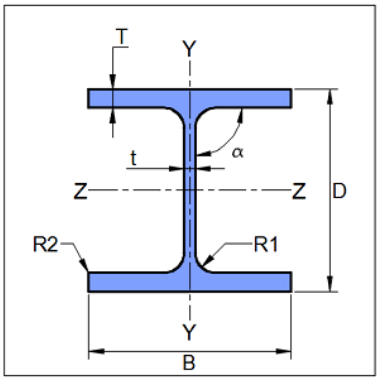
Company Name	IIT Bombay	Project Title	Base Plate
Group/Team Name	Osdag	Subtitle	Welded Base Plate
Designer	Engineer#1	Job Number	1.3.1.2
Date	04 /02 /2021	Client	Dr. Pradyumna M, Bengaluru

1 Input Parameters

Main Module	Moment Connection
Module	Base Plate Connection
Connectivity	Welded Column Base
End Condition	Pinned
Axial Compression (kN)	880.0
Axial Tension/Uplift (kN)	0.0
Shear Force (kN)	
- Along major axis (z-z)	25.0
- 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		PBP 360 X 178.4	
Material		E 300 (Fe 440)	
Ultimate Strength, F_u (MPa)		440.0	
Yield Strength, F_y (MPa)		290.0	
Mass, m (kg/m)	178.4	I_z (cm^4)	52200.0
Area, A (cm^2)	227.0	I_y(cm^4)	18900.0
None	None	r_z (cm)	15.2
D (mm)	362.0	r_y (cm)	9.1
B (mm)	379.0	Z_z (cm^3)	2880.0
T (mm)	20.9	Z_y (cm^3)	1000.0
t (mm)	21.0	Z_{pz} (cm^3)	3260.0
Flange Slope	90	Z_{py} (cm^3)	1530.0
R_1 (mm)	15.0		
R_2 (mm)	0.0		

Base Plate - Design Preference

Material	E 250 (Fe 410 W)A
Ultimate Strength, F_u (MPa)	410
Yield Strength, F_y (MPa)	250

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Stiffener/Shear Key - Design Preference	
Material	E 250 (Fe 410 W)A
Anchor Bolt Outside Column Flange - Input and Design Preference	
Diameter (mm)	['M20']
Property Class	['10.9']
Anchor Bolt Type	End Plate Type
Anchor Bolt Galvanized?	Yes
Designation	M20X356.5 IS5624 GALV
Hole Type	Over-sized
Total Length (mm)	356.5
Material Grade, F_u (MPa)	1040.0
Anchor Bolt Inside Column Flange - Input and Design Prefereself.anchor_grade_list_outnce	
Diameter (mm)	N/A
Property Class	N/A
Anchor Bolt Type	N/A
Anchor Bolt Galvanized?	N/A
Designation	N/A
Hole Type	N/A
Total Length (mm)	N/A
Material Grade, F_u (MPa)	N/A
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)		$\sigma_{\text{br}} = 0.45 f_{ck}$ $= 0.45 \times 30$ $= 13.5$ [Ref. IS 456:2000, Cl.34.4]	OK
Grout Thickness (mm)		$t_g = 50$	OK
Epsilon - stiffener plate		$\epsilon_{\text{st}} = \sqrt{\frac{250}{f_{y_{\text{st}}}}}$ $= \sqrt{\frac{250}{250}}$ $= 1.0$ [Ref. IS 800:2007, Table2]	OK

2.2 Load Consideration

Check	Required	Provided	Remarks
Axial Compression (kN)	$P_x = 880.0$	$P_u = \max(P_{\text{x}},\ 0.3P_{\text{d}}),\ \text{but},\ \leq P_{\text{d}}$ $= \max(880.0,\ 0.3 \times 5984.55)$ $= \max(880.0,\ 1795.37)$ ≤ 5984.55 $= 1795.37$ [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)	$V_d = 614.1$	$V_1 = 25.0$	Pass
Shear Force - along minor (y-y) axis (kN)	$V_d = 614.1$	$V_2 = 10.0$	Pass

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Check	Required	Provided	Remarks
Interaction Ratio	I.R. < 1.0	I.R. axial $= P_x/P_d$ $= 880.0/5984.55$ $= 0.15$ I.R. moment $= M_z/M_{dz}$ $= 0.0/0.0$ $= 0.0$ I.R. sum $=$ I.R. axial + I.R. moment $= 0.15 + 0.0$ $= 0.15$	Pass

