bolt diameter-grade combination [(20.0, 6.8), (20.0, 8.8), (20.0, 9.8), (24.0, 6.8), (24.0, 8.8), (24.0, 9.8), (30.0, 6.8), (30.0, 8.8), (30.0, 9.8)]
2020-12-18 00:13:14 - Osdag - WARNING - [Column Web] The web of the column is not susceptible to shear bucking due to the reaction transferred by the beam to the column
2020-12-18 00:13:14 - Osdag - INFO - The minimum required thickness of the web i.e. 8.0 mm is satisfied
2020-12-18 00:13:14 - Osdag - INFO - Additional stiffening of the column web is not required
2020-12-18 00:13:14 - Osdag - INFO - [Optimisation] Performing the design by optimising the plate thickness, using the thin plate and large (suitable) bolt diameter approach
2020-12-18 00:13:14 - Osdag - INFO - If you wish to optimise the bolt diameter-grade combination, pass a higher value of plate thickness using the Input Dock
2020-12-18 00:13:14 - Osdag - INFO - The provided beam can accommodate a single column of bolt on either side of the web [Ref. based on detailing requirement]

2020-12-18 00:13:14 - Osdag - INFO - Performing the design with a single column of bolt on each side

2020-12-18 00:13:14 - Osdag - INFO - [Flange Strength] The reaction at the compression flange of the beam 538.1 kN is less than the flange capacity 700.0 kN. The flange strength requirement is satisfied.

2020-12-18 00:13:14 - Osdag - ERROR - [End Plate] The selected trial end plate of 16.0 mm is insufficient and fails in the moment capacity check

2020-12-18 00:13:14 - Osdag - INFO - The minimum required thickness of end plate is 19.3 mm

2020-12-18 00:13:14 - Osdag - INFO - Re-designing the connection with a plate of available higher thickness

2020-12-18 00:13:14 - Osdag - ERROR - [Bolt Design] The bolt of 20.0 mm diameter and 6.8 grade fails the tension check

2020-12-18 00:13:14 - Osdag - ERROR - Total tension demand on bolt (due to direct tension + prying action) is 177.75580968488762 kN and exceeds the bolt tension capacity (105.84 kN)

2020-12-18 00:13:14 - Osdag - INFO - Re-designing the connection with a bolt of higher grade and/or diameter

2020-12-18 00:13:14 - Osdag - ERROR - [Bolt Design] The bolt of 20.0 mm diameter and 6.8 grade fails the combined shear + tension check

2020-12-18 00:13:14 - Osdag - ERROR - The Interaction Ratio (IR) of the critical bolt is 2.83

2020-12-18 00:13:14 - Osdag - INFO - Re-designing the connection with a bolt of higher grade and/or diameter