Company Name	IIT Bombay	Project Title	Shear Connection
Group/Team Name	Osdag	Subtitle	End Plate
Designer	Engineer#1	Job Number	1.1.2.1.1
Date	04 /02 /2021	Client	Mr. Pratip Bhattacharya, Kolkata

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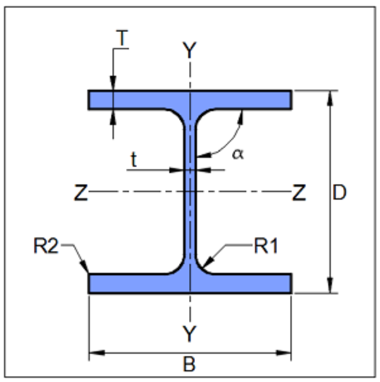
1 Input Parameters

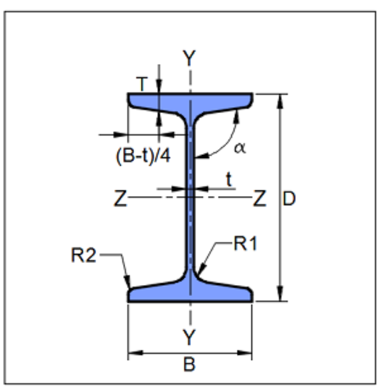
Main Module	Shear Connection
Module	End Plate Connection
Connectivity	Column Flange-Beam Web
Shear Force (kN)	240.0
Axial Force (kN)	125.0

Supporting Section - Mechanical Properties



Supporting Section		PBP 300 X 109.54	
Material		E 350 (Fe 490)	
Ultimate Strength, F_u (MPa)		490	
Yield Strength, F_y (MPa)		350	
Mass, m (kg/m)	109.54	I_z (cm^4)	23400.0
Area, A (cm^2)	139.0	I_y(cm^4)	7680.0
D (mm)	308.0	r_z (cm)	12.9
B (mm)	311.0	r_y (cm)	7.42
t (mm)	15.3	Z_z (cm^3)	1520.0
T (mm)	15.3	Z_y (cm^3)	494.0
Flange Slope	90	Z_{pz} (cm^3)	1710.0
R_1 (mm)	15.0	Z_{py} (cm^3)	758.0
R_2 (mm)	0.0		

Supported Section - Mechanical Properties



Supported Section		LB 400	
Material		E 250 (Fe 410 W)A	
Ultimate Strength, F_u (MPa)		410	
Yield Strength, F_y (MPa)		250	
Mass, m (kg/m)	56.82	I_z (cm^4)	19300.0
Area, A (cm^2)	72.4	I_y(cm^4)	716.0
D (mm)	400.0	r_z (cm)	16.3
B (mm)	165.0	r_y (cm)	3.14
t (mm)	8.0	Z_z (cm^3)	965.0
T (mm)	12.5	Z_y (cm^3)	86.8
Flange Slope	98	Z_{pz} (cm^3)	1090.0
R_1 (mm)	16.0	Z_{py} (cm^3)	151.0
R_2 (mm)	8.0		

Bolt Details - Input and Design Preference	
Diameter (mm)	[16, 20, 24, 30]
Property Class	[4.8, 5.6, 6.8, 9.8]
Type	Bearing Bolt
Hole Type	Standard
Bolt Tension	Non pre-tensioned
Slip Factor, (μ_f)	0.3
Detailing - Design Preference	
Edge Preparation Method	Rolled, machine-flame cut, sawn and planed
Gap Between Members (mm)	10.0
Are the Members Exposed to Corrosive Influences?	False
Plate Details - Input and Design Preference	
Thickness (mm)	[14, 16, 18, 20, 22, 25, 28]
Material	E 250 (Fe 410 W)A
Ultimate Strength, Fu (MPa)	410
Yield Strength, Fy (MPa)	250
Weld Details - Input and Design Preference	
Weld Type	Fillet
Type of Weld Fabrication	Shop Weld
Material Grade Overwrite, Fu (MPa)	490.0

2 Design Checks

Design Status	Pass

2.1 Section Design Check

Check	Required	Provided	Remarks
Shear Capacity (kN)	240.0	$V_{d_y} = \frac{A_v f_y}{\sqrt{3}\gamma_{m0}}$ $= \frac{400.0 \times 8.0 \times 250}{\sqrt{3} \times 1.1 \times 1000}$ $= 419891.10486518237$ [Ref. IS 800:2007, Cl.10.4.3]	Pass
Tension Capacity (kN)	125.0	$T_{\mathrm{dg}} = \frac{A_g f_y}{\gamma_{m0}}$ $A_g = lt = 400.0 \times 8.0$ $= \frac{3200.0 \times 250}{1.1 \times 10^3}$ $= 727272.73$ [Ref. IS 800:2007, Cl.6.2]	Pass

