Perma-Column Deck Post Design Manual

DP4430, DP4440, DP4448, DP4460, DP6630, DP6640, DP6648, DP6660, DP6430, DP6440, DP6448 and DP6460 models

Project Number E342-18

Dimitry Reznik, P.E.
Timber Tech Engineering, Inc
E-Mail: dar@timbertecheng.com

April 8, 2020

www.timbertecheng.com

East: 22 Denver Road, Suite B Denver, PA 17517
717.335.2750 Fax: 717.335.2753

West: 406 S. Main St, P.O. Box 509 Kouts, IN 46347
219.766.2499 Fax: 219.766.2394

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1. Deck Post Design Overview

The Perma-Column Deck Post is designed to support wood decks, porches or other similar structures, and is intended to be used as an alternative to embedded wood posts and cast-in-place concrete piers. This manual contains drawings, descriptions and design assumptions for twelve (12) Deck Post models, tables showing axial compression, axial tension, shear and bending strengths of each model, and tables showing downward, uplift and lateral strengths of several foundation (soil) options. Each Deck Post assembly consists of a reinforced concrete column designed in accordance with The American Concrete Institute (ACI 318-14) and an epoxy powder coated steel bracket designed in accordance with The American Institute of Steel Construction (AISC 360-16). The structural design is based on the allowable stress design (ASD) and the load and resistance factor (LRFD) design methodologies with references to ESR-4237 report by ICC Evaluation Service (ICC-ES). The lateral and rotational stability of the Deck Post is provided by surrounding soils below grade and the wood framing of the structure above the ground (if applicable). The “U” shaped steel bracket at the top of the concrete post does not have any usable rotational rigidity and bending strength and should be modeled as a “hinge”.

The allowable (ASD) and design (LRFD) downward, uplift and shear loads at the top of the Deck Post may not exceed the values reported in Tables 7.1 through 8.1. The values in Table 7.1 are calculated using structural properties of the Deck Post and the steel bracket-to-wood connections as specified in ESR-4237 and exclude all considerations of surrounding soils (see Section 4: Deck Post Design). Tables 7.2 through 8.1 include the downward, uplift and lateral strengths of the soil around the Deck Posts using soil assumptions provided in Section 6. The values in Tables 7.2 through 8.1 are provided for demonstration purposes only as soil types and consistency vary. The analysis and design of the soils (foundation) is the responsibility of the project engineer or the building designer.

Wood member sizes, connections, post spacing, footing size, lateral bracing and height limitations of the structure above the Deck Post should follow the prescriptive code requirements. For construction that falls outside the prescriptive code limitations, the Deck Post shall be part of an engineered design.

2. Deck Post Description

The Perma-Column Deck Post is a 10 ksi reinforced pre-cast concrete column with a u-shaped steel bracket (saddle). The Deck Post is embedded into the ground and, except for a short segment above grade (maximum 10 inches), the post is laterally restrained along the full length by surrounding compacted soils. Having a continuous lateral restraint, the ACI 318 classifies the Deck Post as a “short column” or a “pedestal”. The steel bracket at the top of the concrete column is welded to #4 A706 (grade 60) weldable vertical reinforcing bars. A short segment of a ½” pipe size tubing (PST) is welded to the vertical rebar near the bottom of the column. The ½” PST is positioned approximately 2-1/4 inches from the base of the column and provides an opening through which to insert the uplift load resisting attachments: 2”x2”x8 ½” steel uplift angles or a DP Extender fastened with a ½” through bolt, or a #4 horizontal reinforcing bar inserted through the post can be used for wind uplift resistance.

The dimensions for the twelve models are given in Table 2.1. The DP4430, DP4440, DP4448 and DP4460 models are to be used with 4x nominal wood posts or 3-1/2” wide wood beams, the DP6630, DP6640, DP6648 and DP6660 models are to be used with 6x6 nominal wood posts or 5-1/2 inch wide wood beams, and the DP6430, DP6440, DP6448 and DP6460 models are to be used with 6x6 full size wood posts or 6” wide wood beams. The DP4430, DP4440, DP4448 and DP4460 are reinforced with one #4 rebar centered and continuous through the entire column length. The DP6630, DP6640, DP6648, DP6660, DP6430, DP6440, DP6448 and DP6460 are reinforced with two #4 rebar positioned in a “V” shape with it’s vertex near the bottom of the column. Every model may not be stocked in all areas, check with your Deck Post supplier. The “*Minimum Embedment*” depth column in Table 2.1 ensures that the top of the concrete post projects above ground a maximum of ten (10) inches; see also Section 4: Deck Post Design and Section 8: DP Extender.

TABLE 2.1: DECK POST DESCRIPTION					
Model ID	Width *(in)*	Depth *(in)*	Length *(in)*	Minimum Embedment *(in)*	Reinforcement
DP4430	3-5/8	3-1/2	30	20	(1) #4 Rebar
DP4440	3-5/8	3-1/2	40	30	(1) #4 Rebar
DP4448	3-5/8	3-1/2	48	38	(1) #4 Rebar
DP4460	3-5/8	3-1/2	60	50	(1) #4 Rebar
DP6630	5-5/8	5	30	20	(2) #4 Rebar
DP6640	5-5/8	5	40	30	(2) #4 Rebar
DP6648	5-5/8	5	48	38	(2) #4 Rebar
DP6660	5-5/8	5	60	50	(2) #4 Rebar
DP6430	6-1/8	5	30	20	(2) #4 Rebar
DP6440	6-1/8	5	40	30	(2) #4 Rebar
DP6448	6-1/8	5	48	38	(2) #4 Rebar
DP6460	6-1/8	5	60	50	(2) #4 Rebar
Note: Every model may not be stocked in all areas, please check with your Deck Post supplier.					

IMPORTANT NOTE: The Deck Post must not project more than ten (10) inches above grade as measured from top of adjacent ground to top of the concrete post (bottom of steel u-bracket). This limitation must not be ignored.

3. Steel Bracket Design

The forces applied from a wood deck, or similar structure, to the "U" shaped steel bracket are a vertical uplift force, a downward gravity force, and a horizontal shear force. The wood beam or column should have direct bearing on the bottom to transfer axial loads directly to the concrete deck post. The steel bracket is assumed to have no rotational rigidity and moment strength. The dimensions and physical properties for the steel brackets are given in Table 3.1. All mechanical fasteners are to be installed as per the manufacturer's recommendations and this design manual. Each steel bracket is made of 1/8" thick ASTM A1018 SS Grade 40 steel plate. The DP4430, DP4440 and DP4448 brackets have four holes for #14 x 3-inch grade 5 galvanized wood screws on each side, staggered; the, DP6630, DP6640, DP6648, DP6660, DP6430, DP6440, DP6448 and DP6460 brackets have five holes on each side, also staggered.

TABLE 3.1: STEEL BRACKET DESCRIPTION					
Model ID	Pocket Width *(in)*	Length *(in)*	Height *(in)*	Bracket Thickness *(in)*	Total Number of Holes *(in)*
DP4430	3-5/8	3-1/2	5	1/8	8
DP4440	3-5/8	3-1/2	5	1/8	8
DP4448	3-5/8	3-1/2	5	1/8	8
DP4460	3-5/8	3-1/2	5	1/8	8
DP6630	5-5/8	5	7	1/8	10
DP6640	5-5/8	5	7	1/8	10
DP6648	5-5/8	5	7	1/8	10
DP6660	5-5/8	5	7	1/8	10
DP6430	6-1/8	5	7	1/8	10
DP6440	6-1/8	5	7	1/8	10
DP6448	6-1/8	5	7	1/8	10
DP6460	6-1/8	5	7	1/8	10

4. Deck Post Design

The Deck Post is designed to resist axial compression, bending, shear, bending and axial tension forces; the allowable strengths (ASD) and the design strengths (LRFD) are reported in Table 7.1 and ICC ESR-4237.

The **axial compression strength** is calculated using ACI 318-14 Equation 22.4.2.2: $P_o = 0.85f'_c\,(A_g - A_{st}) + f_yA_{st}$. To address accidental eccentricity, ACI requires that P_o is multiplied by a 0.80 or 0.85 multiplier for concrete columns with transverse reinforcement consisting of ties or spirals, respectively (ACI 318 Table 22.4.2.1). Because the Deck Post does not have any transverse reinforcement, the multiplier is reduced to 0.60. With this multiplier, the axial strength of the Deck Post is equal to the strength of a column made of plain structural concrete (no vertical or transverse reinforcement):

$$P_n = 0.60[0.85f'_c\,(A_g - A_{st}) + f_yA_{st}] \qquad \text{(Eq. 4-1)}$$

The **bending strength** of the Deck Post is calculated in accordance with ACI 318-14, chapters 10 and 22 (Eq. 4-2). The maximum reinforcement ratio limit, ρ_{max}, is set so that the tension strain, ϵ_t, in the tension rebar is 0.005 or greater (Eq. 4-3) and the bending strength reduction factor, φ, is 0.90. The analysis includes bending about the "x" and the "z" axes; however, for simplicity and to avoid confusion on site, only the smallest bending value is reported for each model in Table 7.1. For biaxial bending, the sum of the individual unities about each axis may not exceed 1 (Eq. 4-4).

$$M_n = A_sf_y(d-a/2) \qquad \text{(Eq. 4-2)}$$

$$\rho_{max} = 0.85\beta_1(f'_c/f_y)[0.003 / (0.003+0.005)] \qquad \text{(Eq. 4.3)}$$

$$m_x/M + m_z/M \leq 1 \qquad \text{(Eq. 4-4)}$$

Because of the absence of transverse reinforcement, the **shear strength** of the Deck Post is calculated using ACI provisions for *plain structural concrete* (Eq 4-5). ACI 318 allows the use of plain structural concrete for a *pedestal* which is defined as a "*member with a ratio of height-to-least lateral dimension less than or equal to 3, used primarily to support axial compressive load*…" ACI 318 commentary, Section R14.3.3.1 clarifies that the ratio limit applies only to the unsupported height - the ten (10) inch segment of the Deck Post that extends above grade. The Deck Post is intended to support primarily axial compression load and, having only a ten (10) inch segment extend above grade, the intended use and ratio limit of the pilaster, as defined, are satisfied.

$$\varphi V_n = \varphi\ (4/3)\sqrt{(f'_c)}bh \qquad \text{(Eq. 4-5)}$$

$(\varphi = 0.60)$

The **tensile strength** of the Deck Post is defined by the strength of the external and internal steel components and connections: the u-shaped steel bracket, vertical rebar, weld connection between the rebar and the steel bracket, weld connection between the rebar and the steel sleeve (pipe) at the bottom of the post, shear strength of the bolt through the sleeve, and the strength of the external steel angles at the bottom. Under pure tension load, the concrete around the steel components is considered non-structural.

Under **combined tension and bending loading**, the sum of the tension and bending unities may not exceed 1:

$$t/T + m/M \leq 1 \qquad \text{(Eq. 4-6)}$$

When a Deck Post is subjected to a **combined axial compression and bending loading**, the balanced failure occurs when the tension steel just begins to yield (ϵ_s = 0.002) as the concrete reaches its limiting strain ϵ_u of 0.003. Because of the 0.60 multiplier used in the axial compression strength equation, a multiplier associated with the accidental eccentric loading, the design bending strength under the combined loading is never less than the design bending strength without the axial compression load. Similarly, the design axial compression strength under combined loading is never less than the design axial compression strength without the bending loading. This is visually demonstrated in Figure 4. The Deck Post, therefore, may be subjected to axial and bending loading simultaneously up to the axial compression and bending strengths reported in Table 7.1 - no reductions are required for combined axial compression and bending loading.

