Chapter 5

ECP Steel Piers™

Technical Design Manual

- **PPB-166 Slab Bracket System**
- **PPB-200 Under Footing Pier System**
- **PPB-250 Under Footing Pier System**
- **PPB-300 ECP Steel Pier™ System**
- **PPB-350 ECP Steel Pier™ System**
- **PPB-400 ECP Steel Pier™ System**

ECP Steel Pier™ Design

EARTH CONTACT PRODUCTS
"Designed and Engineered to Perform"

Earth Contact Products, LLC reserves the right to change design features, specifications and products without notice, consistent with our efforts toward continuous product improvement. Please check with Engineering Department, Earth Contact Products to verify that you are using the most recent information and specifications.

Introduction

The ECP Steel Pier™ belongs to a family of underpinning products that are sometimes referred to as micropiles, push piers, or resistance piers. These underpinning products are hydraulically driven into the soil using the structural weight of the building as a reaction force. A friction reduction collar is attached to the bottom end of the lead section of pier pipe. The purpose of the collar is to create an opening in the soil that has a larger diameter than the pier pipe that follows. This dramatically reduces the skin friction on the pier pipe as it is driven into the soil. This feature allows the installer to load test and to verify that the pier has encountered firm bearing stratum or rock that is suitable to support the design load.

The ECP Steel Pier™ like other resistance piers is an end-bearing pier that does not rely upon, nor requires, skin friction to produce support. Each pier is field load tested after it is installed. The piers are able to develop a factor of safety because the piers are installed and load tested individually using the structural weight from a large part of the building as a reaction force. The ability of the system to develop a significant factor of safety comes from the much higher load the pier during pier installation and a lower load when the lifting load is transferred to the pier during restoration. The piers are driven one at a time using the weight of the entire structure as the reaction during the installation. During load transfer and restoration, hydraulic jacks are placed at multiple pier locations, which places only the lower design/working load on each pier.

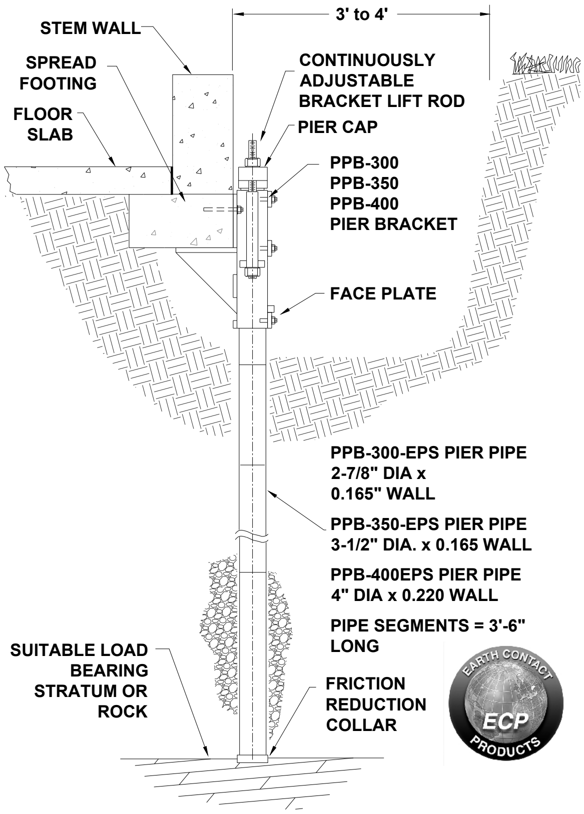


Figure 1. Typical configuration for the ECP Steel Pier™ System with Type PPB Utility Bracket attachment to the footing.

A building with substantial construction and rigidity can develop greater factor safety on each pier than a structure with a weaker, more flexible structure.

Features and Innovations

The patented ECP Steel Pier™ is the fourth generation of a product invented by Don May dating back to the 1970's. This resistance steel pier incorporates many advances over previous versions. An important improvement to the ECP Steel Pier™ system is a reduction in the eccentricity between centerline of the pier pipe and the foundation bracket. This means that there is less moment (twisting) at the pier bracket when in is loaded. This feature translates to greater load capacities. The system offers nearly unlimited elevation recovery as the adjustment of the pier bracket elevation is accomplished by hex nuts attached to continuously threaded rods as opposed to the limitations imposed by the use of shims and pins on other systems. The ECP Steel Pier™ is also more "installer friendly" because the inner chamber of the drive stand is quickly accessible by temporarily removing face plates on the pier bracket and drive stand. In addition, a pier alignment guide is integral with one of the drive stand face plates. The addition of a retaining plate that safely secures the heavy hydraulic drive cylinder to the drive stand is a large advancement for operator safety. The drive cylinder had a tendency to work loose in earlier designs. Other than a control sleeve that is only used on the PPB-350, all of the pier brackets are designed to securely align and guide the pier pipe without additional tools.

