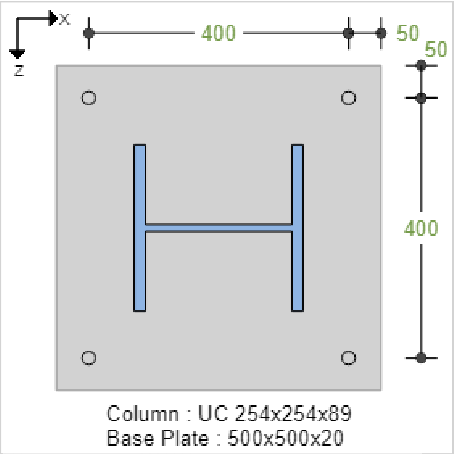
1.0 INPUT

1.1 Design Options

Design Code		=	**American Standard LRFD**
Unit		=	**SI Unit**

1.2 Column and Base Plate

Type		=	**Standard**
Section		=	**UC 254x254x89**
Overall Depth	D	=	**260.2** mm
Flange Width	B	=	**256.3** mm
Flange Thickness	T	=	**17.3** mm
Web Thickness	t	=	**10.3** mm
Column Area	Area	=	**11191.7** mm^2
Major Axis		=	**Z - Axis**
Length of Base Plate	L_{pl}	=	**500** mm
Breadth of Base Plate	B_{pl}	=	**500** mm
Thickness of Base Plate	t_{pl}	=	**20** mm



1.3 Bolts and Anchorage

1.3.1 Holding Down Bolts

Bolt Grade	F_b	=	**4.6**
Bolt Yield Strength	Y_b	=	**240** N/mm^2
Bolt Ultimate Strength	U_b	=	**400** N/mm^2
Bolt Size	d	=	**M20**
Number of Bolts	N_b	=	**4** Nos
Horizontal Edge Distance	e_x	=	**50** mm
Vertical Edge Distance	e_z	=	**50** mm

1.3.2 Bolt Anchorage

Anchorage		=	**Defined**
Reinforcement Ductility Effect		=	**Considered**
Embedment Depth	E_b	=	**400** mm
Width of Anchor Plate / Nut	b_a	=	**90** mm
Thickness of Anchor Plate / Nut	t_a	=	**12** mm

1.4 Pedestal

Length	L_p	=	**800** mm
Breadth	B_p	=	**800** mm
Height	H_p	=	**1200** mm
Clear Cover for Pedestal	C_{ped}	=	**50** mm

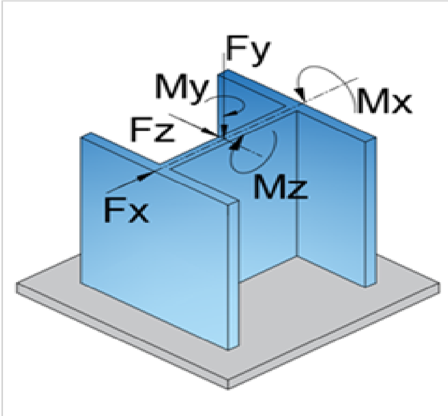
1.4.1 Anchorage Reinforcement

1.4.1.1 Tension

Main Bars per Bolt = **1 No. of Φ16**

1.4.1.2 Shear

Ties per Bolt = **2 No. of Φ10**



1.5 Steel Properties

Column Yield Strength f_{yc} = **250** N/mm²

Base Plate Yield Strength f_{yb} = **250** N/mm²

1.6 Reinforced Concrete Properties

Grout Pads = **Provided**

Compressive Strength of Concrete f'_c = **30** N/mm²

Yield Strength of Reinforcement f_y = **420** N/mm²

1.7 Loads

Load Case	Horizontal F_x (kN)	Vertical F_y (kN)	Horizontal F_z (kN)	Moment		
				M_x (kN-m)	M_y (kN-m)	M_z (kN-m)
LC 1	20.000	150.000	0.000	0.000	0.000	0.000
LC 2	0.000	300.000	0.000	10.000	1.000	5.000
LC 3	25.000	0.000	10.000	10.000	2.000	5.000
LC 4	10.000	75.000	0.000	15.000	2.000	10.000
LC 5	0.000	-100.000	0.000	0.000	0.000	0.000
LC 6	0.000	-25.000	0.000	10.000	1.000	5.000

