Company Name	IIT Bombay	Project Title	Tension Member
Group/Team Name	Osdag	Subtitle	Bolted to End Gusset
Designer	Engineer#1	Job Number	2.1.2
Date	04 /02 /2021	Client	Dr. Pradyumna M, Bengaluru

1 Input Parameters

Module	Tension Member Design - Bolted to End Gusset
Axial (kN)*	330.0
Length (mm) *	2200.0
Section Profile*	Back to Back Angles
Section Size*	Ref List of Input Section
Section Material	E 250 (Fe 410 W)A
Ultimate Strength, F_u (MPa)	410
Yield Strength, F_y (MPa)	240
Bolt Details - Input and Design Preference	
Diameter (mm)	[16, 20, 24]
Property Class	[6.8, 8.8]
Type	Bearing Bolt
Hole Type	Over-sized
Detailing - Design Preference	
Edge Preparation Method	Rolled, machine-flame cut, sawn and planed
Are the Members Exposed to Corrosive Influences?	False
Plate Details - Input and Design Preference	
Thickness (mm)	[10, 12, 14, 16, 20]
Material	E 250 (Fe 410 W)A

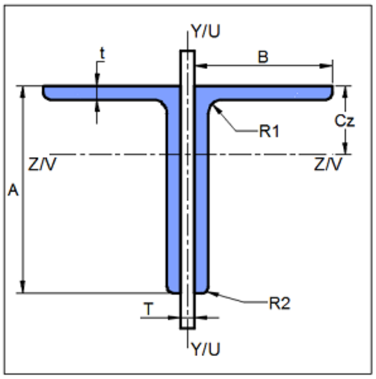
1.1 List of Input Section

Section Size*	'20 x 20 x 3', '20 x 20 x 4', '25 x 25 x 3', '25 x 25 x 4', '25 x 25 x 5', '30 x 30 x 3', '30 x 30 x 4', '30 x 30 x 5', '35 x 35 x 3', '35 x 35 x 4', '35 x 35 x 5', '35 x 35 x 6', '40 x 40 x 3', '40 x 40 x 4', '40 x 40 x 5', '40 x 40 x 6', '45 x 45 x 3', '45 x 45 x 4', '45 x 45 x 5', '45 x 45 x 6', '50 x 50 x 3', '50 x 50 x 4', '50 x 50 x 5', '50 x 50 x 6', '55 x 55 x 4', '55 x 55 x 5', '55 x 55 x 6', '55 x 55 x 8', '60 x 60 x 4', '60 x 60 x 5', '60 x 60 x 6', '60 x 60 x 8', '65 x 65 x 4', '65 x 65 x 5', '65 x 65 x 6', '65 x 65 x 8', '70 x 70 x 5', '70 x 70 x 6', '70 x 70 x 8', '70 x 70 x 10', '75 x 75 x 6', '75 x 75 x 8', '75 x 75 x 10', '80 x 80 x 6', '80 x 80 x 8', '80 x 80 x 10', '80 x 80 x 12', '90 x 90 x 6', '90 x 90 x 8', '90 x 90 x 10', '90 x 90 x 12', '100 x 100 x 6', '100 x 100 x 8', '100 x 100 x 10', '100 x 100 x 12', '110 x 110 x 8', '110 x 110 x 10', '110 x 110 x 12', '110 x 110 x 16', '130 x 130 x 8', '130 x130 x 10', '130 x130 x 12', '130 x130 x 16', '150 x 150 x 10', '150 x 150 x 12', '150 x 150 x 16', '150 x 150 x 20', '200 x 200 x 12', '200 x 200 x 16', '200 x 200 x 20', '200 x 200 x 25', '50 x 50 x 7', '50 x 50 x 8', '55 x 55 x 10', '60 x 60 x 10', '65 x 65 x 10', '70 x 70 x 7', '100 x 100 x 7', '100 x 100 x 15', '120 x 120 x 8', '120 x 120 x 10', '120 x 120 x 12', '120 x 120 x 15', '130 x 130 x 9', '150 x 150 x 15', '150 x 150 x 18', '180 x 180 x 15', '180 x 180 x 18', '180 x 180 x 20', '200 x 200 x 24', '30 x 20 x 3', '30 x 20 x 4', '30 x 20 x 