Company Name	IIT Bombay	Project Title	Sample Member Design
Group/Team Name	Osdag	Subtitle	Tension Member Bolted
Designer	Engineer #1	Job Number	2.1.3
Date	18 /12 /2020	Client	Pratip Bhattacharya, TCE, Kolkata

1 Input Parameters

Module	Tension Member Bolted
Axial (kN)*	180.0
Length (mm) *	2500.0
Section Profile*	Star Angles
Section Size*	Ref List of Input Section
Section Material	E 165 (Fe 290)
Section Ultimate Strength, f_u (MPa)	290
Section Yield Strength, f_y (MPa)	165
Bolt Details - Input and Design Preference	
Diameter (mm)	[16, 20]
Property Class	[5.6, 5.8, 6.8]
Type	Bearing Bolt
Hole Type	Standard
Detailing - Design Preference	
Edge Preparation Method	Sheared or hand flame cut
Are the Members Exposed to Corrosive Influences?	False
Plate Details - Input and Design Preference	
Thickness (mm)	[10, 12, 14]
Material	E 250 (Fe 410 W)A
Ultimate Strength, Fu (MPa)	410
Yield Strength, Fy (MPa)	250

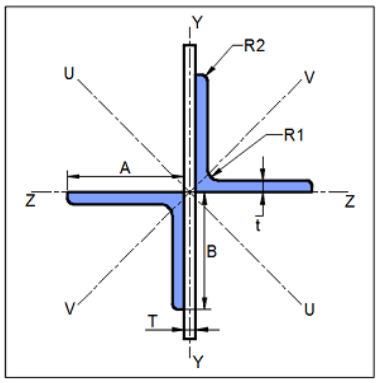
1.1 List of Input Section

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 5', '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*		('75 x 75 x 5', 'Star Angles')	
Material		E 165 (Fe 290)	
Mass, m (kg/m)		11.54	
Area, A (cm^2)		1472.0	
A (mm)	75.0	r_z (cm)	3.1
B (mm)	75.0	r_y (cm)	3.1
t (mm)	5.0	r_u (cm)	3.25
T (mm)	10.0	r_v (cm)	2.94
R_1 (mm)	7.0	Z_z (cm^3)	18.83
R_2 (mm)	0.0	Z_y (cm^3)	18.83
I_z (cm^4)	141.26	Z_{pz} (cm^3)	30.03
I_y(cm^4)	141.26	Z_{py} (cm^3)	30.03
I_u (cm^4)	155.29	Radius of gyration, r (cm)	29.4
I_v(cm^4)	127.23		

2.2 Spacing Check

Check	Required	Provided	Remarks
Min. Diameter (mm)		$d = 16$	
Hole Diameter (mm)		$d_0 = 18$	
Minimum Bolts (nos)		$r_l = 1$	
Min. Gauge Distance (mm)	$p/g_{min} = 2.5\ d$ $= 2.5 \times 16.0$ $= 40.0$ [$Ref\ IS\ 800:2007,\ Cl.\ 10.2.2$]	40	Pass

Check	Required	Provided	Remarks
Min. Edge Distance (mm)	$e_{min} = 1.5\ d_0$ $= 1.5 \times 18.0$ $= 27.0$ [*Ref. IS* 800 : 2007, *Cl.* 10.2.4.2]	30	**Pass**
Spacing Check	$depth = 2\ e + (r_l - 1)\ g$ $= 2 \times 30 + (1 - 1) \times 40$ $= 60$	63.0	**Pass**

2.3 Member Check

Check	Required	Provided	Remarks
Tension Yielding Capacity (kN)		$T_{dg} = \frac{A_g f_y}{\gamma_{mo}}$ $= \frac{1472.0 \times 165}{1.1 \times 10^3}$ $= 220.8$ [*Ref. IS* 800 : 2007, *Cl.* 6.2]	

