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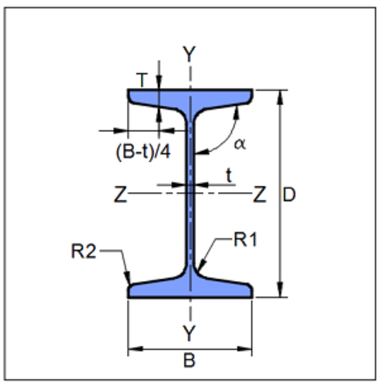
Company Name	IIT Bombay	Project Title	Sample Connection Design
Group/Team Name	Osdag	Subtitle	End Plate
Designer	Engineer #1	Job Number	1.1.2.2.1
Date	17 /12 /2020	Client	S R Satish Kumar, Professor, IIT Madras

1 Input Parameters

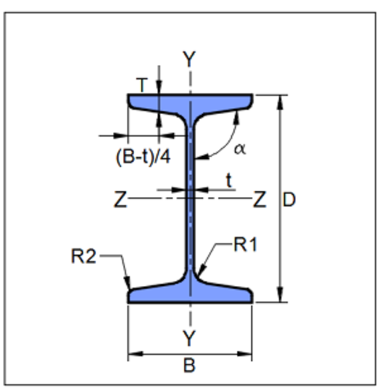
Main Module	Shear Connection
Module	End Plate
Connectivity	Column Web-Beam Web
Shear Force (kN)	220.0
Axial Force (kN)	30.0

Supporting Section - Mechanical Properties



Supporting Section		HB 350	
Material		E 250 (Fe 410 W)A	
Ultimate Strength, Fu (MPa)		410	
Yield Strength, Fy (MPa)		250	
Mass, m (kg/m)	67.42	I_z (cm^4)	19100.0
Area, A (cm^2)	85.9	I_y(cm^4)	2450.0
D (mm)	350.0	r_z (cm)	14.9
B (mm)	250.0	r_y (cm)	5.34
t (mm)	8.3	Z_z (cm^3)	1090.0
T (mm)	11.6	Z_y (cm^3)	196.0
Flange Slope	94	Z_{pz} (cm^3)	1210.0
R_1 (mm)	12.0	Z_{py} (cm^3)	324.0
R_2 (mm)	6.0		

Supported Section - Mechanical Properties



Supported Section		WB 300	
Material		E 250 (Fe 410 W)A	
Ultimate Strength, Fu (MPa)		410	
Yield Strength, Fy (MPa)		250	
Mass, m (kg/m)	48.12	I_z (cm^4)	9820.0
Area, A (cm^2)	61.3	I_y(cm^4)	990.0
D (mm)	300.0	r_z (cm)	12.6
B (mm)	200.0	r_y (cm)	4.01
t (mm)	7.4	Z_z (cm^3)	654.0
T (mm)	10.0	Z_y (cm^3)	99.0
Flange Slope	96	Z_{pz} (cm^3)	731.0
R_1 (mm)	11.0	Z_{py} (cm^3)	171.0
R_2 (mm)	5.5		

Bolt Details - Input and Design Preference	
Diameter (mm)	[16, 20, 24]
Property Class	[4.6, 4.8, 5.6, 5.8]
Type	Bearing Bolt
Hole Type	Over-sized
Bolt Tension	Non pre-tensioned
Slip Factor, (mu_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, 20]
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)	500.0

2 Design Checks

Design Status	Pass

2.1 Section Design Check

Check	Required	Provided	Remarks
Shear Capacity (kN)	220.0	$V_{dy} = \frac{A_v\ f_y}{\sqrt{3}\ \gamma_{mo}}$ $= \frac{300.0 \times 7.4 \times 250}{\sqrt{3} \times 1.1 \times 1000}$ $= 291299.4540002203$ $[Ref. IS\ 800:2007, Cl. 10.4.3]$	**Pass**
Tension Capacity (kN)	30.0	$T_{dg} = \frac{A_g f_y}{\gamma_{mo}}$ $A_g = l \times t = 300.0 \times 7.4$ $= \frac{2220.0 \times 250}{1.1 \times 10^3}$ $= 504545.45$ $[Ref.\ IS\ 800:2007,\ Cl.\ 6.2]$	**Pass**

