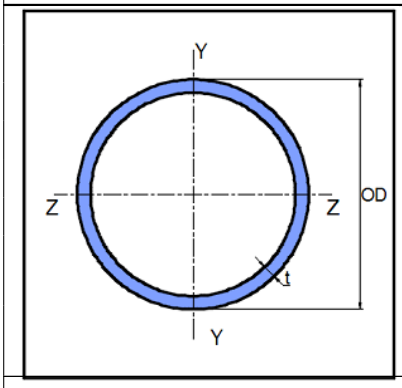
Company Name	IIT Bombay	Project Title	Sample Connection Design
Group/Team Name	Osdag	Subtitle	Base Plate Connection
Designer	Engineer #1	Job Number	1.3.3.2
Date	18 /12 /2020	Client	Meera Raghunandan, Professor, IIT Bombay

1 Input Parameters

Main Module	Moment Connection
Module	Base Plate
Connectivity	Hollow/Tubular Column Base
End Condition	Fixed
Axial Compression (kN)	775.0
Axial Tension/Uplift (kN)	0.0
Shear Force (kN)	
- Along major axis (z-z)	45.0
- Along minor axis (y-y)	10.0
Bending Moment (kNm)	
- Major axis (M_{z-z})	0.0
- Minor axis (M_{y-y})	0.0

Column Section - Mechanical Properties



Column Section		CHS 355.6 x 10	
Material		E 300 (Fe 440)	
Ultimate Strength, f_u (MPa)		440.0	
Yield Strength, f_y (MPa)		300.0	
Mass, m (kg/m)	85.23	None	None
Area, A (cm^2)	108.57	t (mm)	10.0
Nominal bore, NB (mm)	350	2nd Moment of area, I (cm^4/m)	16223.5
Out diameter, OD (mm)	355.6	Radius of gyration, r (cm)	122.2

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
Ultimate Strength, f_u (MPa)	410
Yield Strength, f_y (MPa)	250

Anchor Bolt - Input and Design Preference	
Diameter (mm)	['M20']
Property Class	['8.8']
Anchor Bolt Type	End Plate Type
Anchor Bolt Galvanized?	Yes
Designation	M20X344.5 IS5624 GALV
Hole Type	Over-sized
Total Length (mm)	344.5
Material Grade, f_u (MPa)	830.0
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)	440.0
Detailing - Design Preference	
Edge Preparation Method	b - Rolled, machine-flame cut, sawn and planed
Are the Members Exposed to Corrosive Influences?	Yes
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)		$\sigma_{br} = 0.45fck$ $= 0.45 \times 35$ $= 15.75$ $[Ref.\ IS\ 456 : 2000,\ Cl.\ 34.4]$	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)	$P_x = 775.0$	$P_u = max(P_x,\ 0.3P_d),\ but,\ \leq P_d$ $= max(775.0,\ 0.3 \times 2961.0)$ $= max(775.0,\ 888.3)$ ≤ 2961.0 $= 888.3$ $[Ref.IS\ 800 : 2007, Cl.\ 10.7]$ $Note:\ P_d\ is\ the\ design\ axial\ capacity\ of\ the\ column$	Pass
Shear Force - along major (z-z) axis (kN)	$V_d = 317.06$	$V_1 = 45.0$	Pass
Shear Force - along minor (y-y) axis (kN)	$V_d = 317.06$	$V_2 = 10.0$	Pass

Check	Required	Provided	Remarks
Interaction Ratio	IR < 1.0	$IR,\ axial = P_x/P_d$ $= 775.0/2961.0$ $= 0.26$ $IR,\ moment = M_z/M_{dzz}$ $= 0.0/0.0$ $= 0.0$ $IR,\ sum = IR,\ axial + IR,\ moment$ $= 0.26 + 0.0$ $= 0.26$	**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		8.8	**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)	$e_{max} = 40 + 4t$ $Where, t = min(10, 10)$ $= 40 + (4 \times 10)$ $e_{max} = 80.0$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.3$]	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**
Max. Edge Distance (mm)	$e'_{max} = 40 + 4t$ $Where, t = min(10, 10)$ $= 40 + (4 \times 10)$ $e'_{max} = 80.0$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.2.4.3$]	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)	$L = OD + 2(c + e)$ $= 355.6 + 2 \times (55 + 55.0)$ $= 575.6$ [*Ref. based on detailing requirement*]	575.6	**Pass**
Width (mm)	$W = OD + 2(c + e')$ $= 355.6 + 2 \times (55 + 55.0)$ $= 575.6$ [*Ref. based on detailing requirement*]	575.6	**Pass**