Another innovation on the ECP PPB-300 & PPB-350 Steel Pier™ Systems is the patented "Inertia Sleeve". This state of the art method of increasing the moment of inertia (stiffness) of the pier pipe and the "Inertia Sleeve" strengthens the coupled joints, which is unmatched in the industry. The pier pipe and "Inertia Sleeve" combination produces a more rigid pier system with a higher moment of inertia (stiffness) than the pier pipe alone.

The "Inertia Sleeve" does not carry any of the axial compressive pier load; the function of this product is only to increase pier stiffness in weak soils to prevent buckling. (See Figure 3, next page)

The "Inertia Sleeve" consists of a piece of pipe that fits snugly inside the existing pier pipe. At one end the "Inertia Sleeve" has a nine inch long coupling that fits through, and spans across, the coupled pier joint. The "Inertia Sleeve" is installed concurrent with the pier pipe installation and only takes the time necessary to pick up the "Inertia Sleeve" product and to let it drop by gravity into the current pier section prior to installing the next section of pier pipe.

The installed cost of this pier strengthening product is hardly more than the purchase price of the "Inertia Sleeve" product, yet it creates a stiffer pier system that is more resistant to buckling when installed through weak soil.

Product Benefits

- **Ultimate-Limit Capacities: Up to 115,000 lb.**
- **Proof Test Loads: Up to 86,000 lb.**
- **Standard Lift – 4" Fully Adjustable**
- **Greater Lift Capability With Optional Longer Bracket Rods**
- **Installs From Outside or Inside the Structure**
- **Installs With Portable Hydraulic Equipment**
- **Installs With Little or No Vibration**
- **Friction Reduction Collar On Lead Pier Section Reduces Skin Friction**
- **Installs To Rock or Verified End Bearing Stratum**
- **100% of Piers Are Field Load Tested to Verify Capacity During Installation**
- **Manufacturer's Warranty**

Pier Installation Sequences

Quiet vibration free hydraulic equipment is used to install ECP Steel Piers™. All installation equipment is portable and can be carried in a wheelbarrow. After all of the piers are installed and load tested, the structure can be immediately restored by transferring the structural load to the piers. There are no days wasted waiting for concrete to cure and no soil to transport from the site. A measured factor of safety is verified, as the piers are 100% load tested to a force greater than the actual working load prior to being put in service.

Projects are usually completed in days, not weeks. Should geologic conditions change, the piers can be easily inspected, tested and/or adjusted.

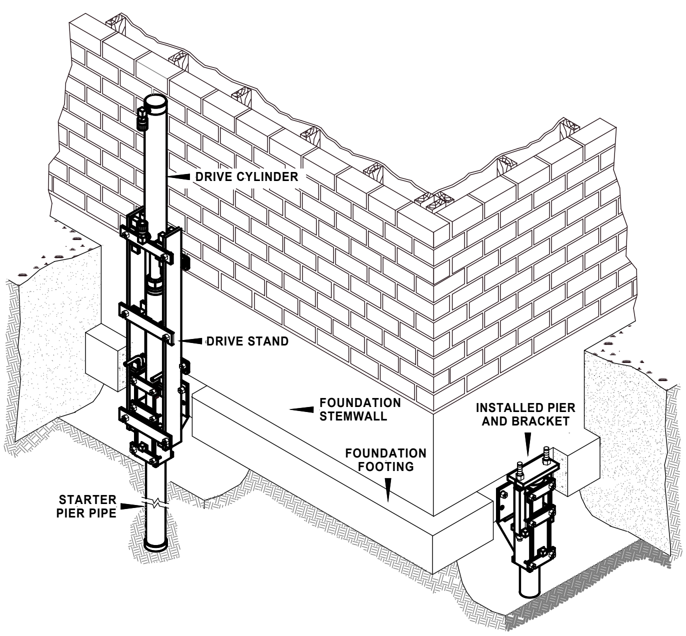


Figure 2. Typical Steel Pier™ Installation with Utility Bracket.

PPB Utility Bracket Installation

The following nine steps illustrate the typical installation procedure for the PPB-300, PPB-350 or PPB-400 Utility Bracket. Figure 2 shows a structure with a spread footing. The detail on the left side of Figure 2 illustrates the configuration used when installing the resistance pier system and driving the pier pipe. On the right side of Figure 2 is the configuration of the installed pier system following the transfer of the structural load to the pier. Please contact ECP engineering department for *ECP Typical Specifications* that provide the specific and detailed product installation requirements and procedures.