5', '40 x 25 x 3', '40 x 25 x 4', '40 x 25 x 5', '40 x 25 x 6', '45 x 30 x 3', '45 x 30 x 4', '45 x 30 x 5', '45 x 30 x 6', '50 x 30 x 3', '50 x 30 x 4', '50 x 30 x 5', '50 x 30 x 6', '60 x 40 x 5', '60 x 40 x 6', '60 x 40 x 8', '65 x 45 x 5', '65 x 45 x 6', '65 x 45 x 8', '70 x 45 x 5', '70 x 45 x 6', '70 x 45 x 8', '70 x 45 x 10', '75 x 50 x 5', '75 x 50 x 6', '75 x 50 x 8', '75 x 50 x 10', '80 x 50 x 5', '80 x 50 x 6', '80 x 50 x 8', '80 x 50 x 10', '90 x 60 x 6', '90 x 60 x 8', '90 x 60 x 10', '90 x 60 x 12', '100 x 65 x 6', '100 x 65 x 8', '100 x 65 x 10', '100 x 75 x 6', '100 x 75 x 8', '100 x 75 x 10', '100 x 75 x 12', '125 x 75 x 6', '125 x 75 x 8', '125 x 75 x 10', '125 x 95 x 6', '125 x 95 x 8', '125 x 95 x 10', '125 x 95 x 12', '150 x 115 x 8', '150 x 115 x 10', '150 x 115 x 12', '150 x 115 x 16', '200 x 100 x 10', '200 x 100 x 12', '200 x 100 x 16', '200 x 150 x 10', '200 x 150 x 12', '200 x 150 x 16', '200 x 150 x 20', '40 x 20 x 3', '40 x 20 x 4', '40 x 20 x 5', '60 x 30 x 5', '60 x 30 x 6', '60 x 40 x 7', '65 x 50 x 5', '65 x 50 x 6', '65 x 50 x 7', '65 x 50 x 8', '70 x 50 x 5', '70 x 50 x 6', '70 x 50 x 7', '70 x 50 x 8', '75 x 50 x 7', '80 x 40 x 5', '80 x 40 x 6', '80 x 40 x 7', '80 x 40 x 8', '80 x 60 x 6', '80 x 60 x 7', '80 x 60 x 8', '90 x 65 x 6', '90 x 65 x 7', '90 x 65 x 8', '90 x 65 x 10', '100 x 50 x 6', '100 x 50 x 7', '100 x 50 x 8', '100 x 50 x 10', '100 x 65 x 7', '120 x 80 x 8', '120 x 80 x 10', '120 x 80 x 12', '125 x 75 x 12', '135 x 65 x 8', '135 x 65 x 10', '135 x 65 x 12', '150 x 75 x 9', '150 x 75 x 15', '150 x 90 x 10', '150 x 90 x 12', '150 x 90 x 15', '200 x 100 x 15', '200 x 150 x 15', '200 x 150 x 18'

2 Design Checks

Design Status	Pass

2.1 Selected Member Data



Section Size*		('80 x 50 x 6', 'Back to Back Angles')	
Material		E 250 (Fe 410 W)A	
Mass, m (kg/m)		11.84	
Area, A (cm^2)		1510.0	
A (mm)	80.0	I_v(cm^4)	98.8
B (mm)	50.0	r_z (cm)	2.56
t (mm)	6.0	r_y (cm)	1.84
T (mm)	20.0	r_u (cm)	1.84
R_1 (mm)	7.0	r_v (cm)	2.56
R_2 (mm)	0.0	Z_z (cm^3)	18.5
C_y (mm)	N/A	Z_y (cm^3)	10.25
C_z (mm)	26.6	Z_{pz} (cm^3)	33.0
I_z (cm^4)	98.8	Z_{py} (cm^3)	17.97
I_y(cm^4)	51.23	Radius of gyration, r (cm)	18.4
I_u (cm^4)	51.23		

2.2 Spacing Check

Check	Required	Provided	Remarks
Min. Diameter (mm)		$d = 16$	
Hole Diameter (mm)		$d_0 = 20$	
Minimum Bolts (nos)		$r_l = 1$	
Min. Gauge Distance (mm)	$p/g_{\min} = 2.5d$ $= 2.5 \times 16.0$ $= 40.0$ [Ref. IS 800:2007, Cl.10.2.2]	40	Pass