2.7 Base Plate Analysis

Check	Required	Provided	Remarks
Min. Area Required (mm^2)	$A_{req_{min}} = \frac{P_u}{\sigma_{br}}$ $= \frac{888.3000000000001 \times 10^3}{15.75}$ $= 56.4 \times 10^3$	$A_{provided} = L \times W$ $= 575.6 \times 575.6$ $= 331.32 \times 10^3$	**Pass**
Effective Bearing Area (mm^2)	$A_{breff} = \frac{\pi}{4} \times (OD + 2c)^2$ $= \frac{\pi}{4} \times (355.6 + 2c)^2$ *Note : c is the projection beyond the face of the column* [*Reference : Design of Steel Structures – N.Subramanian, (2019 edition) Chapter 15,*]		**OK**

Check	Required	Provided	Remarks
Projection (mm)	$A_{breff} = A_{req_{min}}$ $= 56.4 \times 10^3$ $Therefore,\ \frac{\pi}{4} \times (355.6 + 2c)^2 = 56.4 \times 10^3$ $c = 43.81$ $projection = max(c,\ e)$ $= max(43.81,\ 55.0)$ $= 55.0$ [$Reference:$ *Design of Steel Structures – N.Subramanian, (2019 edition) Chapter 15,*]	55	**Pass**
Actual Bearing Stress (N/mm^2)	15.75	$\sigma_{br\,actual} = \frac{P_u}{A_{provided}}$ $= \frac{888.3000000000001 \times 10^3}{331.32 \times 10^3}$ $= 2.68$	**Pass**
Thickness of Base Plate (mm)	$t < t_p \leq 120$ $10.0 < t_p \leq 120$	$t_p = c \left[\frac{2.5\ \sigma_{br\,actual}\ \gamma_{m0}}{f_{y_{plate}}}\right]^{0.5}$ $= 55 \times \left[\frac{2.5\ \times 2.68 \times\ 1.1}{250}\right]^{0.5}$ $= 9.44$ $= 10$ [$Ref.\ IS\ 800:2007,\ Cl.7.4.3.1$]	**Pass**

2.8 Anchor Bolt Design

Check	Required	Provided	Remarks

Company Name	IIT Bombay	Project Title	Sample Connection Design
Group/Team Name	Osdag	Subtitle	Base Plate Connection
Designer	Engineer #1	Job Number	1.3.3.2
Date	18 /12 /2020	Client	Meera Raghunandan, Professor, IIT Bombay

Check	Required	Provided	Remarks
Shear Capacity (kN)		$V_{dsb} = \frac{f_{ub}\ n_n\ A_{nb}}{\sqrt{3}\ \gamma_{mb}}$ $= \frac{830.0 \times 1 \times 245}{1000 \times \sqrt{3}\ \times\ 1.25}$ $= 93.92$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.3.3$]	OK
Kb		$k_b = min\left(\frac{e}{3d_0}, \frac{f_{ub}}{f_u}, 1.0\right)$ $= min\left(\frac{55.0}{3 \times 24.0}, \frac{830.0}{440.0}, 1.0\right)$ $= min(0.76, 1.89, 1.0)$ $= 0.76$ [$Ref\ IS\ 800:2007,\ Cl.\ 10.3.4$]	OK
Bearing Capacity (kN)		$V_{dpb} = \frac{2.5\ k_b\ d\ t\ f_u}{\gamma_{mb}}$ $= \frac{2.5 \times 0.76 \times 20 \times 10 \times 410}{1000 \times 1.25}$ $= 124.64$ $= 0.7 \times 124.64$ $= 87.25$ *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)		$V_{db} = min\ (V_{dsb}, V_{dpb})$ $= min\ (93.92, 87.25)$ $= 87.25$ [$Ref.\ IS\ 800:2007,\ Cl.\ 10.3.2$]	OK