2.2 Bolt Design

Check	Required	Provided	Remarks
Diameter (mm)		24	
Property Class		4.6	
Plate Thickness (mm)		14	
No. of Bolt Columns	2	2	**Pass**
No. of Bolt Rows		3	**Pass**
Min. Pitch Distance (mm)	$p_{min} = 2.5\ d$ $= 2.5 \times 24$ $= 60.0$ $[Ref\ IS\ 800:2007,\ Cl.\ 10.2.2]$	60	**Pass**

Check	Required	Provided	Remarks
Max. Pitch Distance (mm)	$p/g_{max} = \min(32\ t,\ 300\ mm)$ $= \min(32 \times 7.4,\ 300\ mm)$ $= \min(236.8,\ 300\ mm)$ $= 236.8$ $Where,\ t = min(20.0, 7.4)$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.2.3]$	60	**Pass**
Min. End Distance (mm)	$e_{min} = 1.5\ d_0$ $= 1.5 \times 30.0$ $= 45.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.2]$	45	**Pass**
Max. End Distance (mm)	$e_{max} = 12\ t\ \varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 14 \times \sqrt{\frac{250}{240}} = 171.46$ $e_2 = 12 \times 8.3 \times \sqrt{\frac{250}{250}} = 99.6$ $e_{max} = min(e_1, e_2) = 99.6$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.3]$	45	**Pass**
Min. Edge Distance (mm)	$e'_{min} = 1.5\ d_0$ $= 1.5 \times 30.0$ $= 45.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.2]$	45	**Pass**

Check	Required	Provided	Remarks
Max. Edge Distance (mm)	$e'_{max} = 12\ t\ \varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 14 \times \sqrt{\frac{250}{240}} = 171.46$ $e_2 = 12 \times 8.3 \times \sqrt{\frac{250}{250}} = 99.6$ $e'_{max} = min(e_1, e_2) = 99.6$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.3]$	45	**Pass**
Min. Gauge Distance (mm)	$g_{min} = 2(e`_{min} + s) + t_w$ $= 2(45.0 + 5) + 7.4$ $= 107.4$	108	**Pass**
Shear Capacity (kN)		$V_{dsb} = \frac{f_{ub}\ n_n\ A_{nb}}{\sqrt{3}\ \gamma_{mb}}$ $= \frac{400.0 \times 1 \times 353}{1000 \times \sqrt{3}\ \times\ 1.25}$ $= 65.22$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.3]$	
Kb		$k_b = min\left(\frac{e}{3d_0}, \frac{p}{3d_0} - 0.25, \frac{f_{ub}}{f_u}, 1.0\right)$ $= min\left(\frac{45}{3 \times 30.0}, \frac{60}{3 \times 30.0} - 0.25, \frac{400.0}{410}, 1.0\right)$ $= min(0.5, 0.42, 0.98, 1.0)$ $= 0.42$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.4]$	
Bearing Capacity (kN)		$V_{dpb} = \frac{2.5\ k_b\ d\ t\ f_u}{\gamma_{mb}}$ $= \frac{2.5 \times 0.42 \times 24 \times 8.3 \times 410}{1000 \times 1.25}$ $= 48.02$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.4]$	

Check	Required	Provided	Remarks
Capacity (kN)	$V_{bv} = \frac{V}{n}$ $= \frac{220.0}{6}$ $= 36.67$	$V_{db} = min\ (V_{dsb}, V_{dpb})$ $= min\ (65.22, 48.02)$ $= 48023.136000000006$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.2]$	
Long Joint Reduction Factor		$l_j = (n_r - 1) \times p$ $= (3 - 1) \times 60 = 120$ $l = 120$ $15 \times d = 15 \times 24 = 360$ $since,\ l_j < 15 \times d\ then\ \beta_{lj} = 1.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.3.1]$	
Large Grip Length Reduction Factor		$l_g = \Sigma\ (t_p + t_{member})$ $= 32.3$ $5d = 120$ $8d = 192$ $since,\ l_g < 5d\ ;\ \beta_{lg} = 1.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.3.2]$	
Packing Plate Reduction Factor		$t_{pk} = gap$ $= 10.0mm$ $since,\ t_{pk} \geq 6mm\ then\ V_{rd} = \beta_{pk}\ V_{db}$ $\beta_{pk} = 1.0 - 0.0125 \times 10.0 = 0.875$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.3.3]$	
Bolt Capacity (post reduction factor) (kN)	36.67	$V_{rd} = \beta_{lj}\ \beta_{lg}\beta_{pk} \times V_{db}$ $= 1.0 \times 1.0 \times 0.875 \times 48.02$ $= 42.02$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.3]$	

