Engineering Analysis

PermaPost Metal Fastening Plates
Connection to 2" x 20 Gauge Steel Column and 2.375" x 13 Gauge Steel Column

Report E8260.01-122-34

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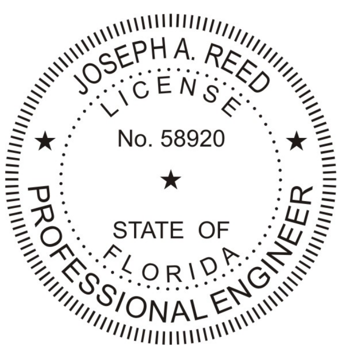
June 29, 2015
Revision 1: July 1, 2015



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Scope

Architectural Testing, Inc., an Intertek company, was contracted by HB&G Building Products to perform an uplift capacity analysis and anchorage calculations for the 4", 4.25" and 5" PermaPost metal fastening plates. The PermaPost metal fastening plates are used to anchor either a 2" diameter by 20 gauge steel post or a 2.375" diameter by 13 gauge steel post. Each post has a non-structural, decorative covering.

Referenced standard utilized in this project include:

Cold Formed Steel Design Manual, American Iron and Steel Institute, 1996.

Steel Construction Manual, Fourteenth Edition. American Institute of Steel Construction, Inc., 2011.

Metal Curtain Wall Fasteners, American Architectural Manufacturers Association, Report AAMA TIR-A9-1991, 1991.

ANSI/AWC NDS-2012 National Design Specification for Wood Construction, American Wood Council, 2012.

Product Description

HB&G Building Products provided drawings of the three different PermaPost metal fastening plates. Each plate is fabricated from 11 gauge, HD galvanized mild steel. A post will be anchored to the metal fastening plates by a single 3/8" diameter Grade 8 steel bolt. As a base plate, the PermaPosts can be anchored to either 2 x 6 Southern Yellow Pine, preservative-treated deck boards or a minimum 4" thick, 3,000 psi, normal weight concrete slab. As a cap plate, the PermaPost can be anchored to a two-ply Southern Yellow Pine wood header.

Analyses

Maximum Allowable Wind Uplift Load

Each PermaPost metal fastening plate was analyzed with both column sizes and assumed anchored to both substrates. Uplift loads for the columns acting on the plates are assumed to be concentric and vertical. Bending of the column upon the plate was not considered in the analysis. Maximum loads per plate and tube application are based on the lowest values of the plate interaction with the substrate and tube that is connected to it. Load duration factors for wind loads are utilized. Maximum allowable wind uplift loads are presented in Table 1 (page 3).

Table 1 Allowable Wind Uplift Values for PermaPost Plates

Condition	Allowable Uplift Load (pounds)	Comments
4" PermaPost with 2" dia. Post	932	Limited by withdrawal of wood screw from wood substrate for all conditions.
4" PermaPost with 2.375" dia. Post	932	
4.25" PermaPost with 2" dia. Post	932	
4.25" PermaPost with 2.375" dia. Post	932	
5" PermaPost with 2" dia. Post	932	
5" PermaPost with 2.375" dia. Post	932	

Notes:

1. At base: PermaPost Plate installed into a minimum 2 x 6 SYP #2 flat plank with four (4) #14 x 1-1/2" Round Head, Stainless Steel Wood Screws.

   or

   PermaPost Plate installed into a minimum 4" thick f'c = 3,000 psi concrete slab with four (4) Powers Tapper+ 1/4" x 2" concrete screws. Minimum embedment of 1-3/4". Minimum Edge Distance of 2".

2. At cap: PermaPost Plate installed into a minimum 2 x 6 SYP #2 two-ply header with four (4) #14 x 1-1/2" Round Head, Stainless Steel Wood Screws.

Summary

Maximum allowable wind uplift loads for 4", 4.25" and 5" PermaPost metal fastening plates with either the 2" diameter or 2.375" diameter columns on either wood base or concrete base and a two-ply wood header at the cap are presented in Table 1. Wind uplift loads on the plates are assumed centered at the column attachment and only vertical loads are considered. Uplift or overturning due to other load types (for example lateral or eccentric loads from the column) must be evaluated by the Engineer of Record for the project.