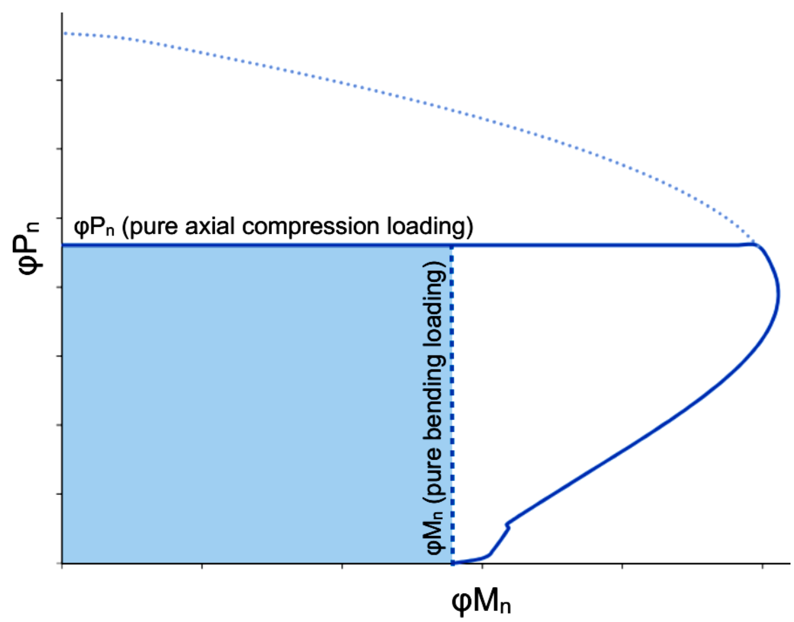


Figure 4: Design axial compression strength vs. design bending strength interaction diagram

5. Wood Connection Design

The wood beam or column is assumed to have a specific gravity of 0.36 or greater and is fastened to the steel bracket with #14 x 3" grade 5 galvanized wood screws. All metal components, including steel bracket and screw fasteners, must be suitable for treated wood applications. The wood-to-steel connection is designed per the National Design Specification for Wood Construction (NDS), 2015 edition, by the American Wood Council. The NDS adjustment factors are as follows:

Load Duration Factor	$C_D = 1.6$
Wet Service Factor	$C_M = 0.7$
(All other factors = 1.0)	

A barrier membrane between the pressure treated wood post or beam and the steel bracket is not necessary. The steel bracket is protected by the Perma-Column EpoxyZirc Coating pretreatment, a process in which Zirconium molecules chemically crystallize the steel molecules, effectively changing the surface of the steel into a compound that does not oxidize. The ASTM B-117 Salt Spray Testing results show that the Perma-Column EpoxyZirc Coating outperforms the G185 galvanized coating, which is thicker than the galvanized coating prescribed by the ASTM A653.

6. Foundation Design

The foundation design in this manual is intended only for demonstrational purposes to establish a base line of what a designer may expect from a non-constrained shallow post foundation consisting of medium to dense soils described as *silty or clayey fine to coarse sand* (United Soil Classification: SM, SC, SP-SM, SP-SC, SW-SM, SW-SC). Other soil consistencies and types have different strength characteristics and are outside of the scope of this manual. The foundation is designed in accordance with ASAE EP486.3, Shallow Post Foundation Design by the American Society of Agricultural and Biological Engineers as referenced in International Building Code (IBC) using the following design parameters (EP486.3, Table 1):

• Unified Soil Classification	SM, SC, SP-SM, SP-SC, SW-SM, SW-SC
• Consistency	Medium to dense
• Moist Unit Weight, γ	110 lb/ft^3
• Drained Soil Friction Angle, φ	35 degrees
• Required Post Embedment, d	see Table 2.1
• Concrete Collar Width, w	see Figure 6.1 & Table 7.2
• Concrete Collar Thickness, t_c	see Figure 6.1 & Table 7.2
• Footing Width, t_w	see Figure 6.1 & Table 7.2
• Footing Thickness, t_f	see Figure 6.1 & Table 7.2

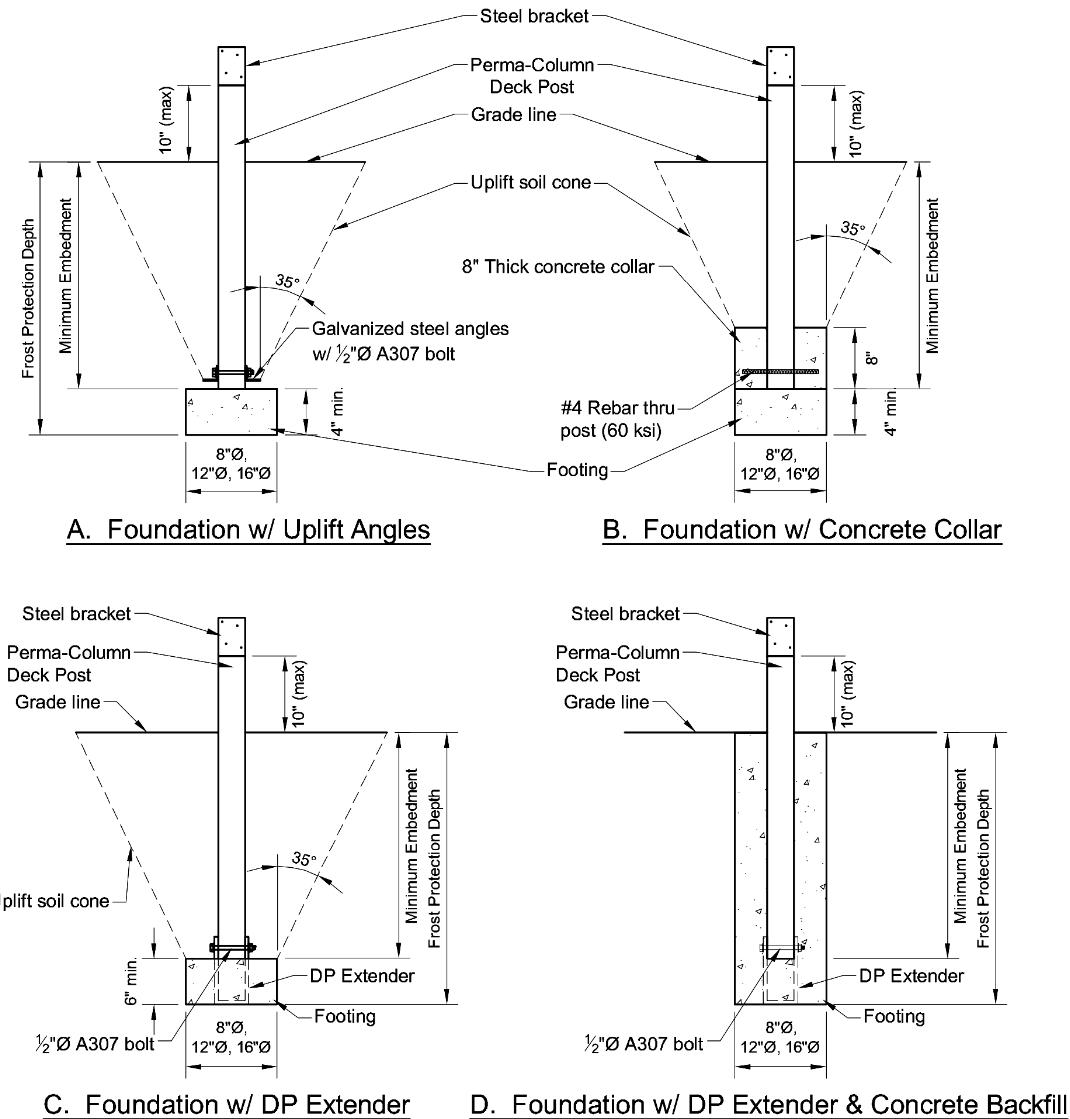


Figure 6.1: Foundation Details

NOTE: A building designer may consider any foundation option for Deck Posts supporting wood beams. Unless the Deck Post is constrained at grade (concrete slab), the foundation option D should be considered the preferred option for Deck Posts supporting wood columns.

The **shear strength** of the foundation for all options in Figure 6.1 is calculated using the Simplified Method (EP486.3, Section 11.4) formula for a non-constrained shallow post foundation without concrete collars. In option B, the concrete collar is very small and its contribution to the lateral resistance is insignificant and is conservatively ignored. In option D, the width of the concrete collar is used as the width of the "post" in the non-constrained shallow post foundation equation. In option B, the thickness (height) of a concrete collar is intentionally limited to eight (8) inches to increase the uplift resistance of the system. Increasing the thickness of the concrete collar will reduce the dimension between the top of the concrete and grade, resulting in reduced size of uplift soil cone and reduced uplift strength of the foundation. For this option, the thickness of the concrete collar may be increased only by increasing the embedment depth of the deck post such that the dimension between top of concrete collar and grade remains unchanged.

The **uplift strength** of the foundation is designed in accordance with EP486.3 Chapter 12. The uplift resistance is provided by the weight of the concrete collar, if present, and the weight of the soil cone, see Figure 6.1. The option D uplift resistance is limited only to the weight of the concrete fill below and around the deck post. The tabulated uplift strengths are only applicable to footings installed as described in this manual. Uplift resistance can be achieved by any of the following methods:

- Steel uplift angles (see Figure 6.1, option A)
- Concrete collar with rebar inserted through column (see Figure 6.1, option B)
- DP Extender (see Figure 6.1, options C and D)
- Molded Plastic FootingPad (see Figure 9.1)

The **bearing strength** of the foundation is calculated using 2000 psf allowable soil bearing capacity, converted to LRFD design system using 1.4 multiplier (LRFD = ASD x 1.4). The **minimum frost depth** and **footing thickness** requirement is determined by local authorities and is outside of the scope of this manual. The DP4430, DP6430 and DP6630 models embedded twenty (20) inches with a four (4) inch thick footing provide twenty-four (24) inches of frost protection, while DP4440, DP6640 and DP6440 models embedded thirty (30) inches with a six (6) inch thick footing provide thirty-six (36) inches of frost protection. The 48-inch and 60-inch long models provide deeper embedment depths. An optional DP Extender can be used with all models to increase the footing depth for frost protection. Table 6.1 shows several options that may be used to achieve the required frost depth specified by the local authority.

TABLE 6.1: FROST PROTECTION OPTIONS

Option* #	Deck Post *Length (in)*	Projection Above *Grade (in)*	Embedment Depth *(in)*	Footing Thickness *(in)*	DP Extender *Length (in)*	Frost Protection *Depth (in)*
1	30	10	20	4	n/a	24
2	30	6	24	6	n/a	30
3	30	10	20	12	12	32
4	40	10	30	6	n/a	36
5	40	6	34	6	n/a	40
6	40	10	30	12	12	42
7	40	10	30	18	18	48
8	48	6	42	6	n/a	48
9	60	10	50	6	n/a	56
10	60	6	54	6	n/a	60

**Other frost protection option combinations may be used to achieve different frost protection depths*

7. Deck Post Design Chart

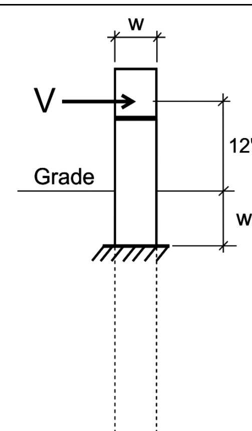


Figure 7.1: Free Body Diagram for Simplified Method per EP486.3

Table 7.1 shows the axial compression, bending, shear, and tensile strengths of the twelve (12) Deck Post models using Allowable Strength Design (ASD) and Load and Resistance Factored Design (LRFD) methods (values provided by ICC ESR-4237 report). Tables 7.2 through 8.1 show the downward (bearing), lateral and uplift strengths of the foundation system as dictated by the strength and stability requirements of the surrounding soil. Tables 7.2 through 8.1 include (7) foundation systems, six (6) shown in Figure 6.1 and one (1) in Section 9 for the twelve (12) Deck Post models using the materials, design methods and design assumptions described in this manual. Consistent with provisions of ASABE EP486.3, the weight of the concrete column and steel bracket is not added to the uplift resistance of the foundation and may be considered on the load side of the equation. The downward, horizontal and uplift loads applied to the u-bracket at the top of the concrete post may not exceed the axial compression, shear, and tensile strengths of the Deck Post as reported in Table 7.1 and the bearing, lateral and uplift strengths of the soils (foundation) as reported in Tables 7.2 through 8.1. The steel u-bracket at the top of the Deck Post does not have the ability to transfer moments into the concrete post. However, the horizontal load applied to the bracket above grade and the resisting lateral soil forces below grade will generate internal bending moments in the Deck Post. The magnitude of the internal bending moments must be calculated by the designer using the established engineering standards such as ASABE EP486.3 or standard engineering mechanics. A free body diagram of the *Simplified Method* (EP 486.3) is shown in Figure 7.1. The bending moment may be calculated as M = V(12+w), where w is the width of the concrete post in the direction of the loading as shown in Figure 7.1. An in-depth discussion on this topic is also available in the Post-Frame Building Design Manual by National Frame Building Association (NFBA PFBDM). The internal bending moments must not exceed the bending strength of the Deck Post as reported in Table 7.1.