Check	Required	Provided	Remarks
Tension Demand - per anchor bolt (kN)	$T_b = \frac{P_t}{n_{out}/2}$ $= \frac{0}{4/2}$ $= \frac{0}{2}$ $= 0.0$	$T_{db} = 0.90\ f_{ub}\ A_n\ /\ \gamma_{mb}$ $< f_{yb}\ A_{sb}\ (\gamma_{mb}\ /\ \gamma_{m0})$ $= min\Big(0.90\ \times 830.0 \times 245\ /\ 1.25,$ $660.0 \times 314 \times (1.25/1.1)\Big)$ $= min(146.41,\ 235.5)$ $= 146.41$ $[Ref.\ IS\ 800:2007,\ Cl.\ 10.3.5]$	
Anchor Length - above concrete footing (mm)		$l_1 = t_g\ +\ t_p\ +\ t_w\ +\ t_n\ +\ 20$ $= 50\ +\ 10\ +\ 8.5\ +\ 18.0\ +\ 20$ $= 106.5$	**Pass**
Anchor Length - below concrete footing (mm)		$l_2 = 238.0$ $[Reference:\ IS\ 5624:1993,\ Table\ 1]$	**Pass**
Anchor Length - total (mm)	$200 \leq\ l_a\ \leq 800$ $[Reference:\ IS\ 5624:1993,\ Table\ 1]$	$l_a = l_1\ +\ l_2$ $= 106.5\ +\ 238.0$ $= 344.5$	**Pass**

2.9 Stiffener Design

Check	Required	Provided	Remarks
No. of Stiffeners		4	**OK**
Length of Stiffener (mm)		$L_{st} = \frac{L - OD}{2}$ $= \frac{575.6 - 355.6}{2}$ $= 110$	**OK**
Height of Stiffener (mm)		$H_{st} = L_{st} + 50$ $= 110 + 50$ $= 160$	**OK**

Company Name	IIT Bombay	Project Title	Sample Connection Design
Group/Team Name	Osdag	Subtitle	Base Plate Connection
Designer	Engineer #1	Job Number	1.3.3.2
Date	18 /12 /2020	Client	Meera Raghunandan, Professor, IIT Bombay

Check	Required	Provided	Remarks
Thickness of Stiffener (mm)	$t_{st} = \left(\frac{L_{st}}{13.6 \times \epsilon_{st}}\right) \geq T$ $= \left(\frac{110}{13.6 \times 1.0}\right) \geq 10.0$ $= max(8.09, 10.0)$ [$Ref.\ IS\ 800:2007,\ Table\ 2$]	14	**Pass**
Stress (average) at Stiffener (N/mm^2)	15.75	$\sigma_{st} = \sigma_{br\,actual}$ $= 2.68$	**Pass**
Max. Shear on Stiffener (kN)	$V_{st} = \sigma_{st}\ (W\ L_{st})$ $= 2.68 \times (575.6 \times 110)$ $= 169.687$	$V_{d\,st} = \frac{A_{vg}\ f_{y_{st}}}{\sqrt{3}\ \gamma_{m0}}$ $= \frac{(H_{st} \times t_{st}) \times f_{y_{st}}}{\sqrt{3} \times \gamma_{m0}}$ $= \frac{(160 \times 14) \times 250}{\sqrt{3} \times 1.1 \times 10^3}$ $= 293.924$ *Note :* *Stiffener is not restricted to low shear* [$Ref.\ IS\ 800:2007\ (Cl.\ 8.4.1)$	**Pass**
High Shear Check	$V_{st} \leq 0.6 \times V_{d\,st}$ $\leq 0.6 \times 293.924$ ≤ 176.35	$V_{st} = 169.687$	**Pass**
Section Modulus of the Stiffener (mm^3)		$z_{e\,st} = 59.73 \times 10^3$	**OK**
Max. Moment on Stiffener (kNm)	$M_{st} = V_{st} \times \frac{L_{st}}{2}$ $= 169.687 \times \frac{110}{2} \times 10^{-3}$ $= 9.333$	$M_{d\,st} = \frac{\beta_b\ z_{e\,st}\ f_{y_{st}}}{\gamma_{m0}}$ $= \frac{1 \times\ z_{e\,st}\ f_{y_{st}}}{\gamma_{m0}} \quad (\beta_b = 1)$ $= \frac{1 \times\ 59.73 \times 10^3 \times 250}{1.1 \times 10^6}$ $= 13.576$ [$Ref.\ IS\ 800:2007\ (Cl.\ 8.2.1.2)$	**Pass**
Weld Size (mm)	5	6	**Pass**