Attached Drawings

Permapost Anti-Uplift Mount – 4.00 Inch Bracket Rev 05-06-15, HB&G Building Products, 05/06/16. (1 page)

Permapost Anti-Uplift Mount – 4.25 Inch Bracket Rev 05-06-15, HB&G Building Products, 05/06/16. (1 page)

Permapost Anti-Uplift Mount – 5.00 Inch Bracket Rev 05-06-15, HB&G Building Products, 05/06/16. (1 page)

Calculations

Material Properties

Column Properties
2" diameter, 20 gauge
Wall thickness = 0.0359"
Steel Grade 33: F_y = 33 ksi ; F_u = 45 ksi

2.375" diameter, 13 gauge
Wall thickness = 0.0897"
Steel Grade 33: F_y = 33 ksi ; F_u = 45 ksi

Base Plate Properties
11 Gauge (0.1196" thick)
Steel Grade 33: F_y = 33 ksi ; F_u = 45 ksi

Bolt Properties
3/8" diameter HD galvanized Grade 8 (0.375" diameter)
F_y = 130,000 psi
F_{nt} = 150,000 psi
$\Omega = 2.0$

Strength of Bolt Connection

Shear of 3/8" Grade 8 Bolt

$V_a = F_n A_b / \Omega$ (AISC J3-1)
$V_a = [(150{,}000)(0.0775\ in^2)]/2.0$ = 5,812 lbs. Single Shear
V_a = 1,454 lbs. x 2 (double shear) = 11,624 lbs.

Strength of Bolt Connection (Continued)

Strength of 3/8" bolt hole at 11 Gauge Uplift Plate with edge distance

$P_n = teF_u/\Omega$ (AISI Eq. E3.1-1)
P_n = (0.1196" x 0.438" x 45,000 psi)/2.0 = 1,178.67 lbs.
P_n = 1,178.67 lbs. x 2 (two connection points) = 2,357 lbs.

Strength of 3/8" bolt hole at 20 Gauge Tube with edge distance

$P_n = teF_u/\Omega$ (AISI Eq. E3.1-1)
P_n = (0.0359" x 0.8147" x 45,000 psi)/2.0 = 658 lbs.
P_n = 658 lbs. x 2 (double shear) = 1,316 lbs.

Strength of 3/8" bolt hole at 13 Gauge Tube with edge distance

$P_n = teF_u/\Omega$ (AISI Eq. E3.1-1)
P_n = (0.0897" x 0.8147" x 45,000 psi)/2.0 = 1,644 lbs.
P_n = 1,644 lbs. x 2 (double shear) = 3,288 lbs.

Bearing of 3/8" Grade 8 bolt on 11 Gauge Uplift Plate

$P_u = Cm_f dtF_u/\Omega$ (AISI Eq. E3.3.1-1)
P_u = (3 x 1 x 0.375" x 0.1196" x 45,000)/2.5
P_u = 2,422 lbs. x 2 (double shear) = 4,844 lbs.

Bearing of 3/8" Grade 8 bolt on 20 Gauge Tube

$P_u = Cm_f dtF_u/\Omega$ (AISI Eq. E3.3.1-1)
P_u = (3 x 1 x 0.375" x 0.0359" x 45,000)/2.5
P_u = 727 lbs. x 2 (double shear) = 1,454 lbs.

Bearing of 3/8" Grade 8 bolt on 13 Gauge Tube

$P_u = Cm_f dtF_u/\Omega$ (AISI Eq. E3.3.1-1)
P_u = (3 x 1 x 0.375" x 0.0897" x 45,000)/2.5
P_u = 1,816 lbs. x 2 (double shear) = 3,632 lbs.

Strength of Bolt Connection (Continued)

Bending of 3/8" diameter Grade 8 bolt: 5" plate with 2" diameter tube

$S = \pi d^3/32 = \pi(0.375")^3/32 = 0.0052$ in^3
$F_b = (1.3)(0.6\ F_y) = (1.3)(0.6)(130{,}000$ psi$) = 101{,}400$ psi (1.3 factor for weak axis bending)
$F_b = M/S = (VL/2)/S$ (L/2 for guided bending)
L = 5" (plate width) – 2" (tube diameter)/2 = 1.5"
$V = 2SF_b/L = (2)(0.0052$ in$^3)(101{,}400$ psi$)/1.5" = 703$ lbs. single shear.
V = 703 lbs. x 2 (double shear) = 1,406 lbs.

