

May 19, 2011

Jian Zhao, PhD

Civil Engineering and Mechanics

University of Wisconsin - Milwaukee

NEESR

Subject: Anchor Design Examples (ACI 355 vs. MathCAD)

Dear Dr. Zhao:

I have recalculated the ACI 355 anchor design examples (1 through 9) to the updated MathCAD shown attached to this email. The two solutions still seem to be identical. The following pages are the summary. Thank you.

Sincerely,

Aquilino O. Dael

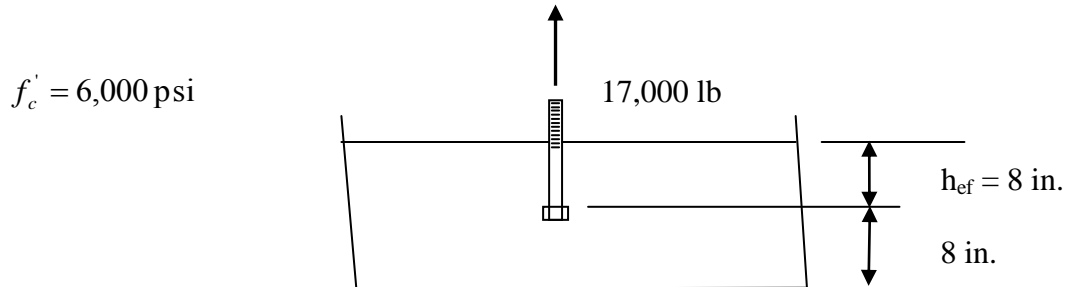
BSCE-Structural

2849 N. FREDERICK AVE., MILWAUKEE, WI • 53211

PHONE: 414-207-3359 • EMAIL: ADAEL@UWM.EDU

Example 1 - Single Headed Anchor in Tension Away from Edges

Check the capacity of a single anchor, 1 in. diameter, F1554 Grade 36 headed bolt with heavy-hex head installed in the top of a foundation without edge effects to resist a factored load of 17,000 lb tension (determined from ACI 318 9.2.1). The foundation is located in an area of high seismic risk. Assume normal weight concrete and that a crack forms in the plane of the anchor.

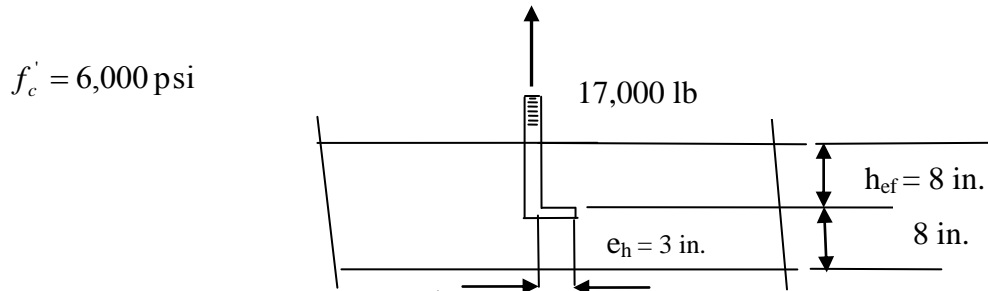


Note: Foundation reinforcement not shown for clarity

SUMMARY AND COMPARISON				
Mode of Failure in Tension	ACI 335 (lb)	MathCAD 14 (lb)	Difference (lb)	%
Steel	19,771 lb	19,771 lb	0	0
Concrete Breakout	22,084 lb	22,084 lb	0	0
Concrete Pullout	37,825 lb	37,825 lb	0	0
Side-Face Blowout	NA	19,771 lb	0	0

Example 2 – Single Hooked Anchor in Tension Away from Edges

Check the capacity of a single anchor, 1 in. diameter, F1554 Grade 36 standard hooked bolt (L-bolt) installed in the top of a foundation without edge effects to resist a factored load of 17,000 lb tension (determined from ACI 318 9.2.1). The foundation is located in an area of high seismic risk. Assume normal weight concrete and that a crack forms in the plane of the anchor.