2.2 Bolt Design

Check	Required	Provided	Remarks
Diameter (mm)		16	
Property Class		6.8	
Plate Thickness (mm)		14	
No. of Bolt Columns	2	2	Pass
No. of Bolt Rows		5	Pass
Min. Pitch Distance (mm)	$p_{\min} = 2.5d$ $= 2.5 \times 16$ $= 40.0$ [Ref. IS 800:2007, Cl.10.2.2]	50	Pass

Check	Required	Provided	Remarks
Max. Pitch Distance (mm)	$p/g_{\max} = \min(32t,\ 300)$ $= \min(32 \times 8.0,\ 300)$ $= \min(256.0,\ 300)$ $= 256.0$ Where, $t = \min(28.0, 8.0)$ [Ref. IS 800:2007, Cl.10.2.3]	50	**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)	$e_{\max} = 12 t \varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 14 \times \sqrt{\frac{250}{240}} = 171.46$ $e_2 = 12 \times 15.3 \times \sqrt{\frac{250}{350}} = 155.17$ $e_{\max} = \min(e_1,\ e_2) = 155.17$ [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)	$e'_{\max} = 12t\varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 14 \times \sqrt{\frac{250}{240}} = 171.46$ $e_2 = 12 \times 15.3 \times \sqrt{\frac{250}{350}} = 155.17$ $e'_{\max} = min(e_1,\ e_2) = 155.17$ [Ref. IS 800:2007, Cl.10.2.4.3]	30	**Pass**
Min. Gauge Distance (mm)	$g_1 = 2(e`_{min} + s) + t_w$ $= 2(27.0 + 5) + 8.0$ $= 72.0$ $g_2 = 2(e`_{min} + R_r) + T_w$ $= 2(27.0 + 15.0) + 15.3$ $= 99.3$ $g_{min} = max(g_1, g_2)$ $= 99.3$	106	**Pass**
Shear Capacity (kN)		$V_{\text{dsb}} = \frac{f_{ub} n_n A_{nb}}{\sqrt{3}\gamma_{mb}}$ $= \frac{600.0 \times 1 \times 157}{1000 \times \sqrt{3}\ \times\ 1.25}$ $= 43.51$ [Ref. IS 800:2007, Cl.10.3.3]	
Kb		$k_b = \min\left(\frac{e}{3d_0},\ \frac{p}{3d_0} - 0.25,\ \frac{f_{ub}}{f_u},\ 1.0\right)$ $= \min\left(\frac{30}{3 \times 18.0},\ \frac{50}{3 \times 18.0} - 0.25,\ \frac{600.0}{410},\ 1.0\right)$ $= \min(0.56, 0.68, 1.46, 1.0)$ $= 0.56$ [Ref. IS 800:2007, Cl.10.3.4]	

Check	Required	Provided	Remarks
Bearing Capacity (kN)		$V_{\text{dpb}} = \frac{2.5 k_b d t f_u}{\gamma_{mb}}$ $= \frac{2.5 \times 0.56 \times 16 \times 14 \times 410}{1000 \times 1.25}$ $= 102.86$ [Ref. IS 800:2007, Cl.10.3.4]	
Capacity (kN)	$V_{bv} = \frac{V}{n}$ $= \frac{240.0}{10}$ $= 24.0$	$V_{\text{db}} = \min\ (V_{\text{dsb}},\ V_{\text{dpb}})$ $= \min\ (43.51,\ 102.86)$ $= 43509.1162861302$ [Ref. IS 800:2007, Cl.10.3.2]	
Long Joint Reduction Factor		$l_j = (n_r - 1) \times p$ $= (5 - 1) \times 50 = 200$ $l = 200$ $15 \times d = 15 \times 16 = 240$ since, $l_j < 15 \times d$ then $\beta_{lj} = 1.0$ [Ref. IS 800:2007, Cl.10.3.3.1]	
Large Grip Length Reduction Factor		$l_g = \Sigma\ (t_p + t_{\text{member}})$ $= 39.3$ $5d = 80$ $8d = 128$ since, $l_g < 5d$; $\beta_{lg} = 1.0$ [Ref. IS 800:2007, Cl.10.3.3.2]	
Packing Plate Reduction Factor		$t_{pk} = \text{gap}$ $= 10.0\text{mm}$ since, $t_{pk} \geq 6\text{mm}$, then $V_{\text{rd}} = \beta_{pk}\ V_{\text{db}}$ $\beta_{pk} = 1.0 - 0.0125 \times 10.0 = 0.875$ [Ref. IS 800:2007, Cl.10.3.3.3]	