2.3 Plate Washer and Nut Details - Anchor Bolt Outside Column Flange

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 - Outside Column Flange

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

2.5 Anchor Bolt Summary - Inside Column Flange

Check	Required	Provided	Remarks
Diameter (mm)	0	N/A	**N/A**
Number of Bolts	0	$n_{in} = 0$	**N/A**
Property Class	N/A	N/A	**N/A**

2.6 Detailing Checks - Outside Column Flange

Check	Required	Provided	Remarks
Min. End Distance (mm)	$e_{min} = 1.5d_0$ $= 1.5 \times 24.0$ $= 36.0$ [Ref. IS 800:2007, Cl.10.2.4.2]	55	**Pass**
Max. End Distance (mm)	$e_{max} = 40 + 4t$ Where, $t = \min(22, 22)$ $= 40 + (4 \times 22)$ $e_{max} = 128.0$ [Ref. IS 800:2007, Cl.10.2.4.3]	55	**Pass**
Min. Edge Distance (mm)	$e'_{min} = 1.5d_0$ $= 1.5 \times 24.0$ $= 36.0$ [Ref. IS 800:2007, Cl.10.2.4.2]	55	**Pass**

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Designer	Engineer#1	Job Number	1.3.1.2
Date	04 /02 /2021	Client	Dr. Pradyumna M, Bengaluru

Check	Required	Provided	Remarks
Max. Edge Distance (mm)	$e'_{max} = 40 + 4t$ Where, $t = \min(22, 22)$ $= 40 + (4 \times 22)$ $e'_{max} = 128.0$ [Ref. IS 800:2007, Cl.10.2.4.3]	55	**Pass**
Min. Pitch Distance (mm)	N/A	0.0	**N/A**
Max. Pitch Distance (mm)	N/A	0.0	**N/A**

2.7 Base Plate Dimension (L X W)

Check	Required	Provided	Remarks
Length (mm)	$L = D + 2(e + e)$ $= 362.0 + 2 \times (55 + 55)$ $= 582.0$ [Ref. based on detailing requirement]	582.0	**Pass**
Width (mm)	$W = (0.85B) + 2(e' + e')$ $= (0.85 \times 379.0) + 2 \times (55 + 55)$ $= 542.15$ [Ref. based on detailing requirement]	599.0	**Pass**

2.8 Base Plate Analysis

Check	Required	Provided	Remarks
Min. Area Required (mm^2)	$A_{req_{min}} = \frac{P_u}{\sigma_{br}}$ $= \frac{1795.365 \times 10^3}{13.5}$ $= 132.99 \times 10^3$	$A_{provided} = L \times W$ $= 582.0 \times 599.0$ $= 348.62 \times 10^3$	**Pass**

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Check	Required	Provided	Remarks
Effective Bearing Area (mm^2)	$A_{breff} = (D + 2c)(B + 2c) - \left[\left(D - 2(T + c)\right)\left(B - t\right)\right]$ $= (362.0 + 2c)(379.0 + 2c) - \left[\left(362.0 - 2 \times (20.9 + c)\right)\left(379.0 - 21.0\right)\right]$ Note: c is the projection beyond the face of the column. [Reference: Design of Steel Structures, by N.Subramanian, (2019 edition)]		**OK**
Projection (mm)	$A_{breff} = A_{req_{min}}$ $= 132.99 \times 10^3$ Therefore, $(362.0 + 2c)(379.0 + 2c) - \left[\left(362.0 - 2(20.9 + c)\right)\left(379.0 - 21.0\right)\right] = 132.99 \times 10^3$ $c = 2.86$ projection = max(c, e) = max(2.86, 55) = 55 [Reference: Design of Steel Structures, by N.Subramanian, (2019 edition)]	55	**Pass**
Actual Bearing Stress (N/mm^2)	13.5	$\sigma_{bractual} = \frac{P_u}{A_{provided}} = \frac{1795.365 \times 10^3}{348.62 \times 10^3} = 5.15$	**Pass**

Check	Required	Provided	Remarks
Thickness of Base Plate (mm)	$(T,\ t) < t_p \leq 120$ $(20.9,\ 21.0) < t_p \leq 120$	$t_p = c\left[\frac{2.5\ \sigma_{\text{br actual}}\ \gamma_{m0}}{f_{y\,\text{plate}}}\right]^{0.5}$ $= 55 \times \left[\frac{2.5\ \times 5.15 \times\ 1.1}{250}\right]^{0.5}$ $= 13.09$ $= 22$ [Ref. IS 800:2007, Cl.7.4.3.1]	**Pass**