TABLE 7.1: DECK POST STRENGTH VALUES

	LRFD				ASD			
Model ID	P_{LRFD} (lb)	M_{LRFD} (lb-ft)	V_{LRFD} (lb)	T_{LRFD} (lb)	P_{ASD} (lb)	M_{ASD} (lb-ft)	V_{ASD} (lb)	T_{ASD} (lb)
DP4430	46,076	1,400	952	956	28,798	875	595	636
DP4440	46,076	1,400	952	956	28,798	875	595	636
DP4448	46,076	1,400	952	956	28,798	875	595	636
DP4460	46,076	1,400	952	956	28,798	875	595	636
DP6630	101,268	2,981	2,109	1,658	63,293	1,863	1,318	1,103
DP6640	101,268	2,981	2,109	1,658	63,293	1,863	1,318	1,103
DP6648	101,268	2,981	2,109	1,658	63,293	1,863	1,318	1,103
DP6660	101,268	2,981	2,109	1,658	63,293	1,863	1,318	1,103
DP6430	109,556	3,215	2,297	1,289	68,472	2,009	1,436	857
DP6440	109,556	3,215	2,297	1,289	68,472	2,009	1,436	857
DP6448	109,556	3,215	2,297	1,289	68,472	2,009	1,436	857
DP6460	109,556	3,215	2,297	1,289	68,472	2,009	1,436	857

Table 7.1 Footnotes:

1. P_{LRFD} = Maximum compression/gravity load strength (φP_n) of the Deck Post based on LRFD design
2. P_{ASD} = Maximum compression/gravity load strength (P_n/Ω) of the Deck Post based on ASD design
3. M_{LRFD} = Maximum bending strength (φM_n) of the Deck Post based on LRFD design (loaded about any axis)
4. M_{ASD} = Maximum bending strength (M_n/Ω) of the Deck Post based on ASD design (loaded about any axis)
5. V_{LRFD} = Maximum shear strength (φV_n) of the Deck Post based on LRFD design (loaded in any direction)
6. V_{ASD} = Maximum shear strength (V_n/Ω) of the Deck Post based on ASD design (loaded in any direction)
7. T_{LRFD} = Maximum tensile strength (φT_n) of the Deck Post based on LRFD design
8. T_{ASD} = Maximum tensile strength (T_n/Ω) of the Deck Post based on ASD design
9. See Section 4 for biaxial load and combined axial and bending load application
10. Values in Table 7.1 are provided by ICC Evaluation Services Report ESR-4237
11. Values in Table 7.1 do not include considerations of strength and stability of the surrounding soils (foundation)

TABLE 7.2: FOUNDATION (SOIL) BEARING STRENGTH						
	8" Ø Pier or Footer		12" Ø Pier or Footer		16" Ø Pier or Footer	
Model ID	ASD (lb)	LRFD (lb)	ASD (lb)	LRFD (lb)	ASD (lb)	LRFD (lb)
DP4430	700	980	1570	2200	2800	3920
DP4440	700	980	1570	2200	2800	3920
DP4448	700	980	1570	2200	2800	3920
DP4460	700	980	1570	2200	2800	3920
DP6630	700	980	1570	2200	2800	3920
DP6640	700	980	1570	2200	2800	3920
DP6648	700	980	1570	2200	2800	3920
DP6660	700	980	1570	2200	2800	3920
DP6430	700	980	1570	2200	2800	3920
DP6440	700	980	1570	2200	2800	3920
DP6448	700	980	1570	2200	2800	3920
DP6460	700	980	1570	2200	2800	3920

Table 7.2 Footnotes:

1. The values in Table 7.2 are limited to foundation options A through D in Figure 6.1.
2. The values in Table 7.2 are provided for demonstrational purposes only. Perma-Column, LLC, is not responsible for the analysis and design of soils (foundation). The analysis and design of soils (foundation) is the responsibility of the project engineer or the building designer.

TABLE 7.3: FOUNDATION (SOIL) LATERAL STRENGTH								
	No Concrete Backfill (Options A-C)		8" Ø Concrete Backfill (Option D)		12" Ø Concrete Backfill (Option D)		16" Ø Concrete Backfill (Opton D)	
Model ID	ASD (lb)	LRFD (lb)	ASD (lb)	LRFD (lb)	ASD (lb)	LRFD (lb)	ASD (lb)	LRFD (lb)
DP4430	24	34	55	77	83	116	110	154
DP4440	64	90	146	204	219	307	291	407
DP4448	110	154	255	357	380	532	505	707
DP4460	205	287	474	664	705	987	940	1316
DP6630	34	48	55	77	83	116	110	154
DP6640	91	127	146	204	219	307	291	407
DP6648	158	221	255	357	380	532	505	707
DP6660	295	413	474	664	705	987	940	1316
DP6430	34	48	55	77	83	116	110	154
DP6440	91	127	146	204	219	307	291	407
DP6448	158	221	255	357	380	532	505	707
DP6460	295	413	474	664	705	987	940	1316

Table 7.3 Footnotes:

1. Soils should be verified by construction testing; if soils are not verified by testing, all values in Table 7.3 must be adjusted (reduced) by a 0.55 multiplier.
2. The calculations are based on ASABE EP486.3, Chapter 11 (Simplified Method), using soil properties as described in this manual.
3. The lateral strength of the foundation is measured at the top of the concrete pier (bottom of the steel u-bracket) maximum 10 inches above grade.

4. The values in Table 7.3 are limited to foundation options A through D in Figure 6.1.
5. The values in Table 7.3 are provided for demonstrational purposes only. Perma-Column, LLC, is not responsible for the analysis and design of soils (foundation). The analysis and design of soils (foundation) is the responsibility of the project engineer or the building designer.

TABLE 7.4: FOUNDATION (SOIL) UPLIFT STRENGTH								
	2"x2"x8.5" Steel Angles		8" Ø Concrete Collar		12" Ø Concrete Collar		16" Ø Concrete Collar	
Model ID	ASD (lb)	LRFD (lb)	ASD (lb)	LRFD (lb)	ASD (lb)	LRFD (lb)	ASD (lb)	LRFD (lb)
DP4430	220	308	119	156	223	284	352	441
DP4440	529	740	315	430	528	711	774	1032
DP4448	863	1209	553	763	839	1222	1272	1729
DP4460	1538	2153	1039	1445	1635	2260	2277	3135
DP6630	241	338	103	137	207	265	336	423
DP6640	584	817	294	406	508	687	754	1007
DP6648	955	1338	529	734	869	1193	1248	1699
DP6660	1705	2387	1010	1408	1605	2223	2247	3098
DP6430	240	336	100	134	204	262	334	420
DP6440	582	814	291	402	504	683	750	1003
DP6448	953	1334	525	729	865	1188	1244	1694
DP6460	1702	2383	1005	1402	1600	2217	2243	3092

Table 7.4 Footnotes:

1. Soils should be verified by construction testing; if the soils are not verified by testing, all values in Table 7.4 must be adjusted by a 0.54 multiplier.
2. The calculations are based on ASABE EP486.3, Chapter 12, using soil properties as described in this manual.
3. The values in Table 7.4 are limited to foundation options A and B in Figure 6.1.
4. The values in Table 7.4 are provided for demonstrational purposes only. Perma-Column, LLC, is not responsible for the analysis and design of soils (foundation). The analysis and design of soils (foundation) is the responsibility of the project engineer or the building designer.

TABLE 7.5: FOUNDATION UPLIFT STRENGTH WITH SOLID-FILLED CONCRETE BACKFILL						
	8" Ø Concrete Backfill		12" Ø Concrete Backfill		16" Ø Concrete Backfill	
Model ID	ASD (lb)	LRFD (lb)	ASD (lb)	LRFD (lb)	ASD (lb)	LRFD (lb)
DP4430	44	62	116	163	217	304
DP4440	66	93	174	244	325	455
DP4448	84	117	221	309	412	577
DP4460	110	154	291	407	543	760
DP6630	26	37	99	138	199	279
DP6640	39	55	148	207	298	418
DP6648	50	70	187	262	378	530
DP6660	66	92	246	344	498	697
DP6430	23	33	96	134	196	275
DP6440	35	49	143	200	294	412
DP6448	44	62	182	254	373	522
DP6460	58	82	239	334	491	687

Table 7.5 Footnotes:
1. The uplift resistance is calculated as weight of the concrete backfill divided by the factor of safety of 1.5 for the ASD design. The weight of the Deck Post is not included in the uplift resistance.
2. The relationship between the LRFD and ASD values is described using the following expression: LRFD = ASD x 1.4.
3. The values in Table 7.5 are limited to foundation option D in Figure 6.1.
4. The values in Table 7.5 are provided for demonstrational purposes only. Perma-Column, LLC, is not responsible for the analysis and design of soils (foundation). The analysis and design of soils (foundation) is the responsibility of the project engineer or the building designer.

8. DP Extender

All Deck Post models can be fitted with an optional DP Extender. DP extender is a 1/8”x3½” “U” shaped steel bracket that can extend 4” to 24” past the bottom of the concrete column and is attached to the column with (1) ½” ASTM A307 through bolt. The DP Extender may increase the depth of footing for frost protection. The main benefit, however, is the ability to install a column prior to installing a footing pad and pour the concrete footing and collar simultaneously in one single pour to create a strong monolithic foundation. Table 8.1 shows the uplift strength of the foundation (soils) for Deck Posts with the DP Extender on 8 Ø inch, 12 Ø inch and 16 Ø inch footers. Table 8.1 assumes a six (6) inch thick concrete footer poured just to the bottom of the concrete post (no concrete collar). If the top of the concrete footer is higher than the bottom of the concrete post, values in Table 8.1 should not be used and the designer should instead reference Tables 7.4 and 7.5.

TABLE 8.1: FOUNDATION UPLIFT STRENGTH WITH DP EXTENDER						
	8" Ø Concrete Footing		12" Ø Concrete Footing		16" Ø Concrete Footing	
Model ID	ASD (lb)	LRFD (lb)	ASD (lb)	LRFD (lb)	ASD (lb)	LRFD (lb)
DP4430	262	359	439	593	643	861
DP4440	546	756	875	1205	1239	1695
DP4448	855	1189	1346	1864	1877	2589
DP4460	1447	2018	2245	3123	3092	4290
DP6630	245	338	422	573	626	840
DP6640	525	730	854	1178	1218	1669
DP6648	830	1157	1321	1832	1852	2558
DP6660	1417	1979	2215	3083	3062	4251
DP6430	242	335	419	570	623	837
DP6440	525	725	851	1174	1214	1664
DP6448	826	1152	1317	1827	1848	2553
DP6460	1412	1972	2210	3077	3057	4244

Table 8.1 Footnotes:

1. The values in Table 8.1 are limited to foundation option C in Figure 6.1.
2. No concrete collar; top of concrete (footer) is at the bottom of the concrete Deck Post (Figure 6.1, Option C).
3. Concrete footer below Deck Post is 6 inches or thicker.
4. Soils should be verified by construction testing; if soils are not verified by construction testing, all values in Table 8.1 must be adjusted (reduced) by a 0.54 multiplier.
5. The values in Table 8.1 are provided for demonstrational purposes only. Perma-Column, LLC, is not responsible for the analysis and design of soils (foundation). The analysis and design of soils (foundation) is the responsibility of the project engineer or the building designer.

9. AG-CO Molded Plastic FootingPad

All Perma-Column Deck Post models can be installed on AG-CO 10 inch or 16 inch molded plastic FootingPads manufactured by AG-CO Products, Inc., see Figure 9.1. **The internal steel components at the bottom of the Perma-Column Deck Post for this option are different from the standard models and may not be available in some regions.** Specifically, the ½" PST, described in Section 2 of this manual, is threaded on the inside and placed vertically. The vertical tube extends from the bottom face of the concrete column to vertical rebar where it is welded with ¼" fillet weld all around. The AG-CO molded plastic FootingPad is fastened to the vertical threaded pipe of the Perma-Column Deck Post via one ½"x1½" and ½"x2½" grade 5 bolt for 10 inch and 16 inch FootingPad models respectively. The bolt is installed with a 2" diameter x 1/8" flat washer on the bottom face of the FootingPad. A more thorough description of this product and installation requirements are provided by ESR-2147 report by ICC-ES and GEE111711-10 report by NTA, Inc.

Figure 9.1: Deck Post on AG-CO Molded Plastic FootingPad

Governed by the bolt-head-pull-through test (GEE111711-10 report by NTA, Inc), the ultimate **uplift strength** of the 10 inch and 16 inch AG-CO Molded Plastic FootingPad is 908 lb and 1315 lb, respectively. With the safety factor of 3, the recommended allowable uplift strength (ASD) of the 10 inch and 16 inch FootingPad is 300 lb and 430 lb, respectively. The recommended design uplift strength (LRFD) is 420 lb and 600 lb, respectively (LRFD = ASD x 1.4). The uplift strength of the FootingPad controls the design: the uplift strength of the foundation (soil) is greater than the uplift strength of the AG-CO Molded Plastic FootingPad. However, soil properties vary and may be less favorable than what is assumed in this manual in Section 6. If the properties of the soil in Section 6 are not verified by construction testing, the uplift strength of the foundation (soil) will control the foundation design with 30 inch Deck Post models. The analysis and design of the foundation (soil) is the responsibility of the project engineer or the building designer.