1. **Site survey:** Pier placements are determined and locations of all underground utilities are verified.
2. **Excavation:** Small excavations are dug for access at each placement location. The excavation required at the foundation is usually about 3 feet square.
3. **Preparation of the foundation:** The footing is notched (if required) to situate the pier bracket under the stem wall. The bearing area under the footing is chipped a smooth and level condition and the face of the stem wall is adjusted to vertical (plumb) at the point of bracket attachment.
4. **Utility Bracket Attachment:** The utility bracket is secured to the footing using two anchor bolts. Then the drive stand and the hydraulic cylinder are mounted to the bracket. (Shown on left side of Figure 2.)
5. **Pier Pipe Installation:** The piers may be installed from outside or inside the structure. The pier pipe is advanced into the soil using a small portable high-pressure hydraulic pump. The pier pipe is 3-1/2 feet long so low overhead clearance is not a problem during installation. Pier installation continues until rock or suitable bearing is encountered below the unstable soil near the surface.
6. **Proof Load Test:** Every pier is load tested to insure that rock or other firm bearing is verified to be substantial enough to withstand a load greater than required to restore and support the structure. The structure provides the reaction force for installing and testing. Typically Factor of Safeties from 1.25 to 3.0 can typically be generated.
7. **Preparations for Restoration:** Once all piers have been installed, load tested, and the installation data recorded; lifting head assemblies and hydraulics are placed at the placements, which are connected to one or more manifolds and hydraulic hand pumps.
8. **Restoration:** Under careful supervision, the structural load is transferred from the failing soil under the foundation to the steel pier system. The structure is gently and evenly lifted to the specified design elevation. The nuts at the pier caps are secured at each placement and the lifting equipment is removed. (Please see Figure 1.)
9. **Clean Up:** The soil that was excavated at each pier placement location is replaced and compacted. The site is left clean and neat.

PPB Utility Bracket Components

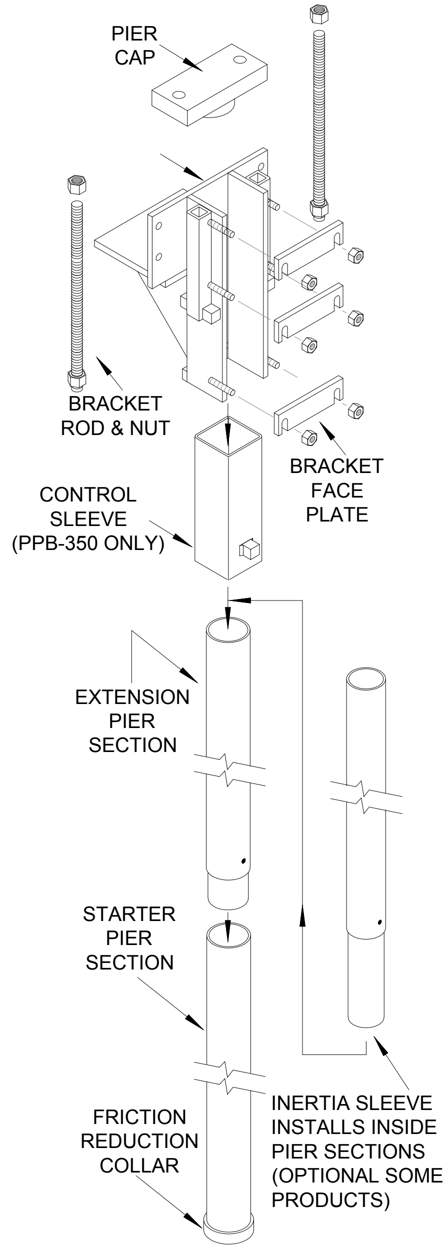


Figure 3. Component configuration for typical PPB-300, PPB-350 & PPB-400 Utility Brackets

PPB-166 Slab Jack Installation

The following nine steps illustrate the typical installation procedure for the ECP PPB-166 Slab Jack Bracket. Figure 4 shows the configuration used to install the pier pipe and the installation tools mounting configuration. Please contact ECP engineering department for *ECP Typical Specifications* that provide the specific and detailed product installation requirements and procedures.

1. **Site survey:** Pier placements are determined and locations of all underground utilities verified.
2. **Core Drill/Excavation**: Core drill an eight inch diameter hole through the slab. Excavate soil below hole to a depth of 14 to 16 inches.
3. **PPB-166 Bracket Placement:** The Bearing Plate shall be temporarily placed on the soil at the bottom of the hole and aligned with the center of the hole in the concrete. The drive stand and hydraulic cylinder are connected to the bracket using 3/4 inch diameter B7 all-thread rods.
4. **Pier Pipe Installation:** Each three foot long section of pier pipe is advanced into the soil using a portable high-pressure hydraulic pump. Overhead clearance is usually not a problem when using short pier sections. The pier pipe is advanced into the soil until rock or suitable bearing is encountered below the failing unstable soil directly under the slab.
5. **Proof Load Test:** Every pier is load tested to insure that rock or other firm bearing is verified to be substantial enough to withstand a load greater than required to restore and support the slab. Some slabs can provide sufficient reaction force for installation and testing, but supplement weights around the access hole are sometime necessary to develop addition reaction force and to reduce slab stress cracks. Tests typically apply no more than 75% of the ultimate capacity.
6. **Preparations for Restoration:** Once pier pipe has been installed, load tested, and the data recorded for all placements; the all of the bearing plates, lifting head assemblies and hydraulics are installed on the piers. Hydraulic rams are connected to one or more manifolds and hydraulic hand pumps.

