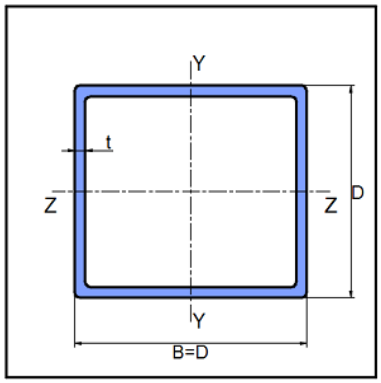
Company Name	IIT Bombay	Project Title	Sample Connection Design
Group/Team Name	Osdag	Subtitle	Base Plate Connection
Designer	Engineer #1	Job Number	1.3.3.1
Date	18 /12 /2020	Client	Yogesh D Pisal, Aker Powergas, Mumbai

1 Input Parameters

Main Module			Moment Connection	
Module			Base Plate	
Connectivity			Hollow/Tubular Column Base	
End Condition			Fixed	
Axial Compression (kN)			650.0	
Axial Tension/Uplift (kN)			0.0	
Shear Force (kN)				
- Along major axis (z-z)			0.0	
- Along minor axis (y-y)			0.0	
Bending Moment (kNm)				
- Major axis (M_{z-z})			0.0	
- Minor axis (M_{y-y})			0.0	
Column Section - Mechanical Properties				
	Column Section		SHS 180 x 180 x 8.0	
	Material		E 300 (Fe 440)	
	Ultimate Strength, f_u (MPa)		440.0	
	Yield Strength, f_y (MPa)		300.0	
	Mass, m (kg/m)	41.91	r_z (cm)	6.97
	Area, A (cm^2)	53.39	r_y (cm)	6.97
	None	None	Z_z (cm^3)	287.86
	D (mm)	180.0	Z_y (cm^3)	287.86
	B (mm)	180.0	Z_{pz} (cm^3)	340.68
	t (mm)	8.0	Z_{py} (cm^3)	340.68
	I_z (cm^4)	2590.73		
	I_y(cm^4)	2590.73		
Base Plate - Design Preference				
Material			E 250 (Fe 410 W)A	
Ultimate Strength, f_u (MPa)			410	
Yield Strength, f_y (MPa)			250	
Stiffener/Shear Key - Design Preference				
Material			E 250 (Fe 410 W)A	

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Ultimate Strength, f_u (MPa)	410
Yield Strength, f_y (MPa)	250
Anchor Bolt - Input and Design Preference	
Diameter (mm)	['M20', 'M24', 'M30']
Property Class	['8.8', '10.9']
Anchor Bolt Type	End Plate Type
Anchor Bolt Galvanized?	Yes
Designation	M20X346.5 IS5624 GALV
Hole Type	Over-sized
Total Length (mm)	346.5
Material Grade, f_u (MPa)	1040.0
None	
Friction Coefficient (between concrete and anchor bolt)	0.3
Weld - Design Preference	
Type of Weld Fabrication	Shop Weld
Material Grade Overwrite, f_u (MPa)	510.0
Detailing - Design Preference	
Edge Preparation Method	b - Rolled, machine-flame cut, sawn and planed
Are the Members Exposed to Corrosive Influences?	No
Design - Design Preference	
Design Method	Limit State Design
Base Plate Analysis	Effective Area Method

2 Design Checks

Design Status	Pass

2.1 Design Parameters

Check	Required	Provided	Remarks
Bearing Strength of Concrete (N/mm^2)		$\sigma_{br} = 0.45fck$ $= 0.45 \times 25$ $= 11.25$ $[Ref.\ IS\ 456 : 2000,\ Cl.\ 34.4]$	OK
Grout Thickness (mm)		t_g = 50	OK
Epsilon - stiffener plate		$\epsilon_{st} = \sqrt{\frac{250}{f_{y\,st}}}$ $= \sqrt{\frac{250}{250}}$ $= 1.0$ $[Ref.\ IS\ 800 : 2007,\ Table\ 2]$	OK

2.2 Load Consideration

Check	Required	Provided	Remarks
Axial Compression (kN)	$P_x = 650.0$	$P_u = max(P_x,\ 0.3P_d),\ but,\ \leq P_d$ $= max(650.0,\ 0.3 \times 1456.09)$ $= max(650.0,\ 436.83)$ ≤ 1456.09 $= 650.0$ $[Ref.IS\ 800 : 2007, Cl.\ 10.7]$ $Note:\ P_d\ is\ the\ design\ axial\ capacity\ of\ the\ column$	Pass
Shear Force - along major (z-z) axis (kN)	$V_d = 123.95$	$V_1 = 0.0$	
Shear Force - along minor (y-y) axis (kN)	$V_d = 123.95$	$V_2 = 0.0$	