The allowable vertical bearing strength of the FootingPad is provided in Table 1 of ESR-2147 report. The building designer may convert the ASD values provided in ESR-2147 to LRFD using the following relationship: LRFD = ASD x 1.4. The allowable lateral strength for the Deck Post and the foundation (soil) is provided in Tables 7.1 and 7.3.

Installation of a concrete collar above the FootingPad is not permitted for reasons described in the Foundation Design Section of this manual. The bottom of the molded plastic FootingPad must be located below the frost depth line as determined by the local authorities.

10. Summary and Conclusion

The Perma-Column Deck Post is designed to support wood decks, porches or other similar structures. The Deck Post can be used as an alternative to cast-in-place concrete piers and embedded wood posts that are incorporated in code-approved prescriptive specifications or an engineered design. This manual provides the axial compression, axial tension, shear and bending strengths of the (12) Deck Post models and the downward, uplift and lateral strengths of different foundation sizes and styles. The projection above grade, embedment depth, and footing thickness can be adjusted to accommodate a wide range of frost depth requirements. The Perma-Column Deck Post is a permanent foundation solution for the small structures market.

Perma-Column Deck Post

DP4430, DP4440, DP4448, DP4460, DP6630, DP6640, DP6648, DP6660, DP6430, DP6440, DP6448 and DP6460 models

CALCULATIONS

(Revision 3)

IBC 2018

ACI 318-14

ANSI/AISC 360-16

ANSI/AWC NDS 2015

timbertech

ENGINEERING

TTE Project Number S007-12

Prepared by

Dimitry Reznik, P.E.
Timber Tech Engineering, Inc
dar@timbertecheng.com

April 8, 2020

(supersedes all prior versions)

www.timbertecheng.com

East: 22 Denver Road, Suite B Denver, PA 17517
717.335.2750 Fax: 717.335.2753

West: 406 S. Main St, P.O. Box 509 Kouts, IN 46347
219.766.2499 Fax: 219.766.2394

Summary of changes

Revision 1:

- All ACI 318-14 references updated
- The multiplier in ACI 318 Table 22.1.2.1 is reduced from 0.80 to 0.60. The mathematical justification for this reduction is provided in the *Perma-Column Deck Post Axial Strength* section of the calculations. The original calculations, dated 4-4-2018, used a 0.50 multiplier but did not provide a mathematical justification for the selection of this multiplier.

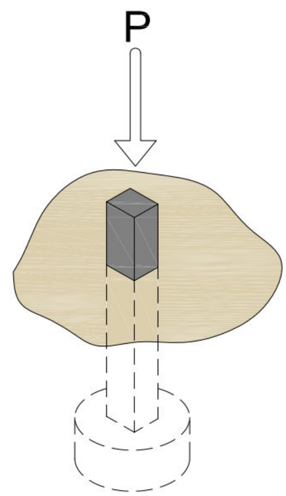
Revision 2:

- Deck Post models DP4448, DP4460, DP6648, DP6660, DP6448 and DP6460 are added to the calculations.

Revision 3:

- Deck Post model DP4640 removed from the calculatioins

1. PERMA-COLUMN DECK POST AXIAL STRENGTH



Perma-Column Deck Post is embedded into the ground and, with the exception of a short segment above grade (maximum 10 inches per the manufacturer's literature), the post is laterally restrained along full length by surrounding compacted soils. Having continuous lateral restraint, the Deck Post is a "short column" with design axial strength, ϕP_n, defined in ACI 318 Sections 10.5, 22.4, Table 22.4.2.1, and Equation 22.4.2.2. The profile section dimensions, however, are too small to fit ties or stirrups. To address this concern, the 0.80 multiplier in Table 22.4.2.1 is reduced to 0.60. This reduction factor is a ratio of the design axial strength of the plain structural concrete to the design axial strength of the reinforced concrete column without the 0.80 multiplier. In other words, with this multiplier, the design axial strength of the reinforced column is equal to the design axial strength of the plain structural concrete column.

ACI 318 allows the use of plain structural concrete for a pedestal, which is defined as a "member with a ratio of height-to-least lateral dimension less than or equal to 3, used primarily to support axial compressive load.." ACI 318 commentary section R14.3.3.1 clarifies that the said ratio applies only to the unsupported height - distance from grade to top of concrete column (pedestal). Per the manufacturer's literature, the Perma-Column Deck Post is embedded into the ground with only 10" or shorter segment exposed above ground.

The calculations are completed using the Load Resistance and Factor Design (LRFD) consistent with the ACI 318 adopted method, and the results are presented in terms of the Design Axial Strength. This post will be used primarily to support wood construction (deck). The wood construction industry in the USA has not fully embraced the LRFD design methodology, and the governing standard, the National Design Specification for Wood Construction (NDS) is founded on and favors the Allowable Strength Design (ASD) over the LRFD design, though the LRFD conversion is possible using the conversion factor. To allow for easier transition between the two methods, the Design Axial Strength in the calculations below is converted to the Allowable Axial Strength using the conversion factor α = 1/1.6 = 0.625. The calculations are completed in Microsoft Excel (2016) using the listed equations.

GOVERNING CODE:

Building Code Requirements for Structural Concrete, ACI 318

GOVERNING EQUATIONS:

Design Axial Strength	$\phi P_n = \phi 0.60[0.85f_c'(A_g\text{-}A_s)+f_yA_s]$	(ACI 318, 10.5, 22.4.2.1, Eq. 22.4.2.2)
Strength Reduction Factor	$\phi = 0.65$	(ACI 318, Table 21.2.2, b)
Concrete comp. strength, f'_c	10000 psi	
Steel yield strength, f_y	60000 psi	
LRFD to ASD Conversion Factor	α = 1/1.6 = 0.625.	

CALCULATIONS:

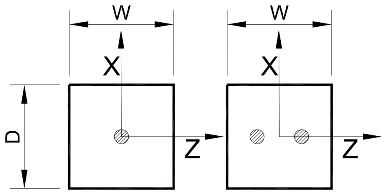
TABLE 1: Design Axial Strength and Allowable Axial Capacity of Reinforced Concrete Post

Model ID	Width *(in)*	Depth *(in)*	Reinforcement	A_g (in^2)	A_s (in^2)	A_c (in^2)	P_n (lbs)	ϕ	ϕP_n (lbs)	α	$P_{allowable}$ (lbs)
DP4430	3.625	3.5	(1) #4 Rebar	12.7	0.20	12.5	70886	0.65	46076	0.625	28798
DP4440	3.625	3.5	(1) #4 Rebar	12.7	0.20	12.5	70886	0.65	46076	0.625	28798
DP4448	3.625	3.5	(1) #4 Rebar	12.7	0.20	12.5	70886	0.65	46076	0.625	28798
DP4460	3.625	3.5	(1) #4 Rebar	12.7	0.20	12.5	70886	0.65	46076	0.625	28798
DP6630	5.625	5	(2) #4 Rebar	28.1	0.40	27.7	155798	0.65	101268	0.625	63293
DP6640	5.625	5	(2) #4 Rebar	28.1	0.40	27.7	155798	0.65	101268	0.625	63293
DP6648	5.625	5	(2) #4 Rebar	28.1	0.40	27.7	155798	0.65	101268	0.625	63293
DP6660	5.625	5	(2) #4 Rebar	28.1	0.40	27.7	155798	0.65	101268	0.625	63293
DP6430	6.125	5	(2) #4 Rebar	30.6	0.40	30.2	168548	0.65	109556	0.625	68472
DP6440	6.125	5	(2) #4 Rebar	30.6	0.40	30.2	168548	0.65	109556	0.625	68472
DP6448	6.125	5	(2) #4 Rebar	30.6	0.40	30.2	168548	0.65	109556	0.625	68472
DP6460	6.125	5	(2) #4 Rebar	30.6	0.40	30.2	168548	0.65	109556	0.625	68472

*$A_c = A_g - A_s$

2. PERMA-COLUMN DECK POST BENDING STRENGTH

Perma-Column Deck Post is manufactured with 10,000 psi concrete and reinforced with #4 Grade 60 longitudinal rebar(s). The design bending strength is calculated in accordance with ACI 318 Chapters 10 and 22 using the Load and Resistance Factored Design (LRFD) methodology. The design strength, ϕM_n, is also converted to the allowable bending strength format using the conversion factor $\alpha = 1/1.6 = 0.625$. The maximum reinforcement ratio limit, ρ_{max}, is set so that the tension strain, ϵ_t, in the tension rebar is 0.005 or greater to ensure that the strength reduction factor, ϕ, of 0.90 is adequate. The calculations are completed in Microsoft Excel (2016) using the listed equations.



GOVERNING CODE:

Building Code Requirements for Structural Concrete, ACI 318

GOVERNING EQUATIONS:

Design Bending Strength	$\phi M_n = \phi A_s f_y (d - a/2)$	
Depth of Rectangular Stress Block	$a = A_s f_y / (0.85 f_c b)$	
Strength Reduction Factor	$\phi = 0.90$	(ACI 318, Table 21.2.2, $\epsilon_t \geq 0.005$)
Maximum reinforcement ratio	$\rho_{max} = 0.85\beta_1 (f'_c/f_y)[0.003 / (0.003+0.005)]$	($\beta_1 = 0.65$ for $f'_c \geq 8000$ psi)
Minimum reinforcement	$A_{s,min} = 3\sqrt{(f'_c)} bd / f_y$	
LRFD to ASD Conversion Factor	$\alpha = 1/1.6 = 0.625.$	
Concrete comp. strength	10000 psi	
Steel yield strength	60000 psi	

CALCULATIONS:

TABLE 2A: Bending about the "z" axis: Design Bending Strength and Allowable Bending Strength of Reinforced Concrete Post

Model ID	Width (in)	Depth (in)	Reinforcement (tension rebar)	A_s (in^2)	$A_{s, max}$ (in^2)	$A_{s, min}$ (in^2)	a (in)	d_{top} (in)	d_{btm} (in)	ϕ	ϕM_n (ft-lb)	α	$M_{allowable}$ (ft-lb)
DP4430	3.625	3.500	(1) #4 Rebar	0.20	0.22	0.03	0.39	1.75	1.75	0.90	1400	0.625	875
DP4440	3.625	3.500	(1) #4 Rebar	0.20	0.22	0.03	0.39	1.75	1.75	0.90	1400	0.625	875
DP4448	3.625	3.500	(1) #4 Rebar	0.20	0.22	0.03	0.39	1.75	1.75	0.90	1400	0.625	875
DP4460	3.625	3.500	(1) #4 Rebar	0.20	0.22	0.03	0.39	1.75	1.75	0.90	1400	0.625	875
DP6630	5.625	5.000	(2) #4 Rebar	0.40	0.49	0.07	0.50	2.50	2.50	0.90	4048	0.625	2530
DP6640	5.625	5.000	(2) #4 Rebar	0.40	0.49	0.07	0.50	2.50	2.50	0.90	4048	0.625	2530
DP6648	5.625	5.000	(2) #4 Rebar	0.40	0.49	0.07	0.50	2.50	2.50	0.90	4048	0.625	2530
DP6660	5.625	5.000	(2) #4 Rebar	0.40	0.49	0.07	0.50	2.50	2.50	0.90	4048	0.625	2530
DP6430	6.125	5.000	(2) #4 Rebar	0.40	0.53	0.08	0.46	2.50	2.50	0.90	4085	0.625	2553
DP6440	6.125	5.000	(2) #4 Rebar	0.40	0.53	0.08	0.46	2.50	2.50	0.90	4085	0.625	2553
DP6448	6.125	5.000	(2) #4 Rebar	0.40	0.53	0.08	0.46	2.50	2.50	0.90	4085	0.625	2553
DP6460	6.125	5.000	(2) #4 Rebar	0.40	0.53	0.08	0.46	2.50	2.50	0.90	4085	0.625	2553

TABLE 2B: Bending about the "x" axis: Design Bending Strength and Allowable Bending Strength of Reinforced Concrete Post