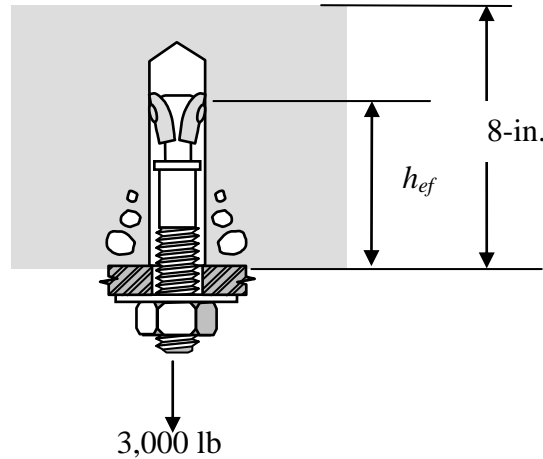
Note: Foundation reinforcement not shown for clarity

SUMMARY AND COMPARISON: $e_h = 3.0 \text{ in} = 4.5D$				
Mode of Failure in Tension	ACI 335 (lb)	MathCAD 14 (lb)	Difference (lb)	%
Steel	19,771	19,771	0	0
Concrete Breakout	22,084	22,084	0	0
Concrete Pullout	8,505	8,505	0	0
Side-Face Blowout	NA	0 lb	0	0

SUMMARY AND COMPARISON: $e_h = 4.5 \text{ in} = 4.5D$				
Mode of Failure in Tension	ACI 335 (lb)	MathCAD 14 (lb)	Difference (lb)	%
Steel	19,771	19,771	0	0
Concrete Breakout	22,084	22,084	0	0
Concrete Pullout	12,757	12,757	0	0
Side-Face Blowout	NA	0	0	0

Example 3 – Single Post-Installed Anchor in Tension Away from Edges

Determine the minimum diameter post-installed torque-controlled expansion anchor for installation in the bottom of an 8-in. slab with a concrete compressive strength of $f'_c = 4,000$ psi to support a 3,000 lb service dead load. The anchor will be in the tension zone (cracking at service load level is assumed), away from edges and other anchors in normal weight concrete.

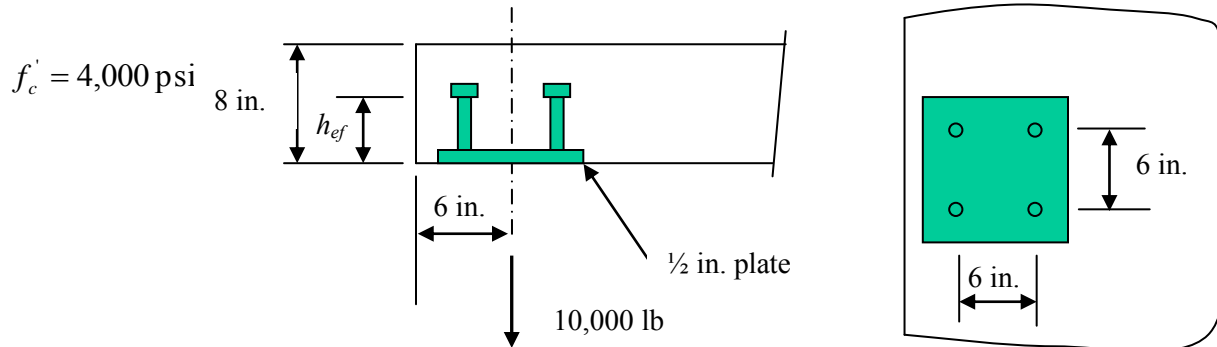


See Table C of this document for sample anchor installation and performance data. The data in Table C is not from any specific anchor and should not be used for design in accordance with ACI 318-05, Appendix D. However it is similar to what would be expected from testing and an evaluation report prepared by an independent testing and evaluation agency for the manufacturer in accordance with *ACI 355.2-04*.