2.10 Shear Design

Check	Required	Provided	Remarks
Shear Resistance (kN)		$V_r = P_u \times \mu$ $= 888.3 \times 0.45$ $= 399.74$	**OK**
Shear Key Requirement - along column depth	$V_1 = 45.0 \ \ kN$	$V_1 \leq V_r$ $45.0 \leq 399.74$	**Shear key not required**
Shear Key Requirement - along column width	$V_2 = 10.0 \ \ kN$	$V_2 \leq V_r$ $10.0 \leq 399.74$	**Shear key not required**

2.11 Weld Design - Hollow CS to Base Plate Connection

Check	Required	Provided	Remarks
Weld Strength (N/mm^2)	$f_{uw} = min(f_w, \ f_u)$ $= min(440.0, \ 440.0)$ $[Ref. \ IS \ 800 : 2007, \ Cl. \ 10.5.7.1.1]$	$f_{uw} = 440.0$	**Pass**
Total Weld Length (mm)		1117	**Pass**
Weld Size (mm)	3	4	**Pass**

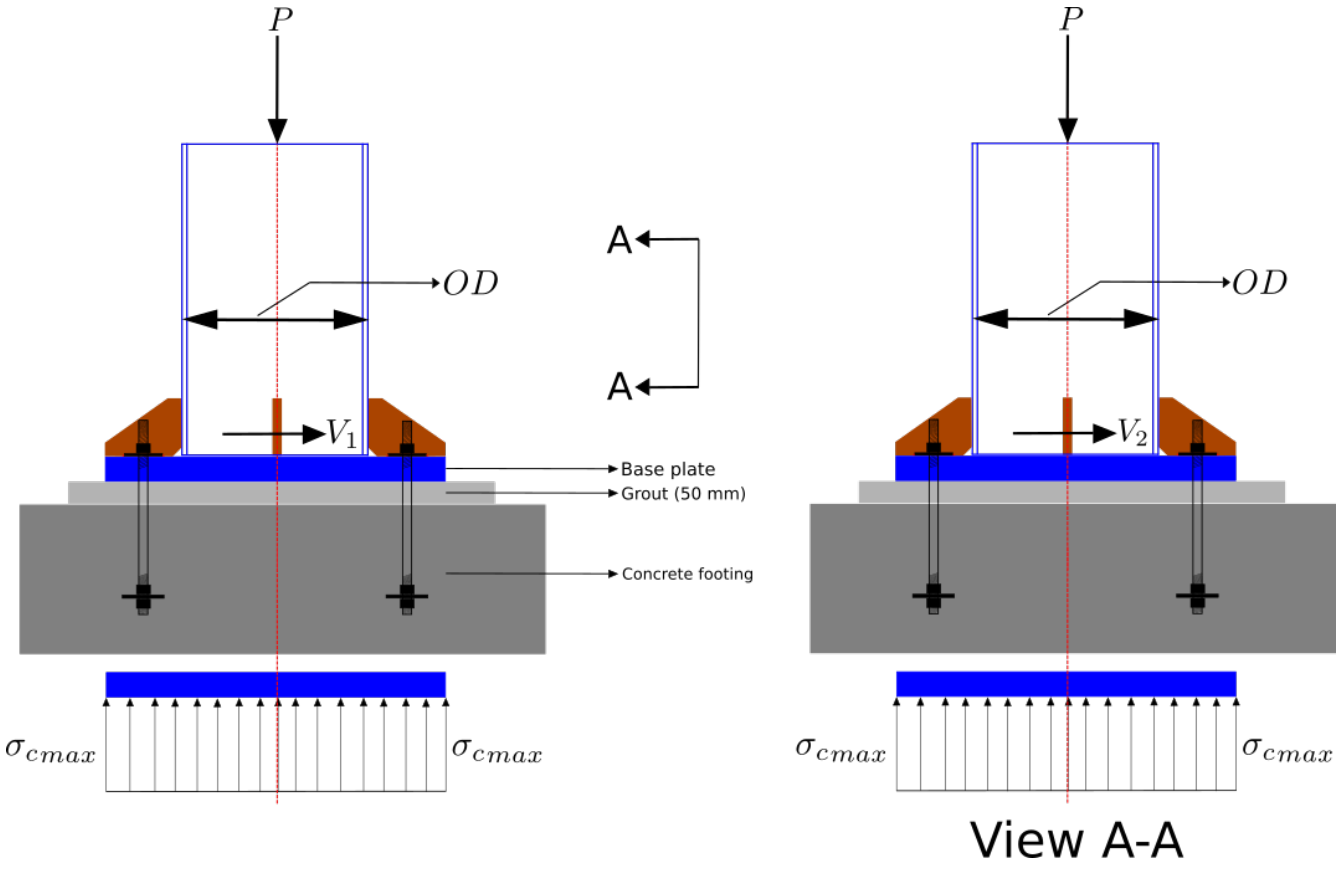


Figure 1: Typical Base Plate Details

3 2D Drawings (Typical)