Check	Required	Provided	Remarks
Interaction Ratio	IR < 1.0	$IR,\ axial = P_x/P_d$ $= 650.0/1456.09$ $= 0.45$ $IR,\ moment = M_z/M_{dzz}$ $= 0.0/0.0$ $= 0.0$ $IR,\ sum = IR,\ axial + IR,\ moment$ $= 0.45 + 0.0$ $= 0.45$	**Pass**

2.3 Plate Washer and Nut Details

Check	Required	Provided	Remarks
Plate Washer Size (mm)		$Square - 45X45$ $[Ref.\ IS\ 6649 : 1985,\ Table\ 2]$	**Pass**
Plate Washer Thickness (mm)		$t_w = 8.5$ $[Ref.\ IS\ 6649 : 1985,\ Table\ 2]$	**Pass**
Plate Washer Hole Diameter (mm)		$d_h = 22$ $[Ref.\ IS\ 6649 : 1985,\ Table\ 2]$	**Pass**
Nut (hexagon) Thickness (mm)		$t_n = 18.0$ $[Ref.\ IS\ 1364 - 3 : 2002,\ Table\ 1]$	**Pass**
End Plate Size (mm)		Square - 90 X 90	**Pass**
End Plate Thickness (mm)		14	**Pass**

2.4 Anchor Bolt Summary

Check	Required	Provided	Remarks
Diameter (mm)		20	**Pass**
Number of Bolts		$n_{out} = 4$	**Pass**
Property Class		10.9	**Pass**

2.5 Detailing Checks

Check	Required	Provided	Remarks
Min. End Distance (mm)	$e_{min} = 1.5\ d_0$ $= 1.5 \times 24.0$ $= 36.0$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.2$]	55.0	**Pass**
Max. End Distance (mm)	$e_{max} = 12\ t\ \varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 12 \times \sqrt{\frac{250}{250}} = 144.0$ $e_2 = 12 \times 12 \times \sqrt{\frac{250}{250}} = 144.0$ $e_{max} = min(e_1, e_2) = 144.0$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.3$]	55.0	**Pass**
Min. Edge Distance (mm)	$e'_{min} = 1.5\ d_0$ $= 1.5 \times 24.0$ $= 36.0$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.2$]	55.0	**Pass**

Check	Required	Provided	Remarks
Max. Edge Distance (mm)	$e'_{max} = 12\ t\ \varepsilon;\ \varepsilon = \sqrt{\frac{250}{f_y}}$ $e_1 = 12 \times 12 \times \sqrt{\frac{250}{250}} = 144.0$ $e_2 = 12 \times 12 \times \sqrt{\frac{250}{250}} = 144.0$ $e'_{max} = min(e_1, e_2) = 144.0$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.3$]	55.0	**Pass**
Min. Pitch Distance (mm)	N/A	0.0	**N/A**
Max. Pitch Distance (mm)	N/A	0.0	**N/A**

2.6 Base Plate Dimension (L X W)

Check	Required	Provided	Remarks
Length (mm)	$L = D\ +\ 2\ (c\ +\ e)$ $= 180.0\ +\ 2 \times\ (55\ +\ 55.0)$ $= 400.0$ [$Ref.$ *based on detailing requirement*]	400.0	**Pass**
Width (mm)	$W = B\ +\ 2\ (c\ +\ e')$ $= 180.0\ +\ 2 \times (55\ +\ 55.0)$ $= 400.0$ [$Ref.$ *based on detailing requirement*]	400.0	**Pass**

