ASDIP Steel
STRUCTURAL ENGINEERING SOFTWARE

Small Moment Base Plate Example

Design Guide 1, 2nd Edition
Base Plate and Anchor Rod Design
AISC - Oct 2006

B.5 Example: Small Moment Base Plate Design, Triangular Pressure Distribution Approach

Design a base plate for axial dead and live loads equal to 100 and 160 kips, respectively, and moments from the dead and live loads equal to 250 and 400 kip-in., respectively. Bending is about the strong axis for the wide flange column W12×96 with d = 12.7 in. and b_f = 12.2 in. The ratio of the concrete to base plate area is unity; F_y of the base plate is 36 ksi and f_c' of the concrete is 4 ksi.

1. Choose trial base plate sizes (B and N) based on geometry of column and 4-anchor requirements.

$$N > d + (2 \times 3.0 \text{ in.}) = 12.7 + 6 = 18.7 \text{ in.}$$
$$B > b_f + (2 \times 3.0 \text{ in.}) = 12.2 + 6 = 18.2 \text{ in.}$$

Try N = 19 in., B = 19 in.

2. Determine plate cantilever dimension, m or n, in direction of applied moment.

$$m = \frac{(N - 0.95d)}{2} = \frac{19.0 - 0.95(12.7 \text{ in.})}{2} = 3.47 \text{ in.}$$
$$n = \frac{B - 0.80b_f}{2} = \frac{19 - 0.80(12.2 \text{ in.})}{2} = 4.62 \text{ in.}$$

(Not in direction of applied moment)

3. Determine applied loads, P and M, based on ASD or LRFD load combinations.

LRFD	ASD
P_u = 1.2(100) + 1.6(160) = 376 kips M_u = 1.2(250) + 1.6(400) = 940 kip-in.	P_a = 100 + 160 = 260 kips M_a = 250 + 400 = 650 kip-in.

4. Determine eccentricity e and e_{kern}.

LRFD	ASD
$e_u = \frac{M_u}{P_u} = \frac{940}{376} = 2.5 \text{ in.}$	$e_a = \frac{M_u}{P_u} = \frac{650}{260} = 2.5 \text{ in.}$

$$e_{kern} = \frac{N}{6} = \frac{19.0}{6} = 3.17 \text{ in.}$$

Thus, $e = 2.5$ in. < $e_{kern} = 3.17$ in., this is a small moment base, no tension exists between base plate and foundation.

5. Determine base pressures for a 1-in. strip of plate.

Due to axial compression:

$$f_{p(ax)} = \frac{P}{A} = \frac{P}{BN}$$

LRFD	ASD
$f_{p(ax)} = \frac{P_u}{BN} = \frac{376 \text{ kips}}{19 \text{ in.} \times 19 \text{ in.}} = 1.04 \text{ ksi}$	$f_{p(ax)} = \frac{P_a}{BN} = \frac{260 \text{ kips}}{19 \text{ in.} \times 19 \text{ in.}} = 0.720 \text{ ksi}$

Due to applied moment:

$$f_{p(b)} = \frac{M}{S_{pl}} = \frac{6Pe}{BN^2}$$

LRFD	ASD
$f_{p(ax)} = f_{p(bu)} = \frac{6P_u e}{BN^2} = \frac{6(376 \text{ kips})(2.50 \text{ in.})}{19 \text{ in.} \times (19 \text{ in.})^2} = 0.822 \text{ kips/in.}$	$f_{p(ax)} = f_{p(ba)} = \frac{6P_a e}{BN^2} = \frac{6(260 \text{ kips})(2.50 \text{ in.})}{19 \text{ in.} \times (19 \text{ in.})^2} = 0.569 \text{ kips/in.}$

Combined pressure:

LRFD	ASD
$f_{pu(max)} = f_{p(ax)u} + f_{p(b)u} = 1.042 + 0.822 = 1.86 \text{ kips/in.}$	$f_{pa(max)} = f_{p(ax)u} + f_{p(b)u} = 0.720 + 0.569 = 1.29 \text{ kips/in.}$
$f_{pu(min)} = f_{p(ax)u} + f_{p(b)u} = 1.042 - 0.822 = 0.220 \text{ kips/in.}$	$f_{pa(min)} = f_{p(ax)u} + f_{p(b)u} = 0.720 - 0.569 = 0.151 \text{ kips/in.}$