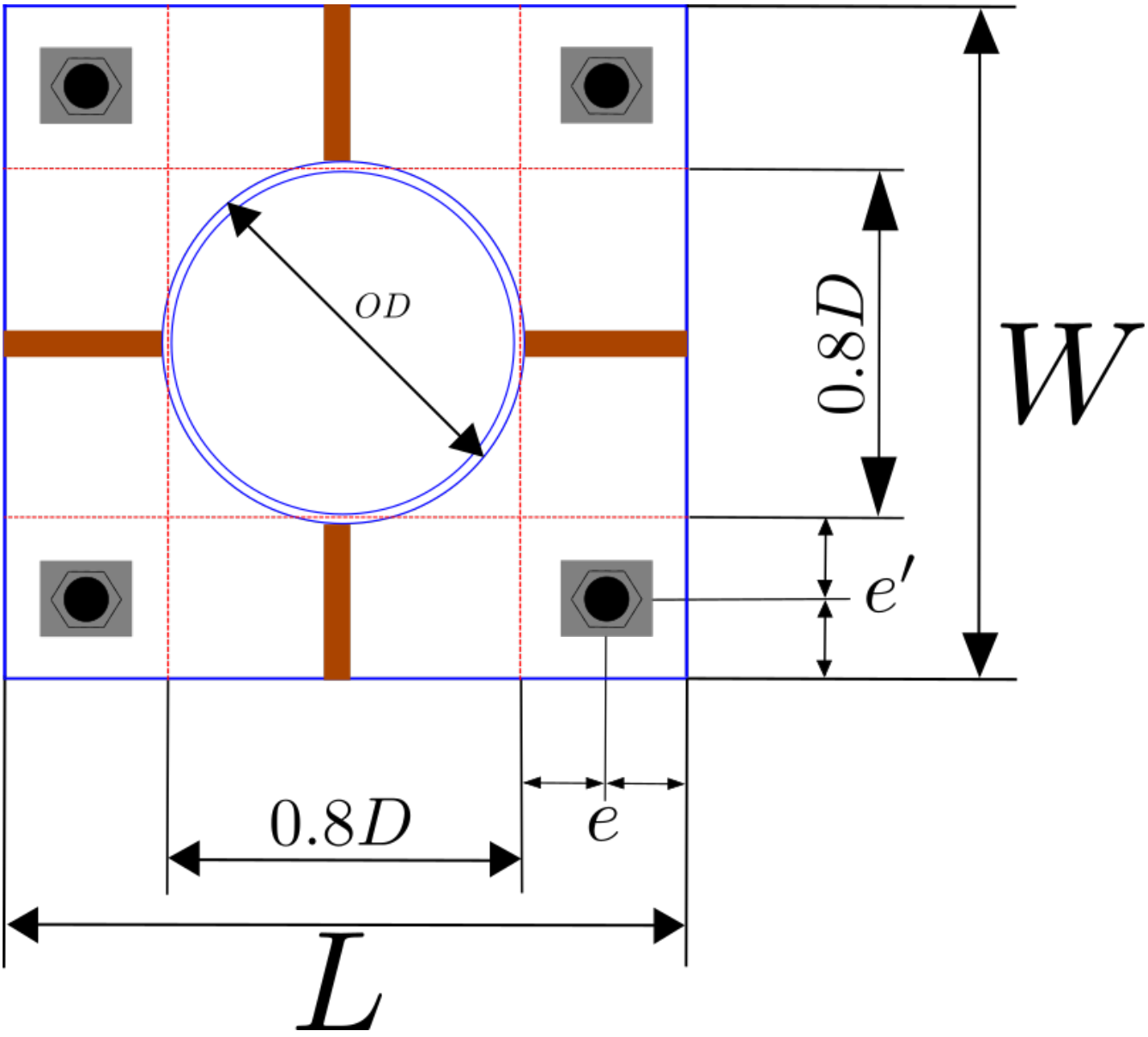


Figure 2: Typical Base Plate Detailing

