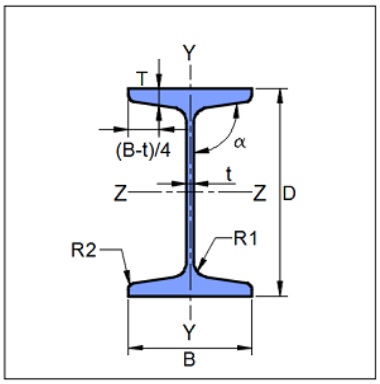
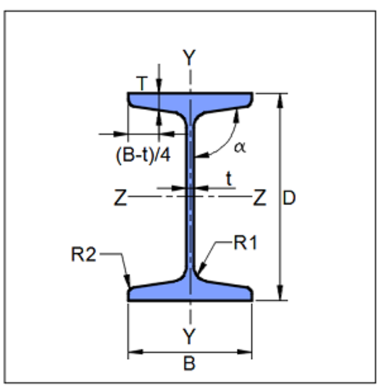
		Created with	
Company Name	IIT Bombay	Project Title	Shear Connection
Group/Team Name	Osdag	Subtitle	Cleat Angle
Designer	Engineer#1	Job Number	1.1.3.1.1
Date	04 /02 /2021	Client	Prof. Meera Raghunandan, IIT Bombay

1 Input Parameters

Main Module			Shear Connection	
Module			Cleat Angle Connection	
Connectivity			Column Flange-Beam Web	
Shear Force (kN)			130.0	
Supporting Section - Mechanical Properties				
	Supporting Section		HB 250	
	Material		E 250 (Fe 410 W)A	
	Ultimate Strength, F_u (MPa)		410	
	Yield Strength, F_y (MPa)		250	
	Mass, m (kg/m)	50.98	I_z (cm^4)	7730.0
	Area, A (cm^2)	64.9	I_y(cm^4)	1960.0
	D (mm)	250.0	r_z (cm)	10.9
	B (mm)	250.0	r_y (cm)	5.49
	t (mm)	6.9	Z_z (cm^3)	619.0
	T (mm)	9.7	Z_y (cm^3)	156.0
	Flange Slope	94	Z_{pz} (cm^3)	678.0
	R_1 (mm)	10.0	Z_{py} (cm^3)	262.0
	R_2 (mm)	5.0		
Supported Section - Mechanical Properties				
	Supported Section		MB 300	
	Material		E 250 (Fe 410 W)A	
	Ultimate Strength, F_u (MPa)		410	
	Yield Strength, F_y (MPa)		250	
	Mass, m (kg/m)	46.02	I_z (cm^4)	8990.0
	Area, A (cm^2)	58.6	I_y(cm^4)	486.0
	D (mm)	300.0	r_z (cm)	12.3
	B (mm)	140.0	r_y (cm)	2.87
	t (mm)	7.7	Z_z (cm^3)	599.0
	T (mm)	13.1	Z_y (cm^3)	69.4
	Flange Slope	98	Z_{pz} (cm^3)	681.0
	R_1 (mm)	14.0	Z_{py} (cm^3)	117.0
	R_2 (mm)	7.0		
Bolt Details - Input and Design Preference				

Diameter (mm)	[16, 20]
Property Class	[4.6, 4.8]
Type	Bearing Bolt
Hole Type	Standard
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

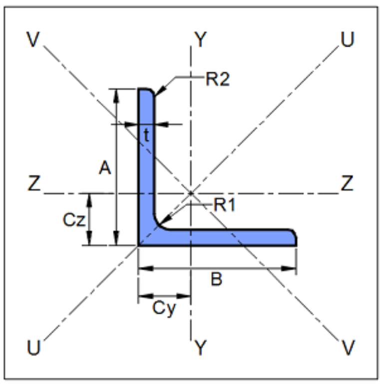
1.1 List of Input Section

Cleat Angle List	’90 x 90 x 10’, ’90 x 90 x 12’, ’100 x 100 x 6’, ’100 x 100 x 8’