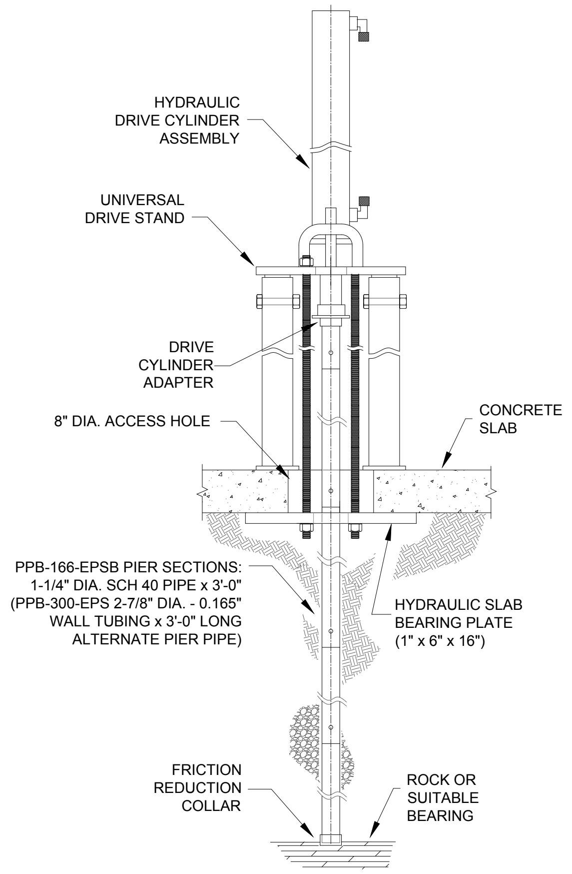
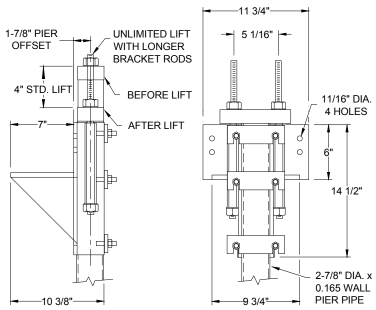


Figure 4. PPB-166 Slab Jack installation configuration

7. **Restoration:** Under careful supervision, the load is transferred from the failing soil under the slab to the steel pier system. The slab is gently and evenly lifted to as close to the original elevation as the construction will allow or to the specified elevation. The nuts at the pier caps are secured at each placement, and then the lifting equipment is removed.
8. **Filling the Voids:** A lean concrete mud slurry (2-1/2 sack mix) shall always be pumped under low pressure to fill all voids created when the slab was lifted.
9. **Clean Up:** The soil that was excavated from each pier placement shall be removed and disposed of in a safe and legal manner. The core drilled holes shall be filled with structural concrete and finished to match the existing floor. The site shall be left clean and neat.

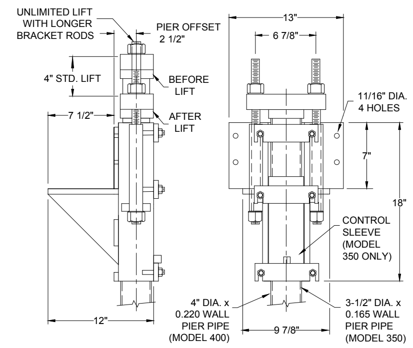
ECP Steel Pier™ – Product Configurations

A. PPB-300 Utility Bracket



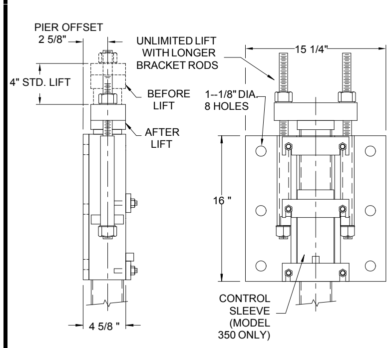
Ultimate-Limit Bracket Capacity
79,000 pounds

B. PPB-350-400 Utility Bracket



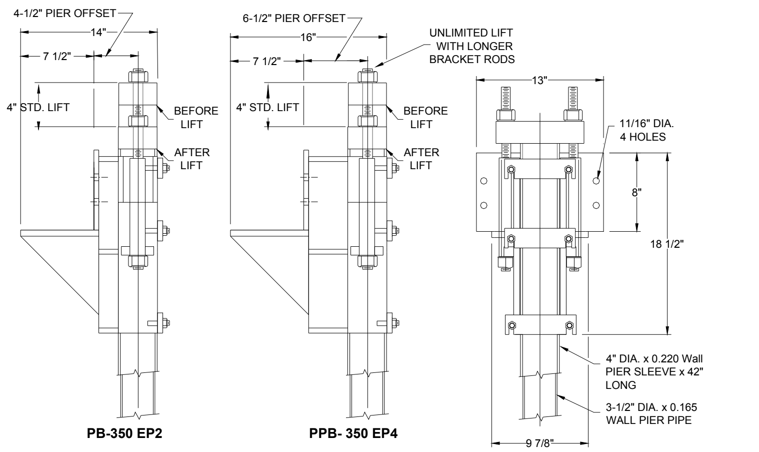
Ultimate-Limit Bracket Capacity
99,000 pounds