Check	Required	Provided	Remarks
Min. Edge Distance (mm)	$e_{\min} = 1.5d_0$ $= 1.5 \times 20.0$ $= 30.0$ [Ref. IS 800:2007, Cl.10.2.4.2]	30	**Pass**
Spacing Check	$\text{depth} = 2\ e + (r_l - 1)\ g$ $= 2 \times 30 + (1 - 1) \times 40$ $= 60$	67.0	**Pass**

2.3 Member Check

Check	Required	Provided	Remarks
Tension Yielding Capacity (kN)		$T_{\text{dg}} = \frac{A_g f_y}{\gamma_{m0}}$ $= \frac{1510.0 \times 250}{1.1 \times 10^3}$ $= 343.18$ [Ref. IS 800:2007, Cl.6.2]	

Check	Required	Provided	Remarks
Tension Rupture Capacity (kN)		$\beta = 1.4 - 0.076 \times \frac{w}{t} \times \frac{f_y}{0.9 f_u} \times \frac{b_s}{L_c} \leq \frac{0.9 f_u \gamma_{m0}}{f_y \gamma_{m1}} \geq 0.7$ $= 1.4 - 0.076 \times \frac{50.0}{6.0} \times \frac{250}{0.9 \times 410} \times \frac{90.5}{280} \leq \frac{0.9 \times 410 \times 1.1}{250 \times 1.25} \geq 0.7$ $= 1.26$ $T_{\text{dn}} = 2 \times \left(\frac{0.9 A_{nc} f_u}{\gamma_{m1}} + \frac{\beta A_{go} f_y}{\gamma_{m0}}\right)$ $= 2 \times \left(\frac{0.9 \times 324.0 \times 410}{1.25} + \frac{1.26 \times 300.0 \times 250}{1.1}\right)$ $= 363.11$ [Ref. IS 800:2007, Cl.6.3.3]	
Block Shear Capacity (kN)		$T_{\text{dbl1}} = \frac{A_{\text{vg}} f_y}{\sqrt{3} \gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}}$ $T_{\text{dbl2}} = \frac{0.9 A_{vn} f_u}{\sqrt{3} \gamma_{m1}} + \frac{A_{tg} f_y}{\gamma_{m0}}$ $T_{\text{db}} = \min(T_{db1},\ T_{db2}) = 418.6$ [Ref. IS 800:2007, Cl.6.4]	
Tension Capacity (kN)	330.0	$T_{\text{d}} = \min(T_{\text{dg}},\ T_{\text{dn}},\ T_{\text{db}})$ $= \min(343.18, 363.11, 418.6)$ $= 343.18$ [Ref.IS 800:2007, Cl.6.1]	Pass

Check	Required	Provided	Remarks
Slenderness	$\frac{KL}{r} \leq 400$	$\frac{KL}{r} = \frac{1 \times 2200.0}{18.4}$ $= 119.57$ [Ref. IS 800:2007, Cl.7.1.2]	Pass
Utilization Ratio	≤ 1	Utilization Ratio $= \frac{F}{T_d} = \frac{330.0}{343.18}$ $= 0.96$	
Axial Load Considered (kN)	$A_{c\text{min}} = 0.3A_c$ $= 0.3 \times 343.18$ $= 102.95$ $A_{c\text{max}} = 343.18$ [Ref. IS 800:2007, Cl.10.7]	$A_u = 330.0$	Pass

2.4 Bolt Design

Check	Required	Provided	Remarks
Diameter (mm)	Bolt Quantity Optimization	$d = 16$	
Hole Diameter (mm)		$d_0 = 20$	
Property Class	Bolt Grade Optimization	6.8	
Bolt Ultimate Strength (N/mm2)		$f_{u_b} = 600.0$	
Bolt Yield Strength (N/mm2)		$f_{y_b} = 480.0$	
Nominal Stress Area (mm2)		$A_{n_b} = 157$ $([Ref.\ IS\ 1367-3\ (2002)])$	
Min. Pitch Distance (mm)	$p_{\text{min}} = 2.5d$ $= 2.5 \times 16.0$ $= 40.0$ [Ref. IS 800:2007, Cl.10.2.2]	40	Pass