2.9 Anchor Bolt Design - Outside Column Flange

Check	Required	Provided	Remarks
Shear Capacity (kN)		$V_{\text{dsb}} = \frac{f_{ub} n_n A_{nb}}{\sqrt{3}\gamma_{mb}}$ $= \frac{1040.0 \times 1 \times 245}{1000 \times \sqrt{3}\ \times\ 1.25}$ $= 117.69$ [Ref. IS 800:2007, Cl.10.3.3]	**OK**
Kb		$k_b = \min\left(\frac{e}{3d_0},\ \frac{f_{ub}}{f_u},\ 1.0\right)$ $= \min\left(\frac{55}{3 \times 24.0},\ \frac{1040.0}{440.0},\ 1.0\right)$ $= \min(0.76,\ 2.36,\ 1.0)$ $= 0.76$ [Ref. IS 800:2007, Cl.10.3.4]	**OK**

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Check	Required	Provided	Remarks
Bearing Capacity (kN)		$V_{\text{dpb}} = \frac{2.5 k_b d t f_u}{\gamma_{mb}}$ $= \frac{2.5 \times 0.76 \times 20 \times 22 \times 410}{1000 \times 1.25}$ $= 274.21$ $= 0.7 \times 274.21$ $= 191.95$ 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)		$V_{\text{db}} = \min\ (V_{\text{dsb}},\ V_{\text{dpb}})$ $= \min\ (117.69,\ 191.95)$ $= 117.69$ [Ref. IS 800:2007, Cl.10.3.2]	**OK**
Tension Demand - per anchor bolt (kN)	$T_{\text{b}} = \frac{P_t}{n_{\text{out}}/2}$ $= \frac{0}{4/2}$ $= \frac{0}{2}$ $= 0.0$	$T_{\text{db}} = 0.90 f_{ub} A_n\ /\ \gamma_{mb}$ $<\ f_{yb} A_{sb} (\gamma_{mb}\ /\ \gamma_{m0})$ $= \min\left(0.90 \times 1040.0 \times 245\ /\ 1.25,\right.$ $\left. 940.0 \times 314 \times (1.25/1.1)\right)$ $= \min(183.46,\ 335.41)$ $= 183.46$ [Ref. IS 800:2007, Cl.10.3.5]	
Anchor Length - above concrete footing (mm)		$l_1 = t_g + t_p + t_w + t_n + 20$ $= 50 + 22 + 8.5 + 18.0 + 20$ $= 118.5$	**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]	$l_a = l_1 \ + \ l_2$ $= 118.5 \ + \ 238.0$ $= 356.5$	Pass

2.10 Shear Design

Check	Required	Provided	Remarks
Shear Resistance (kN)		$V_r = P_u \times \mu$ $= 1795.37 \times 0.45$ $= 807.91$	OK
Shear Key Requirement - along column depth	$V_1 = 25.0 \ \ kN$	$V_1 \leq V_r$ $25.0 \leq 807.91$	Shear key not required
Shear Key Requirement - along column width	$V_2 = 10.0 \ \ kN$	$V_2 \leq V_r$ $10.0 \leq 807.91$	Shear key not required

2.11 Weld Design - Column to Base Plate Connection

Check	Required	Provided	Remarks
Weld Strength (N/mm^2)	$f_{u_w} = \min(f_w, \ f_u)$ $= \min(440.0, \ 440.0)$ [Ref. IS 800:2007, Cl.10.5.7.1.1]	$f_{u_w} = 440.0$	Pass
Total Weld Length - at flange (mm)		1394	Pass
Total Weld Length - at web (mm)		540	Pass
Weld Size (mm)	6	10	Pass