6. Determine pressure at critical bending plane [m distance from $f_{p(max)}$].

LRFD	ASD
$f_{pu(m)} = f_{pu(max)} - 2f_{p(b)u}\left(\frac{m}{N}\right) = 1.86 - \frac{2(0.822)(3.47 \text{ in.})}{19 \text{ in.}} = 1.56 \text{ kips/in.}$	$f_{pa(m)} = f_{pa(max)} - 2f_{p(b)a}\left(\frac{m}{N}\right) = 1.29 - \frac{2(0.569)(3.47 \text{ in.})}{19 \text{ in.}} = 1.08 \text{ kips/in.}$

7. Determine M_{pl} for bending about critical planes at m and n.

Bending of a 1-in.-wide strip of plate about a plane at m, in the direction of applied moment:

LRFD	ASD
$M_{u\,pl} = \left(f_{pu(m)}\right)\left(\frac{m^2}{2}\right) + \left(f_{pu(max)} - f_{pu(m)}\right)\left(\frac{m^2}{3}\right)$	$M_{a\,pl} = \left(f_{pa(m)}\right)\left(\frac{m^2}{2}\right) + \left(f_{pa(max)} - f_{pa(m)}\right)\left(\frac{m^2}{3}\right)$
$M_{u\,pl} = (1.56 \text{ kips/in.})\frac{(3.47 \text{ in.})^2}{2} + (1.86 - 1.56 \text{ kips/in.})\frac{(3.47 \text{ in.})^2}{3} = 10.6 \text{ kip-in.}$	$M_{u\,pl} = (1.08 \text{ kips/in.})\frac{(3.47 \text{ in.})^2}{2} + (1.29 - 1.08 \text{ kips/in.})\frac{(3.47 \text{ in.})^2}{3} = 7.34 \text{ kip-in.}$

Bending about a plane at n, perpendicular to applied moment. For the case of axial loads plus small moments, the procedure shown below can be used (using the axial load only). For axial loads plus large moments, a more refined analysis is required.

LRFD	ASD
$M_{u\,pl} = f_{p(ax)u}\left(\frac{n^2}{2}\right) = 1.04 \text{ kips/in.} \frac{(4.62 \text{ in.})^2}{2} = 11.1 \text{ kip-in./in.}$	$M_{a\,pl} = f_{p(ax)a}\left(\frac{n^2}{2}\right) = 0.720 \text{ kips/in.} \frac{(4.62 \text{ in.})^2}{2} = 7.68 \text{ kip-in./in.}$

The critical moment is the larger of M_{pl} about m and n critical planes.

LRFD	ASD
$M_{u\,crit} = 11.1$ kip-in./in.	$M_{a\,crit} = 7.68$ kip-in./in.

8. Determine required plate thickness:

   Note: Since the M_{pl} is expressed in units of kip-in./in., the plate thickness expressions can be formatted without the plate width (B) as such:

LRFD	ASD
$t_{u\,req} = \sqrt{\dfrac{4M_{u\,crit}}{\phi F_y}}$ $= \sqrt{\dfrac{4 \times 11.1 \text{ kip-in.}}{0.90 \times 36 \text{ ksi}}}$ $= 1.17 \text{ in.}$	$t_{a\,req} = \sqrt{\dfrac{4M_{a\,crit}\Omega}{F_y}}$ $= \sqrt{\dfrac{4 \times 7.68 \text{ kip-in.} \times 1.67}{36 \text{ ksi}}}$ $= 1.19 \text{ in.}$

9. Use plate size:

   N = 19 in.

   B = 19 in.

   t = 1¼ in.