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Check	Required	Provided	Remarks
Tension Rupture Capacity (kN)		$\beta = 1.4 - 0.076 \times \frac{w}{t} \times \frac{f_y}{0.9 f_u} \times \frac{b_s}{L_c}$ $\leq \frac{0.9\ f_u\ \gamma_{m0}}{f_y\ \gamma_{m1}} \geq 0.7$ $= 1.4 - 0.076 \times \frac{75.0}{5.0} \times \frac{165}{0.9 \times 290} \times \frac{113.5}{150}$ $\leq \frac{0.9 \times 290 \times 1.1}{165 \times 1.25} \geq 0.7$ $= 0.85$ $T_{dn} = 2 \times (\frac{0.9 A_{nc} f_u}{\gamma_{m1}} + \frac{\beta A_{go} f_y}{\gamma_{m0}})$ $= 2 \times (\frac{0.9 \times 260.0 \times 290}{1.25} + \frac{0.85 \times 375.0 \times 165}{1.1})$ $= 204.2$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 6.3.3]$	
Block Shear Capacity (kN)		$T_{dbl1} = \frac{A_{vg} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}}$ $T_{dbl2} = \frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{m1}} + \frac{A_{tg} f_y}{\gamma_{m0}}$ $T_{db} = min(T_{db1}, T_{db2}) = 194.32$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 6.4]$	
Tension Capacity (kN)	180.0	$T_d = min(T_{dg}, T_{dn}, T_{db})$ $= min(220.8, 204.2, 194.32)$ $= 194.32$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 6.1]$	**Pass**
Slenderness	$\frac{KL}{r} \leq 400$	$\frac{KL}{r} = \frac{1 \times 2500.0}{29.4}$ $= 85.03$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 7.1.2]$	**Pass**

Check	Required	Provided	Remarks
Utilization Ratio	≤ 1	$Utilization\ Ratio = \frac{F}{T_d} = \frac{180.0}{194.32}$ $= 0.93$	
Axial Load Considered (kN)	$Ac_{min} = 0.3A_c$ $= 0.3 \times 220.8$ $= 66.24$ $Ac_{max} = 220.8$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.7]$	$A_u = 180.0$	**Pass**

2.4 Bolt Design

Check	Required	Provided	Remarks
Diameter (mm)	Bolt Quantity Optimization	$d = 16$	
Hole Diameter (mm)		$d_0 = 18$	
Property Class	Bolt Grade Optimization	5.6	
Bolt Ultimate Strength (N/mm2)		$f_{ub} = 500.0$	
Bolt Yield Strength (N/mm2)		$f_{yb} = 300.0$	
Nominal Stress Area (mm2)		$A_{nb} = 157$ ($[Ref\ IS\ 1367 - 3\ (2002)]$)	
Min. Pitch Distance (mm)	$p_{min} = 2.5\ d$ $= 2.5 \times 16.0$ $= 40.0$ $[Ref\ IS\ 800:2007,\ Cl.\ 10.2.2]$	50	**Pass**

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Check	Required	Provided	Remarks
Max. Pitch Distance (mm)	$p/g_{max} = \min(32\ t,\ 300\ mm)$ $= \min(32 \times 5.0,\ 300\ mm)$ $= \min(160.0,\ 300\ mm)$ $= 160.0$ $Where,\ t = min(10.0, 5.0)$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.2.3]$	50	**Pass**
Min. Gauge Distance (mm)	$p_{min} = 2.5\ d$ $= 2.5 \times 16.0$ $= 40.0$ $[Ref\ IS\ 800 : 2007,\ Cl.\ 10.2.2]$	0	
Max. Gauge Distance (mm)	$p/g_{max} = \min(32\ t,\ 300\ mm)$ $= \min(32 \times 5.0,\ 300\ mm)$ $= \min(160.0,\ 300\ mm)$ $= 160.0$ $Where,\ t = min(10.0, 5.0)$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.2.3]$	0	
Min. End Distance (mm)	$e_{min} = 1.7\ d_0$ $= 1.7 \times 18.0$ $= 30.6$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.2.4.2]$	35	**Pass**

Check	Required	Provided	Remarks
Max. End Distance (mm)	$e_{max} = 12\ t\ \varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 5.0 \times \sqrt{\frac{250}{165}} = 73.85$ $e_2 = 12 \times 10.0 \times \sqrt{\frac{250}{250}} = 120.0$ $e_{max} = min(e_1, e_2) = 73.85$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.2.4.3]$	35	**Pass**
Min. Edge Distance (mm)	$e_{min} = 1.5\ d_0$ $= 1.5 \times 18.0$ $= 27.0$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.2.4.2]$	31.5	**Pass**
Max. Edge Distance (mm)	$e_{max} = 12\ t\ \varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 5.0 \times \sqrt{\frac{250}{165}} = 73.85$ $e_2 = 12 \times 10.0 \times \sqrt{\frac{250}{250}} = 120.0$ $e_{max} = min(e_1, e_2) = 73.85$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.2.4.3]$	31.5	**Pass**
Kb		$k_b = min\left(\frac{e}{3d_0},\ \frac{p}{3d_0} - 0.25,\ \frac{f_{ub}}{f_u},\ 1.0\right)$ $= min\left(\frac{35}{3 \times 18.0},\ \frac{50}{3 \times 18.0} - 0.25,\ \frac{500.0}{290},\ 1.0\right)$ $= min(0.65, 0.68, 1.72, 1.0)$ $= 0.65$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.3.4]$	