Model ID	Width (in)	Depth (in)	Reinforcement (tension rebar)	A_s (in^2)	$A_{s, max}$ (in^2)	$A_{s, min}$ (in^2)	a (in)	d_{top}* (in)	d_{btm}* (in)	ϕ	ϕM_n (ft-lb)	α	$M_{allowable}$ (ft-lb)
DP4430	3.625	3.500	(1) #4 Rebar	0.20	0.23	0.03	0.39	1.81	1.81	0.90	1456	0.625	910
DP4440	3.625	3.500	(1) #4 Rebar	0.20	0.23	0.03	0.39	1.81	1.81	0.90	1456	0.625	910
DP4448	3.625	3.500	(1) #4 Rebar	0.20	0.23	0.03	0.39	1.81	1.81	0.90	1456	0.625	910
DP4460	3.625	3.500	(1) #4 Rebar	0.20	0.23	0.03	0.39	1.81	1.81	0.90	1456	0.625	910
DP6630	5.625	5.000	(1) #4 Rebar	0.20	0.67	0.12	0.25	4.18	3.44	0.90	2981	0.625	1863
DP6640	5.625	5.000	(1) #4 Rebar	0.20	0.67	0.12	0.25	4.18	3.44	0.90	2981	0.625	1863
DP6648	5.625	5.000	(1) #4 Rebar	0.20	0.67	0.12	0.25	4.18	3.44	0.90	2981	0.625	1863
DP6660	5.625	5.000	(1) #4 Rebar	0.20	0.67	0.12	0.25	4.18	3.44	0.90	2981	0.625	1863
DP6430	6.125	5.000	(1) #4 Rebar	0.20	0.78	0.14	0.23	4.68	3.69	0.90	3215	0.625	2009
DP6440	6.125	5.000	(1) #4 Rebar	0.20	0.78	0.14	0.23	4.68	3.69	0.90	3215	0.625	2009
DP6448	6.125	5.000	(1) #4 Rebar	0.20	0.78	0.14	0.23	4.68	3.69	0.90	3215	0.625	2009
DP6460	6.125	5.000	(1) #4 Rebar	0.20	0.78	0.14	0.23	4.68	3.69	0.90	3215	0.625	2009

*: *The longitudinal rebar in 6000 series are positioned in a "V" shape, and the depth to center of tension rebar varies along the length of the Deck Post. The Design Moment Strength is calculated conservatively using the smallest dimension "d", (d_{btm}) while $A_{s, min}$ is calculated using the largest possible dimension (d_{top}).*

3. PERMA-COLUMN DECK POST AXIAL AND BENDING STRENGTH UNDER COMBINED LOADING

This section of the calculations describes the behavior of the Perma-Column Deck Post subjected to combined axial and bending loading. The balanced failure occurs when the tension steel just begins to yield (ϵ_s = 0.002) as the concrete reaches its limiting strain ϵ_u of 0.003. This condition is highlighted in the calculations tables. The strength interaction diagram is presented below each calculations table. The axial design strength is limited by expression $\varphi P_n = \varphi 0.60[0.85 f_c'(A_g - A_s) + f_y A_s]$ which has a conservative 0.60 multiplier due to the absence of lateral ties and stirrups as discussed in earlier section. This limitation is represented by a flat line in the strength interaction diagram. As expected, when the compression axial load is increased, the design bending moment strength is also increased until the point where this trend is reversed. The calculations are completed in Microsoft Excel (2016) using the listed equations.

Because of the 0.60 multiplier that severely limits the design axial strength, the design bending strength under the combined loading is never less than the design bending strength without the axial loads as is shown in the strength interaction diagram. This behavior is verified by looking at two Deck Post models: DP4430 and DP6630, and the pattern is expected to be the same for all models regardless of the direction of the bending forces. It is, therefore, concluded that, whether the column is subjected to singular or combined bending and axial compression loads, the individual factored axial and bending forces should not exceed the design axial compression and bending strengths as determined by the singular load analyses in previous sections.

GOVERNING CODE:

Building Code Requirements for Structural Concrete, ACI 318

GOVERNING EQUATIONS:

Design Bending Strength	$\phi M_n = \phi A_s f_y (d - a/2)$	(pure bending)
Design Axial Strength	$\phi P_n = \phi 0.60[0.85 f_c'(A_g - A_s) + f_y A_s]$	(pure axial)

Design Axial and Bending Strength under Combined Loading	$\phi M_n = \phi[0.85 f'_c ab(h/2 - a/2) + A_s f_s (d - h/2)]$
	$\phi P_n = \phi[0.85 f'_c ab - A_s f_s] \quad \leq \quad \phi P_n = \phi 0.60[0.85 f_c'(A_g - A_s) + f_y A_s]$

Depth of Rectangular Stress Block	$a = c\beta_1 \leq h$, where c = distance to the elastic neutral axis (NA)
Strain in rebar	$\epsilon_s = \epsilon\,(d-c)/c$
Distance to N/A for balanced failure	$c_b = d\epsilon_u / (\epsilon_u + \epsilon_y)$, where $\epsilon_y = f_y/E$
Stress in rebar	$f_s = \epsilon_u u E_s\,(d-c)/c \leq f_y$
Concrete Compressive Resultant	$C = 0.85 f'_c ab$

CALCULATIONS FOR DP4430:

β_1	0.65	
Steel Yield Strength, F_y	60000	psi
Concrete comp. strength, f'_c	10000	psi
Column Depth, h	3.5	in
Column Width, b	3.625	in
Dimension d to rebar	1.75	in
Diameter of longitudinal rebar	0.5	in

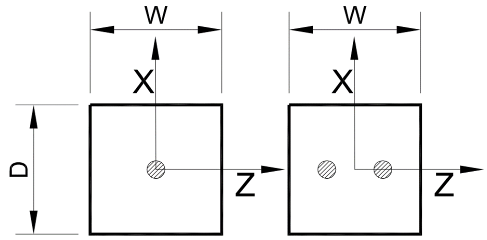
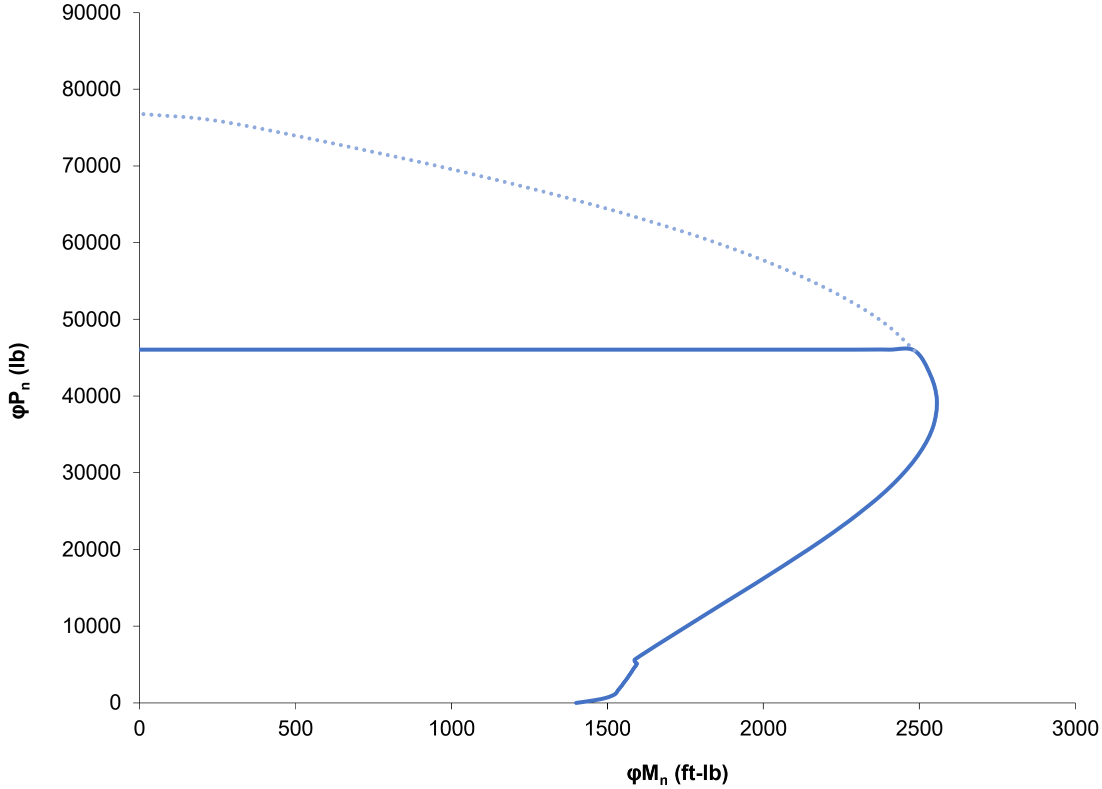


TABLE 3A: STRENGTH INTERACTION CHART FOR DECK POST SUBJECTED TO COMBINED AXIAL AND BENDING LOADS (ABOUT Z AXIS)

	c	a	A_s	f_s	$0.85f'_cab$	A_sf_s	ϕ_a	ϕP_n*	ϕP_n	ϕ_b	ϕM_n
	(in)	(in)	(in^2)	(psi)	(lb)	(lb)		(lb)	(lb)		(ft-lb)
0.006	0.60	0.39	0.20	-	-	12000	0.65		0	0.90	1400
0.005	0.64	0.42	0.20	60000	12874	12000	0.65		568	0.90	1488
0.005	0.69	0.45	0.20	60000	13749	12000	0.65		1137	0.87	1523
0.004	0.73	0.47	0.20	60000	14623	12000	0.65		1705	0.83	1535
0.004	0.77	0.50	0.20	60000	15497	12000	0.65		2273	0.80	1546
0.003	0.82	0.53	0.20	60000	16372	12000	0.65		2842	0.77	1556
0.003	0.86	0.56	0.20	60000	17246	12000	0.65		3410	0.74	1566
0.003	0.90	0.59	0.20	60000	18120	12000	0.65		3978	0.72	1576
0.003	0.95	0.62	0.20	60000	18995	12000	0.65		4547	0.69	1585
0.002	0.99	0.64	0.20	60000	19869	12000	0.65		5115	0.67	1594
0.002	*1.04*	*0.67*	0.20	60000	*20743*	12000	0.65		5683	0.65	1588
0.001	1.25	0.81	0.20	35149	24964	7030	0.65		11657	0.65	1819
0.001	1.46	0.95	0.20	17485	29184	3497	0.65		16696	0.65	2018
0.000	1.67	1.08	0.20	4285	33404	857	0.65		21156	0.65	2186
	1.88	1.22	0.20	-5954	37624	-1191	0.65		25230	0.65	2322
	2.09	1.36	0.20	-14128	41844	-2826	0.65		29036	0.65	2427
	2.30	1.50	0.20	-20804	46065	-4161	0.65		32647	0.65	2501
	2.51	1.63	0.20	-26360	50285	-5272	0.65		36112	0.65	2544
	2.72	1.77	0.20	-31055	54505	-6211	0.65	39465	39465	0.65	2555
	2.93	1.91	0.20	-35076	58725	-7015	0.65	42731	42731	0.65	2535
	3.14	2.04	0.20	-38557	62946	-7711	0.65	45927	45927	0.65	2484
	3.35	2.18	0.20	-41601	67166	-8320	0.65	49066	46076	0.65	2402
	3.56	2.32	0.20	-44285	71386	-8857	0.65	52158	46076	0.65	2288
	3.78	2.45	0.20	-46669	75606	-9334	0.65	55211	46076	0.65	2142
	3.99	2.59	0.20	-48801	79826	-9760	0.65	58231	46076	0.65	1966
	4.20	2.73	0.20	-50719	84047	-10144	0.65	61224	46076	0.65	1758
	4.41	2.86	0.20	-52454	88267	-10491	0.65	64192	46076	0.65	1519
	4.62	3.00	0.20	-54030	92487	-10806	0.65	67140	46076	0.65	1248
	4.83	3.14	0.20	-55469	96707	-11094	0.65	70071	46076	0.65	947
	5.04	3.28	0.20	-56787	100927	-11357	0.65	72985	46076	0.65	614
	5.25	3.41	0.20	-58000	105148	-11600	0.65	75886	46076	0.65	249
	∞						0.65	76793	46076		0

* *The values in this column show what the Design Axial Strength would have been without the 0.60 multiplier*

FIGURE 3A: DESIGN AXIAL STRENGTH VS DESIGN BENDING MOMENT INTERACTION DIAGRAM



CALCULATIONS FOR DP6630:

β_1	0.65	
Steel Yield Strength, F_y	60000	psi
Concrete comp. strength, f'_c	10000	psi
Column Depth, h	5	in
Column Width, b	5.625	in
Dimension d to rebar	2.50	in
Diameter of longitudinal rebar	0.5	in