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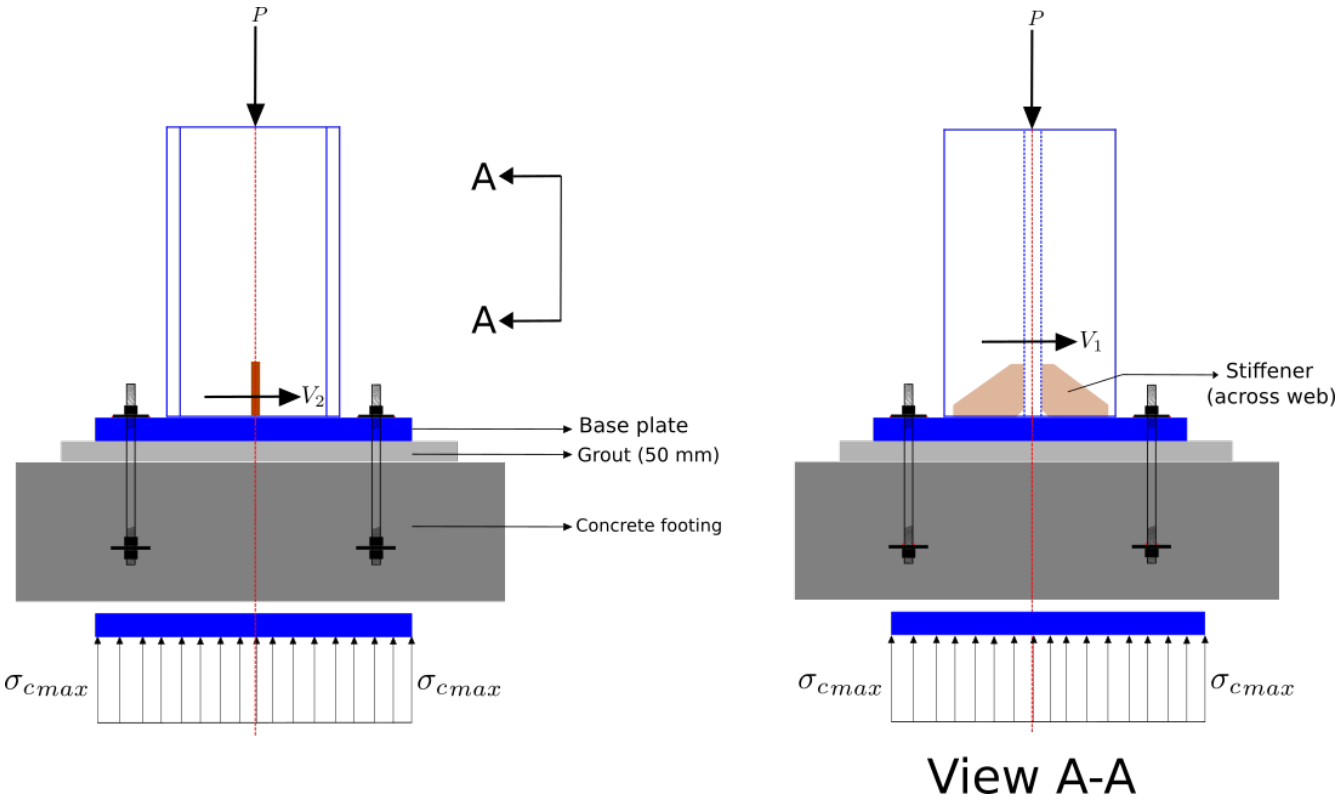

Figure 1: Typical Base Plate Details

3 2D Drawings (Typical)