2.7 Base Plate Analysis

Check	Required	Provided	Remarks
Min. Area Required (mm^2)	$A_{req_{min}} = \frac{P_u}{\sigma_{br}}$ $= \frac{650.0 \times 10^3}{11.25}$ $= 57.78 \times 10^3$	$A_{provided} = L \times W$ $= 400.0 \times 400.0$ $= 160.0 \times 10^3$	**Pass**
Effective Bearing Area (mm^2)	$A_{breff} = (D + 2c)(B + 2c)$ $= (180.0 + 2c)(180.0 + 2c)$ *Note : c is the projection beyond the face of the column* [*Reference : Design of Steel Structures – N.Subramanian, (2019 edition) Chapter 15,*]		**OK**
Projection (mm)	$A_{breff} = A_{req_{min}}$ $= 57.78 \times 10^3$ *Therefore*, $(180.0 + 2c)(180.0 + 2c) = 57.78 \times 10^3$ $c = 30.19$ $projection = max(c,\ e)$ $= max(30.19,\ 55.0)$ $= 55.0$ [*Reference : Design of Steel Structures – N.Subramanian, (2019 edition) Chapter 15,*]	55	**Pass**
Actual Bearing Stress (N/mm^2)	11.25	$\sigma_{br\,actual} = \frac{P_u}{A_{provided}}$ $= \frac{650.0 \times 10^3}{160.0 \times 10^3}$ $= 4.06$	**Pass**

Check	Required	Provided	Remarks
Thickness of Base Plate (mm)	$t < t_p \leq 120$ $8.0 < t_p \leq 120$	$t_p = c \left[\frac{2.5\ \sigma_{bractual}\ \gamma_{m0}}{f_{y_{plate}}}\right]^{0.5}$ $= 55 \times \left[\frac{2.5\ \times 4.06 \times\ 1.1}{250}\right]^{0.5}$ $= 11.62$ $= 12$ $[Ref.\ IS\ 800 : 2007,\ Cl.7.4.3.1]$	**Pass**

2.8 Anchor Bolt Design

Check	Required	Provided	Remarks
Shear Capacity (kN)		$V_{dsb} = \frac{f_{ub}\ n_n\ A_{nb}}{\sqrt{3}\ \gamma_{mb}}$ $= \frac{1040.0 \times 1 \times 245}{1000 \times \sqrt{3}\ \times\ 1.25}$ $= 117.69$ $[Ref.\ IS\ 800 : 2007,\ Cl.\ 10.3.3]$	**OK**
Kb		$k_b = min\left(\frac{e}{3d_0}, \frac{f_{ub}}{f_u}, 1.0\right)$ $= min\left(\frac{55.0}{3 \times 24.0}, \frac{1040.0}{440.0}, 1.0\right)$ $= min(0.76, 2.36, 1.0)$ $= 0.76$ $[Ref\ IS\ 800 : 2007,\ Cl.\ 10.3.4]$	**OK**

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Designer	Engineer #1	Job Number	1.3.3.1
Date	18 /12 /2020	Client	Yogesh D Pisal, Aker Powergas, Mumbai

Check	Required	Provided	Remarks
Bearing Capacity (kN)		$V_{dpb} = \frac{2.5\ k_b\ d\ t\ f_u}{\gamma_{mb}}$ $= \frac{2.5 \times 0.76 \times 20 \times 12 \times 410}{1000 \times 1.25}$ $= 149.57$ $= 0.7 \times 149.57$ $= 104.7$ *Note : The bearing capacity is reduced since the hole type is Over − sized or Short − slotted* [*Ref. IS* 800 : 2007, *Cl.* 10.3.4]	**OK**
Bolt Capacity (kN)		$V_{db} = min\ (V_{dsb}, V_{dpb})$ $= min\ (117.69, 104.7)$ $= 104.7$ [*Ref. IS* 800 : 2007, *Cl.* 10.3.2]	**OK**
Tension Demand - per anchor bolt (kN)	$T_b = \frac{P_t}{n_{out}/2}$ $= \frac{0}{4/2}$ $= \frac{0}{2}$ $= 0.0$	$T_{db} = 0.90\ f_{ub}\ A_n\ /\ \gamma_{mb}$ $<\ f_{yb}\ A_{sb}\ (\gamma_{mb}\ /\ \gamma_{m0})$ $= min\Big(0.90\ \times 1040.0 \times 245\ /\ 1.25,$ $940.0 \times 314 \times (1.25/1.1)\Big)$ $= min(183.46,\ 335.41)$ $= 183.46$ [*Ref. IS* 800 : 2007, *Cl.* 10.3.5]	
Anchor Length - above concrete footing (mm)		$l_1 = t_g\ +\ t_p\ +\ t_w\ +\ t_n\ +\ 20$ $= 50\ +\ 12\ +\ 8.5\ +\ 18.0\ +\ 20$ $= 108.5$	**Pass**
Anchor Length - below concrete footing (mm)		$l_2 = 238.0$ [*Reference : IS* 5624 : 1993, *Table* 1]	**Pass**