Check	Required	Provided	Remarks
Bolt Capacity (post reduction factor) (kN)	24.0	$V_{\text{rd}} = \beta_{lj}\ \beta_{lg}\beta_{pk}V_{\text{db}}$ $= 1.0 \times 1.0 \times 0.875 \times 43.51$ $= 38.07$ [Ref. IS 800:2007, Cl.10.3.3]	
Bolt Tension Force (kN)	$T_{ba} = \frac{P}{n}$ $= \frac{125.0}{10}$ $= 12.5$		

Check	Required	Provided	Remarks
Bolt Prying Force (kN)	$Q = \frac{l_v}{2l_e}\left[T_e - \frac{\beta\eta f_o b_e t^4}{27 l_e l_v^2}\right]$ $l_v = e - \frac{R_1}{2} = 30 - \frac{16.0}{2} = 44.0$ mm $f_o = 0.7 f_{ub} = 0.7 \times 600.0 = 420.0$ N/mm^2 $l_e = \min\left(e, 1.1t\sqrt{\frac{\beta f_o}{f_y}}\right) = \min\left(30, 1.1 \times 14 \times \sqrt{\frac{2 \times 420.0}{250}}\right) = \min(30,\ 28.23) = 28.23$ mm $\beta = 2$ (non pre-tensioned bolt) $\eta = 1.5$ $b_e = \frac{B}{n_c} = \frac{165.0}{2} = 50$ mm $Q = \frac{44.0}{2 \times 28.23} \times \left[12.5 - \left(\frac{2 \times 1.5 \times 420.0 \times 50 \times 14^4}{27 \times 28.23 \times 44.0^2}\right) \times 10^{-3}\right]$ $Q = 8.38$ [Ref. IS 800:2007, Cl.10.4.7]		

Check	Required	Provided	Remarks
Bolt Tension Force (kN)	$T_f = T_1 + Q$ $= 12.5 + 8.38$ $= 20.88$	$T_{db} = 0.90 f_{ub} A_n \;/\; \gamma_{mb}$ $< \; f_{yb} A_{sb} (\gamma_{mb} \;/\; \gamma_{m0})$ $= \min\Big(0.90 \times 600.0 \times 157 \;/\; 1.25,$ $600.0 \times 201 \times (1.25/1.1)\Big)$ $= \min(67.82,\; 137.05)$ $= 67.82$ [Ref. IS 800:2007, Cl.10.3.5]	Pass
Interaction Ratio	≤ 1	$\left(\frac{V_{sb}}{V_{db}}\right)^2 + \left(\frac{T_b}{T_{db}}\right)^2 \leq 1.0$ $\left(\frac{24.0}{38.07}\right)^2 + \left(\frac{20.88}{67.82}\right)^2 = 0.49$ [Ref. IS 800:2007, Cl.10.3.6]	Pass

2.3 Plate Design

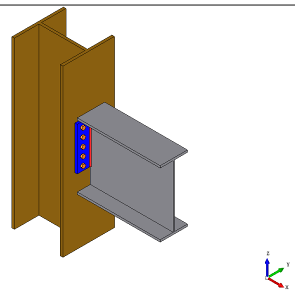
Check	Required	Provided	Remarks
Min. Plate Height (mm)	$0.6 \times (d_b - 2 \times t_f - 2 \times r_r)$ $= 0.6 \times (400.0 - 2 \times 12.5 - 2 \times 16.0)$ $= 205.8$ [Ref. INSDAG, Ch.5, sec.5.2.3]	260	Pass
Max. Plate Height (mm)	$d_b - 2(t_{bf} + r_{b1} + \text{gap})$ $= 400.0 - 2 \times (12.5 + 16.0 + 10)$ $= 343.0$	260	Pass
Min. Plate Thickness (mm)	$t_w = 8.0$	14	Pass
Min. Plate Width (mm)	$w_{p_{\min}} = g` + e`_{\min}\ 2$ $= 106 + 27.0 \times 2$ $= 160.0$	166	Pass
Max. Plate Width (mm)	$w_{p_{\max}} = T_f$ $= 311.0$	166	Pass