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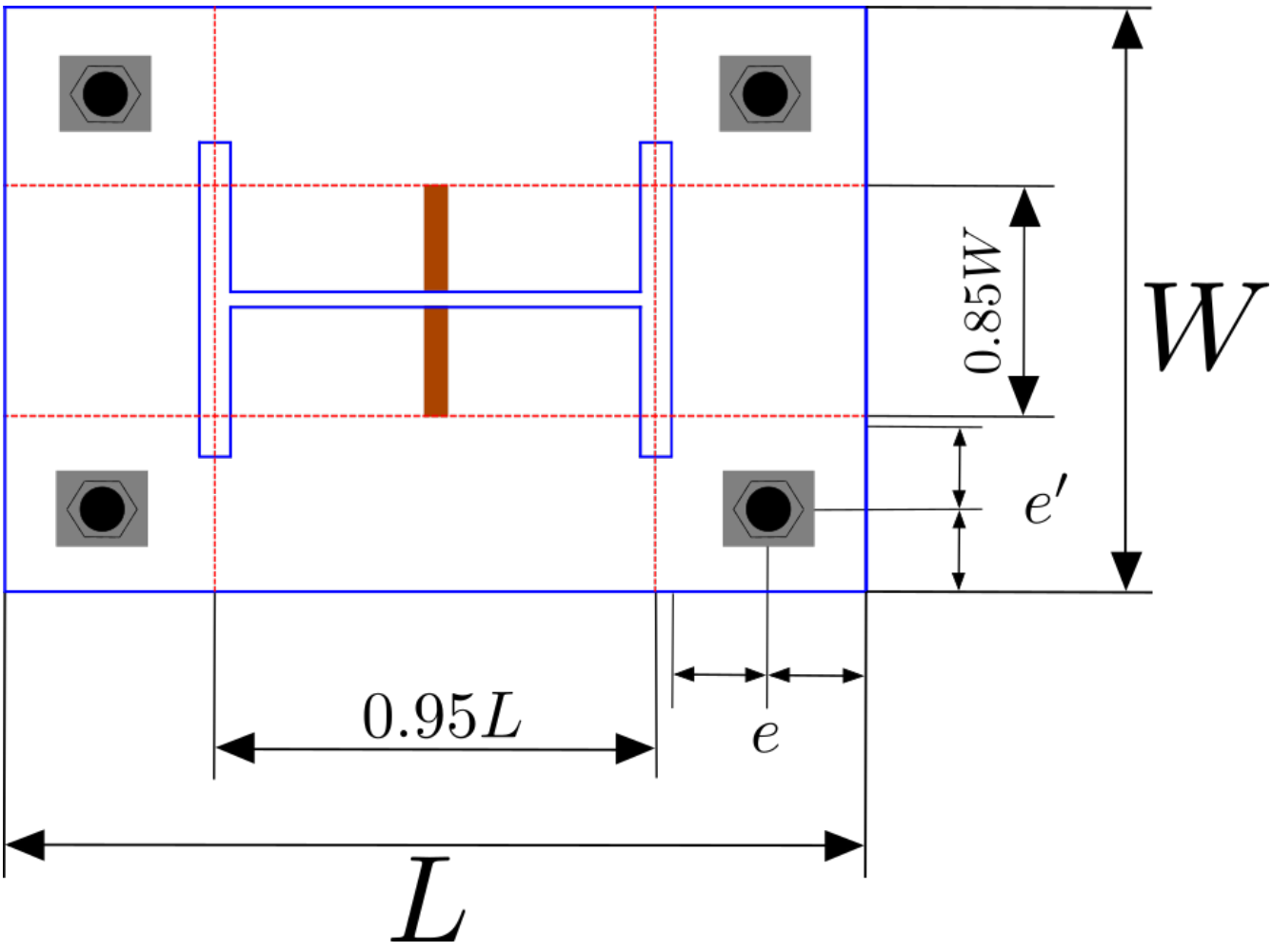