Check	Required	Provided	Remarks
Anchor Length - total (mm)	$200 \leq\ l_a\ \leq 800$ $[Reference:\ IS\ 5624:1993,\ Table\ 1]$	$l_a = l_1\ +\ l_2$ $= 108.5\ +\ 238.0$ $= 346.5$	**Pass**

2.9 Stiffener Design

Check	Required	Provided	Remarks
No. of Stiffeners		4	**OK**
Length of Stiffener (mm)		$L_{st1} = \frac{L-D}{2}\quad along\ column\ D$ $= \frac{400.0-180.0}{2}$ $= 110.0$ $L_{st2} = \frac{W-B}{2}\quad along\ column\ B$ $= \frac{400.0-180.0}{2}$ $= 110.0$	**OK**
Height of Stiffener (mm)		$H_{st1} = L_{st1} + 50$ $= 110.0 + 50$ $= 160.0$ $H_{st2} = L_{st2} + 50$ $= 110.0 + 50$ $= 160.0$	**OK**
Thickness of Stiffener (mm)	$t_{st} = \left(\frac{L_{st}}{13.6 \times \epsilon_{st}}\right) \geq T$ $= \left(\frac{110.0}{13.6 \times 1.0}\right) \geq 8.0$ $= max(8.09, 8.0)$ $[Ref.\ IS\ 800:2007,\ Table\ 2]$	16	**Pass**
Stress (average) at Stiffener (N/mm^2)	11.25	$\sigma_{st} = \sigma_{br\,actual}$ $= 4.06$	**Pass**

Check	Required	Provided	Remarks
Max. Shear on Stiffener (kN)	$V_{st} = \sigma_{st}\ (W\ L_{st})$ $= 4.06 \times (400.0 \times 110.0)$ $= 178.64$	$V_{d\,st} = \frac{A_{vg}\ f_{y_{st}}}{\sqrt{3}\ \gamma_{m0}}$ $= \frac{(H_{st} \times t_{st}) \times f_{y_{st}}}{\sqrt{3} \times \gamma_{m0}}$ $= \frac{(160.0 \times 16) \times 250}{\sqrt{3} \times 1.1 \times 10^3}$ $= 335.913$ *Note : Stiffener is not restricted to low shear* [*Ref. IS* 800 : 2007 (*Cl.* 8.4.1)	**Pass**
High Shear Check	$V_{st} \leq 0.6 \times V_{d\,st}$ $\leq 0.6 \times 335.913$ ≤ 201.55	$V_{st} = 178.64$	**Pass**
Section Modulus of the Stiffener (mm^3)		$z_{e\,st} = 68.27 \times 10^3$	**OK**
Max. Moment on Stiffener (kNm)	$M_{st} = V_{st} \times \frac{L_{st}}{2}$ $= 178.64 \times \frac{110.0}{2} \times 10^{-3}$ $= 9.825$	$M_{d\,st} = \frac{\beta_b\ z_{e\,st}\ f_{y_{st}}}{\gamma_{m0}}$ $= \frac{1 \times\ z_{e\,st}\ f_{y_{st}}}{\gamma_{m0}} \quad (\beta_b = 1)$ $= \frac{1 \times\ 68.27 \times 10^3 \times 250}{1.1 \times 10^6}$ $= 15.515$ [*Ref. IS* 800 : 2007 (*Cl.* 8.2.1.2)	**Pass**
Weld Size (mm)	5	6	**Pass**

2.10 Weld Design - Hollow CS to Base Plate Connection

Check	Required	Provided	Remarks
Weld Strength (N/mm^2)	$f_{uw} = min(f_w,\ f_u)$ $= min(510.0,\ 440.0)$ [*Ref. IS* 800 : 2007, *Cl.* 10.5.7.1.1]	$f_{uw} = 440.0$	**Pass**
Total Weld Length (mm)		720	**Pass**
Weld Size (mm)	5	8	**Pass**