2 Design Checks

Design Status	Pass

2.1 Selected Member Data



Section Size		90 x 90 x 10	
Material		E 250 (Fe 410 W)A	
Ultimate Strength, Fu (MPa)		410	
Yield Strength, Fy (MPa)		250	
Mass, m (kg/m)	13.47	I_u (cm^4)	205.0
Area, A (cm^2)	17.1	I_v(cm^4)	53.6
A (mm)	90.0	r_z (cm)	2.75
B (mm)	90.0	r_y (cm)	2.75
t (mm)	10.0	r_u (cm)	3.46
R_1 (mm)	8.5	r_v (cm)	1.77
R_2 (mm)	0.0	Z_z (cm^3)	20.2
C_y (mm)	26.0	Z_y (cm^3)	20.2
C_z (mm)	26.0	Z_{pz} (cm^3)	36.4
I_z (cm^4)	129.0	Z_{py} (cm^3)	20.2
I_y(cm^4)	129.0		

2.2 Initial Section Check

Check	Required	Provided	Remarks
Shear Yielding Capacity (kN)	130.0	$V_{d_y} = \frac{A_v f_y}{\sqrt{3}\gamma_{m0}}$ $= \frac{300.0 \times 7.7 \times 250}{\sqrt{3} \times 1.1 \times 1000}$ $= 303.11$ [Ref. IS 800:2007, Cl.10.4.3]	Pass
Allowable Shear Capacity (kN)	130.0	$V_d = 0.6\ V_{dy}$ $= 0.6 \times 303.11$ $= 181.87$ [Limited to low shear]	Pass

2.3 Load Consideration

Check	Required	Provided	Remarks
Applied Shear Force (kN)	130.0	$V_{y_{\min}} = \min(0.15V_{d_y},\ 40.0)$ $= \min(0.15 \times 303.11,\ 40.0)$ $= 40$ $V_u = \max(V_y,\ V_{y_{\min}})$ $= \max(130.0, 40)$ $= 130.0$ [Ref. IS 800:2007, Cl.10.7]	

2.4 Bolt Design - Connected to Beam

Check	Required	Provided	Remarks
Diameter (mm)		20	
Property Class		4.6	
Cleat Angle Connection		90 x 90 x 10	
No. of Bolt Columns		1	
No. of Bolt Rows		3	
Min. Pitch Distance (mm)	$p_{\min} = 2.5d$ $= 2.5 \times 20$ $= 50.0$ [Ref. IS 800:2007, Cl.10.2.2]	75	Pass
Max. Pitch Distance (mm)	$p_{\max} = \min(32t,\ 300)$ $= \min(32 \times 7.7,\ 300)$ $= \min(246.4,\ 300)$ $= 246.4$ Where, $t = \min(10.0, 7.7)$ [Ref. IS 800:2007, Cl.10.2.3]	75	Pass

Check	Required	Provided	Remarks
Min. Gauge Distance (mm)	$g_{\min} = 2.5d$ $= 2.5 \times 20$ $= 50.0$ [Ref. IS 800:2007, Cl.10.2.2]	N/A	
Max. Gauge Distance (mm)	$g_{\max} = \min(32t,\ 300)$ $= \min(32 \times 7.7,\ 300)$ $= \min(246.4,\ 300)$ $= 246.4$ Where, $t = \min(10.0, 7.7)$ [Ref. IS 800:2007, Cl.10.2.3]	N/A	
Min. End Distance (mm)	$e_{\min} = 1.5d_0$ $= 1.5 \times 22.0$ $= 33.0$ [Ref. IS 800:2007, Cl.10.2.4.2]	35	Pass
Max. End Distance (mm)	$e_{\max} = 12t\varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 10.0 \times \sqrt{\frac{250}{250}} = 120.0$ $e_2 = 12 \times 7.7 \times \sqrt{\frac{250}{250}} = 92.4$ $e_{\max} = \min(e_1,\ e_2) = 92.4$ [Ref. IS 800:2007, Cl.10.2.4.3]	35	Pass
Min. Edge Distance (mm)	${e'}_{\min} = 1.5d_0$ $= 1.5 \times 22.0$ $= 33.0$ [Ref. IS 800:2007, Cl.10.2.4.2]	35	Pass