Check	Required	Provided	Remarks
Max. Pitch Distance (mm)	$p/g_{\max} = \min(32t,\ 300)$ $= \min(32 \times 6.0,\ 300)$ $= \min(192.0,\ 300)$ $= 192.0$ Where, $t = \min(20.0, 6.0)$ [Ref. IS 800:2007, Cl.10.2.3]	40	**Pass**
Min. Gauge Distance (mm)	$p_{\min} = 2.5d$ $= 2.5 \times 16.0$ $= 40.0$ [Ref. IS 800:2007, Cl.10.2.2]	0	
Max. Gauge Distance (mm)	$p/g_{\max} = \min(32t,\ 300)$ $= \min(32 \times 6.0,\ 300)$ $= \min(192.0,\ 300)$ $= 192.0$ Where, $t = \min(20.0, 6.0)$ [Ref. IS 800:2007, Cl.10.2.3]	0	
Min. End Distance (mm)	$e_{\min} = 1.5d_0$ $= 1.5 \times 20.0$ $= 30.0$ [Ref. IS 800:2007, Cl.10.2.4.2]	30	**Pass**

Check	Required	Provided	Remarks
Max. End Distance (mm)	$e_{\max} = 12t\varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 6.0 \times \sqrt{\frac{250}{250}} = 72.0$ $e_2 = 12 \times 20.0 \times \sqrt{\frac{250}{240}} = 244.95$ $e_{\max} = \min(e_1,\ e_2) = 72.0$ [Ref. IS 800:2007, Cl.10.2.4.3]	30	Pass
Min. Edge Distance (mm)	$e_{\min} = 1.5d_0$ $= 1.5 \times 20.0$ $= 30.0$ [Ref. IS 800:2007, Cl.10.2.4.2]	33.5	Pass
Max. Edge Distance (mm)	$e_{\max} = 12t\varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 6.0 \times \sqrt{\frac{250}{250}} = 72.0$ $e_2 = 12 \times 20.0 \times \sqrt{\frac{250}{240}} = 244.95$ $e_{\max} = \min(e_1,\ e_2) = 72.0$ [Ref. IS 800:2007, Cl.10.2.4.3]	33.5	Pass
Kb		$k_b = \min\left(\frac{e}{3d_0}, \frac{p}{3d_0} - 0.25, \frac{f_{ub}}{f_u}, 1.0\right)$ $= \min\left(\frac{30}{3 \times 20.0}, \frac{40}{3 \times 20.0} - 0.25, \frac{600.0}{410}, 1.0\right)$ $= \min(0.5, 0.42, 1.46, 1.0)$ $= 0.42$ [Ref. IS 800:2007, Cl.10.3.4]	

Check	Required	Provided	Remarks
Shear Capacity (kN)		$V_{\text{dsb}} = \frac{f_{ub} n_n A_{nb}}{\sqrt{3}\gamma_{mb}}$ $= \frac{600.0 \times 2 \times 157}{1000 \times \sqrt{3} \times 1.25}$ $= 87.02$ [Ref. IS 800:2007, Cl.10.3.3]	
Bearing Capacity (kN)		$V_{\text{dpb}} = \frac{2.5 k_b d t f_u}{\gamma_{mb}}$ $= \frac{2.5 \times 0.42 \times 16.0 \times 12.0 \times 410}{1000 \times 1.25}$ $= 46.29$ [Ref. IS 800:2007, Cl.10.3.4]	
Capacity (kN)		$V_{\text{db}} = \min\ (V_{\text{dsb}},\ V_{\text{dpb}})$ $= \min\ (87.02,\ 46.29)$ $= 46.29$ [Ref. IS 800:2007, Cl.10.3.2]	
No. of Bolts	$R_u = \sqrt{V_u^2 + A_u^2}$ $n_{\text{trial}} = R_u / V_{bolt}$ $R_u = \frac{\sqrt{0.0^2 + 330.0^2}}{46.29}$ $= 8$	$n = 8$	
No. of Bolt Columns		$n_c = 8$	
No. of Bolt Rows		$n_r = 1$	