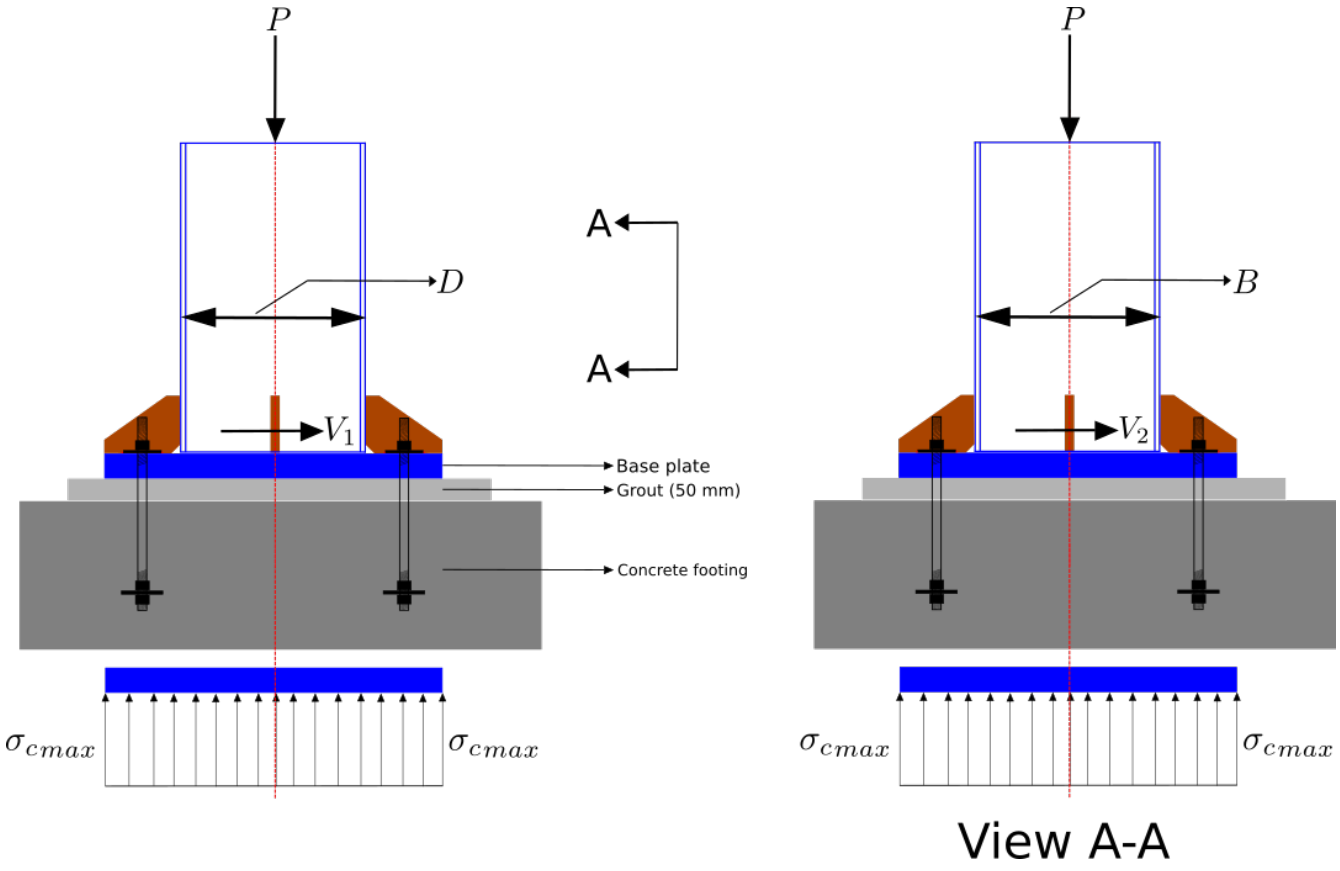


Figure 1: Typical Base Plate Details

3 2D Drawings (Typical)