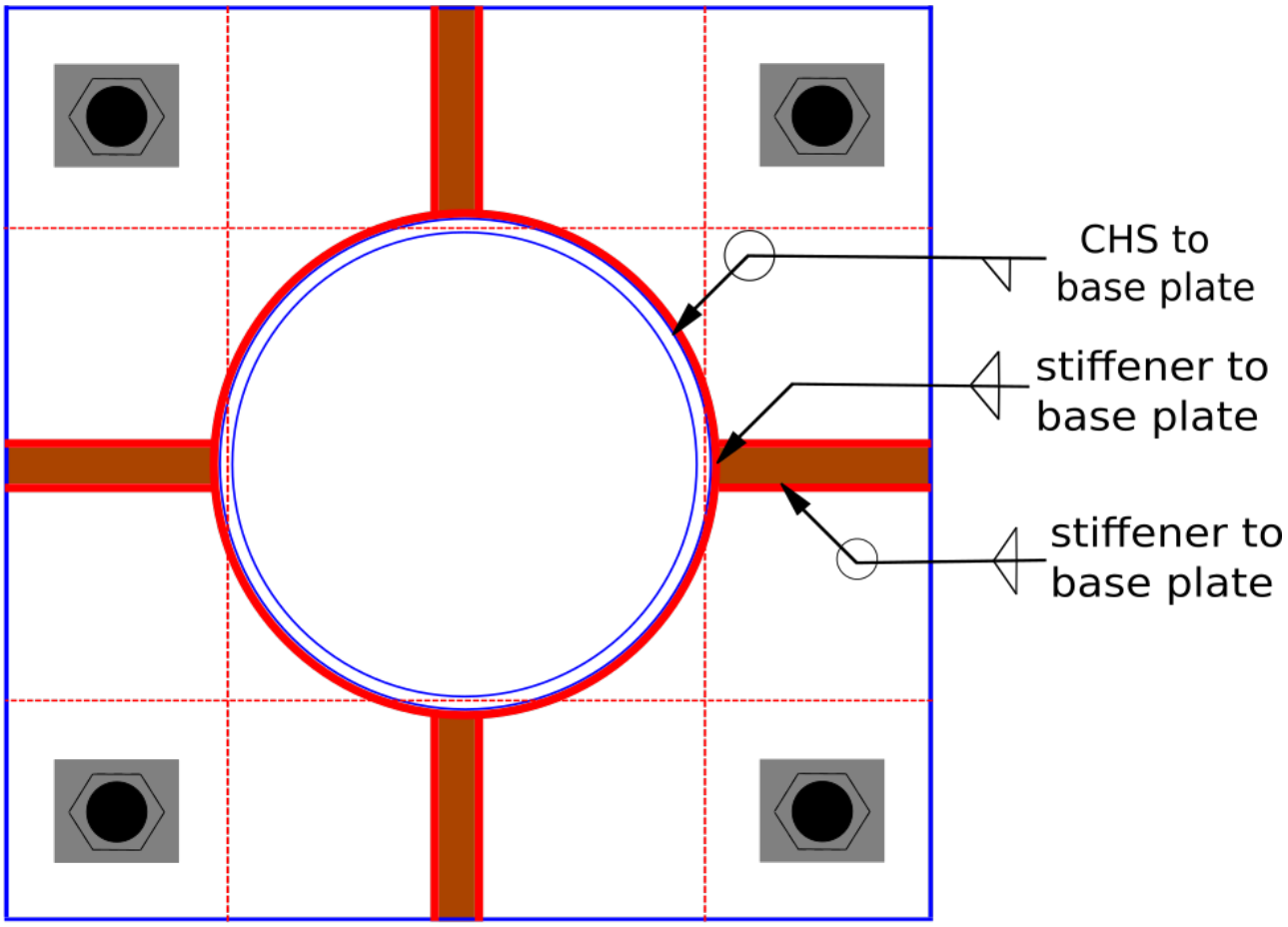
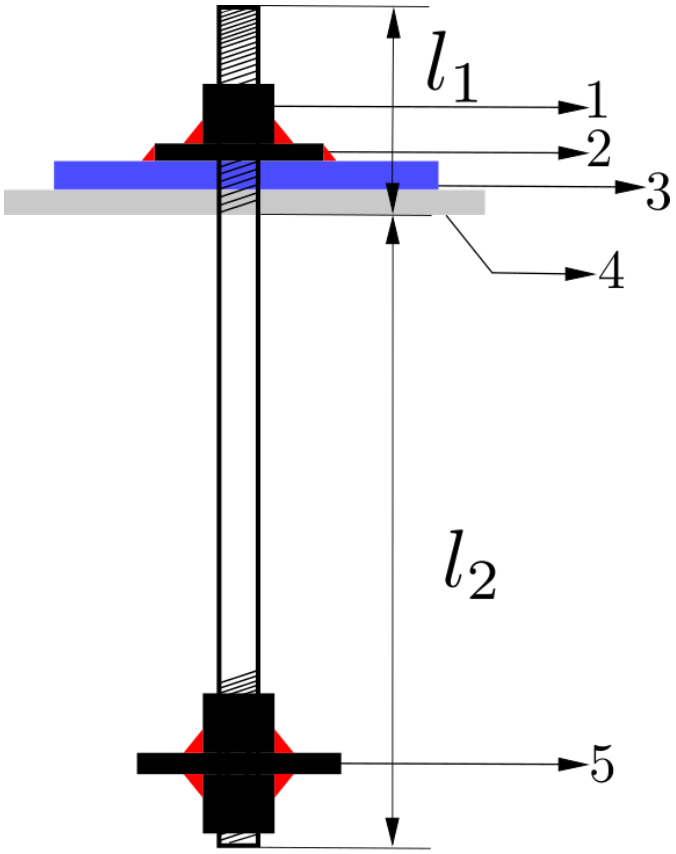