Check	Required	Provided	Remarks
Max. Edge Distance (mm)	$e'_{\max} = 12t\varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 10.0 \times \sqrt{\frac{250}{250}} = 120.0$ $e_2 = 12 \times 7.7 \times \sqrt{\frac{250}{250}} = 92.4$ $e'_{\max} = min(e_1,\ e_2) = 92.4$ [Ref. IS 800:2007, Cl.10.2.4.3]	35	**Pass**
Moment Demand (kNm)		$M_d = (V_u \times \text{ecc} + M_w)$ $\text{ecc} = \text{eccentricity}$ $M_w = \text{external moment acting on web}$ $= \frac{(130.0 \times 10^3 \times 53.5 + 0.0 \times 10^6)}{10^6}$ $= 6955.0$	
Bolt Force Parameter(s) (mm)	$l_n = \text{length available}$ $l_n = p\ (n_r - 1)$ $= 75 \times (3 - 1)$ $= 150$ $y_{\max} = l_n/2$ $= 150/2$ $= 75.0$ $x_{\max} = g(n_c - 1)/2$ $= 0.0 \times (1 - 1)/2$ $= 0.0$		

Check	Required	Provided	Remarks
Bolt.Force (kN)	$vbv = V_u/(n_r \times n_c) = \frac{130.0}{(3 \times 1)} = 43.33$ $tmh = \frac{M_d \times y_{\max}}{\Sigma r_i^2} = \frac{6955.0 \times 75.0}{11.25} = 46.37$ $tmv = \frac{M_d \times x_{\max}}{\Sigma r_i^2} = \frac{6955.0 \times 0.0}{11.25} = 0.0$ $abh = \frac{A_u}{(n_r \times n_c)} = \frac{0.0}{(3 \times 1)} = 0.0$ $v_{\text{res}} = \sqrt{(vbv + tmv)^2 + (tmh + abh)^2} = \sqrt{(43.33 + 0.0)^2 + (46.37 + 0.0)^2} = 63.46$		
Shear Capacity (kN)		$V_{\text{dsb}} = \frac{f_{ub} n_n A_{nb}}{\sqrt{3}\gamma_{mb}} = \frac{400.0 \times 2 \times 245}{1000 \times \sqrt{3} \times 1.25} = 90.53$ [Ref. IS 800:2007, Cl.10.3.3]	

Check	Required	Provided	Remarks
Kb		$k_b = \min\left(\frac{e}{3d_0},\ \frac{p}{3d_0} - 0.25,\ \frac{f_{ub}}{f_u},\ 1.0\right)$ $= \min\left(\frac{35}{3 \times 22.0},\ \frac{75}{3 \times 22.0} - 0.25,\ \frac{400.0}{410},\ 1.0\right)$ $= \min(0.53, 0.89, 0.98, 1.0)$ $= 0.53$ [Ref. IS 800:2007, Cl.10.3.4]	
Bearing Capacity (kN)		$V_{\text{dpb}} = \frac{2.5 k_b d t f_u}{\gamma_{mb}}$ $= \frac{2.5 \times 0.53 \times 20 \times 7.7 \times 410}{1000 \times 1.25}$ $= 66.93$ [Ref. IS 800:2007, Cl.10.3.4]	
Capacity (kN)		$V_{\text{db}} = \min\ (V_{\text{dsb}},\ V_{\text{dpb}})$ $= \min\ (90.53,\ 66.93)$ $= 66.93$ [Ref. IS 800:2007, Cl.10.3.2]	
Long Joint Reduction Factor		$l_j = (n_r - 1) \times p$ $= (3 - 1) \times 75 = 150$ $l = 150$ $15 \times d = 15 \times 20 = 300$ 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		$l_g = \Sigma\ (t_p + t_{\text{member}})$ $= 27.7$ $5d = 100$ $8d = 160$ since, $l_g < 5d$; $\beta_{lg} = 1.0$ [Ref. IS 800:2007, Cl.10.3.3.2]	Pass