Check	Required	Provided	Remarks
Bolt Tension Force (kN)	$T_{ba} = \frac{P}{n} = \frac{30.0}{6} = 5.0$		

Check	Required	Provided	Remarks
Bolt Prying Force (kN)	$Q = \frac{l_v}{2 \times l_e}\left[T_e - \frac{\beta \times \eta \times f_o \times b_e \times t^4}{27 \times l_e \times l_v^2}\right]$ $l_v = e - \frac{R_1}{2} = 45 - \frac{11.0}{2} = 45.3\ mm$ $f_o = 0.7 \times f_{ub} = 0.7 \times 400.0 = 280.0\ N/mm^2$ $l_e = min\left(e, 1.1\ t\sqrt{\frac{\beta\ f_o}{f_y}}\right) = min\left(45, 1.1 \times 14 \times \sqrt{\frac{2 \times 280.0}{250}}\right) = min(45, 23.05) = 23.05\ mm$ $\beta = 2\ (non\ pre-tensioned\ bolt)$ $\eta = 1.5$ $b_e = \frac{B}{n_c} = \frac{200.0}{2} = 60\ mm$ $Q = \frac{45.3}{2 \times 23.05} \times \left[5.0 - \left(\frac{2 \times 1.5 \times 280.0 \times 60 \times 14^4}{27 \times 23.05 \times 45.3^2}\right) \times 10^{-3}\right]$ $Q = 4.4$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.4.7]$		

Check	Required	Provided	Remarks
Bolt Tension Force (kN)	$T_f = T_1 + Q$ $= 5.0 + 4.4$ $= 9.4$	$T_{db} = 0.90\ f_{ub}\ A_n\ /\ \gamma_{mb}$ $<\ f_{yb}\ A_{sb}\ (\gamma_{mb}\ /\ \gamma_{m0})$ $= min\Big(0.90\ \times 400.0 \times 353\ /\ 1.25,$ $400.0 \times 452 \times (1.25/1.1)\Big)$ $= min(101.66,\ 205.45)$ $= 98.62$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.5]$	**Pass**
Interaction Ratio	≤ 1	$\left(\frac{V_{sb}}{V_{db}}\right)^2 + \left(\frac{T_b}{T_{db}}\right)^2 \leq 1.0$ $\left(\frac{36.67}{42.02}\right)^2 + \left(\frac{9.4}{98.62}\right)^2 = 0.77$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.6]$	**Pass**

2.3 Plate Design

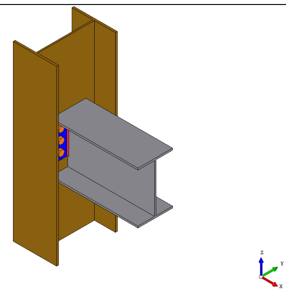
Check	Required	Provided	Remarks
Min. Plate Height (mm)	$0.6\times(d_b - 2 \times t_f - 2 \times r_r)$ $= 0.6 \times (300.0 - 2 \times 10.0 - 2 \times 11.0)$ $= 154.8$ $[Ref.\ INSDAG - Chpt.5,\ Sect.5.2.3]$	210	**Pass**
Max. Plate Height (mm)	$d_b - 2(t_{bf} + r_{b1} + gap)$ $= 300.0 - 2 \times (10.0 + 11.0 + 10)$ $= 258.0$	210	**Pass**
Min. Plate Thickness (mm)	$t_w = 7.4$	14	**Pass**
Min. Plate Width (mm)	$w_{p_{min}} = g` + e`_{min}\ 2$ $= 108 + 45.0 \times 2$ $= 198.0$	198	**Pass**
Max. Plate Width (mm)	$w_{p_{max}} = D - 2T_f - 2R_r$ $= 350.0 - 2 \times 250.0 - 2 \times 12.0$ $= 302.8$	198	**Pass**