2.0 OUTPUT

2.1 Plate Geometry

Bolt Spacing $S_b = L_{pl} - 2 * e_x$ **400** mm

Bolt Gauge $S_g = B_{pl} - 2 * e_z$ **400** mm

2.2 Base Plate

Ref: AISC Steel Design Guide 1

Combination	Base Plate					
	Axial Compression Capacity (kN)		Plate Bearing (kN/m)		Thickness (mm)	
	Actual	Allowable	Actual	Allowable	Compression	Tension
LC1	150.0	6630.0	300.0	13260.0	10.8	0.0
LC2	300.0	6630.0	750.0	13260.0	17.0	0.0
LC3	0.0	6630.0	13260.0	13260.0	12.4	9.6
LC4	75.0	6630.0	13260.0	13260.0	19.8	6.3
LC5	-100.0	6630.0	0.0	13260.0	0.0	11.8
LC6	-25.0	6630.0	13260.0	13260.0	10.3	11.4

2.2.1 Axial Compression Capacity

Governing Combination - LC 2

Base Plate Area	$A_1 = B_{pl} * L_{pl}$	**250000** mm²
Maximum Area of Supporting Surface		

$$A_2 = \left(B_{pl} + 2 * min\left(\frac{B_p - B_{pl}}{2}, \frac{L_p - L_{pl}}{2}\right)\right) * \left(L_{pl} + 2 * min\left(\frac{B_p - B_{pl}}{2}, \frac{L_p - L_{pl}}{2}\right)\right)$$ **640000** mm²

Nominal Strength of Concrete Under Plate	$P_p = 0.85 * f'_c * A_1 * \sqrt{\frac{A_2}{A_1}}$	**10200** kN
Str. Reduction Factor - Plate Compression	Φ_c	**0.65**
Minimum Area of Base Plate Required	$A_{1req} = \frac{F_y}{\Phi_c * 2 * 0.85 * f'_c}$	**9049.7** mm²
Factored Bearing Strength	$P_{pf} = P_p * \Phi_c$	**6630** kN

Pass - Base Plate Dimension Sufficient

2.2.2 Plate Bearing Check

Governing Combination - LC 3

Major Axis Moment	$M_a = M_z$	**5** kN-m
Minor Axis Moment	$M_i = M_x$	**10** kN-m
Resultant Moment	$M = abs\left(M_a + M_i * \frac{L_{pl}}{B_{pl}}\right)$	**15** kN-m
Maximum Concrete Bearing Stress	$f_{pmax} = \Phi_c * 0.85 * f'_c * min\left(\sqrt{\frac{A_2}{A_1}}, 2\right)$	**26.52** N/mm²
Maximum Bearing Pressure per unit Width	$q_{max} = f_{pmax} * B_{pl}$	**13260** kN/m
Critical Eccentricity	$e_{cr} = \frac{L_{pl}}{2} - \frac{F_y}{2 * q_{max}}$	**250** mm
Actual Eccentricity	$e = L_{pl}$	**500** mm

since, e >= ecr Large Moment

Bearing Length - Quadratic Solution 1	Y_1	**897.2** mm
Bearing Length - Quadratic Solution 2	Y_2	**2.8** mm
Length of Bearing	$Y = min(Y_1, Y_2)$	**2.8** mm
Bearing Pressure per unit Width	q	**13260** kN/m

Pass - Base Plate Dimensions Sufficient

2.2.3 Plate Thickness Calculation

Governing Combination - LC 4

2.2.3.1 Base Plate Yielding Limit at Bearing Interface

Strength Reduction Factor - Plate Flexure	Φ_f	**0.9**

Bending Line Cantilever Distance	$m = \frac{L_{pl} - 0.95 * D}{2}$	**126.4** mm
Cantilever Distance	$x_l = \frac{S_b - D}{2} + \frac{T}{2}$	**78.6** mm
Length of Bearing	Y	**6.8** mm
Major Axis Moment	$M_a = M_z$	**10** kN-m
Minor Axis Moment	$M_i = M_x$	**15** kN-m
Resultant Moment	$M = M_a + M_i * \frac{L_{pl}}{B_{pl}}$	**25** kN-m