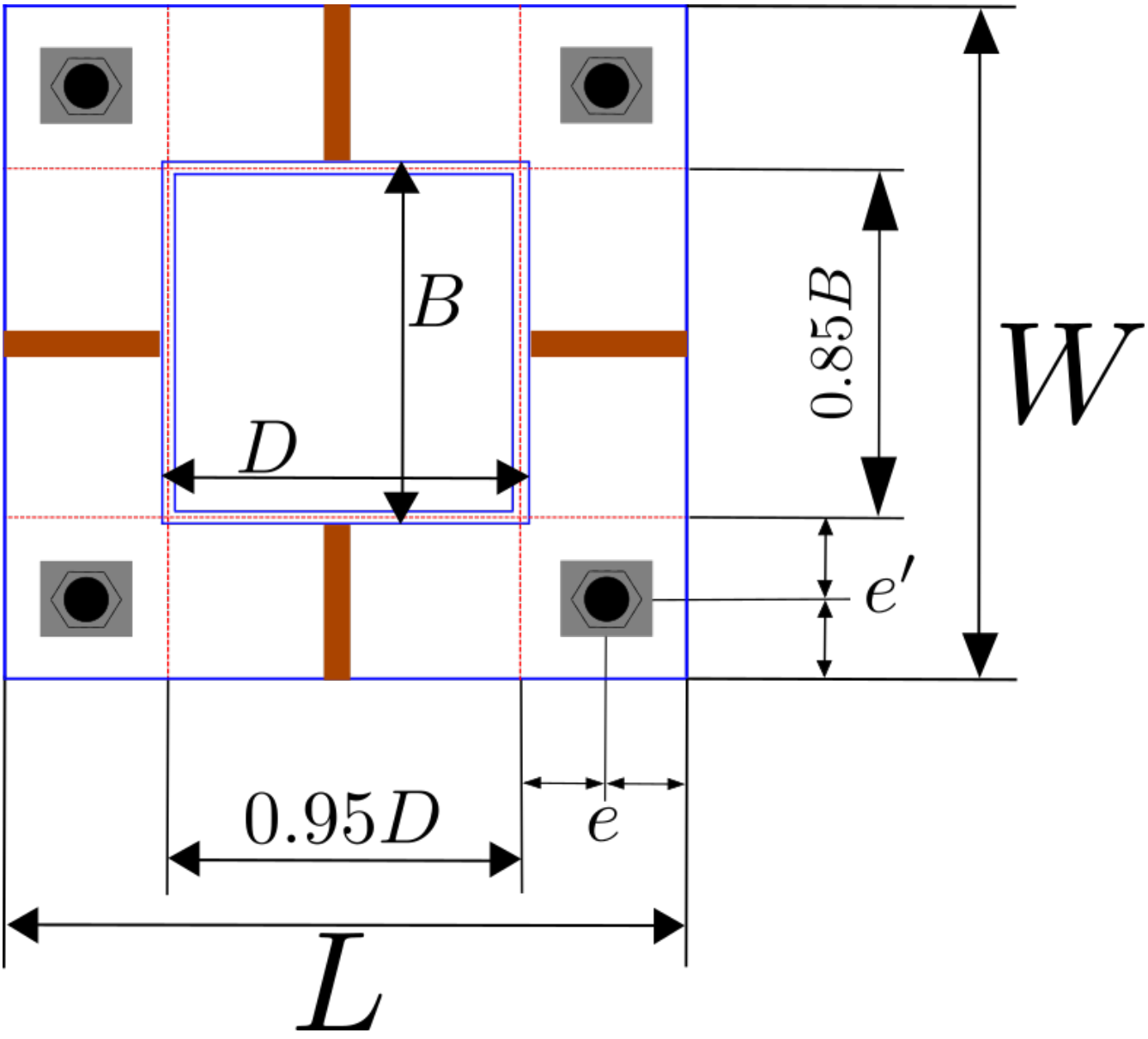


Figure 2: Typical Base Plate Detailing