Figure 2: Typical Base Plate Detailing

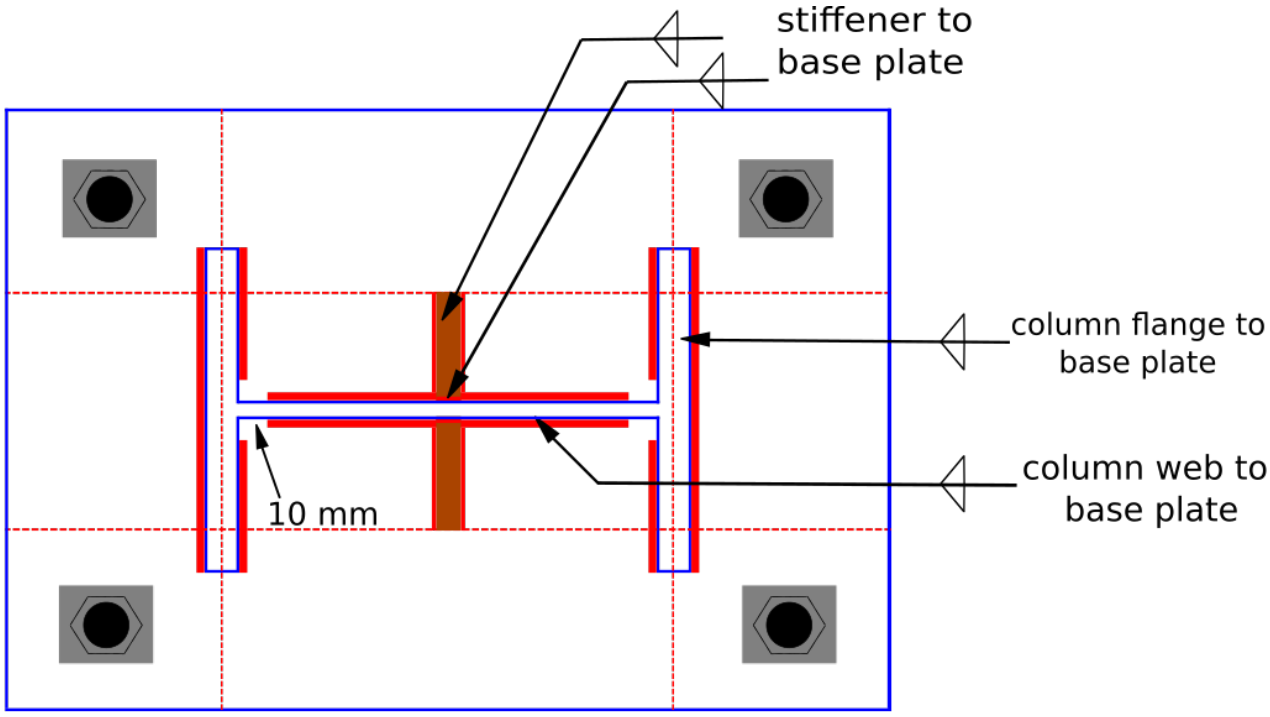
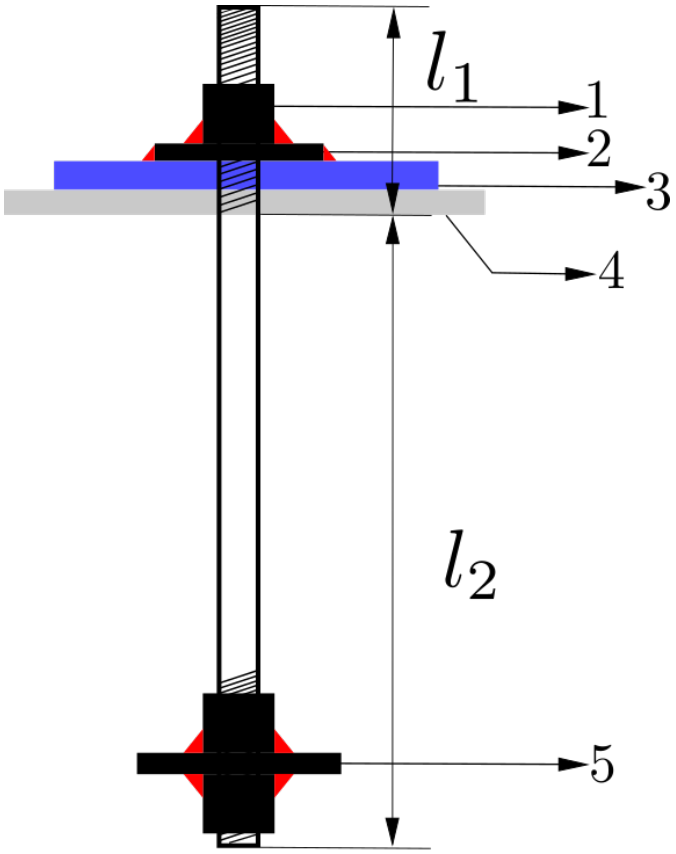