SUMMARY AND COMPARISON: $d_a = 5/8$ in & $h_{ef} = 4.5$ in				
Mode of Failure in Tension	ACI 335 (lb)	MathCAD 14 (lb)	Difference (lb)	%
Steel	12,712	12,713	1	0.008
Concrete Breakout	6,671	6,671	0	0
Concrete Pullout	5,337	5,337	0	0
Side-Face Blowout	NA	0 lb	0	0

Example 4 - Group of Headed Studs in Tension Near an Edge

Design a group of four welded, AWS D1.1 Type B welded headed studs spaced 6-in. on center each way and concentrically loaded with a 10,000 lb service dead load. The anchor group is to be installed in the bottom of an 8-in. thick normal weight concrete slab made with the centerline of the connection 6-in. from a free edge of the slab.



Note: Reinf. not shown for clarity

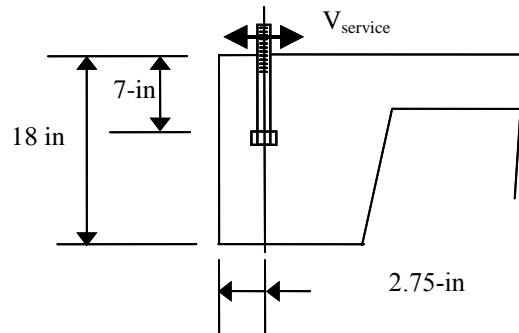
SUMMARY AND COMPARISON				
Mode of Failure in Tension	ACI 335 (lb)	MathCAD 14 (lb)	Difference (lb)	%
Steel	38,220	38,220	0	0
Concrete Breakout	14,201	14,244	43	0.30
Concrete Pullout	52,774	52,774	0	0
Side-Face Blowout	NA	38,220	0	0

Example 5 - Single Headed Bolt in Shear Near an Edge

Determine the reversible service wind load shear capacity for a single ½-in. diameter cast-in hex headed bolt meeting ASTM F1554 Grade 36. The headed bolt is installed in a normal weight continuous concrete foundation with a 7 in. embedment and a 2¾ in. edge distance. No supplemental reinforcing is present.

Note: This is the minimum anchorage requirement at the foundation required by IBC 2003 Section 2308.6 for conventional light-frame wood construction. The 2¾-in edge distance represents a typical connection at the base of framed walls using wood 2×6 sill members.

$$f'_c = 4,000 \text{ psi}$$



Note: Foundation reinforcement not shown for clarity

SUMMARY AND COMPARISON				
Mode of Failure in Shear	ACI 335 (lb)	MathCAD 14 (lb)	Difference (lb)	%
Steel Strength	3,212	3,212	0	0
Concrete Breakout	1,514	1,515	1	0.07
Concrete Pryout	19,350	19,334	16	0.08

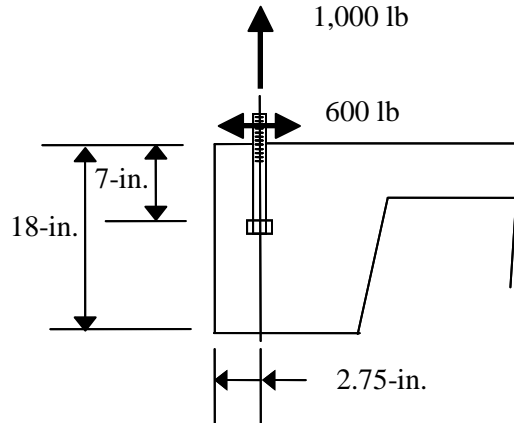
Example 6 - Single Headed Bolt in Tension and Shear Near an Edge

Determine if a single ½-in. diameter cast-in hex-headed bolt installed with a 7 -in. embedment depth and a 2 ¾-in. edge distance in a normal weight, continuous concrete foundation is adequate for a service tension load from wind of 1,000 lb and reversible service shear load from wind of 600 lb. No supplemental reinforcing is present.