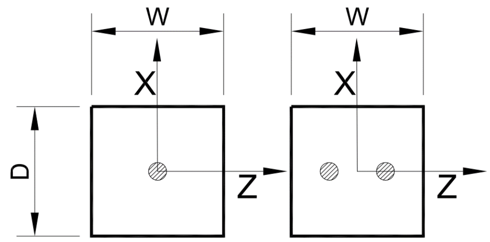


TABLE 3B: STRENGTH INTERACTION CHART FOR DECK POST SUBJECTED TO COMBINED AXIAL AND BENDING LOADS (ABOUT Z AXIS)

	c (in)	a (in)	A_s (in^2)	f_s (psi)	$0.85f'_cab$ (lb)	A_sf_s (lb)	ϕ_a	ϕP_n* (lb)	ϕP_n (lb)	ϕ_b	ϕM_n (ft-lb)
0.007	0.77	0.50	0.40	-	-	24000	0.65		0	0.90	4048
0.006	0.84	0.55	0.40	60000	26198	24000	0.65		1429	0.90	4374
0.005	0.91	0.59	0.40	60000	28397	24000	0.65		2858	0.90	4692
0.005	0.98	0.64	0.40	60000	30595	24000	0.65		4287	0.87	4826
0.004	1.06	0.69	0.40	60000	32793	24000	0.65		5716	0.83	4867
0.004	1.13	0.73	0.40	60000	34991	24000	0.65		7144	0.79	4906
0.003	1.20	0.78	0.40	60000	37190	24000	0.65		8573	0.76	4944
0.003	1.27	0.82	0.40	60000	39388	24000	0.65		10002	0.73	4979
0.003	1.34	0.87	0.40	60000	41586	24000	0.65		11431	0.70	5013
0.002	1.41	0.92	0.40	60000	43785	24000	0.65		12860	0.68	5044
0.002	*1.48*	*0.96*	0.40	60000	*45983*	24000	0.65		14289	0.65	5029
0.001	1.79	1.16	0.40	34501	55633	13800	0.65		27191	0.65	5780
0.001	2.10	1.37	0.40	16540	65284	6616	0.65		38134	0.65	6426
0.000	2.41	1.57	0.40	3206	74934	1282	0.65		47874	0.65	6967
	2.72	1.77	0.40	-7086	84585	-2834	0.65		56822	0.65	7401
	3.03	1.97	0.40	-15270	94235	-6108	0.65		65223	0.65	7731
	3.34	2.17	0.40	-21933	103885	-8773	0.65		73228	0.65	7955
	3.65	2.37	0.40	-27464	113536	-10985	0.65		80939	0.65	8073
	3.96	2.58	0.40	-32128	123186	-12851	0.65	88424	88424	0.65	8086
	4.27	2.78	0.40	-36114	132836	-14446	0.65	95733	95733	0.65	7993
	4.58	2.98	0.40	-39561	142487	-15824	0.65	102902	101268	0.65	7795
	4.90	3.18	0.40	-42570	152137	-17028	0.65	109957	101268	0.65	7491
	5.21	3.38	0.40	-45220	161788	-18088	0.65	116919	101268	0.65	7082
	5.52	3.59	0.40	-47572	171438	-19029	0.65	123803	101268	0.65	6567
	5.83	3.79	0.40	-49673	181088	-19869	0.65	130622	101268	0.65	5947
	6.14	3.99	0.40	-51562	190739	-20625	0.65	137386	101268	0.65	5221
	6.45	4.19	0.40	-53268	200389	-21307	0.65	144103	101268	0.65	4390
	6.76	4.39	0.40	-54818	210040	-21927	0.65	150778	101268	0.65	3453
	7.07	4.59	0.40	-56232	219690	-22493	0.65	157419	101268	0.65	2411
	7.38	4.80	0.40	-57526	229340	-23011	0.65	164028	101268	0.65	1263
	7.69	5.00	0.40	-58717	238991	-23487	0.65	170610	101268	0.65	10
	∞						0.65	168781	101268		0

* *The values in this column show what the Design Axial Strength would have been without the 0.60 multiplier*

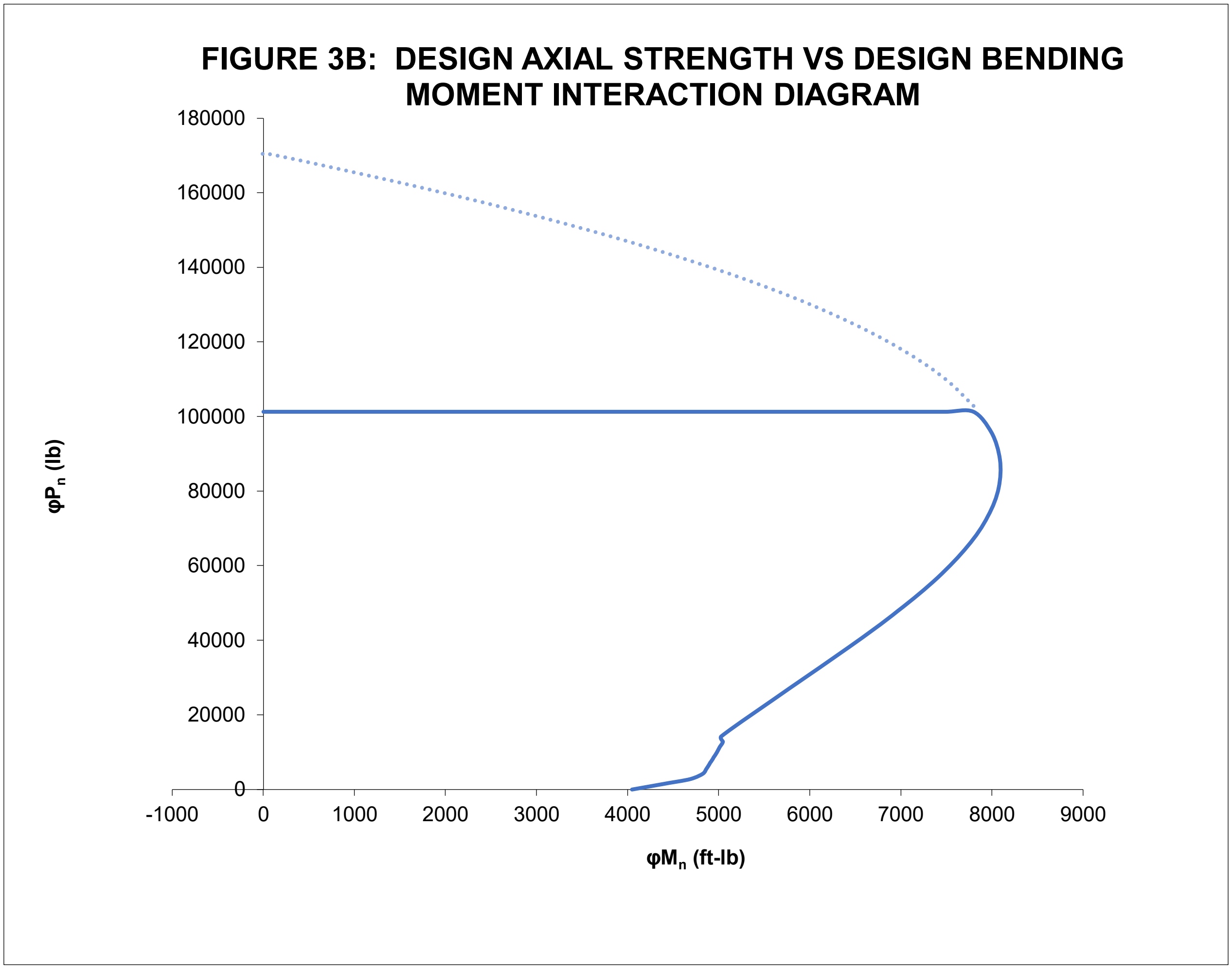


FIGURE 3B: DESIGN AXIAL STRENGTH VS DESIGN BENDING MOMENT INTERACTION DIAGRAM
φPn (lb)
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
φMn (ft-lb)

4. PERMA-COLUMN DECK POST SHEAR STRENGTH (CONCRETE)

The design shear strength of the Perma-Column Deck Post is calculated using ACI 318 equations for reinforced concrete and for plain structural concrete. Because of the absence of the shear reinforcement, however, it is recommended that the design shear capacity is limited to values calculated using plain structural concrete equations. This approach is useful as the calculated design shear strength values are the same for any load direction. The shear strength design calculations for reinforced concrete are shown for comparative analysis purposes: for smaller shapes, regardless of the load direction, and larger shapes with load parallel to the short face, the reinforced and plain structural concrete calculations produce similar results. Only for larger shapes with load parallel to longer faces (larger dimensions "d"), the reinforced concrete calculations produce significantly higher design strength values. ACI 318 allows the use of plain structural concrete for pedestal, which is defined as "*member with a ratio of height-to-least lateral dimension less than or equal to 3, used primarily to support axial compressive load..*" ACI 318 commentary section R14.3.3.1 later clarifies that the said ratio applies only to the unsupported height - distance from grade to top of concrete column (pedestal). Per the manufacturer's literature, the Perma-Column Deck Post is embedded into ground with only 10" or shorter segment exposed above ground. In the worst case scenario, the height-to-least lateral dimension ratio is 10 / 3.5 = 2.86 < 3. It is therefore not unreasonable to apply structural plain concrete methods for calculating design shear strengths.

To stay consistent with the design preferences and terminology of the wood industry, the design shear strength is also expressed in terms of the allowable shear strength using a conservative LRFD to ASD conversion factor of $\alpha = 1 / 1.6 = 0.625$. The calculations are completed in Microsoft Excel (2016) using the listed equations.

GOVERNING CODE:

Building Code Requirements for Structural Concrete, ACI 318

GOVERNING EQUATIONS:

Design Shear Strength	$\phi V_n = \phi 2\sqrt{(f'_c)}bd$	Reinforced Concrete	(ACI 318, Eq. 22.5.5.1)
Design Shear Strength	$\phi V_n = \phi(4/3)\sqrt{(f'_c)}bh$	Plain Structural Concrete	(ACI 318, Table 14.5.5.1)

Strength Reduction Factor, ϕ	0.75	Reinforced Concrete	(ACI 318, Table 21.2.1)
Strength Reduction Factor, ϕ	0.60	Plain Structural Concrete	(ACI 318, Table 21.2.1)
LRFD to ASD Conversion Factor, α	0.625	$\alpha = 1 / 1.6$	
Concrete comp. strength, f'_c	10000 psi		

CALCULATIONS:

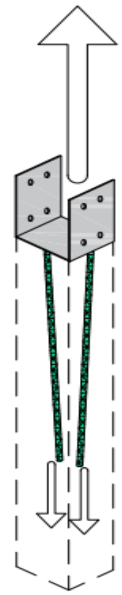
TABLE 4: Design Shear Strength and Allowable Shear Strength for Concrete Deck Post

			REINFORCED CONCRETE								PLAIN CONCRETE	
			Load Parallel to Depth				Load Parallel To width					
Model ID	Width (in)	Depth (in)	d_{top} (in)	d_{btm} (in)	ϕV_n (lbf)	$V_{allowable}$ (lbf)	d_{top}* (in)	d_{btm}* (in)	ϕV_n (lbf)	$V_{allowable}$ (lbf)	ϕV_n (lbf)	$V_{allowable}$ (lbf)
DP4430	3.625	3.500	1.75	1.75	952	595	1.81	1.81	986	616	1015	634
DP4440	3.625	3.500	1.75	1.75	952	595	1.81	1.81	986	616	1015	634
DP4448	3.625	3.500	1.75	1.75	952	595	1.81	1.81	986	616	1015	634
DP4460	3.625	3.500	1.75	1.75	952	595	1.81	1.81	986	616	1015	634
DP6630	5.625	5.000	2.50	2.50	2109	1318	4.18	3.44	2900	1813	2250	1406
DP6640	5.625	5.000	2.50	2.50	2109	1318	4.18	3.44	2900	1813	2250	1406
DP6648	5.625	5.000	2.50	2.50	2109	1318	4.18	3.44	2900	1813	2250	1406
DP6660	5.625	5.000	2.50	2.50	2109	1318	4.18	3.44	2900	1813	2250	1406
DP6430	6.125	5.000	2.50	2.50	2297	1436	4.68	3.69	3388	2117	2450	1531
DP6440	6.125	5.000	2.50	2.50	2297	1436	4.68	3.69	3388	2117	2450	1531
DP6448	6.125	5.000	2.50	2.50	2297	1436	4.68	3.69	3388	2117	2450	1531
DP6460	6.125	5.000	2.50	2.50	2297	1436	4.68	3.69	3388	2117	2450	1531

* For load parallel to width of the Deck Post, the dimension "d" varies along the length of the column as the rebar is placed using "v" shape with the vertex located near bottom of column. The design shear strength is conservatively calculated using the smallest "d" dimension (d_{btm}).

5. PERMA-COLUMN DECK POST TENSILE STRENGTH

The design tension strength of the Perma-Column Deck Post is dependent entirely on the strength of the external and internal steel components and connections: steel bracket, rebar, weld connection between rebar and steel bracket, weld connection between rebar and steel sleeve (pipe) at bottom, through bolt at bottom (through sleeve) and external steel angles at bottom. Under tension forces, the concrete around the steel components is considered non-structural.