Bending of 3/8" diameter Grade 8 bolt: 5" plate with 2.375" diameter tube

$S = \pi d^3/32 = \pi(0.375")^3/32 = 0.0052$ in^3
$F_b = (1.3)(0.6\ F_y) = (1.3)(0.6)(130{,}000$ psi$) = 101{,}400$ psi (1.3 factor for weak axis bending)
$F_b = M/S = (VL/2)/S$ (L/2 for guided bending)
L = 5" (plate width) – 2.375" (tube diameter)/2 = 1.3125"
$V = 2SF_b/L = (2)(0.0052$ in$^3)(101{,}400$ psi$)/1.3125" = 803$ lbs. single shear.
V = 803 lbs. x 2 (double shear) = 1,606 lbs.

Bending of 3/8" diameter Grade 8 bolt: 4.25" plate with 2" diameter tube

$S = \pi d^3/32 = \pi(0.375")^3/32 = 0.0052$ in^3
$F_b = (1.3)(0.6\ F_y) = (1.3)(0.6)(130{,}000$ psi$) = 101{,}400$ psi (1.3 factor for weak axis bending)
$F_b = M/S = (VL/2)/S$ (L/2 for guided bending)
L = 4.25" (plate width) – 2" (tube diameter)/2 = 1. 125"
$V = 2SF_b/L = (2)(0.0052$ in$^3)(101{,}400$psi$)/1.125" = 937$ lbs. single shear.
V = 937 lbs. x 2 (double shear) = 1,874 lbs.

Bending of 3/8" diameter Grade 8 bolt: 4.25" plate with 2.375" diameter tube

$S = \pi d^3/32 = \pi(0.375")^3/32 = 0.0052$ in^3
$F_b = (1.3)(0.6\ F_y) = (1.3)(0.6)(130{,}000$ psi$) = 101{,}400$ psi (1.3 factor for weak axis bending)
$F_b = M/S = (VL/2)/S$ (L/2 for guided bending)
L = 4.25" (plate width) – 2.375" (tube diameter)/2 = 0.9375"
$V = 2SF_b/L = (2)(0.0052$ in$^3)(101{,}400$ psi$)/0.9375" = 1{,}124$ lbs. single shear.
V = 1,124 lbs. x 2 (double shear) = 2,248 lbs.

Strength of Bolt Connection (Continued)

<u>Bending of 3/8" diameter Grade 8 bolt: 4" plate with 2" diameter tube</u>

$S = \pi d^3/32 = \pi(0.375")^3/32 = 0.0052$ in^3
$F_b = (1.3)(0.6\ F_y) = (1.3)(0.6)(130{,}000$ psi$) = 101{,}400$ psi (1.3 factor for weak axis bending)
$F_b = M/S = (VL/2)/S$ (L/2 for guided bending)
L = 4" (plate width) – 2" (tube diameter)/2 = 1."
$V = 2SF_b/L = (2)(0.0052$ in$^3)(101{,}400$ psi$)/1" = 1{,}054$ lbs. single shear.
V = 1,054 lbs. x 2 (double shear) = <u>2,108 lbs.</u>

<u>Bending of 3/8" diameter Grade 8 bolt: 4" plate with 2.375" diameter tube</u>

$S = \pi d^3/32 = \pi(0.375")^3/32 = 0.0052$ in^3
$F_b = (1.3)(0.6\ F_y) = (1.3)(0.6)(130{,}000$ psi$) = 101{,}400$ psi (1.3 factor for weak axis bending)
$F_b = M/S = (VL/2)/S$ (L/2 for guided bending)
L = 4" (plate width) – 2.375" (tube diameter)/2 = 0.8125"
$V = 2SF_b/L = (2)(0.0052$ in$^3)(101{,}400$ psi$)/0.8125" = 1{,}298$ lbs. single shear.
V = 1,298 lbs. x 2 (double shear) = <u>2,596 lbs.</u>

Bending capacity for 3/8" diameter, grade 8 bolt depends on plate and tube column configuation. Allowable load specific to plate size and tube column size.

Plate Connection to 2 x 6 SYP #2 Wood Framing

<u>Base Plate Properties</u>
11 Gauge (0.1196" thick)
Steel Grade 33: F_y = 33 ksi ; F_u = 45 ksi

<u>Wood Screw Properties</u>
#14 x 1-1/2" Stainless Steel Wood Screw, round head
Head Diameter = 0.429"
Thread Length = 2/3 x (1-1/2") = 1" (NDS Table L3)
Edge Distance = 1.5(0.25") = 0.375" (NDS Table 11.5.A)
End Distance = 4(0.25") = 1" (NDS Table 11.5.B)
Spacing Between screwd = 4(0.25") = 1" (NDS Table 11.5.C)

<u>Wood base properties</u>
Minimum 2 x 6 Southern Yellow Pine #2, preservative treated.
G = 0.55
Assume wet service conditions C_M = 0.7