<u>Bolt Tension Force</u>

Tension Force at One Side of Bolt Assembly	$T_u = M - \frac{\left(F_y * \frac{S_b}{2}\right)}{S_b}$	**14.4** kN
Tension Force at Other Side of Bolt Assembly	T_{u2}	**1.4** kN
Max Tension in Single Bolt	$T_{rod} = \frac{T_u}{\frac{N_b}{2}}$	**7.2** kN
Moment due to Bearing at Flange Center	$M_{fc} = q_{max} * \left(Y * \left(m - \frac{Y}{2}\right)\right) - (T_{u2} * x_l)$	**11.1** kN-m
Moment due to Bearing at Bolt Center	$M_{bc} = q_{max} * \left(Y * \left(e_x - \frac{Y}{2}\right)\right)$	**4.2** kN-m
Required Plate Thickness - Compression	$t_{preqb} = \sqrt{\frac{4 * M_{fc}}{\Phi_f * f_{yb} * B_{pl}}}$	**19.8** mm

<u>2.2.3.2 Base Plate Yielding Limit At Tension Interface</u>

Required Thickness of Base Plate - Tension	$t_{preqt} = \sqrt{\frac{4 * T_u * x_l}{\Phi_f * B_{pl} * f_{yb}}}$	**6.3** mm
Hence, Required Thickness of Base Plate	$t_{preq} = max(t_{preqt}, t_{preqb})$	**19.8** mm

Since, $t_{pl} \geq t_{preq}$, Pass.

2.3 Anchorage Check

Ref: ACI 318 - 19

Horizontal Bolt Spacing	$S_x = S_b$	**400** mm
Vertical Bolt Spacing	$S_y = \frac{S_g}{\frac{N_b}{2} - 1}$	**400** mm
Horizontal Bolt Edge Distance	$C_{a1} = \frac{L_x - S_x}{2}$	**200** mm
Vertical Bolt Edge Distance	$C_{a2} = \frac{L_y - S_y}{2}$	**200** mm
Minimum Edge Distance	$C_{amin} = min(C_{a1}, C_{a2})$	**200** mm
Maximum Edge Distance	$C_{amax} = max(C_{a1}, C_{a2})$	**200** mm

Effective Embedment Depth

$h_{ef} = min\left(E_b, max\left(\frac{C_{amax}}{1.5}, \frac{max(S_x, S_y)}{3}\right)\right)$ **133.3** mm *Cl. 17.6.2.1.2*

Ultimate Strength $f_{uta} = min(860, 1.9 * Y_b, U_b)$ **400** N/mm² *Cl. 17.6.1.2*

Combination	Applied Tension (kN)	Tension Capacity (kN)	Applied Shear (kN)	Shear Capacity (kN)	Interaction
LC1	0.0	67.3	10.0	28.0	0.0
LC2	0.0	67.3	0.0	28.0	0.0
LC3	16.5	67.3	13.5	28.0	0.7
LC4	7.2	67.3	5.0	28.0	0.3
LC5	25.0	67.3	0.0	28.0	0.0
LC6	23.4	67.3	0.0	28.0	0.0

2.3.1 Anchorage in Tension

Governing Combination - LC 5

Ten. Force at One Side of Bolt Assembly T_u **50** kN

Ten. Force at Other Side of Bolt Assembly T_{u2} **50** kN

Total Tension in Bolts $T = T_u + T_{u2}$ **100** kN

Tension per Bolt T_{rod} **25** kN

2.3.1.1 Steel Strength *Cl. 17.6.1*

Effective Threaded Area of Anchor $A_{se} = \frac{\pi}{4} * \left(d - \frac{0.9743 * 25.4}{8}\right)^2$ **224.5** mm²

Nominal Steel Strength of Anchor $N_{sa} = A_{se} * f_{uta}$ **89.8** kN

Str. Reduction Factor - Steel Tension Φ_{st} **0.75**

Design Steel Strength of Anchor $\Phi N_{sa} = \Phi_{st} * N_{sa}$ **67.4** kN

Steel Strength Ratio in Tension $R_{st} = \frac{T_{rod}}{\Phi N_{sa}}$ **0.37**

2.3.1.2 Concrete Breakout Strength *Cl. 17.6.2*

Conc. Failure Area of Single Anchor $A_{nco} = 9 * h_{ef}^2$ **160000** mm²

Conc. Failure Area of Anchor Group

$A_{nc} = (2 * min(C_{a1}, 1.5 * h_{ef}) + S_b) * (2 * min(C_{a2}, 1.5 * h_{ef}) + S_g)$ **640000** mm²