The calculations are presented in both the LRFD and ASD formats in accordance with the provisions of the governing code (AISC 360). In the two-rebar models, the vertical rebar is not perfectly plumb; the angle with respect to the long axis of the column, however, is insignificant and it's effects are ignored in these calculations.

The calculations are completed in Microsoft Excel (2016) using the listed equations. The internal loads in the steel saddle bracket are determined using Visual Analysis (v.12) by IES, Inc.

GOVERNING CODE:

Specification for Structural Steel Buildings ANSI/AISC 360

GOVERNING EQUATIONS:

- **REBAR AND STEEL SADDLE: AISC 360, SECTION D2**

Design Tensile Strength	$\phi P_n = \phi F_y A_g$	**(tensile yielding)**	$\phi = 0.90$	(D2-1)
	$\phi P_n = \phi F_u A_e$	**(tensile rupture)**	$\phi = 0.75$	(D2-2)
Allowable Tensile Strength	$P_n / \Omega = F_y A_g / \Omega$	**(tensile yielding)**	$\Omega = 1.67$	(D2-1)
	$P_n / \Omega = F_u A_e / \Omega$	**(tensile rupture)**	$\Omega = 2.00$	(D2-2)

- **WELDS: AISC 360, SECTION J2**

Design Strength	$\phi R_n = \phi F_w A_w$	$\phi = 0.75$	(J2-3)
Allowable Strength	$R_n / \Omega = F_w A_w / \Omega$	$\Omega = 2.00$	(J2-3)
	$F_w = 0.60 F_{EXX}$		(T. J2.5)
	$A_w = Lt_e$, where L = length of weld, t_e = effective weld thickness)		

- **BOLT: AISC 360, SECTION J3**

Design Shear Strength	$\phi R_{nv} = \phi F_{nv} A_b$	$\phi = 0.75$	(J3-1)
Allowable Shear Strength	$R_{nv} / \Omega = F_{nv} A_b / \Omega$	$\Omega = 2.00$	(J3-1)
	F_{nv} = 24 ksi	**A307 Bolt**	(T. J3.2)

- **BEARING (BOLT & STEEL BRACKET): AISC 360, SECTION J3**

Design Bearing Strength	$\phi R_n = \phi L_c t F_u \leq 3.0\ dtF_u$	$\phi = 0.75$	(J3-6b)
Allowable Bearing Strength	$R_n / \Omega = L_c t F_u / \Omega \leq 3.0\ dtF_u / \Omega$	$\Omega = 2.00$	(J3-6b)

- **BLOCK SHEAR STRENGTH: AISC 360, SECTION J4.3**

Design Strength	$\phi R_n = \phi(F_U A_{nv} + U_{bs} F_u A_{nt} \leq 0.6 F_y A_{gv} + U_{bs} F_u A_{nt})$	$\phi = 0.75$	(J4-5)
Allowable Strength	$R_n / \Omega = (F_U A_{nv} + U_{bs} F_u A_{nt} \leq 0.6 F_y A_{gv} + U_{bs} F_u A_{nt}) / \Omega$	$\Omega = 2.00$	(J4-5)
	U_{bs} = 1.0		(tension stress is uniform)

- **BENDING IN STEEL SADDLE BRACKET AND UPLIFT STEEL ANGLES: AISC 360, SECTIONS F1 & F11**

Design Bending Strength	$\phi M_n = \phi F_y Z$	$\phi = 0.90$	(F1, F11)
Allowable Bending Strength	$M_n / \Omega = M_n Z / \Omega$	$\Omega = 1.67$	(F1, F11)

CALCULATIONS:

REBAR PROPERTIES

Rebar Diameter, D_r	0.5	in
Rebar Yield Strength, F_y	60	ksi
Rebar Rupture Strength, F_u	90	ksi
Rebar Section Area, A_s	0.20	in^2

BOLT PROPERTIES

Bolt Diameter, D_b	0.5	in
Bolt Area, A_b	0.20	in^2
Bolt Designation	A307	
Nominal Shear Strength, F_{nv}	24	ksi
Minimum Tensile Strength, F_u	60	ksi

STEEL SADDLE BRACKET PROPERTIES

Minimum Tensile Strength, F_u	60	ksi
Minimum Yield Strength, Fy	40	ksi
Thickness of steel, t	0.125	in

WELD PROPERTIES

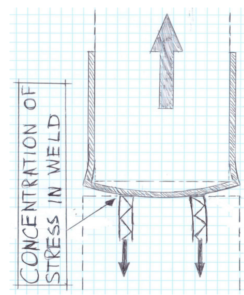
Fillet Weld Leg Size, t	0.25	in
Effective Weld Thickness (throat) , t_e	0.18	in
Total Weld Length, $L = D_r\pi$	1.57	in/bar
Effective Weld Area, $A_w = Lt_e$	0.28	in^2/bar
Electrode Classification Number	70	ksi
Nominal Strength of Weld Metal, F_w	42	ksi

STEEL ANGLE PROPERTIES

Minimum Tensile Strength, F_u	58	ksi
Minimum Yield Strength, F_y	36	ksi
Clear distance from hole to edge, L_c	1.0	in
Thickness of steel angle(s), t	0.125	in

TABLE 5A: DESIGN TENSILE STRENGTH AND ALLOWABLE TENSILE STRENGTH												
	Rebar Tensile Strength					Weld Strength			Bolt Shear Strength (Double Shear)		Bearing Strength (Total) (2)	
		Yielding		Rupture								
	A_s	ϕR_n	R_n / Ω	ϕR_n	R_n / Ω	A_w (1)	ϕR_n	R_n / Ω	ϕR_{nv}	R_{nv} / Ω	ϕR_n	R_n / Ω
Model ID	(in^2)	(lbf)	(lbf)	(lbf)	(lbf)	(in^2)	(lbf)	(lbf)	(lbf)	(lbf)	(lbf)	(lbf)
DP4430	0.20	10800	7186	13500	9000	0.28	8746	5830	8482	4712	16313	10875
DP4440	0.20	10800	7186	13500	9000	0.28	8746	5830	8482	4712	16313	10875
DP4448	0.20	10800	7186	13500	9000	0.28	8746	5830	8482	4712	16313	10875
DP4460	0.20	10800	7186	13500	9000	0.28	8746	5830	8482	4712	16313	10875
DP6630	0.40	21600	14371	27000	18000	0.28	8746	5830	8482	4712	16313	10875
DP6640	0.40	21600	14371	27000	18000	0.28	8746	5830	8482	4712	16313	10875
DP6648	0.40	21600	14371	27000	18000	0.28	8746	5830	8482	4712	16313	10875
DP6660	0.40	21600	14371	27000	18000	0.28	8746	5830	8482	4712	16313	10875
DP6430	0.40	21600	14371	27000	18000	0.28	8746	5830	8482	4712	16313	10875
DP6440	0.40	21600	14371	27000	18000	0.28	8746	5830	8482	4712	16313	10875
DP6448	0.40	21600	14371	27000	18000	0.28	8746	5830	8482	4712	16313	10875
DP6460	0.40	21600	14371	27000	18000	0.28	8746	5830	8482	4712	16313	10875

(1) For models with two rebar, the concentration of stresses in the fillet weld around the rebar is expected to be uneven: higher concentration is expected on the outside semi-circle around rebar due to the location of the uplift forces and bending in the steel bracket as shown in the diagram on the right. For this reason, for all two-rebar models, only half of the effective weld area for each rebar is used in the calculations resulting in all deck post models having the same weld strength value.



(2) Because the bolt is loaded in double shear, the thickness of the bearing surface is doubled: t = 2 x 0.125 = 0.25 inches.

(3) Because the F_u of bolt is greater than F_u of the steel angles, the bearing strength is controlled by the steel angles.

TABLE 5B: DESIGN TENSILE STRENGTH AND ALLOWABLE TENSILE STRENGTH (Cont…)												
	Tensile Strength of Steel Saddle Bracket						Tensile Strength based on Block Shear Strength of Steel Saddle Bracket					
		Yielding		Rupture								
	A_g	ϕR_n	R_n / Ω	A_e	ϕR_n	R_n / Ω	A_{nv}	A_{nt}	A_{gv}	U_{bs}	ϕR_n	R_n / Ω
Model ID	(in^2)	(lbf)	(lbf)	(in^2)	(lbf)	(lbf)	(in^2)	(in^2)	(in^2)		(lbf)	(lbf)
DP4430	0.875	31500	20958	0.750	33750	22500	0.934	0.551	0.969	1.0	42237	28158
DP4440	0.875	31500	20958	0.750	33750	22500	0.934	0.551	0.969	1.0	42237	28158
DP4448	0.875	31500	20958	0.750	33750	22500	0.934	0.551	0.969	1.0	42237	28158
DP4460	0.875	31500	20958	0.750	33750	22500	0.934	0.551	0.969	1.0	42237	28158
DP6630	1.250	45000	29940	1.125	50625	33750	1.210	1.100	1.250	1.0	72000	48000
DP6640	1.250	45000	29940	1.125	50625	33750	1.210	1.100	1.250	1.0	72000	48000
DP6648	1.250	45000	29940	1.125	50625	33750	1.210	1.100	1.250	1.0	72000	48000
DP6660	1.250	45000	29940	1.125	50625	33750	1.210	1.100	1.250	1.0	72000	48000
DP6430	1.250	45000	29940	1.125	50625	33750	1.210	1.100	1.250	1.0	72000	48000
DP6440	1.250	45000	29940	1.125	50625	33750	1.210	1.100	1.250	1.0	72000	48000
DP6448	1.250	45000	29940	1.125	50625	33750	1.210	1.100	1.250	1.0	72000	48000
DP6460	1.250	45000	29940	1.125	50625	33750	1.210	1.100	1.250	1.0	72000	48000

(1) A_g is cumulative (two vertical steel plates), gross area of steel in tension

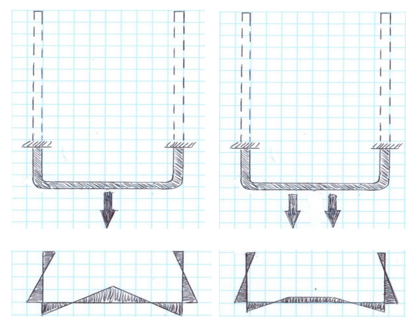
(2) A_e is cumulative (two vertical steel plates) effective net area of steel in tension; there are two 9/32" holes in each steel plate

TABLE 5C: DESIGN TENSILE STRENGTH AND ALLOWABLE TENSILE STRENGTH (Cont…)									
Tensile Strength of Deck Post as Defined by the Bending Strength Of Saddle Steel Bracket									
Model ID	Width[1] (in)	Length (in)	Height (in)	Z[2] (in^3)	ϕM_n (in-lb)	M_n / Ω (in-lb)	k[3] (in^2)	ϕT_n[4] (in-lb)	T_n / Ω[4] (in-lb)
DP4430	3.625	3.50	5.0	0.014	492	327	0.5148	956	636
DP4440	3.625	3.50	5.0	0.014	492	327	0.5148	956	636
DP4448	3.625	3.50	5.0	0.014	492	327	0.5148	956	636
DP4460	3.625	3.50	5.0	0.014	492	327	0.5148	956	636
DP6630	5.625	5.00	7.0	0.020	703	468	0.4242	1658	1103
DP6640	5.625	5.00	7.0	0.020	703	468	0.4242	1658	1103
DP6648	5.625	5.00	7.0	0.020	703	468	0.4242	1658	1103
DP6660	5.625	5.00	7.0	0.020	703	468	0.4242	1658	1103
DP6430	6.125	5.00	7.0	0.020	703	468	0.5456	1289	857
DP6440	6.125	5.00	7.0	0.020	703	468	0.5456	1289	857
DP6448	6.125	5.00	7.0	0.020	703	468	0.5456	1289	857
DP6460	6.125	5.00	7.0	0.020	703	468	0.5456	1289	857

(1) Beam/Post pocket width

(2) Z is plastic section modulus = (Length)(t^2) / 4

(3) Factor "k" represents the maximum moment found anywhere in the steel bracket under 1 pound of tension force (with two rebar, the tension force is a sum of two individual forces from rebar). This factor was determined using a two dimensional computer model for each Deck Post model and equals Moment divided by total applied downward force, k = M/F.