<u>Allowable Tension of #14 Wood Screws (Stainless Steel)</u>

P_{ts}/Ω = 208 lbs. per inch of thread penetration into member: (NDS Table ll.2B)
$P'_{ts} = P_{ts} \times C_D \times C_M$ = 208 lbs. x 1.6 x 0.70 = 233 lbs. per screw
P'_{ts} = 233 lbs. x 4 screws per plate = <u>932 lbs.</u>

<u>Pull-Over of #14 Wood Screw Round Head (Stainless Steel)</u>

$P_{nov} = C_{pov} t_1 F_{tu1}(D_{ws}-D_h)/3.0$
P_{nov} = 1.0(0.1196")(45,000 psi)(0.429" - 0.266")/3.0
P_{nov} = 292 lbs. per screw
P_{nov} = 292 lbs. x 4 screws per plate = <u>1,168 lbs</u>.

Capacity of Plate to 2 x 6 SYP #2 Wood Framing is 932 lb. with four (4) #14 x 1-1/2" wood screws. Tension controls. A duration of load C_D = 1.6 for wind and C_M = 0.7 for wet service factor have been applied. This capacity is for a wind uplift condition in preservative treated SYP #2 lumber.

Plate Connection to Concrete Base

Concrete Screw Properties
Powers Tapper+ 1/4" x 2" concrete screw with minimum 1.75" embedment

Concrete base properties
F_c' = 3,000 psi, un-cracked, normal weight concrete, slab 4" thick minimum. 2" minimum edge distance from plate to slab edge.

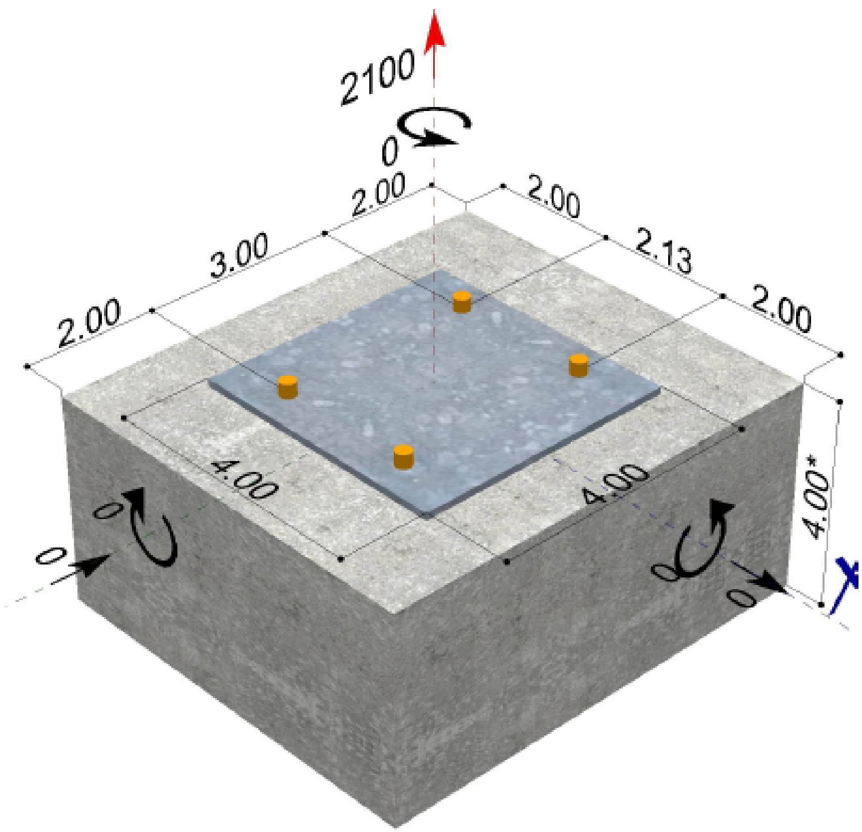
Allowable Tension of Powers Tapper+ 1/4" x 2" concrete screw

ΦP_{ts} = 555 lbs. per screw: (See next 3 pages)
ΦP_{ts} = 555 lbs. x 4 screws per plate = 2,220 lbs.
Convert to ASD for Wind: 2,220 lbs. /1.6 = 1,387 lbs.