Note: This is an extension of Example 5 that includes a tension load on the fastener as well as a shear load.

$$f'_c = 4,000 \text{ psi}$$

ASTM F1554 Grade 36 hex head anchor bolt material

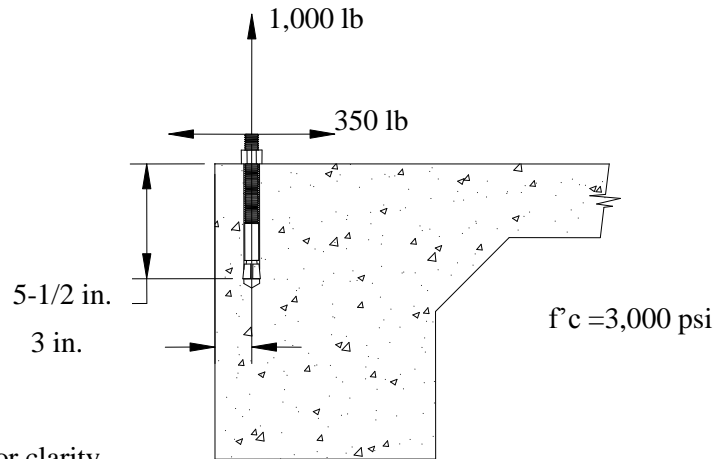


SUMMARY AND COMPARISON				
Mode of Failure in Tension	ACI 335 (lb)	MathCAD 14 (lb)	Difference (lb)	%
Steel	6,177	6,177	0	0
Concrete Breakout	9,675	9,667	8	0.083
Concrete Pullout	6,518	6,518	0	0
Side-Face Blowout	10,508	10,508	0	0

SUMMARY AND COMPARISON				
Mode of Failure in Shear	ACI 335 (lb)	MathCAD 14 (lb)	Difference (lb)	%
Steel Strength	3,212	3,212	0	0
Concrete Breakout	1,514	1,515	11	0.07
Concrete Pryout	19,350	19,334	16	0.08

Example 7 - Single Post-Installed Anchor in Tension and Shear Near an Edge

Determine if a single 1/2 inch diameter post-installed torque-controlled expansion anchor with a minimum 5 1/2 inch effective embedment installed 3 inches from the edge of a continuous normal-weight concrete footing (cast against the earth) is adequate for a service tension load of 1,000 lb for wind and a reversible service shear load of 350 lb for wind. The anchor will be installed in the tension zone and the concrete is assumed to be cracked.



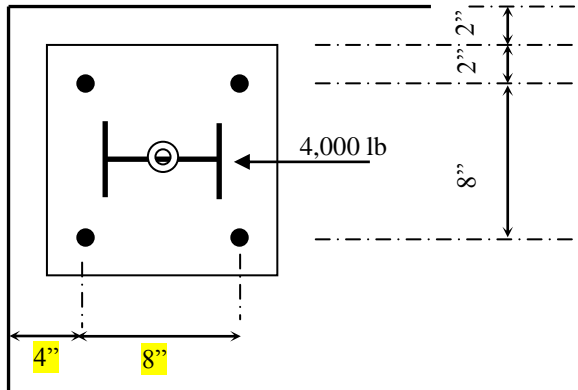
Note: Reinf. not shown for clarity.

See Table C for a sample table of post-installed anchor data from manufacturer (fictitious for example purposes only) as determined from testing in accordance with *ACI 355.2-04*.