Check	Required	Provided	Remarks
Shear Capacity (kN)		$V_{dsb} = \frac{f_{ub}\ n_n\ A_{nb}}{\sqrt{3}\ \gamma_{mb}}$ $= \frac{500.0 \times 1 \times 157}{1000 \times \sqrt{3}\ \times\ 1.25}$ $= 36.26$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.3.3]$	
Bearing Capacity (kN)		$V_{dpb} = \frac{2.5\ k_b\ d\ t\ f_u}{\gamma_{mb}}$ $= \frac{2.5 \times 0.65 \times 16.0 \times 5.0 \times 290}{1000 \times 1.25}$ $= 30.16$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.3.4]$	
Capacity (kN)		$V_{db} = min\ (V_{dsb}, V_{dpb})$ $= min\ (36.26, 30.16)$ $= 30.16$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.3.2]$	
No. of Bolts	$R_u = \sqrt{V_u^2 + A_u^2}$ $n_{trial} = R_u / V_{bolt}$ $R_u = \frac{\sqrt{0.0^2 + 180.0^2}}{30.16}$ $= 6$	$n = 8$	
No. of Bolt Columns		$n_c = 4$	
No. of Bolt Rows		$n_r = 2$	

Check	Required	Provided	Remarks
Long Joint Reduction Factor	$if\ l_j \geq 15d\ then\ V_{rd} = \beta_{lj} V_{db}$ $if\ l_j < 15d\ then\ V_{rd} = V_{db}$ $where,$ $l_j = ((nc\ or\ nr) - 1) \times (p\ or\ g)$ $\beta_{lj} = 1.075 - l/(200d)$ $but\ 0.75 \leq \beta_{lj} \leq 1.0$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.3.3.1]$	$l_j = ((n_c\ or\ n_r) - 1) \times (p\ or\ g)$ $= (4 - 1) \times 50 = 150$ $= (2 - 1) \times 0 = 0$ $l = 150$ $15 \times d = 15 \times 16.0 = 240.0$ $since,\ l_j < 15 \times d\ then\ \beta_{lj} = 1.0$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.3.3.1]$	
Large Grip Length Reduction Factor	$if\ l_g \geq 5\ d\ then\ V_{rd} = \beta_{lg}\ V_{db}$ $if\ l_g < 5d\ then\ V_{rd} = V_{db}$ $l_g \leq 8d$ $where,$ $l_g = \Sigma(t_{ep} + t_{member})$ $\beta_{lg} = 8d/(3d + l_g)$ $but\ \beta_{lg} \leq \beta_{lj}$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.3.3.2]$	$l_g = \Sigma\ (t_p + t_{member})$ $= 15.0$ $5d = 80.0$ $8d = 128.0$ $since,\ l_g < 5d\ ;\ \beta_{lg} = 1.0$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.3.3.2]$	
Capacity (kN)	22.5	$V_{rd} = \beta_{lj}\beta_{lg}V_{db}$ $= 1.0 \times 1.0 \times 30.16$ $= 30.16$	**Pass**