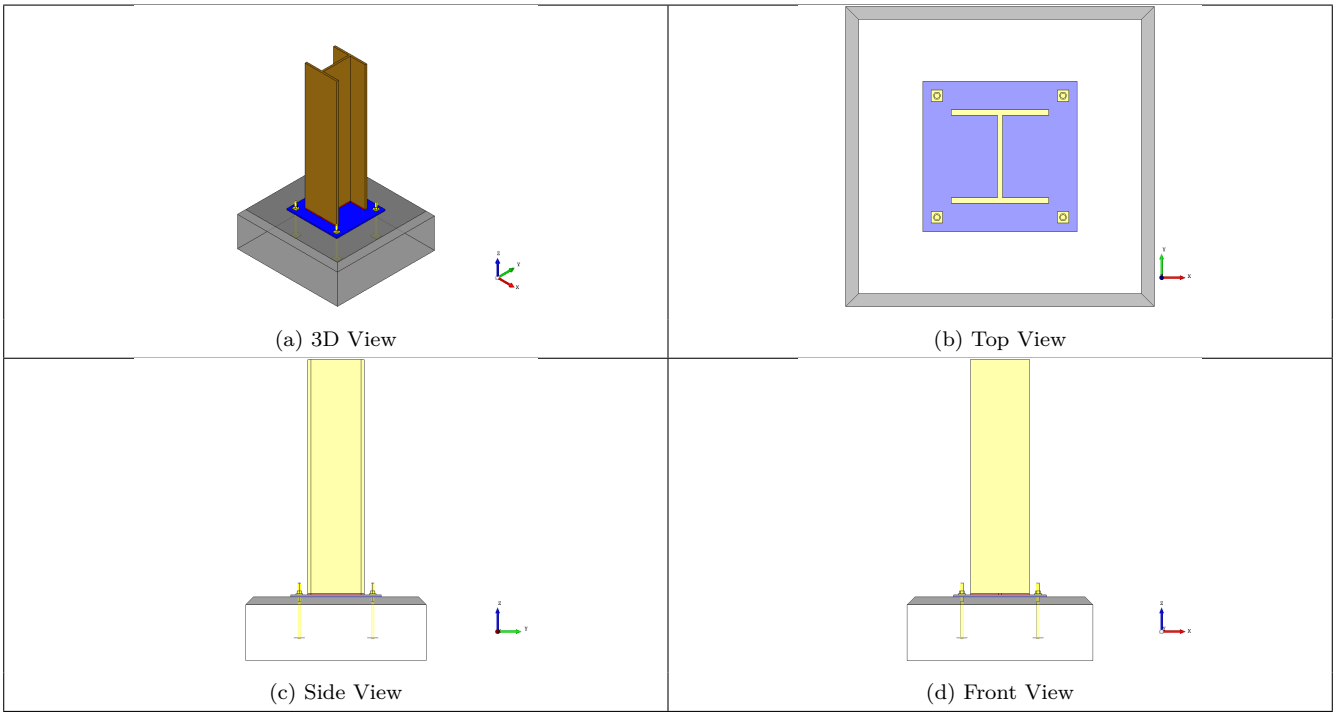
Figure 3: Typical Weld Details



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

2021-02-04 15:18:28 - Osdag - WARNING - [Minimum Design Action] The defined value of axial compression (880.0 kN) is less than 0.3 times the capacity of the column section (1795.37 kN) [Ref. Cl. 10.7, IS 800:2007]
2021-02-04 15:18:28 - Osdag - INFO - Setting the value of axial compression equal to the minimum recommended value
2021-02-04 15:18:28 - Osdag - WARNING - : [Analysis Error] The value of the projection (c) as per the Effective Area Method is 5 mm [Reference: Clause 7.4.1.1, IS 800: 2007]
2021-02-04 15:18:28 - Osdag - WARNING - : [Analysis Error] The computed value of c should at least be equal to the end/edge distance

2021-02-04 15:18:28 - Osdag - INFO - : [Analysis Error] Setting the value of c equal to end/edge distance
2021-02-04 15:18:28 - 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 807.91425 kN
2021-02-04 15:18:28 - Osdag - INFO - The horizontal shear force - 25.0 kN, is less than the shear resistance of the base plate
2021-02-04 15:18:28 - Osdag - INFO - Shear key is not required
2021-02-04 15:18:28 - 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 807.91425 kN
2021-02-04 15:18:28 - Osdag - INFO - The horizontal shear force - 25.0 kN, is less than the shear resistance of the base plate

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2021-02-04 15:18:28 - Osdag - INFO - Shear key is not required
2021-02-04 15:18:28 - Osdag - INFO - [Anchor Bolt Length] The recommended range for the length of the anchor bolt of thread size 20 mm is as follows:
2021-02-04 15:18:28 - Osdag - INFO - [Anchor Bolt Length] Minimum length = 200 mm, Maximum length = 800 mm.
2021-02-04 15:18:28 - Osdag - INFO - [Anchor Bolt Length] The provided length of the anchor bolt is 356.5 mm
2021-02-04 15:18:28 - Osdag - INFO - [Anchor Bolt] Designer/Erector should provide adequate anchorage depending on the availability of standard lengths and sizes, satisfying the recommended range
2021-02-04 15:18:28 - Osdag - INFO - [Anchor Bolt Length] Reference: IS 5624:1993, Table 1
2021-02-04 15:18:28 - Osdag - INFO - : ========== Design Status ==========
2021-02-04 15:18:28 - Osdag - INFO - : Overall base plate connection design is SAFE
2021-02-04 15:18:28 - Osdag - INFO - : ========== End Of Design ==========