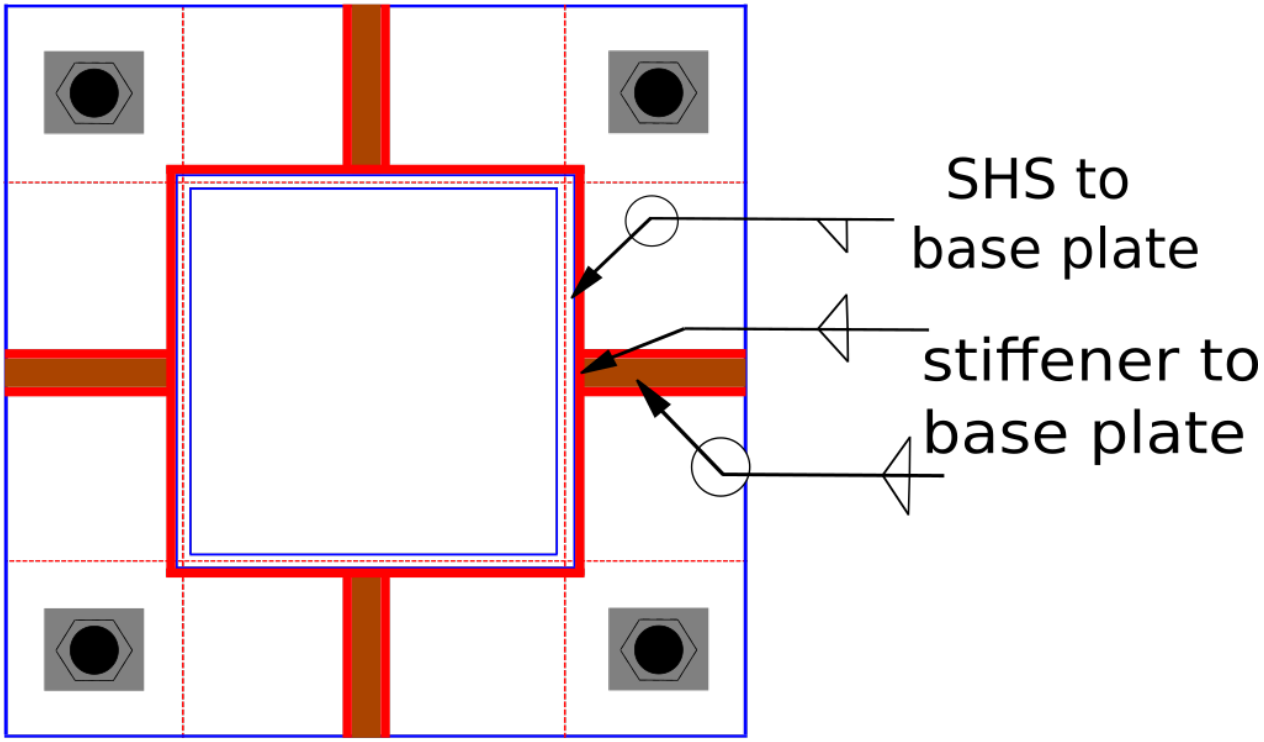
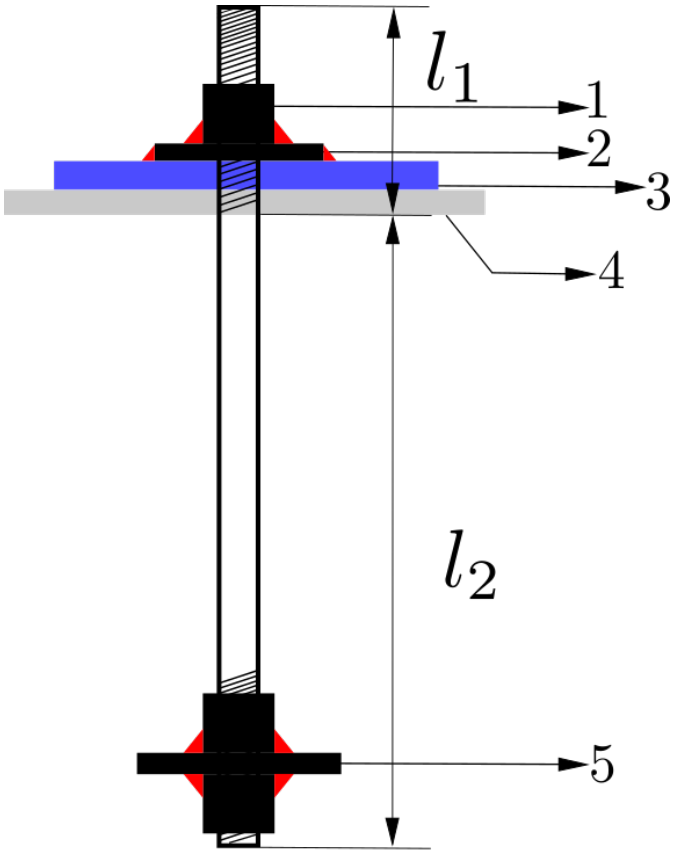