2.5 Gusset Plate Check

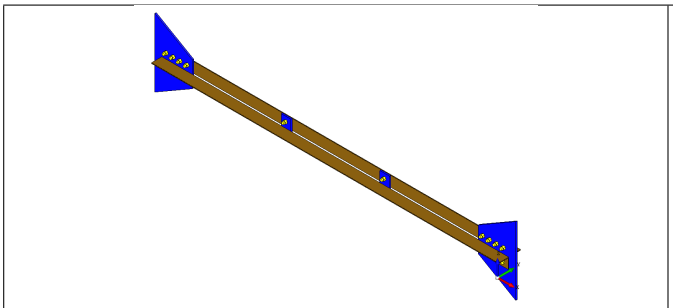
Check	Required	Provided	Remarks
Min.Height (mm)		$H = 2 \times Depth + clearance$ $= (2 \times 75.0) + 30.0$ $= 180$	
Min.Plate Length (mm)		$L = (nc - 1)p + 2e$ $= (4 - 1) \times 50 + (2 \times 35)$ $= 220$	
Min.Member Length (mm)	440	2500.0	**Pass**
Thickness (mm)		$T = 10.0$	
Tension Yielding Capacity (kN)		$T_{dg} = \frac{A_g f_y}{\gamma_{mo}}$ $A_g = l \times t = 150.0 \times 10.0$ $= \frac{1500.0 \times 250}{1.1 \times 10^3}$ $= 340.91$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 6.2]$	
Tension Rupture Capacity (kN)		$T_{dn} = \frac{0.9 A_n f_u}{\gamma_{m1}}$ $= \frac{1 \times\ 0.9 \times (150.0 - 2 \times 18.0) \times 10.0 \times 410}{1.25}$ $= 336.53$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 6.3.1]$	
Block Shear Capacity (kN)		$T_{dbl1} = \frac{A_{vg} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}}$ $T_{dbl2} = \frac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{m1}} + \frac{A_{tg} f_y}{\gamma_{m0}}$ $T_{db} = min(T_{db1}, T_{db2}) = 477.25$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 6.4]$	

Check	Required	Provided	Remarks
Tension Capacity (kN)	$A = 180.0$	$T_d = min(T_{dg}, T_{dn}, T_{db})$ $= min(340.91, 336.53, 477.25)$ $= 336.53$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 6.1]$	**Pass**

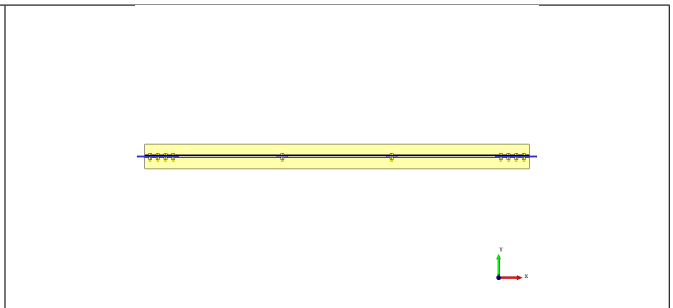
2.6 Intermittent Connection

Check	Required	Provided	Remarks
Connection (nos)		2	
Spacing (mm)	1000	710.0	**Pass**
Diameter (mm)		16	
Property Class		5.6	
No. of Bolt Columns		1	
No. of Bolt Rows		2	
Min.Height (mm)		150	
Min.Plate Length (mm)		70	

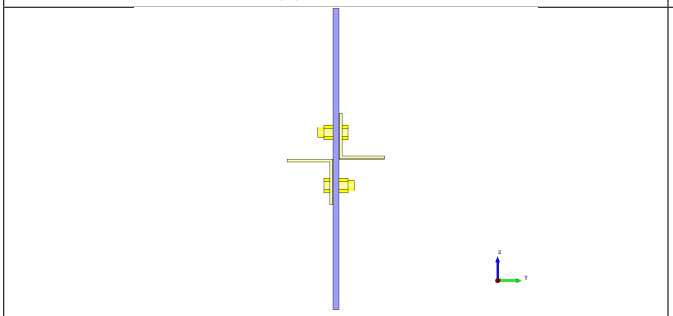
3 3D Views



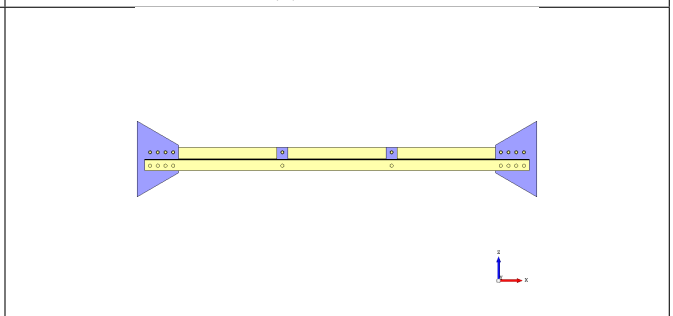
(a) 3D View



(b) Top View



(c) Side View



(d) Front View

4 Design Log

2020-12-18 01:55:56 - Osdag - INFO - :In the case of reverse loading, the slenderness value shall be less than 180 [Ref. Table 3, IS 800:2007].

2020-12-18 01:55:56 - 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].

2020-12-18 01:55:56 - 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.

2020-12-18 01:55:56 - Osdag - INFO - :Overall bolted tension member design is safe.