Check	Required	Provided	Remarks
Long Joint Reduction Factor	if $l_j \geq 15d$ then $V_{\text{rd}} = \beta_{lj} V_{\text{db}}$ if $l_j < 15d$ then $V_{\text{rd}} = V_{\text{db}}$ where, $l_j = ((nc \text{ or } nr) - 1) \times (p \text{ or } g)$ $\beta_{lj} = 1.075 - l/(200d)$ but $0.75 \leq \beta_{lj} \leq 1.0$ [Ref. IS 800:2007, Cl.10.3.3.1]	$l_j = ((n_c \text{ or } n_r) - 1) \times (p \text{ or } g)$ $= (8 - 1) \times 40 = 280$ $= (1 - 1) \times 0 = 0$ $l = 280$ $15 \times d = 15 \times 16.0 = 240.0$ since, $l_j \geq 15\ d$ then $V_{\text{rd}} = \beta_{lj}\ V_{\text{db}}$ $\beta_{lj} = 1.075 - 280/(200\ \times 16.0) = 0.99$ [Ref. IS 800:2007, Cl.10.3.3.1]	
Large Grip Length Reduction Factor	if $l_g \geq 5d$, then $V_{\text{rd}} = \beta_{lg} V_{\text{db}}$ if $l_g < 5d$ then $V_{\text{rd}} = V_{\text{db}}$ $l_g \leq 8d$ where, $l_g = \Sigma(t_{\text{ep}} + t_{\text{member}})$ $\beta_{lg} = 8d/(3d + l_g)$ but $\beta_{lg} \leq \beta_{lj}$ [Ref. IS 800:2007, Cl.10.3.3.2]	$l_g = \Sigma\ (t_p + t_{\text{member}})$ $= 32.0$ $5d = 80.0$ $8d = 128.0$ since, $l_g < 5d$; $\beta_{lg} = 1.0$ [Ref. IS 800:2007, Cl.10.3.3.2]	
Capacity (kN)	41.25	$V_{\text{rd}} = \beta_{lj} \beta_{lg} V_{\text{db}}$ $= 0.99 \times 1.0 \times 46.29$ $= 45.82$	**Pass**