Check	Required	Provided	Remarks
Bolt Capacity (post reduction factor) (kN)		$V_{\text{rd}} = \beta_{lj}\beta_{lg}V_{\text{db}}$ $= 1.0 \times 1.0 \times 66.93$ $= 66.93$	
Capacity (kN)	63.46	66.93	**Pass**

2.5 Bolt Design - Connected to Column

Check	Required	Provided	Remarks
Diameter (mm)		20	
Property Class		4.6	
Cleat Angle Connection		90 x 90 x 10	
No. of Bolt Columns		1	
No. of Bolt Rows		3	
Min. Pitch Distance (mm)	$p_{\text{min}} = 2.5d$ $= 2.5 \times 20$ $= 50.0$ [Ref. IS 800:2007, Cl.10.2.2]	75	**Pass**
Max. Pitch Distance (mm)	$p_{\text{max}} = \min(32t,\ 300)$ $= \min(32 \times 9.7,\ 300)$ $= \min(310.4,\ 300)$ $= 300$ Where, $t = \min(10.0, 9.7)$ [Ref. IS 800:2007, Cl.10.2.3]	75	**Pass**
Min. Gauge Distance (mm)	$g_{\text{min}} = 2.5d$ $= 2.5 \times 20$ $= 50.0$ [Ref. IS 800:2007, Cl.10.2.2]	N/A	

Check	Required	Provided	Remarks
Max. Gauge Distance (mm)	$g_{\max} = \min(32t,\ 300)$ $= \min(32 \times 9.7,\ 300)$ $= \min(310.4,\ 300)$ $= 300$ Where, $t = \min(10.0, 9.7)$ [Ref. IS 800:2007, Cl.10.2.3]	N/A	
Min. End Distance (mm)	$e_{\min} = 1.5 d_0$ $= 1.5 \times 22.0$ $= 33.0$ [Ref. IS 800:2007, Cl.10.2.4.2]	35	Pass
Max. End Distance (mm)	$e_{\max} = 12 t \varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 10.0 \times \sqrt{\frac{250}{250}} = 120.0$ $e_2 = 12 \times 9.7 \times \sqrt{\frac{250}{250}} = 116.4$ $e_{\max} = \min(e_1,\ e_2) = 116.4$ [Ref. IS 800:2007, Cl.10.2.4.3]	35	Pass
Min. Edge Distance (mm)	$e'_{\min} = 1.5 d_0$ $= 1.5 \times 22.0$ $= 33.0$ [Ref. IS 800:2007, Cl.10.2.4.2]	35	Pass

Check	Required	Provided	Remarks
Max. Edge Distance (mm)	$e'_{\text{max}} = 12t\varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 10.0 \times \sqrt{\frac{250}{250}} = 120.0$ $e_2 = 12 \times 9.7 \times \sqrt{\frac{250}{250}} = 116.4$ $e'_{\text{max}} = min(e_1,\ e_2) = 116.4$ [Ref. IS 800:2007, Cl.10.2.4.3]	35	**Pass**
Moment Demand (kNm)		$M_d = (V_u \times \text{ecc} + M_w)$ $\text{ecc} = \text{eccentricity}$ $M_w = \text{external moment acting on web}$ $= \frac{(65.0 \times 10^3 \times 53.5 + 0.0 \times 10^6)}{10^6}$ $= 3477.5$	
Bolt Force Parameter(s) (mm)	$l_n = \text{length available}$ $l_n = p\ (n_r - 1)$ $= 75 \times (3 - 1)$ $= 150$ $y_{\text{max}} = l_n/2$ $= 150/2$ $= 75.0$ $x_{\text{max}} = g(n_c - 1)/2$ $= 0.0 \times (1 - 1)/2$ $= 0.0$		