C. PPB-350-400-WM Wall Bracket



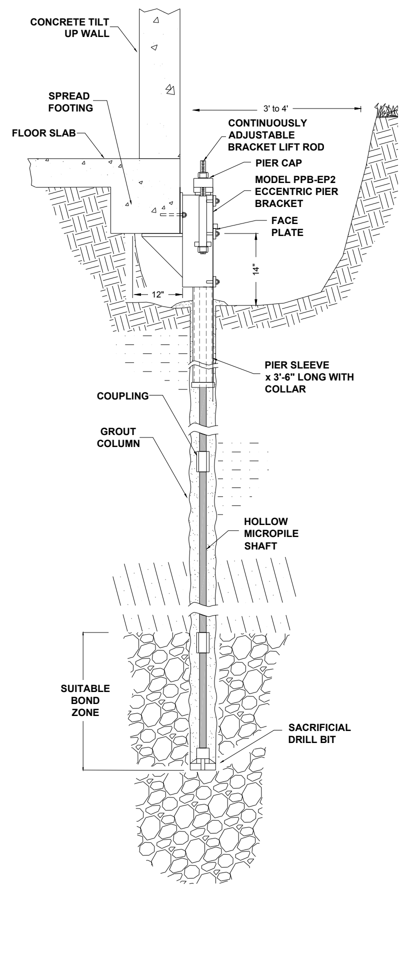
Ultimate-Limit Capacity
Std. Bracket: 107,000 pounds
PPB-400 WM HD Bracket
115,000 pounds (Not Shown)

D. PPB-350-EP2 & PPB-350-EP4 Eccentric Bracket



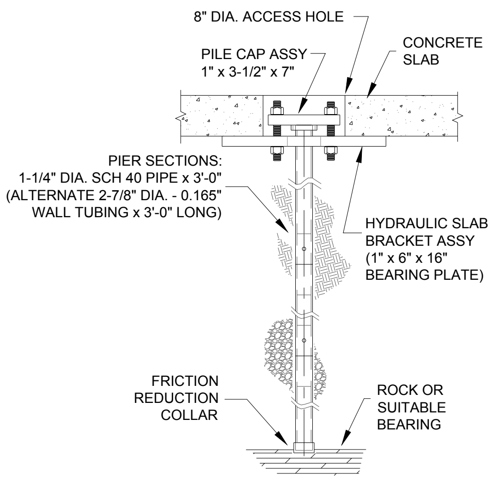
Ultimate-Limit Bracket Capacity: EP2 - 68,000 lb – EP4 - 55,000 lb

E. PPB-350-MP2 Micro Pile



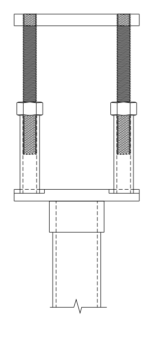
Ultimate-Limit Bracket Capacity
68,000 pounds

F. PPB-166 Slab Jack Bracket Assembly



Ultimate-Limit Bracket Capacity: 22,000 lb
(Pier Pipe Sold Separately)

G. PPB-200 & PPB-250 Under Footing Bracket



Ultimate-Limit Bracket Capacities:

PPB-200 - 50,000 pounds
PPB-250 - 54,000 pounds
(PPB-250 similar, not shown)

Table 1.	ECP Steel Resistance Pier System Ratings				
Fig	Product Designation – Pipe Size	Ultimate-Limit [1] Bracket Only Capacity	Ultimate-Limit [1] Mechanical System Capacity	Maximum Drive Force - "Proof Test" [2]	Recommended Design / Service Load
A	PPB-300 Steel Pier – 2-7/8" dia x 0.165" Wall	79,000 lb	68,000 lb	51,000 lb	34,000 lb
B	PPB-350 Steel Pier – 3-1/2" dia x 0.165" Wall	99,000 lb	86,000 lb	64,500 lb	43,000 lb
B	PPB-400 Steel Pier – 4" dia x 0.220" Wall	99,000 lb	99,000 lb	74,000 lb	49,500 lb
C	PPB-350-WM – 3-1/2" dia x 0.165" Wall	107,000 lb	86,000 lb	64,500 lb	43,000 lb
C	PPB-400-WM – 4" dia x 0.220" Wall	107,000 lb	107,000 lb	80,000 lb	53,500 lb
--	PPB-400- WMHD – 4" dia x 0.220" Wall	115,000 lb	115,000 lb	86,000 lb	57,500 lb
D	PPB-350-EP2 – 3-1/2" dia x 0.165" Wall	68,000 lb	53,000 lb	39,750 lb	26,500 lb
D	PPB-400-EP2 – 4" dia x 0.220" Wall	68,000 lb	54,000 lb	40,500 lb	27,000 lb
D	PPB-350-EP4 – 3-1/2" dia x 0.165" Wall	55,000 lb	42,000 lb	31,500 lb	21,000 lb
E	PPB-350-MP2 – Micro Pile Bracket	68,000 lb	Note: Capacity depends upon drill dia, bar dia & grout strength		
F	PPB-166 – Slab Jack – 1-1/4" Sch. 40[3]	22,000 lb	22,000 lb	16,500 lb	11,000 lb
G	PPB-200 – Ftg Bracket – 2-7/8" dia x 0.165" Wall	50,000 lb	50,000 lb	37,500 lb	25,000 lb
--	PPB-250 – Ftg Bracket – 2-7/8" dia x 0.165" Wall	54,000 lb	54,000 lb	40,500 lb	27,000 lb