2.5 Gusset Plate Check

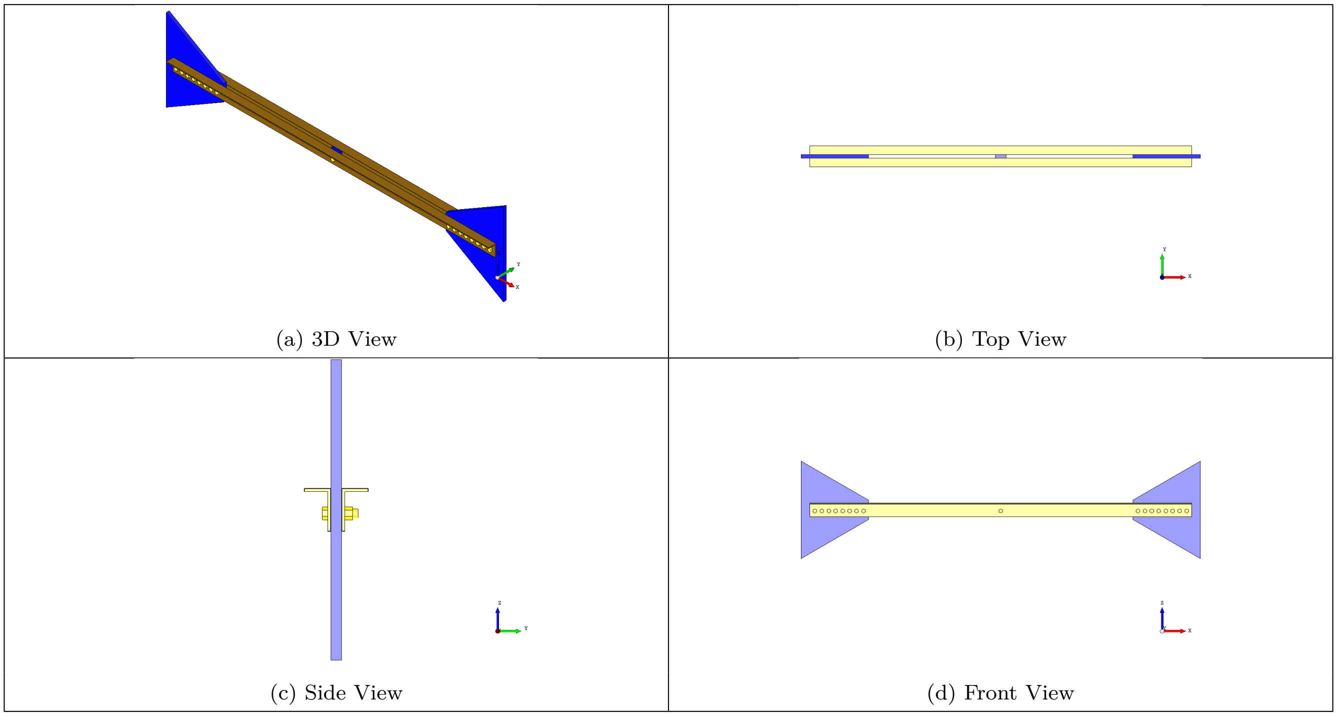
Check	Required	Provided	Remarks
Min.Height (mm)		$H = 1 \times \text{Depth} + \text{Clearance}$ $= (1 \times 80.0) + 30.0$ $= 110$	
Min.Plate Length (mm)		$L = (nc - 1)p + 2e$ $= (8 - 1) \times 40 + (2 \times 30)$ $= 340$	
Min.Member Length (mm)	680	2200.0	Pass
Thickness (mm)		$T = 20.0$	
Tension Yielding Capacity (kN)		$T_{\text{dg}} = \frac{A_g f_y}{\gamma_{m0}}$ $A_g = lt = 80.0 \times 20.0$ $= \frac{1600.0 \times 240}{1.1 \times 10^3}$ $= 349.09$ [Ref. IS 800:2007, Cl.6.2]	
Tension Rupture Capacity (kN)		$T_{\text{dn}} = \frac{0.9 A_n f_u}{\gamma_{m1}}$ $= \frac{1 \times \ 0.9 \times (80.0 - 1 \times 20.0) \times 20.0 \times 410}{1.25}$ $= 354.24$ [Ref. IS 800:2007, Cl.6.3.1]	
Block Shear Capacity (kN)		$T_{\text{dbl1}} = \frac{A_{\text{vg}} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}}$ $T_{\text{dbl2}} = \frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{m1}} + \frac{A_{tg} f_y}{\gamma_{m0}}$ $T_{\text{db}} = \min(T_{db1},\ T_{db2}) = 691.57$ [Ref. IS 800:2007, Cl.6.4]	

Check	Required	Provided	Remarks
Tension Capacity (kN)	$A = 330.0$	$T_{\text{d}} = \min(T_{\text{dg}},\ T_{\text{dn}},\ T_{\text{db}})$ $= \min(349.09, 354.24, 691.57)$ $= 349.09$ [Ref.IS 800:2007, Cl.6.1]	**Pass**

2.6 Intermittent Connection

Check	Required	Provided	Remarks
Connection (nos)		1	
Spacing (mm)	1000	790.0	**Pass**
Diameter (mm)		16	
Property Class		6.8	
No. of Bolt Columns		1	
No. of Bolt Rows		1	
Min.Height (mm)		80	
Min.Plate Length (mm)		60	

3 3D Views



(a) 3D View

(b) Top View

(c) Side View

(d) Front View

4 Design Log

2021-02-04 15:30:38 - Osdag - INFO - :In the case of reverse loading, the slenderness value shall be less than 180 [Ref. Table 3, IS 800:2007].
2021-02-04 15:30:38 - Osdag - INFO - :In the case of reverse loading for double sections, spacing of the intermittent connection shall be less than 600 [Ref. Cl. 10.2.5.5, IS 800:2007].
2021-02-04 15:30:38 - Osdag - INFO - :To reduce the quantity of bolts, define a list of diameter, plate thickness and/or member size higher than the one currently defined.
2021-02-04 15:30:38 - Osdag - INFO - :Overall bolted tension member design is safe.
2021-02-04 15:30:38 - Osdag - INFO - :=========End Of design===========