Check	Required	Provided	Remarks
Bolt.Force (kN)	$vbv = V_u/(n_r \times n_c) = \frac{130.0}{(3 \times 1)} = 21.67$ $tmh = \frac{M_d \times y_{\max}}{\Sigma r_i^2} = \frac{3477.5 \times 75.0}{11.25} = 23.18$ $tmv = \frac{M_d \times x_{\max}}{\Sigma r_i^2} = \frac{3477.5 \times 0.0}{11.25} = 0.0$ $abh = \frac{A_u}{(n_r \times n_c)} = \frac{0.0}{(3 \times 1)} = 0.0$ $v_{\text{res}} = \sqrt{(vbv + tmv)^2 + (tmh + abh)^2} = \sqrt{(21.67 + 0.0)^2 + (23.18 + 0.0)^2} = 31.73$		
Shear Capacity (kN)		$V_{\text{dsb}} = \frac{f_{ub} n_n A_{nb}}{\sqrt{3}\gamma_{mb}} = \frac{400.0 \times 1 \times 245}{1000 \times \sqrt{3} \times 1.25} = 45.26$ [Ref. IS 800:2007, Cl.10.3.3]	

Check	Required	Provided	Remarks
Kb		$k_b = \min\left(\frac{e}{3d_0}, \frac{p}{3d_0} - 0.25, \frac{f_{ub}}{f_u}, 1.0\right)$ $= \min\left(\frac{35}{3 \times 22.0}, \frac{75}{3 \times 22.0} - 0.25, \frac{400.0}{410}, 1.0\right)$ $= \min(0.53, 0.89, 0.98, 1.0)$ $= 0.53$ [Ref. IS 800:2007, Cl.10.3.4]	
Bearing Capacity (kN)		$V_{\text{dpb}} = \frac{2.5 k_b d t f_u}{\gamma_{mb}}$ $= \frac{2.5 \times 0.53 \times 20 \times 7.7 \times 410}{1000 \times 1.25}$ $= 84.31$ [Ref. IS 800:2007, Cl.10.3.4]	
Capacity (kN)		$V_{\text{db}} = \min\ (V_{\text{dsb}},\ V_{\text{dpb}})$ $= \min\ (45.26,\ 84.31)$ $= 45.26$ [Ref. IS 800:2007, Cl.10.3.2]	
Long Joint Reduction Factor		$l_j = (n_r - 1) \times p$ $= (3 - 1) \times 75 = 150$ $l = 150$ $15 \times d = 15 \times 20 = 300$ 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		$l_g = \Sigma\ (t_p + t_{\text{member}})$ $= 19.7$ $5d = 100$ $8d = 160$ since, $l_g < 5d$; $\beta_{lg} = 1.0$ [Ref. IS 800:2007, Cl.10.3.3.2]	Pass

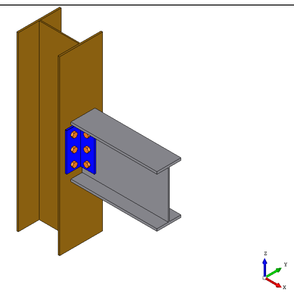
Check	Required	Provided	Remarks
Bolt Capacity (post reduction factor) (kN)		$V_{\text{rd}} = \beta_{lj}\beta_{lg}V_{\text{db}}$ $= 1.0 \times 1.0 \times 45.26$ $= 45.26$	
Capacity (kN)	31.73	45.26	Pass