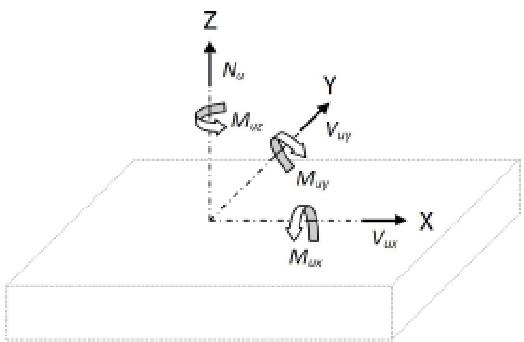
Capacity fo Plate to 4" thick concrete slab is 1,387 lbs. for wind uplift with four (4) Powers Tapper + 1/4" x 2" screws. Minimum 1.75" embedment for all Tapper+ screws into a minimum 4" thick f'c = 3,000 psi concrete slab.

Plate Connection to Concrete Base (Continued)

GEOMETRY:



LOAD ACTIONS: [lb], [ft-lb]



Design loads / actions		
N_u	2100	lb
V_{ux}	0	lb
V_{uy}	0	lb
M_{ux}	0	ft-lb
M_{uy}	0	ft-lb
M_{uz}	0	ft-lb

Eccentric profile
e_x = 0.00 inch; e_y = 0.00 inch

Input data and results must be checked for agreement with the existing circumstances, the standards and guidelines and must be checked for plausibility.

www.powers.com - Powers Fasteners (see website for regional contact information).

Plate Connection to Concrete Base (Continued)

SUMMARY:

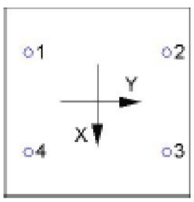
Selected anchor: Tapper+
1/4" ; hnom 1-3/4" (45mm), Grade 2

Effective embedment depth: h_{ef} = 1.230 inch
Approval: ESR-3068 (7/1/2013)
Issued: 7/1/2013

Basic principles of Design:

Design method:	ACI 318-11 (Appendix D)								
Concrete:	Normal weight concrete				uncracked concrete		f'_c	= 3000	psi
Load combination:	taken from Section 9.2								
	Factored loads								
Anchor Parameters:	c_{min} =	1.75	inch	s_{min} =	2.00	inch	h_{min} =	3.25	inch
	c_{ac} =	3.00	inch	s_{cr} =	3.69	inch	Anchor Ductility:		No
Reinforcement:	no reinforcement to limit splitting cracks available								
	Tension:		Condition B			Shear:		Condition B	
Stand-off:	not existent								
Seismic Loads:	No								

Resulting anchor forces / load distribution::



Anchor No.	Tension load	Shear load
#1	525 lb	0 lb
#2	525 lb	0 lb
#3	525 lb	0 lb
#4	525 lb	0 lb
Maximum	525 lb	0 lb

Max. concrete compression strain: 0.00 ‰
Max. concrete compression stress: 0 psi
Resulting tension force: 2100 lb
Resulting compression force: 0 lb

Calculations:	Design proof:	Demand		Capacity		Status	
	Tension load	2100	lb	2220	lb	0.95 ≤ 1.0	OK
	Shear load	-	-	-	-	-	
	Interaction	-	-	-	-	-	

Anchor plate:

Material:	f_{yk} = 33000 psi			
Length x width:	4.00	inch	x 4.00	inch
Actual plate thickness:	0.119	inch		
Calculated plate thickness:	-	inch	not calculated	

Profile: none selected

Input data and results must be checked for agreement with the existing circumstances, the standards and guidelines and must be checked for plausibility.
www.powers.com - Powers Fasteners (see website for regional contact information).

Plate Connection to Concrete Base (Continued)

DESIGN PROOF TENSION LOADING: Reference

Steel strength:

			Reference
N_{sa}	= 2680 lb		D.5.1
$\Phi * N_{sa}$	$= \Phi * N_{sa}$		D.5.1.2
	= 0.65 * 2680 lb = 1742 lb		
N_{ua}	= 525 lb		
Design proof:	$N_{ua} / (\Phi * N_{sa})$ = 525 lb / 1742 lb = 0.30 ≤ 1.00		

Concrete Breakout Strength:

			Reference
h_{ef}	= 1.230	inch	
k_c	= 24.0		
N_b	$= k_c * f'_c{}^{0.5} * \lambda_a * h_{ef}{}^{1.5}$		D.5.2.2
	= 24.0 * 54.77 * 1.00 * 1.364 = 1793 lb		
A_{Nc0}	= 13.62	inch²	
A_{Nc}	= 38.90	inch²	
$\Psi_{ec,N,x}$	= 1.000		D.5.2.4
$\Psi_{ec,N,y}$	= 1.000		D.5.2.4
$\Psi_{ed,N}$	= 1.000		D.5.2.5
$\Psi_{c,N}$	= 1.00		D.5.2.6
c_{ac}	= 3.00	inch	
$c_{a,min}$	= 2.00	inch	
$\Psi_{cp,N}$	= 0.667		D.5.2.7
$\Phi * N_{cbg}$	$= \Phi * (A_{Nc} / A_{Nc0}) * \Psi_{ec,N,x} * \Psi_{ec,N,y} * \Psi_{ed,N} * \Psi_{c,N} * \Psi_{cp,N} * N_b$		D.5.2.1
	= 0.65 * (38.90 / 13.62) * 1.000 * 1.000 * 1.000 * 1.00 * 0.667 * 1793 lb		
	= 2220	lb	
N_{ua}	= 2100	lb	
Design proof:	$N_{ua} / (\Phi * N_{cbg})$ = 2100 lb / 2220 lb = 0.95 ≤ 1.00		

Pullout / Bond strength:

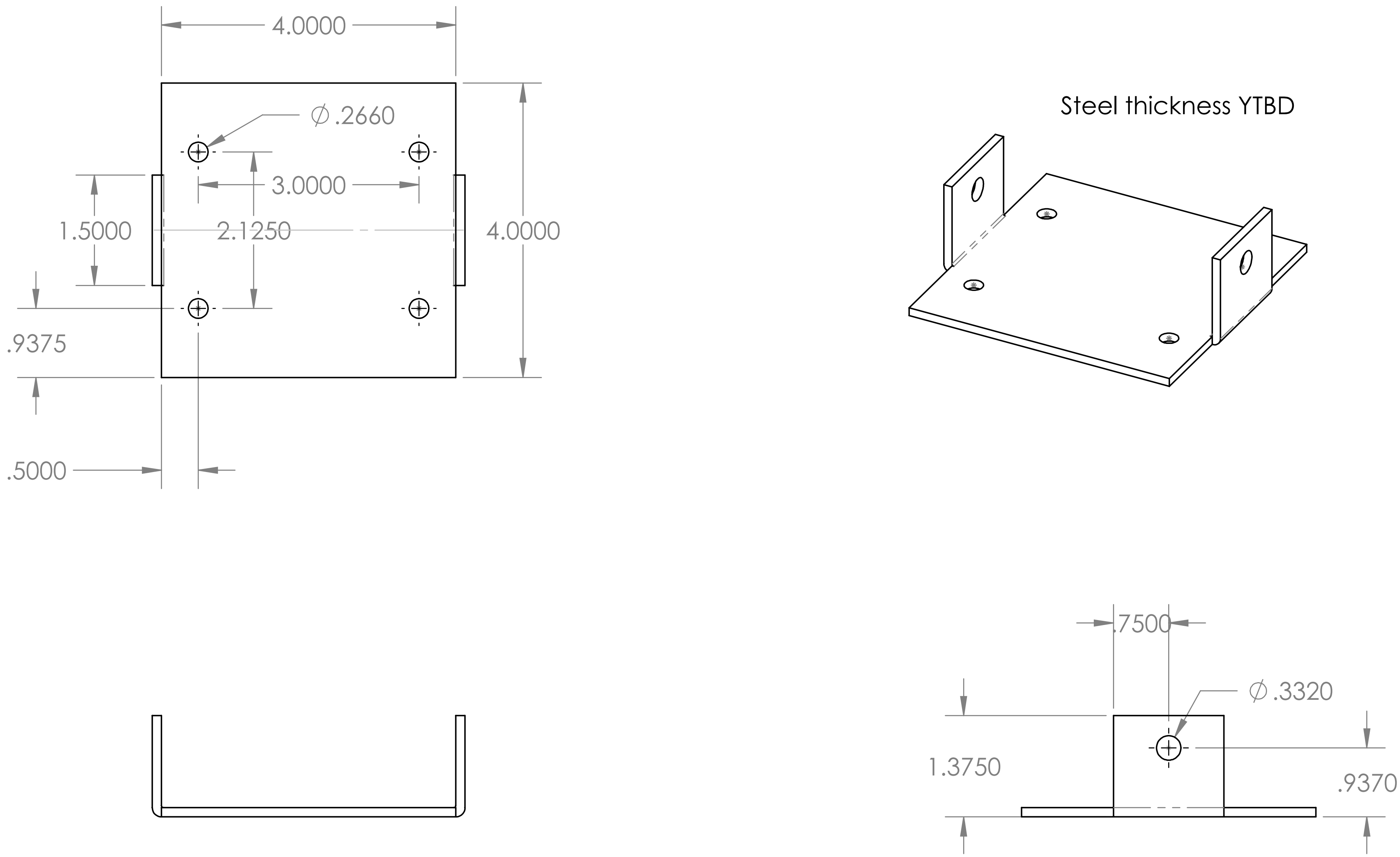
			Reference
$N_{p,uncr}$	= 940	lb	D.5.3.2
$\Phi * N_{pn}$	$= \Phi * (f'_c / 2500)$ ^ n * $N_{p,uncr}$		
	= 0.65 * (3000 / 2500) ^ 0.40 * 940 = 657 lb		
N_{ua}	= 525	lb	
Design proof:	$N_{ua} / (\Phi * N_{pn})$ = 525 lb / 657 lb = 0.80 ≤ 1.00		