STEEL BASE PLATE DESIGN

GEOMETRY

Column Section			W12X87			
		Width		Length		
Column		12.1		12.5	in	
Plate		19.0		19.0	in	OK
Concrete Support	Wp1	9.5	Lp1	9.5	in	OK
	Wp2	9.5	Lp2	9.5	in	OK
Rod Offset		4.0		3.0	in	OK
Thickness of Grout				1.5	in	

SERVICE LOADS (ASD)

Vertical Load P	260.0	kip
Bending Moment M	54.2	k-ft
Horizontal Load V	0.0	kip
Design Eccentricity e	2.5	in

Design Eccentricity Is < L/6

MATERIALS

Plate Steel Strength Fy	36.0	ksi
Pier Concrete Strength f'c	4.0	ksi

AXIALLY LOADED PLATES

Cantilever Model

Bearing Stress fp	0.72	ksi	OK
Critical Section @ Long m	3.56	in	
Critical Section @ Short n	4.66	in	
Plate Thickness tp	1.20	in	

Thornton Model

Bearing Strength Fp/Ω	1.36	ksi
Critical Section @ Int λn' .	2.65	in
Design Moment @ Plate ...	2.54	k-in/in
Plate Thickness tp	0.69	in

BASE PLATES WITH MOMENT

Blodgett Method

Max. Bearing Stress fp	1.29	ksi	OK
Bearing @ Critical Section	1.08	ksi	
Moment @ Critical Section	7.73	k-in/in	
Moment due to Rod Tension	0.00	k-in/in	
Design Moment @ Plate	7.73	k-in/in	
Plate Thickness tp	1.20	in	

DeWolf Method

Max. Bearing Stress fp	1.29	ksi	OK
Bearing @ Critical Section	1.08	ksi	
Moment @ Critical Section	7.73	k-in/in	
Moment due to Rod Tension	0.00	k-in/in	
Design Moment @ Plate	7.73	k-in/in	
Plate Thickness tp	1.20	in	

ASDIP Steel 3.2.5 — **STEEL BASE PLATE DESIGN** — www.asdipsoft.com

ANCHORAGE DESIGN

Rod Material Specification **F1554-36**

(4) Rods , fya = 36.0 ksi, futa = 58.0 ksi

Anchor Rod Size .. **1" diam. x 12.0 in emb.**

Concrete Is Uncracked at Service Load Level

Tension Analysis (kip)

Total Tension Force N	0.0	kip
Tension Force per Rod Ni	0.0	kip

No Reinforcing Bars Provided

Failure Mode	Ω	Nn	N / Nn/Ω	
Steel Strength Nsa	2.00	35.1	0.00	
Rebars Strength Nrg	2.00	N.A.	N.A.	
Conc. Breakout Ncbg	2.14	21.9	0.00	
Pullout Strength Npn	2.14	67.2	0.00	✓
Side Blowout Nsbg	2.14	N.A.	N.A.	

N / Nn/Ω Tension Design Ratio .... 0.00 OK

Shear Analysis (kip)

Shear Taken by Anchor Rods only

Total Shear Force V	0.0	kip
Shear Force per Rod Vi	0.0	kip

All Anchor Rods Are Effective

No Reinforcing Bars Provided

Failure Mode	Ω	Vn	V / Vn/Ω	
Steel Strength Vsa	2.31	16.9	0.00	
Rebars Strength Vrg	2.31	N.A.	N.A.	
Conc. Breakout Vcbg	2.14	12.0	0.00	
Conc. Pryout Vcpg	2.14	43.9	0.00	✓

V / Vn/Ω Shear Design Ratio ...... 0.00 OK

Tension-Shear Interaction

Combined Stress Ratio .... 0.00 OK

DESIGN CODES

Steel design	AISC 360-10 (14th Ed.)
Base plate design	AISC Design Series # 1
Anchorage design ...	ACI 318-11 Appendix D

SUMMARY OF RESULTS

Design Moment @ Plate ...	7.8	k-in/in	
Plate Thickness tp	1.20	in	
Max. Bearing Stress fp	1.29	ksi	
Bearing Strength Fp/Ω	1.36	ksi	
fp / Fp/Ω Design Ratio	0.95		OK

DESIGN IS DUCTILE