Check	Required	Provided	Remarks
Shear Yielding Capacity (kN)		$V_{dy} = \frac{A_v\ f_y}{\sqrt{3}\ \gamma_{mo}}$ $= \frac{210 \times 14 \times 250}{\sqrt{3} \times 1.1 \times 1000}$ $= 385.77$ $[Ref. IS\ 800:2007, Cl. 10.4.3]$	
Block Shear Capacity in Shear (kN)		$V_{dbl1} = \frac{A_{vg} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}}$ $V_{dbl2} = \frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{m1}} + \frac{A_{tg} f_y}{\gamma_{m0}}$ $V_{db} = min(V_{db1}, V_{db2}) = 501.11$ $[Ref.\ IS\ 800:2007,\ Cl.\ 6.4]$	
Shear Capacity (kN)	220.0	$V_d = min(S_c, V_{db})$ $= min(385.77, 501.11)$ $= 385.77$ $[Ref.\ IS\ 800:2007,\ Cl.\ 6.1]$	**Pass**
Moment Capacity (kNm)	$M = T_e \times ecc$ $ecc = \frac{g}{2} - \frac{t_w}{2} - s \quad = 45.3$ $M = 5.0 \times 45.3 \times 10^{-3} \quad = 0.225$	$M_{dzz} = \frac{\beta_b \times Z_p \times fy}{\gamma_{mo} \times 10^6}$ $= \frac{1.0 \times 10290.0 \times 250}{1.1 \times 10^6}$ $= 0.668$ $[Ref.\ IS\ 800:2007,\ Cl.\ 8.2.1.2]$	**Pass**

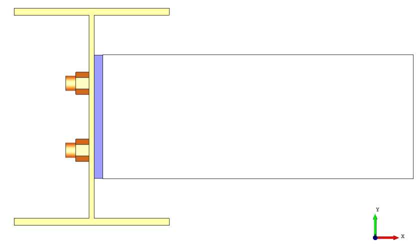
2.4 Weld Design

Check	Required	Provided	Remarks
Min. Weld Size (mm)	$t_{w_{min}}$ *based on thinner part* $= 7$ *or* 7 s_{min} *based on thicker part* $= 5$ $[Ref\ IS\ 800:2007, Table\ 21\ (Cl10.5.2.3)]$	5	**Pass**
Max. Weld Size (mm)	*Thickness of thinner part* $= min(14, 7.4) = 7.4$ $s_{max} = 8$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.5.3.1]$	5	**Pass**
Weld Strength (N/mm)	$R_w = \sqrt{(A_{wh})^2 + (V_{wv})^2}$ $V_{wv} = \frac{V}{l_w} = \frac{220000.0}{420.0}$ $A_{wh} = \frac{A}{l_w} = \frac{30000.0}{420.0}$ $R_w = \sqrt{(71.43)^2 + (523.81)^2}$ $= 555.09$	$f_w = \frac{t_t\ f_u}{\sqrt{3}\ \gamma_{mw}}$ $= \frac{3.5 \times 410}{\sqrt{3} \times 1.25}$ $= 662.8$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.5.7.1.1]$	
Weld Strength (post long joint) (N/mm)	$if\ l \geq 150t_t\ then\ V_{rd} = \beta_{l_w} V_{db}$ $if\ l < 150t_t\ then\ V_{rd} = V_{db}$ *where,* $l\ = pt.length\ or\ pt.height$ $\beta_{l_w} = 1.2 - \frac{(0.2l)}{(150t_t)}$ $but\ 0.6 \leq \beta_{l_w} \leq 1.0$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.5.7.3]$	$l_w\ = h$ $= 210$ $150t_t = 150 \times 3.5 = 525.0$ $since,\ l < 150t_t$ $then\ f_{wrd} = f_w$ $f_{wrd} = 662.8$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.5.7.3]$	
Weld Strength (N/mm)	555.09	662.8	**Pass**

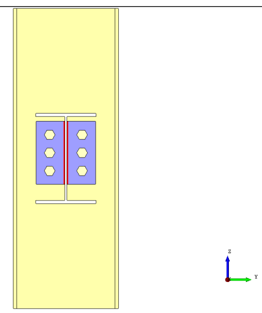
3 3D Views



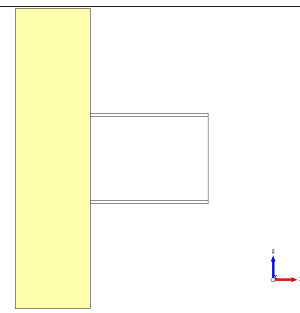
(a) 3D View



(b) Top View



(c) Side View



(d) Front View

4 Design Log