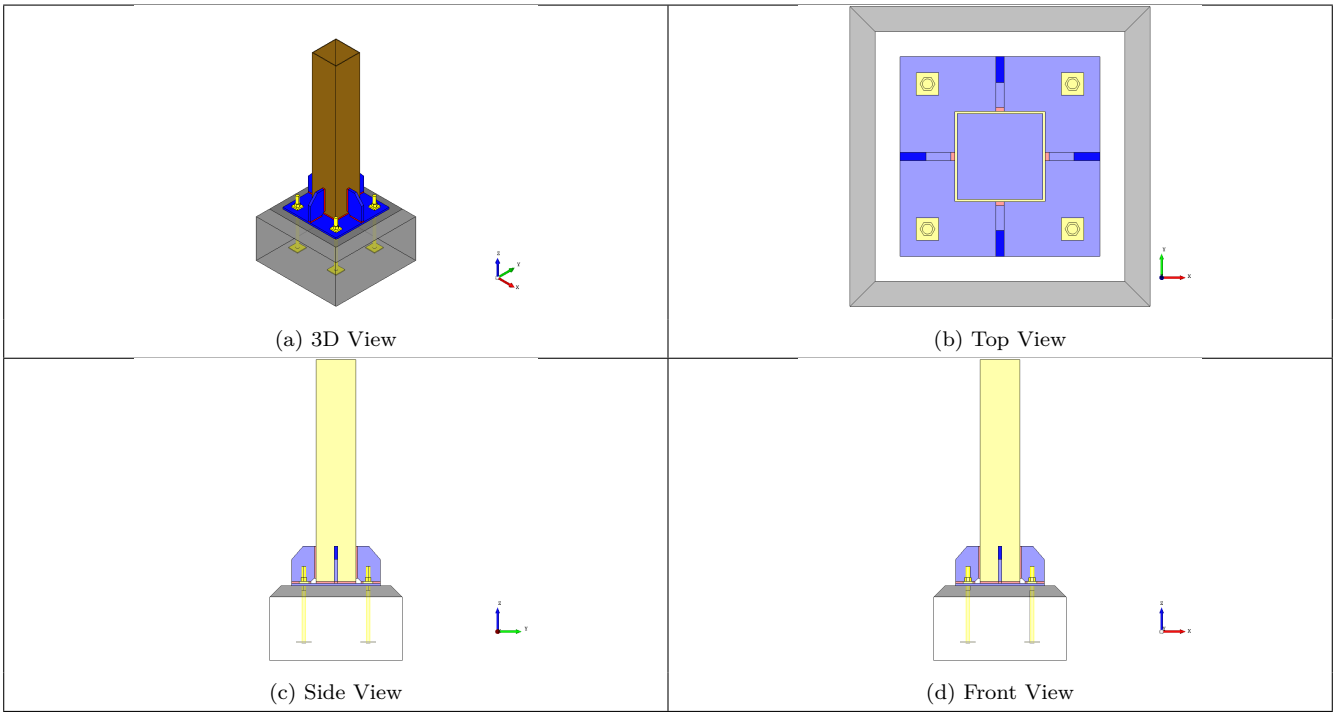
Figure 3: Typical Weld Details



$l_1 = length\ above\ footing$
$l_2 = length\ below\ footing$
$1 = t_n,\ nut\ thickness$
$2 = t_w,\ washer\ thickness$
$3 = t_p,\ plate\ thickness$
$4 = t_g,\ grout\ thickness$
$5 =\ end\ plate\ thickness$

Figure 4: Typical Anchor Bolt Details

4 3D Views



(a) 3D View

(b) Top View

(c) Side View

(d) Front View

5 Design Log

2020-12-18 01:46:13 - Osdag - WARNING - : [Analysis Error] The value of the projection (c) as per the Effective Area Method is 35 mm [Reference: Clause 7.4.1.1, IS 800: 2007]
2020-12-18 01:46:13 - Osdag - WARNING - : [Analysis Error] The computed value of c should at least be equal to the end/edge distance

2020-12-18 01:46:13 - Osdag - INFO - : [Analysis Error] Setting the value of c equal to end/edge distance
2020-12-18 01:46:13 - Osdag - INFO - [Anchor Bolt Length] The recommended range for the length of the anchor bolt of thread size 20 mm is as follows:
2020-12-18 01:46:13 - Osdag - INFO - [Anchor Bolt Length] Minimum length = 200 mm, Maximum length = 800 mm.
2020-12-18 01:46:13 - Osdag - INFO - [Anchor Bolt Length] The provided length of the anchor bolt is 346.5 mm
2020-12-18 01:46:13 - Osdag - INFO - [Anchor Bolt] Designer/Erector should provide adequate anchorage depending on the availability of standard lengths and sizes, satisfying the recommended range
2020-12-18 01:46:13 - Osdag - INFO - [Anchor Bolt Length] Reference: IS 5624:1993, Table 1
2020-12-18 01:46:13 - Osdag - WARNING - [Shear Check - Stiffener] The stiffener fails the shear check
2020-12-18 01:46:13 - Osdag - WARNING - The shear demand on the stiffener (178.64 kN) exceeds 60% of it's capacity (125.97 kN)
2020-12-18 01:46:13 - Osdag - INFO - Increasing the thickness of the stiffener and re-checking against shear demand