2.6 Cleat Angle Check

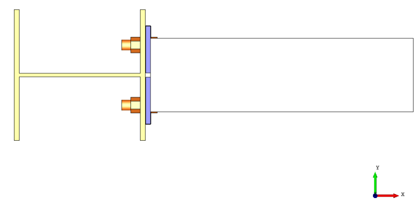
Check	Required	Provided	Remarks
Min. Cleat Angle Height	$0.6 \times (d_b - 2 \times t_f - 2 \times r_r)$ $= 0.6 \times (300.0 - 2 \times 13.1 - 2 \times 14.0)$ $= 147.48$ [Ref. INSDAG, Ch.5, sec.5.2.3]	220	Pass
Max. Cleat Angle Height	$d_b - 2(t_{bf} + r_{b1} + \text{gap})$ $= 250.0 - 2 \times (9.7 + 10.0 + 10)$ $= 245.8$	220	Pass
Min. Leg Length (mm) (on supported leg)	$\max\Big(\text{gap},\ t_{\text{cleat}} + r_{r_{\text{angle}}} + 2e'_{\text{min}} + (n_c - 1)g_{\text{min}}\Big)$ $= \max\Big(10.0,\ 10.0 + 8.5 + 2 \times 33.0 + (1 - 1) \times 50.0\Big)$ $= 84.5$	90.0	Pass
Min. Leg Length (mm) (on supporting leg)	$t_{\text{cleat}} + r_{r_{\text{angle}}} + 2e'_{\text{min}} + (n_c - 1)g_{\text{min}}$ $= 10.0 + 8.5 + 2 \times 33.0 + (1 - 1) \times 50.0$ $= 84.5$	90.0	Pass
Min. Cleat Angle Thickness (mm)	$t_w = 0.5 \times 7.7 = 3.85$	10.0	Pass
Shear Yielding Capacity (kN)		$V_{d_y} = \frac{A_v f_y}{\sqrt{3}\gamma_{m0}}$ $= \frac{2 \times 220 \times 10.0 \times 250}{\sqrt{3} \times 1.1 \times 1000}$ $= 577.35$ [Ref. IS 800:2007, Cl.10.4.3]	

Check	Required	Provided	Remarks
Block Shear Capacity in Shear (kN)		$V_{\text{dbl1}} = \frac{A_{\text{vg}} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}}$ $V_{\text{dbl2}} = \frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{m1}} + \frac{A_{tg} f_y}{\gamma_{m0}}$ $V_{\text{db}} = \min(V_{db1},\ V_{db2}) = 602.22$ [Ref. IS 800:2007, Cl.6.4]	
Shear Capacity (kN)	130.0	$V_d = \min(V_{d_y},\ V_{d_b})$ $= \min(577.35, 602.22)$ $= 577.35$ [Ref. IS 800:2007, Cl.6.1]	**Pass**
Moment Capacity (kNm)	6.96	$M_{d_z} = \frac{\beta_b Z_p fy}{\gamma_{m0} \times 10^6}$ $= \frac{1.0 \times 242000.0 \times 250}{1.1 \times 10^6}$ $= 55.0$ [Ref. IS 800:2007, Cl.8.2.1.2]	**Pass**

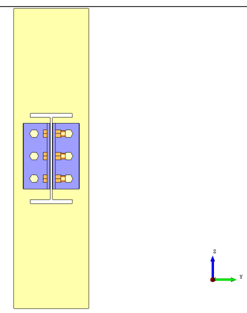
3 3D Views



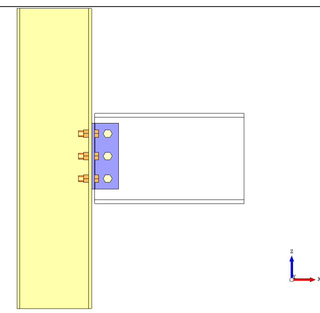
(a) 3D View



(b) Top View



(c) Side View



(d) Front View

4 Design Log