Basic Concrete Breakout Strength $N_b = 24 * h_{ef}^{1.5} * \sqrt{f'_c}$ **84.7** kN

Tension Eccentricity

$e'_n = abs\left(\frac{L_{pL}}{2} - \frac{T_{u2} * (S_b + e_x) + T_u * e_x}{T_u + T_{u2}}\right)$ **161.2** mm

Breakout Eccentricity Factor	$\Psi_{ecn} = min\left(1, \frac{1}{\left(1 + \frac{e'_N}{1.5 * h_{ef}}\right)}\right)$	**1**
Breakout Edge Effect Factor	Ψ_{edn}	**1**
Breakout Cracking Factor	Ψ_{cn}	**1.25**
Breakout Splitting Factor	Ψ_{cpn}	**1**

Nominal Concrete Breakout Strength

$N_{cbg} = \frac{A_{nc}}{A_{nco}} * \Psi_{edn} * \Psi_{ecn} * \Psi_{cn} * N_b * \Psi_{cpn}$		**423.5** kN
Str. Reduction Factor - Concrete Tension	Φ_{ct}	**0.75**
Design Concrete Breakout Strength	$\Phi N_{cbg} = \Phi_{ct} * N_{cbg}$	**317.6** kN
Breakout Strength Ratio in Tension	$R_{bt} = \frac{abs(F_y)}{\Phi N_{cbg}}$	**0.31**

2.3.1.3 Pullout Strength — *Cl. 17.6.3*

Pullout Cracking Factor	Ψ_{cp}	**1.4**
Bearing Area	$A_{bearing} = b_a^2$	**8100** mm²
Pullout Strength of Single Anchor	$N_p = 8 * A_{bearing} * f'_c$	**1944** kN
Nominal Pullout Strength	$N_{pn} = \Psi_{cp} * N_p$	**2721.6** kN
Str. Reduction Factor - Tension Pullout	Φ_{tp}	**0.7**
Design Pullout Strength	$\Phi N_p = \Phi_{tp} * N_{pn}$	**1905.1** kN
Pullout Strength Ratio	$R_{sp} = \frac{T_{rod}}{\Phi N_p}$	**0.01**

2.3.1.4 Concrete Side-Face Blowout Strength — *Cl. 17.6.4*

Side Face Blow out Strength not to be calculated when Effective Embedment Depth (h_{ef}) ≤ 2.5 * C_{amin}

2.3.1.5 Anchor Reinforcement in Tension

Tension Reinforcement Factor	Φ_{tr}	**0.75**
Bar Strength	$N_{rg} = \frac{\pi}{4} * N_{br} * (D_{br})^2 * f_y * N_b$	**337.8** kN
Tension Bar Strength Ratio	$R_{tr} = \frac{abs(F_y)}{\Phi_{tr} * N_{rg}}$	**0.39**
Anchorage Ratio - Tension	R_t	**0.37**

2.3.2 Anchorage in Shear

Governing Combination - LC 3

Resultant Shear	V	**26.9** kN

Resultant Shear per Bolt	V_s	**13.5** kN	

2.3.2.1 Steel Strength

Cl. 17.7.1

Nominal Steel Strength of Anchor	$V_{sa} = 0.6 * 0.8 * A_{se} * f_{uta}$	**43.1** kN	*Cl. 17.7.1.2.1*
Strength Reduction Factor - Steel Shear	Φ_{ss}	**0.65**	
Design Steel Strength of Anchor	$\Phi V_{sa} = \Phi_{cs} * V_{sa}$	**28** kN	
Steel Strength Ratio	$R_{ss} = \frac{V_s}{\Phi V_{sa}}$	**0.48**	

2.3.2.2 Concrete Breakout Strength

Cl. 17.7.2

Conc. Failure Area of Single Anchor - X Dir $A_{vcox} = 4.5 * {C_{a1}}^2$ **180000** mm²