Check	Required	Provided	Remarks
Shear Yielding Capacity (kN)		$V_{d_y} = \frac{A_v f_y}{\sqrt{3}\gamma_{m0}}$ $= \frac{260 \times 14 \times 250}{\sqrt{3} \times 1.1 \times 1000}$ $= 477.63$ [Ref. IS 800:2007, Cl.10.4.3]	
Block Shear Capacity in Shear (kN)		$V_{\text{dbl1}} = \frac{A_{\text{vg}} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}}$ $V_{\text{dbl2}} = \frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{m1}} + \frac{A_{tg} f_y}{\gamma_{m0}}$ $V_{\text{db}} = \min(V_{db1},\ V_{db2}) = 546.43$ [Ref. IS 800:2007, Cl.6.4]	
Shear Capacity (kN)	240.0	$V_d = \min(S_c,\ V_{d_b})$ $= \min(477.63, 546.43)$ $= 477.63$ [Ref. IS 800:2007, Cl.6.1]	**Pass**
Moment Capacity (kNm)	$M = T_e \times \text{ecc}$ $ecc_1 = \frac{g}{2} - \frac{t_w}{2} - s = 44.0$ $ecc_2 = \frac{g}{2} - \frac{T_w}{2} - R_r = 30.35$ $\max(ecc_1,\ ecc_2) = 44.0$ $M = 12.5 \times 44.0 \times 10^{-3} = 0.546$	$M_{d_z} = \frac{\beta_b Z_p fy}{\gamma_{m0} \times 10^6}$ $= \frac{1.0 \times 12740.0 \times 250}{1.1 \times 10^6}$ $= 0.557$ [Ref. IS 800:2007, Cl.8.2.1.2]	**Pass**

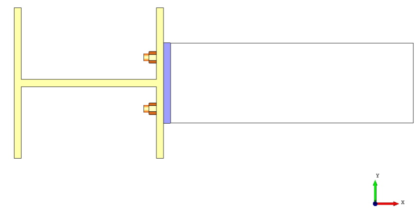
2.4 Weld Design

Check	Required	Provided	Remarks
Min. Weld Size (mm)	$t_{w_{\min}}$ based on thinner part $= \max(8,\ 8)$ $s_{\min}$ based on thicker part $= 5$ [Ref. IS 800:2007, Table 21, Cl.10.5.2.3]	5	**Pass**
Max. Weld Size (mm)	Thickness of thinner part $= \min(14,\ 8.0) = 8.0$ $s_{\max} = 8$ [Ref. IS 800:2007, Cl.10.5.3.1]	5	**Pass**
Weld Strength (N/mm)	$R_{\rm w} = \sqrt{(A_{\rm wh})^2 + (V_{\rm wv})^2}$ $V_{\rm wv} = \frac{V}{l_w} = \frac{240000.0}{416.0}$ $A_{\rm wh} = \frac{A}{l_w} = \frac{125000.0}{416.0}$ $R_{\rm w} = \sqrt{(300.48)^2 + (576.92)^2}$ $= 541.2$	$f_w = \frac{t_t f_u}{\sqrt{3}\gamma_{mw}}$ $= \frac{4.2 \times 410}{\sqrt{3} \times 1.25}$ $= 662.8$ [Ref. IS 800:2007, Cl.10.5.7.1.1]	
Weld Strength (post long joint) (N/mm)	if $l \geq 150t_t$, then $V_{\rm rd} = \beta_{l_w} V_{\rm db}$ if $l < 150t_t$, *then* $V_{\rm rd} = V_{\rm db}$ where, l = plate length or height $\beta_{l_w} = 1.2 - \frac{(0.2l)}{(150t_t)}$ but, $0.6 \leq \beta_{l_w} \leq 1.0$ [Ref. IS 800:2007, Cl.10.5.7.3]	$l_w = h$ $= 260$ $150t_t = 150 \times 4.2 = 630.0$ since, $l < 150t_t$ *then* $f_{\rm wrd} = f_{\rm w}$ $f_{\rm wrd} = 662.8$ [Ref. IS 800:2007, Cl.10.5.7.3.]	
Weld Strength (N/mm)	541.2	662.8	**Pass**

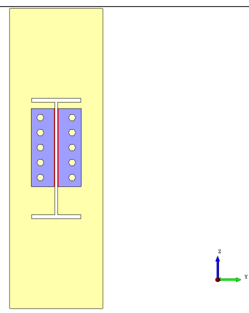
3 3D Views



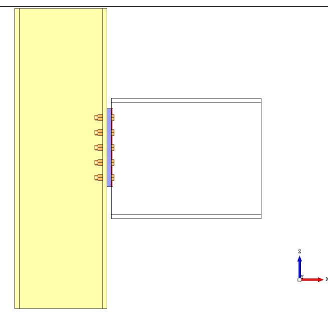
(a) 3D View



(b) Top View



(c) Side View



(d) Front View

4 Design Log

2021-02-04 12:08:24 - Osdag - INFO - End plate is designed with minimum possible plate thickness.

2021-02-04 12:08:24 - Osdag - INFO - Bolt columns are limited to two (one on each side) in shear end plate.

2021-02-04 12:08:24 - Osdag - INFO - === End Of Design ===