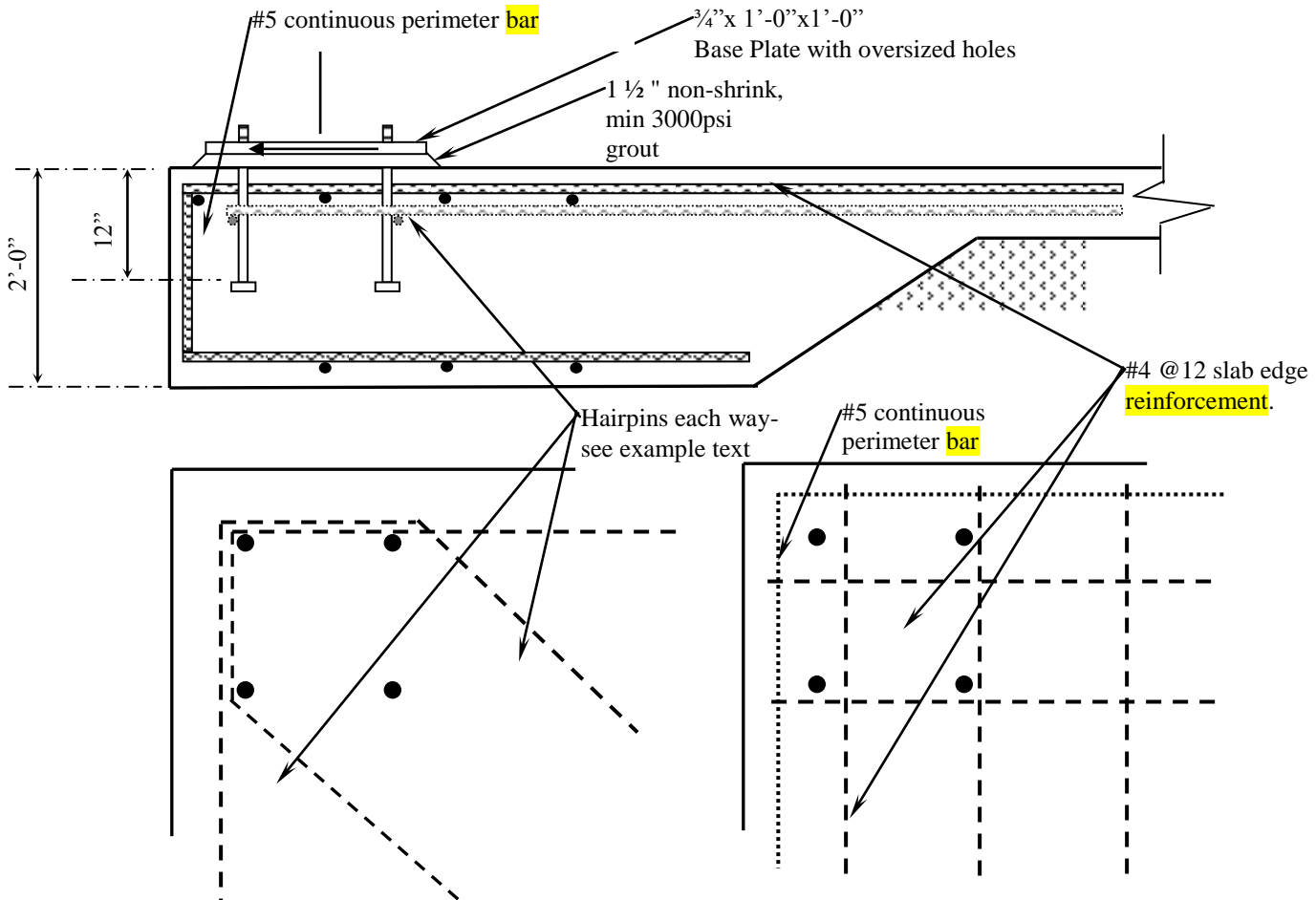
SUMMARY AND COMPARISON				
Mode of Failure in Tension	ACI 335 (lb)	MathCAD 14 (lb)	Difference (lb)	%
Steel	7,988	7,987	1	0.012
Concrete Breakout	3,638	3,644	6	0.165
Concrete Pullout	4,149	4,149	0	0
Side-Face Blowout	NA	0	0	0

SUMMARY AND COMPARISON				
Mode of Failure in Shear	ACI 335 (lb)	MathCAD 14 (lb)	Difference (lb)	%
Steel Strength	4,153	4,154	1	0.024
Concrete Breakout	1,495	1,495	0	0
Concrete Pryout	9,261	9,276	15	0.162