1. Unfactored Failure Limit, use as nominal, "P_n" value per design codes 2. Maximum recommended load to confirm suitable end bearing capacity of pipe
3. Alternate pier pipe – 2-7/8" dia x 0.165" Wall

"Suitable Load Bearing Stratum"

While field load testing of each resistance pier verifies that the pier has encountered suitable end bearing, several definitions can be found for the word "*Rock*". Many times when a soil boring log is available one may want to estimate the approximate depth to load bearing. Presented here are guidelines to assist with the estimating depth to suitable bearing.

When material described in a soil boring reflects a Standard Penetration Test, "N", greater than 50 blows per foot, we generally consider the material to be "rock" or a very hard soil stratum.

Field load tests over the years have confirmed that resistance piers will provide long term support in strata such as these. In many cases suitable bearing can be achieved in less dense material depending upon the pile loading requirements, the type of soil and the soil density.

Thousands of comparisons between soil boring logs and field load tests suggest that *Suitable Load Bearing* is generally achieved in soils where "N" > 35 blows per foot at the termination depth.

Why Determine Structural Loads?

Before one can begin to prepare a foundation underpinning design, an accurate estimate of the foundation loading is required. All loads that are placed upon a structure eventually transfer to the soil through the foundation. Many times all of these loads are not considered during the design. This can lead to an underestimation of the total structural load on the foundation. The result may be a design that has insufficient strength to support and restore the structure. Several problems surface when underestimated structural loads are used for the project design. The first indication of a problem is when the structure cannot be lifted, whereby the contractor usually tries to explain away the problem by saying that he is only trying to "stabilize" the structure or that there is too much "suction" under the slab. Other indications of underestimated foundation loads are the appearance of new foundation fractures and/or continued settlement of the underpinning piers after project completion.

The cost to the foundation contractor due to improperly estimating structural loads can be high. First and foremost is the likelihood of a customer complaint and lack of referrals. In addition, expensive callbacks cut into the company's profits. Finally, the long term solution usually involves installing additional underpinning between the existing piers, which means that the project could easily cost the contractor twice as much as originally planned.

Simplified Tables of Structural Foundation Loads

When attempting a foundation load calculation for the first time, it often seems complicated and imposing. Once the basics are learned, estimating structural loads is quite easy. The simplest way to prepare a foundation load estimate is to break the structure into components, determine the estimated weight for each component and then add all of the results together. The simplified tables below have been prepared for the most common residential structural elements. (See note regarding Building Codes after Table 7 below.)

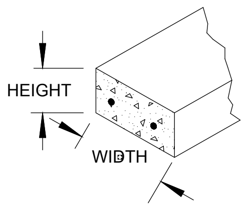


Table 2. Reinforced Concrete Spread Footings

HEIGHT \ WIDTH	8”	12”	15”	18”	20”	24”
	Perimeter Weight – lb/ft					
6”	24	72	90	108	120	144
9”	72	108	135	162	180	216
12”	96	144	180	216	240	288
15”	120	180	225	270	300	360
18”	144	216	270	324	360	432
20”	160	240	300	360	400	480
24”	192	288	360	432	480	576

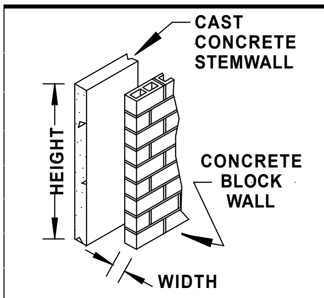


Table 3. Walls, Stem Walls, Basement Walls

WALL WIDTH \ WALL HEIGHT	18”	24”	36”	48”	96”	108”
	Perimeter Weight – lb/ft					
6” Conc. Block	65	86	129	172	344	387
8” Conc. Block	83	110	165	220	440	495
8” Cast Concrete	144	192	288	384	768	964
10” Cast Concrete	180	240	360	480	960	1,080
12” Cast Concrete	216	288	432	576	1,152	1,296