Conc. Failure Area of Anchor Group - X Dir

$$A_{vcx} = \frac{N_b}{2} * min(1.5 * C_{a1}, H_p) * (min(1.5 * C_{a1}, C_{a2}) + 1.5 * C_{a1})$$ **240000** mm²

Basic Concrete Breakout Strength - X Dir.

$$V_{bx} = min\left(7 * \left(2 * \frac{d}{d}\right)^{0.2} * (d)^{0.5}, 9\right) * (f'_c)^{0.5} * (C_{a1})^{1.5}$$ **46.3** kN

Breakout Eccentricity Factor - X Dir. Ψ_{ecvx} **1**

Breakout Edge Effect Factor - X Dir. $\Psi_{edvx} = 0.7 + 0.3 * \left(\frac{C_{a2}}{(1.5 * C_{a1})}\right)$ **0.9**

Conc. Failure Area of Single Anchor - Z Dir $A_{vcoz} = 4.5 * {C_{a2}}^2$ **180000** mm²

Conc. Failure Area of Anchor Group - Z Dir

$$A_{vcz} = 2 * min(1.5 * C_{a2}, H_p) * (min(1.5 * C_{a2}, C_{a1}) + 1.5 * C_{a2})$$ **240000** mm²

Basic Concrete Breakout Strength - Z Dir. **46.3** kN

$$V_{bz} = min\left(7 * \left(2 * \frac{d}{d}\right)^{0.2} * (d)^{0.5}, 9\right) * (f'_c)^{0.5} * (C_{a2})^{1.5}$$ **46.3** kN

Breakout Eccentricity Factor - Z Dir. Ψ_{ecvz} **1**

Breakout Edge Effect Factor - Z Dir. $\Psi_{edvz} = 0.7 + 0.3 * \left(\frac{C_{a1}}{(1.5 * C_{a2})}\right)$ **0.9**

Breakout Cracking Factor Ψ_{cv} **1.4**

Nominal Concrete Breakout Strength - X Dir.

$$V_{cbgx} = \frac{A_{vcx}}{A_{vcox}} * \Psi_{edvx} * \Psi_{ecvx} * \Psi_{cv} * V_{bx}$$ **77.7** kN

Strength Reduction Factor - Concrete Shear Φ_{cs} **0.75**

Design Concrete Breakout Strength - X Dir. $\Phi V_{cbgx} = \Phi_{cs} * V_{cbgx}$ **58.3** kN

Breakout Strength Ratio - X $R_{bsx} = \frac{F_x}{\Phi V_{cbgx}}$ **0.43**

Nominal Concrete Breakout Strength - Z Dir.

$V_{cbgz} = \frac{A_{vcz}}{A_{vcoz}} * \Psi_{edvz} * \Psi_{ecvz} * \Psi_{cv} * V_{bz}$ **77.7** kN

Design Concrete Breakout Strength - Z Dir. $\Phi V_{cbgz} = \Phi_{cs} * V_{cbgz}$ **58.3** kN

Breakout Strength Ratio - Z $R_{bsz} = \frac{F_z}{\Phi V_{cbgz}}$ **0.17**

Resultant Breakout Strength $\Phi V_{cbg} = \sqrt{\Phi V_{cbgx}^2 + \Phi V_{cbgz}^2}$ **82.4**

Resultant Breakout Strength Ratio $R_{bsv} = \frac{V}{\Phi V_{cbg}}$ **0.33**

2.3.2.3 Concrete Pryout Strength

Cl. 17.7.3

Str. Reduction Factor - Concrete Tension Φ_{ct} **0.75**

Conc. Failure Area of Single Anchor $A_{nco} = 9 * h_{ef}^2$ **160000** mm²

Conc. Failure Area of Anchor Group

$A_{nc} = (min(C_{a1}, 1.5 * h_{ef}) + 1.5 * h_{ef}) * (min(C_{a2}, 1.5 * h_{ef}) + 1.5 * h_{ef}) * N_b$ **640000** mm²

Basic Concrete Breakout Strength $N_b = 24 * h_{ef}^{1.5} * \sqrt{f'_c}$ **84.7** kN