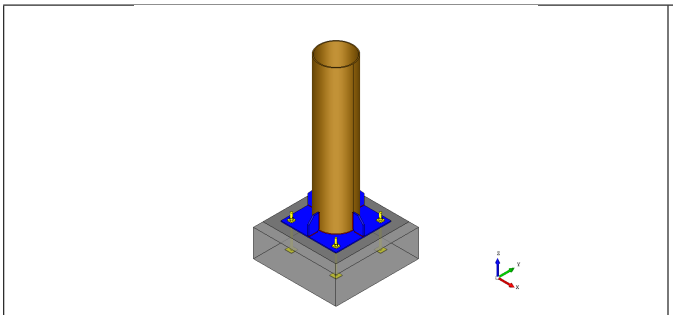
Figure 3: Typical Weld Details



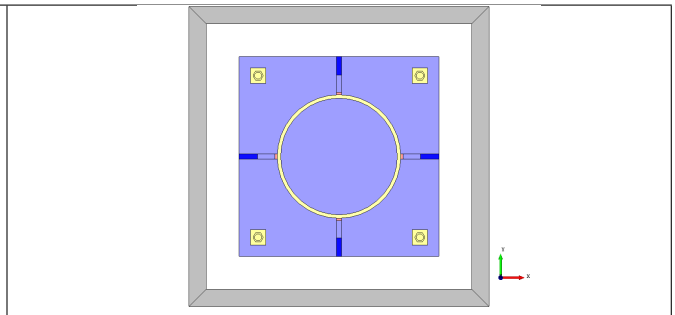
$l_1 = length\ above\ footing$
$l_2 = length\ below\ footing$
$1 = t_n,\ nut\ thickness$
$2 = t_w,\ washer\ thickness$
$3 = t_p,\ plate\ thickness$
$4 = t_g,\ grout\ thickness$
$5 =\ end\ plate\ thickness$