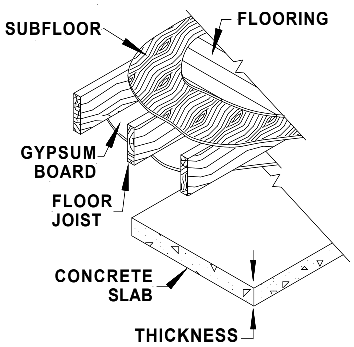


Table 4. Wood Floors & Concrete Slabs

Wood Floor – Span To Girder (2 X 6 or 2 X 8 Joist Framing @ 12” O.C.)	8’	10’	12’	14’	16’
	Perimeter Weight – lb/ft				
3/4” Sub Floor , 3/4” Hardwood & 1/2” Gypsum	48	60	78	91	96
1-1/2” Sub Floor, Carpet, Pad & 1/2” Gypsum	52	65	84	98	104
1-1/2” Sub Floor, 1/4” Ceramic Tile, 1/2” Gypsum	64	80	102	119	128

Concrete Slab	Perimeter Weight
4” Slab – Unfinished	191 lb/ft
4” Slab, Carpet & Pad	195 lb/ft
4” Slab & 1/4” Ceramic Tile	198 lb/ft
6” Slab – Unfinished	432 lb/ft

Table 5. Exterior Walls (8 ft tall)

		Perimeter Weight
Conc. Block	8” Heavy Weight Concrete Block, 1/2” Drywall & Insulation Fill (Not Illustrated)	425 lb/ft
Conc. Block Brick Veneer	8” Heavy Weight Concrete Block, Clay Brick, 1/2” Drywall & Insulation Fill	815 lb/ft
Wood Frame	1/2” Ship Lap or Plywood, 1/2” Sheathing, 2 x 4 Studs @ 16” o.c., 1/2” Drywall & 3-1/2” Insulation	88 lb/ft
Stucco Veneer	1-1/2” Concrete Stucco, 2 x 4 Studs @ 16” o.c., 1/2” Drywall & 3-1/2” Insulation	200 lb/ft
Brick Veneer	Clay Brick, 1/2” Sheathing, 2 x 4 Studs @ 6” o.c., 1/2” Drywall & 3-1/2” Insulation	390 lb/ft

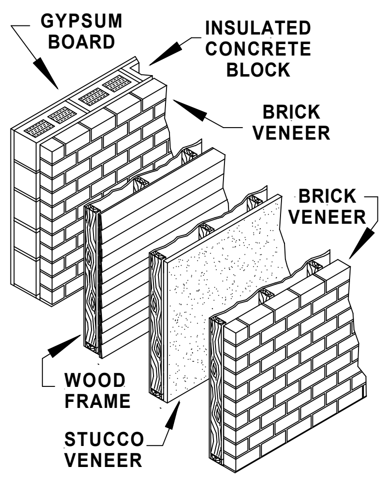
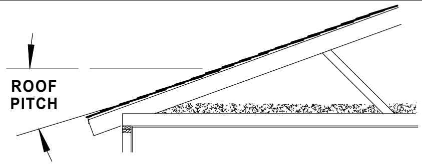


Table 6.	**Roof & Ceiling**				
	**Roof** -- Rafter Framing (2 X 6 or 2 X 8 @ 12" O.C.), 1/2" Wafer Decking, 15# Felt, & 240# Asphalt Shingles (1' Roof Overhang) **Ceiling** – Joist Framing (2 X 6 or 2 X 8 @ 12" O.C.), 1/2" Dry Wall & 10" Blown Insulation (No Attic Storage)				
ROOF PITCH \ SPAN TO INTERIOR SUPPORT	8'	10'	12'	14'	16'
	Perimeter Weight – lb/ft				
2" in 12"	91	116	143	164	185
3" in 12" or 4" in 12"	92	123	145	166	187
6" in 12"	95	127	149	171	193
12" in 12"	107	154	168	193	218

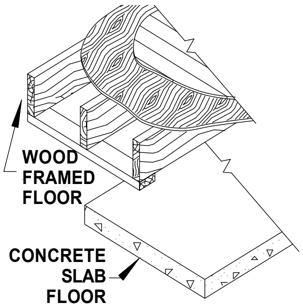


Table 7.	**Live Loads on Floors And Attics**				
Residential Occupant Live Loads – Span to Interior Support or Girder	6'	8'	10'	12'	14'
	Perimeter Weight – lb/ft				
First Floor – Wood Framing -- 40 lb/ft²	120	160	200	240	280
Second Floor -- 30 lb/ft²	90	120	150	180	210
Habitable Attics -- 30 lb/ft²	90	120	150	180	210
Uninhabitable Attics -- 20 lb/ft²	60	80	100	120	140
4" Slab on Grade – 40 lb/ft²	120				

Reference: Excerpts from American Standard Building Code Requirements for Minimum Design Loads in Buildings – A58.1 – 1955

Note: Building techniques and Codes vary across the country; these tables are only to be used as a general guide for structural load estimations on preliminary design work. When in doubt about the construction elements, add 10% to 20% to load estimate or increase factor of safety of the design to 2.2 to 2.5 for "Safe Use" Design.