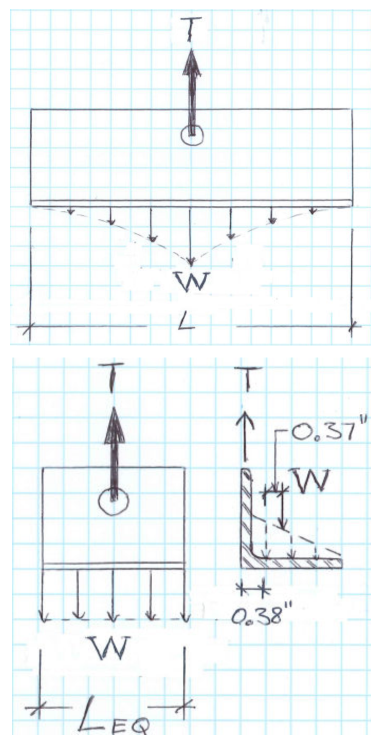


(4) Tension strength as defined by the bending strength of the steel saddle bracket is determined using the following expressions: $\phi T_n = \phi M_n/k$, $T_n / \Omega = (M_n/k) / \Omega$

TABLE 5D: DESIGN TENSILE STRENGTH AND ALLOWABLE TENSILE STRENGTH (Cont..)									
Tensile Strength of Deck Post as Defined by the Bending Strength Of Uplift Steel Angles									
	L	**L_{EQ}**	**Z**	**N_a**	**ϕM_n**	**M_n / Ω**	**x**	**ϕT_n**	**T_n / Ω**
Model ID	**(in)**	**(in)**	**(in^3)**		**(in-lb)**	**(in-lb)**	**(in)**	**(in-lb)**	**(in-lb)**
DP4430	8.000	3.10	0.012	2	392	261	0.37	2121	1411
DP4440	8.000	3.10	0.012	2	392	261	0.37	2121	1411
DP4448	8.000	3.10	0.012	2	392	261	0.37	2121	1411
DP4460	8.000	3.10	0.012	2	392	261	0.37	2121	1411
DP6630	8.000	3.10	0.012	2	392	261	0.37	2121	1411
DP6640	8.000	3.10	0.012	2	392	261	0.37	2121	1411
DP6648	8.000	3.10	0.012	2	392	261	0.37	2121	1411
DP6660	8.000	3.10	0.012	2	392	261	0.37	2121	1411
DP6430	8.000	3.10	0.012	2	392	261	0.37	2121	1411
DP6440	8.000	3.10	0.012	2	392	261	0.37	2121	1411
DP6448	8.000	3.10	0.012	2	392	261	0.37	2121	1411
DP6460	8.000	3.10	0.012	2	392	261	0.37	2121	1411

(1) L is actual length of steel angle

(2) L_{EQ} is the equivalent length or the effective length of the steel angle where the downward forces of the resisting soils are equated to a uniformly distributed load. From the perspective of the flexural stiffness, in views parallel and perpendicular to the angle's long axis, the soil resistance forces are expected to have a linear distribution, starting with zero value at least rigid locations (free ends) and increasing to the maximum value at most rigid locations (center, vertex). The torsional stiffness of the angles, however, also affects the soil load distribution along the angle's length - torsional stiffness is highest near the bolt and lowest near the free ends - resulting in a non-linear load distribution as shown in the figure on the right. The L_{EQ} is therefore approximated to be little under L/2. The results of this method are consistent with the finite element analysis performed in earlier calculations



(3) Z is the plastic section modulus along the L_{EQ} length of one angle = $L_{EQ}\, t^2 / 4$

(4) N_a is the quantity of angles per deck post

(5) x is the distance between downward force W and the location where the thickness of the steel angle starts to increase (near vertex), see the figure on the right. This is the point where the ratio between the bending forces and the bending strength is the greatest. From this point, the bending forces continue to increase linearly, while the bending strength of the steel angle (leg), increases exponentially.

(6) The design tensile strength and the allowable tensile strength, as defined by the bending strength of the steel angles, is determined as follows: $\phi T_n = \phi M_n / x$, $T_n/\Omega = (M_n / \Omega) / x$

6. PERMA-COLUMN DECK POST - CONNECTION TO WOOD BEAMS & COLUMNS

The uplift and horizontal forces are transferred from the wood beam or column into the Perma-Column Deck Post steel bracket through the wood screws. The screws are installed into wood from each side of the steel bracket and are loaded in single shear. The unthreaded screw diameter is 0.25 inches; the minor root diameter is 0.200-0.206 inches. The unthreaded screw segment is only 1/2 of an inch long - too short to be considered effective. Instead, the shear strength of each screw is determined using the minor root diameter of the screw which is most similar to a #14 wood screw as defined in the National Design Specification for Wood Construction (NDS). The following calculations are based on a #14 3 inch long wood screw using NDS Table 12M.

The fastener falls into the "wood screw" category; therefore, the lateral (shear) strength for load directions parallel and perpendicular to wood grain is the same. Only the applicable NDS adjustment factors are included in this report. The calculations are completed in Microsoft Excel (2016) using the listed equations.

GOVERNING CODE:

National Design Specification for Wood Construction, NDS

GOVERNING EQUATIONS:

Design Shear Strength of Connection	$\phi Z'N = \phi\ N\ Z\ C_M\ C_\Delta\ K_F\ \lambda$	NDS Table 11.3.1
Allowable Shear Strength of Connection	$Z'N = N\ Z\ C_D\ C_M\ C_\Delta$	NDS Table 11.3.1

Z = Unadjusted reference lateral (shear) design value for one fastener	NDS Table 12M
Z' = Adjusted lateral design value for one fastener	NDS Table 11.3.1
ϕ = LRFD resistance factor	NDS Table N2
λ = LRFD time effect factor	NDS Table N3
K_F = ASD to LRFD format conversion factor	NDS Table N1
C_D = ASD load duration factor	NDS Table 2.3.2
C_M = Wet service factor	NDS Table 11.3.3
C_Δ = Geometry factor	NDS 12.5.1
N = total quantity of fasteners in the connection	
(Only applicable factors are shown)	

CALCULATIONS:

ϕ =	0.65	C_D =	1.6	C_M =	0.7
λ =	1.0	K_F =	3.32	C_Δ =	1

TABLE 6: VERTICAL AND HORIZONTAL SHEAR STRENGTH OF STEEL-TO-WOOD CONNECTION (SCREWS)

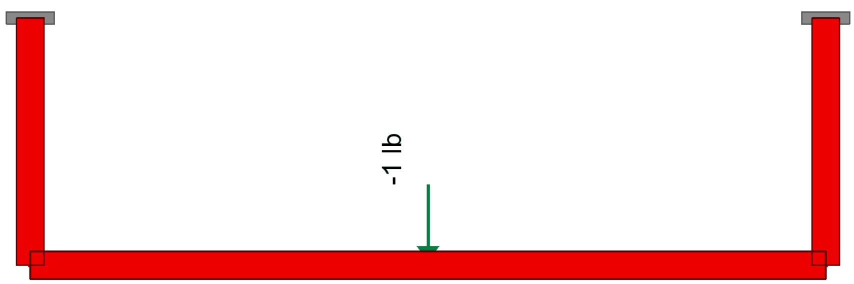
		Southern Pine Mixed Maple		Douglas Fir- Larch		Hem-Fir		Spruce-Pine-Fir		Western Cedars	
	SG =	0.55		0.50		0.43		0.42		0.36	
	Z =	183		170		150		147		130	
	Z' =	205		190		168		165		146	
	ϕZ' =	276		257		227		222		196	
Model ID	**N**	**ϕZ'N (lbf)**	**Z'N (lbf)**	**ϕZ'N (lbf)**	**Z'N (lbf)**	**ϕZ'N (lbf)**	**Z'N (lbf)**	**ϕZ'N (lbf)**	**Z'N (lbf)**	**ϕZ'N (lbf)**	**Z'N (lbf)**
DP4430	8	2212	1640	2054	1523	1813	1344	1776	1317	1571	1165
DP4440	8	2212	1640	2054	1523	1813	1344	1776	1317	1571	1165
DP4448	8	2212	1640	2054	1523	1813	1344	1776	1317	1571	1165
DP4460	8	2212	1640	2054	1523	1813	1344	1776	1317	1571	1165
DP6630	10	2764	2050	2568	1904	2266	1680	2221	1646	1964	1456
DP6640	10	2764	2050	2568	1904	2266	1680	2221	1646	1964	1456
DP6648	10	2764	2050	2568	1904	2266	1680	2221	1646	1964	1456
DP6660	10	2764	2050	2568	1904	2266	1680	2221	1646	1964	1456
DP6430	10	2764	2050	2568	1904	2266	1680	2221	1646	1964	1456
DP6440	10	2764	2050	2568	1904	2266	1680	2221	1646	1964	1456
DP6448	10	2764	2050	2568	1904	2266	1680	2221	1646	1964	1456
DP6460	10	2764	2050	2568	1904	2266	1680	2221	1646	1964	1456

APPENDIX A

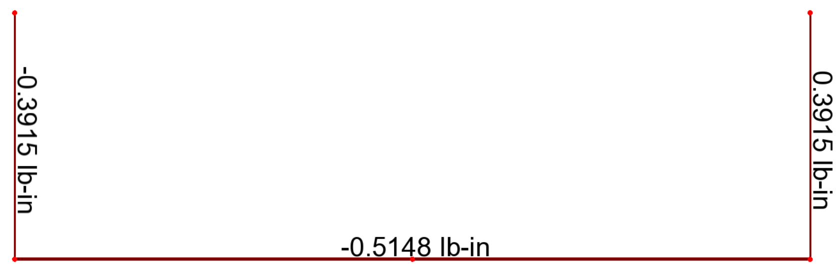
Determination of Bending Moment In Steel Saddle Bracket

Visual Analysis by IES, Inc
Version 12

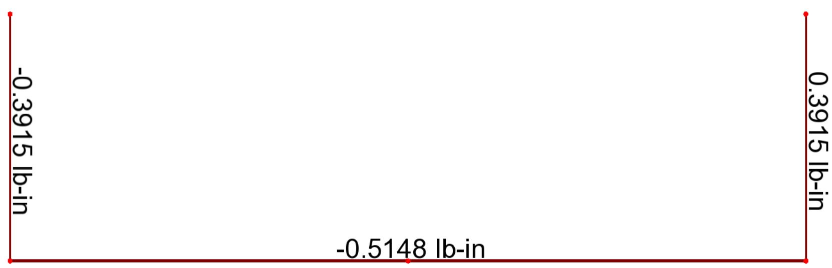
DP4430 & DP4440 Bracket - Uplift
TIMBER TECH ENGINEERING, INC., Dimitry A. Reznik
Mar 22, 2018; 04:02 PM
Load Case: L
IES VisualAnalysis 12.00.0020



DP4430 & DP4440 Bracket - Uplift
TIMBER TECH ENGINEERING, INC., Dimitry A. Reznik
Mar 22, 2018; 04:03 PM
Result Case: L
Member My, moment
IES VisualAnalysis 12.00.0020

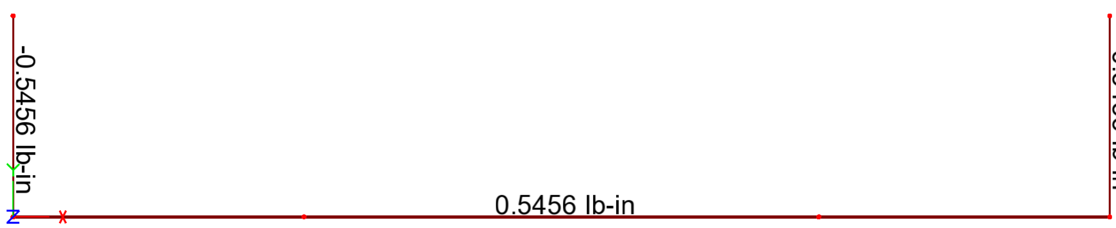


DP4640 Bracket - Uplift
TIMBER TECH ENGINEERING, INC., Dimitry A. Reznik
Mar 22, 2018; 04:10 PM
Result Case: L
Member My, moment
IES VisualAnalysis 12.00.0020



DP6430 & DP6440 Bracket - Uplift
TIMBER TECH ENGINEERING, INC., Dimitry A. Reznik
Mar 22, 2018; 04:06 PM
Load Case: L
IES VisualAnalysis 12.00.0020

DP6430 & DP6440 Bracket - Uplift
TIMBER TECH ENGINEERING, INC., Dimitry A. Reznik
Mar 22, 2018; 04:07 PM
Result Case: L
Member My, moment
IES VisualAnalysis 12.00.0020



DP6630 & DP6640 Bracket - Uplift
TIMBER TECH ENGINEERING, INC., Dimitry A. Reznik
Mar 22, 2018; 04:08 PM
Result Case: L
Member My, moment
IES VisualAnalysis 12.00.0020