Fastening ok!

Input data and results must be checked for agreement with the existing circumstances, the standards and guidelines and must be checked for plausibility.
www.powers.com - Powers Fasteners (see website for regional contact information).

Revision Log

Rev. #	Date	Page(s)	Revision(s)
0	06/29/15	N/A	Original report issue
1	07/01/15	2-7	Replaced 5/16" diameter Grade 2 bolt with 3/8" diameter Grade 8 bolt.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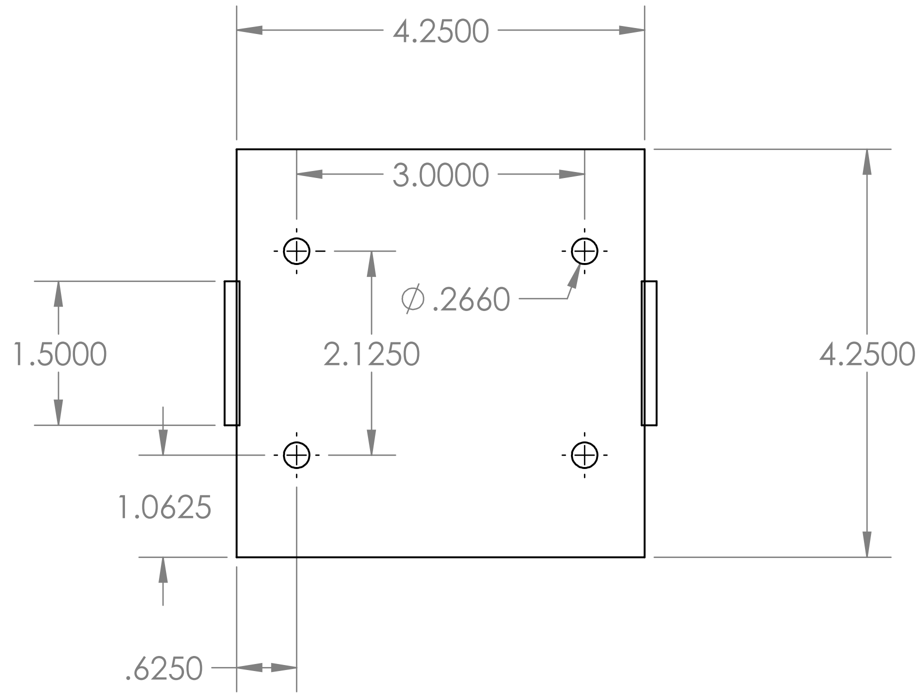
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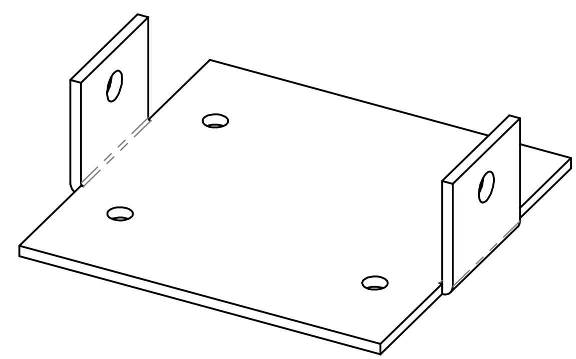
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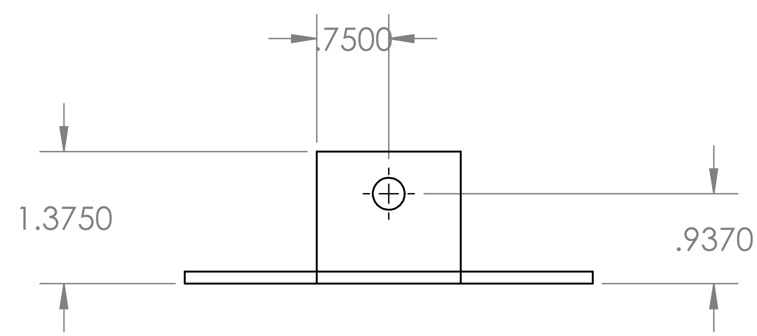
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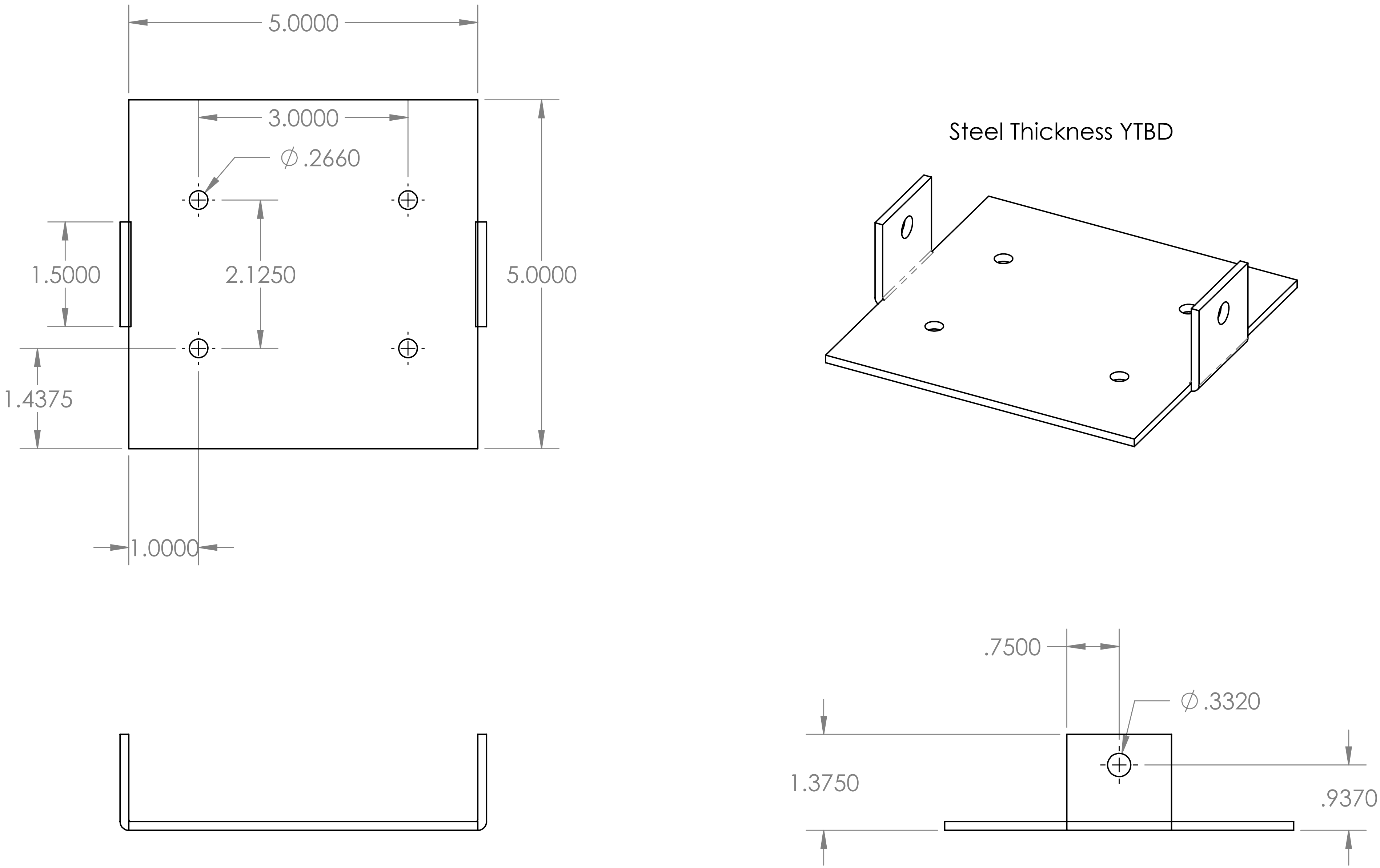
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