Example 8 – Group of Anchors in Tension and Shear with Two Free Edges, and Supplemental Reinforcement



Check the capacity of a fastener group with four $\frac{3}{4}$ " diameter ASTM F1554 Grade 55 cast-in anchor rods embedded 12" using hex nuts into the 2'-0" thick, $f_c' = 3000$ thickened slab made of normal-weight concrete to support a factored **shear** of 4 kips shear and simultaneous uplift of 12 kips. The plate is symmetrically placed at the corner. Seismic forces are not a consideration. **60 ksi reinforcement.**

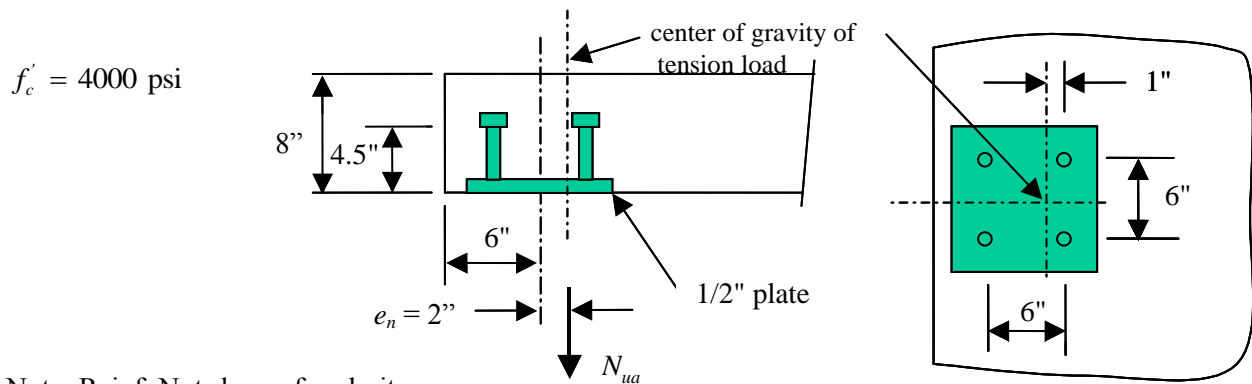


SUMMARY AND COMPARISON				
Mode of Failure in Shear	ACI 335 (lb)	MathCAD 14 (lb)	Difference (lb)	%
Steel Strength	3,1280	3,128	0	0
Concrete Breakout	4,890	4,892	2	0.041
Concrete Pryout	41,000	40,730	270	0.658

Example 9 - Group of Headed Studs in Tension Near an Edge with Eccentricity

Determine the allowable factored tension load, N_{ua} (determined from ACI 318 9.2.1) that can be supported by a group of four $\frac{1}{2}$ in. x 4 in. AWS D1.1 Type B headed studs spaced 6-in. on center each way and welded to a $\frac{1}{2}$ in.-thick embedded plate. The centerline of the structural attachment to the plate has been located 2-in. off of the centerline of the plate resulting in an eccentricity of the tension load of 2 in. The anchor group is installed in the bottom of an 8-in. thick slab with the centerline of the group 6-in. from a free edge of the slab.

Note: This is the configuration chosen as a solution for Example 4 to support a 14,000 lb factored tension load centered on the connection. The only difference is the eccentricity of the tension load. In Step 3 of Example 4, the spacing between anchors dictates that they be designed as an anchor group.



Note: Reinf. Not shown for clarity

SUMMARY AND COMPARISON: $n = 2 / n = 4$ due to eccentricity in tension				
Mode of Failure in Tension	ACI 335 (lb)	MathCAD 14 (lb)	Difference (lb)	%
Steel	19,110/22,932	19,110/22,932	0	0.012
Concrete Breakout	10,935	10,988	63	0.482
Concrete Pullout	26,387/31,664	26,387/31,664	0	0
Side-Face Blowout	NA	19,110/22,932	0	0