Figure 4: Typical Anchor Bolt Details

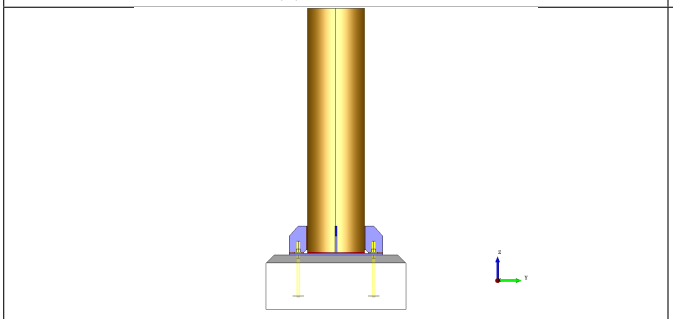
4 3D Views



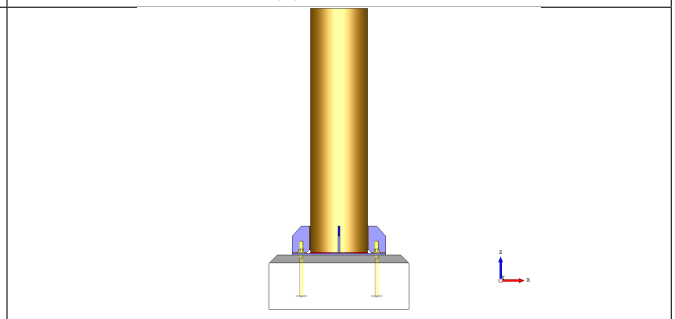
(a) 3D View



(b) Top View



(c) Side View



(d) Front View

5 Design Log

2020-12-18 01:47:24 - Osdag - WARNING - [Minimum Design Action] The defined value of axial compression (775.0 kN) is less than 0.3 times the capacity of the column section (888.3 kN) [Ref. Cl. 10.7, IS 800:2007]
2020-12-18 01:47:24 - Osdag - INFO - Setting the value of axial compression equal to the minimum recommended value
2020-12-18 01:47:24 - Osdag - WARNING - : [Analysis Error] The value of the projection (c) as per the Effective Area Method is 45 mm [Reference: Clause 7.4.1.1, IS 800: 2007]
2020-12-18 01:47:24 - Osdag - WARNING - : [Analysis Error] The computed value of c should at least be equal to the end/edge distance

2020-12-18 01:47:24 - Osdag - INFO - : [Analysis Error] Setting the value of c equal to end/edge distance
2020-12-18 01:47:24 - Osdag - INFO - [Design for Shear] The shear resistance of the base plate assembly due to the friction between the base plate and the grout/concrete material is 399.735 kN
2020-12-18 01:47:24 - Osdag - INFO - The horizontal shear force - 45.0 kN, is less than the shear resistance of the base plate
2020-12-18 01:47:24 - Osdag - INFO - Shear key is not required
2020-12-18 01:47:24 - Osdag - INFO - [Design for Shear] The shear resistance of the base plate assembly due to the friction between the base plate and the grout/concrete material is 399.735 kN
2020-12-18 01:47:24 - Osdag - INFO - The horizontal shear force - 45.0 kN, is less than the shear resistance of the base plate

2020-12-18 01:47:24 - Osdag - INFO - Shear key is not required
2020-12-18 01:47:24 - 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 01:47:24 - Osdag - INFO - [Anchor Bolt Length] Minimum length = 200 mm, Maximum length = 800 mm.
2020-12-18 01:47:24 - Osdag - INFO - [Anchor Bolt Length] The provided length of the anchor bolt is 344.5 mm
2020-12-18 01:47:24 - 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 01:47:24 - Osdag - INFO - [Anchor Bolt Length] Reference: IS 5624:1993, Table 1
2020-12-18 01:47:24 - Osdag - INFO - [Section Classification] The CHS subjected to purely axial load is classified as plastic section [Ref. Table 2, IS 800:2007]
2020-12-18 01:47:24 - Osdag - INFO - The column does not require additional stiffening
2020-12-18 01:47:24 - Osdag - INFO - Providing stiffeners to resist the bending of the base plate due to the bearing stress
2020-12-18 01:47:24 - Osdag - WARNING - [Shear Check - Stiffener] The stiffener fails the shear check
2020-12-18 01:47:24 - Osdag - WARNING - The shear demand on the stiffener (169.69 kN) exceeds 60% of it's capacity (125.97 kN)
2020-12-18 01:47:24 - Osdag - INFO - Increasing the thickness of the stiffener and re-checking against shear demand