Ten. Force at One Side of Bolt Assembly T_u **33** kN

Ten. Force at Other Side of Bolt Assembly T_{u2} **3.6** kN

Tension Eccentricity

$e'_n = abs\left(\frac{L_{pL}}{2} - \frac{T_{u2} * (S_b + e_x) + T_u * e_x}{T_u + T_{u2}}\right)$ **161.2** mm

Breakout Eccentricity Factor $\Psi_{ecn} = min\left(1, \frac{1}{\left(1 + \frac{e'_N}{1.5 * h_{ef}}\right)}\right)$ **0.55**

Breakout Edge Effect Factor Ψ_{edn} **1**

Breakout Cracking Factor Ψ_{cn} **1.25**

Breakout Splitting Factor Ψ_{cpn} **1**

Nominal Concrete Breakout Strength

$N_{cbg} = \frac{A_{nc}}{A_{nco}} * \Psi_{edn} * \Psi_{ecn} * \Psi_{cn} * N_b * \Psi_{cpn}$ **234.5** kN

Strength Reduction Factor - Shear Pryout Φ_{sp} **0.7**

Design Pryout Strength $\Phi V_{cpg} = \Phi_{sp} * 2 * N_{cbg}$ **328.2** kN

Pryout Strength Ratio $R_{ps} = \frac{V}{\Phi V_{cpg}}$ **0.04**

2.3.2.4 Anchor Reinforcement in Shear

Shear Reinforcement Factor Φ_{sr} **0.75**

Diameter of Ties D_s **10**

Bar Strength - X Dir. $V_{rgx} = 2 * \frac{\pi}{4} * (D_s)^2 * f_y * \frac{N_b}{2}$ **132** kN

Bar Strength - Z Dir. $V_{rgz} = 2 * \frac{\pi}{4} * (D_s)^2 * f_y * \frac{N_b}{2}$ **132** kN

Bar Strength $V_{rg} = \sqrt{V_{rgx}^2 + V_{rgz}^2}$ **186.6**

Bar Strength Ratio $R_{sr} = \frac{V}{\Phi_{sr} * V_{rg}}$ **0.14**

Anchorage Ratio - Shear R_s **0.48**

2.3.3 Interaction of Tension and Shear

Cl. 17.8

Governing Combination - LC 3

2.3.3.1 Critical Tension Check - Steel Strength

Applied Tension T_f **16.5** kN

Anchorage Tension Capacity T_c **67.4** kN

Anchorage Ratio - Tension R_t **0.25**

2.3.3.2 Critical Shear Check - Steel Strength

Applied Shear S_f **13.5** kN

Anchorage Shear Capacity S_c **28** kN

Anchorage Ratio - Shear R_s **0.48**

Anchorage Interaction $I_{ts} = R_t + R_s$ **0.73**

Since, Anchorage Interaction (I_{ts}) ≤ 1.2, Pass.

3.0 SUMMARY

3.1 Base Plate

Description	Required	Actual	Critical Combination	Status
Compression Capacity (kN)	300	6630	LC 2	**Pass**
Bearing Pressure per unit Width (kN/m)	13260	13260	LC 3	**Pass**
Plate Thickness (mm)	19.8	20	LC 4	**Pass**

3.2 Anchorage Check

3.2.1 Anchorage in Tension (kN) - LC 5

Description	Force Applied	Capacity	Utilization Ratio	Status
Steel Strength	25	67.4	0.37	**Pass**
Concrete Breakout Strength	100	317.6	0.31	**Pass**

Anchorage Reinforcement Strength	100	337.8	0.39	**Pass**
Pullout Strength	25	1905.1	0.01	**Pass**

3.3 Anchorage in Shear (kN) - LC 3

Description	Force Applied	Capacity	Utilization Ratio	Status
Steel Strength	13.5	28	0.48	**Pass**
Concrete Breakout Strength	26.9	82.4	0.33	**Pass**
Anchorage Reinforcement Strength	26.9	186.6	0.14	**Pass**
Concrete Pryout Strength	13.5	328.2	0.04	**Pass**

3.4 Interaction in Tension and Shear - LC 3

Description	Actual	Allowable	Status
Tension - Steel Strength (kN)	16.5	≤ 67.4	**Pass**
Shear - Steel Strength (kN)	13.5	≤ 28	**Pass**
Anchorage Interaction	0.7	≤ 1.2	**Pass**