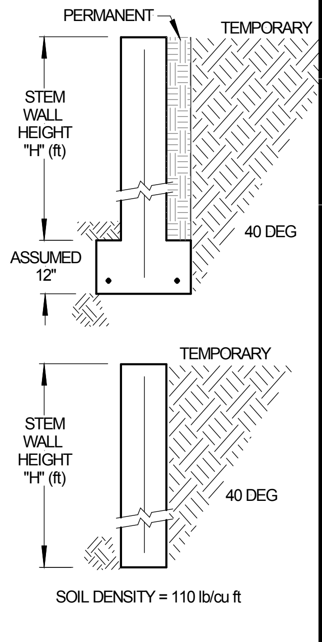
Estimating Structural Loads

Two structural loads are usually specified in the design. "Dead Loads" are permanent weights that are always applied to the foundation. Examples of *Dead Loads* are loads associated with components like the roof framing, the floor structure and the masonry. "Live Loads" are weight on the foundation that can change. *Live Loads* are the weights associated with the occupants, storage, snow and wind pressure, etc. The goal is to achieve an accurate estimated weight along the perimeter of the structure where foundation restoration is needed. The easiest way to accomplish a foundation load estimate is to break the structure into components, estimate weight for each component and then add all of the results together. Tables 2 through 9 provide estimated component loads on a foundation perimeter. One only needs to inspect the structure and be familiar with typical building codes in the area to be able to use the tables provided to estimate the foundation load.

Benefits of Estimating Foundation Loads

- The design will be more accurate and there will be greater restoration success with less chance of a call back from the owner later.
- The designer will have greater confidence presenting his design to owners and engineers when he has prepared a load estimate.
- Pier placements are easily justified because the load analysis determines the pier placement design can provide immediate restoration and long term support.
- The owner will perceive the designer as being a more competent contractor because he is careful and thorough with the design, has attention to details, a solid design.
- Highly detailed proposals are generally more readily accepted than general repair outlines, which translate to more work for the company.
- There will be greater client satisfaction with the final product.

Table 8. Estimated Soil Loads on Footings



Permanent Soil Load on a Footing Toe – W_d

Soil Height Against Wall	2’	4’	6’	7’	8’	9’	10’
Soil Load per inch of Footing Width	18 lb	37 lb	55 lb	64 lb	73 lb	83 lb	92 lb

To determine the permanent soil load on a footing toe, multiply the actual width of the footing toe (in inches) by the unit weight shown above for the soil height against the wall.

Graph 1. Temporary Soil Load (One Side) – W_t

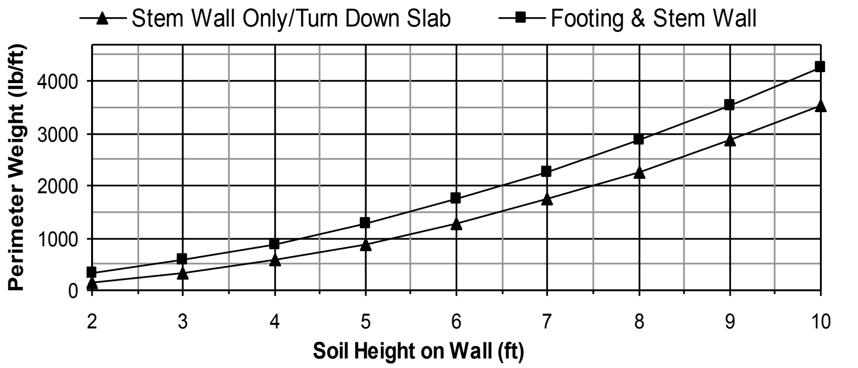


Table 9. Estimating Snow Loads*

0 – 18” Snow = 10 lb/ft²	19” – 38” Snow = 20 lb/ft²	39” – 57” Snow = 30 lb/ft²	58” – 76” Snow = 40 lb/ft²	77” – 96” Snow = 50 lb/ft²

Snow Load Along Perimeter Footing With Hip Style Roof – [(L x W) / 2 (L + W)] x (Snow Load Factor)

Snow Load Along Perimeter – Rafter Side of Roof With Gable Ends – (L x W / 2L) x (Snow Load)

– Gable End of Roof – [1.5 + (Roof overhang)] x (Snow Load)

L = Length of the perimeter wall to be underpinned -- W = Span of roof from exterior wall plus roof overhang

* Verify the locally approved Snow Load Factor with a Building Official in your area.

“Quick and Rough” Structural Load Estimating

Table 10 offers empirical load estimates over a range of typical residential construction techniques from light to heavily built structures.

The estimated loads presented in Table 10 are rough load estimates. Please use this data only for determining quick budget estimates.

Table 10. Ranges for Typical Average Residential Building Loads*

Building Construction (Slab On Grade)	Estimated Foundation Load Range (DL = Dead – LL = Live)	Building Construction (Basement or Crawlspace & Footing)	Estimated Foundation Load Range (DL = Dead – LL = Live)
One Story Wood/Metal/Vinyl Walls with Wood Framing -- Footing with Slab	DL 750 – 850 lb/ft LL 100 – 200 lb/ft	**One Story** Wood/Metal/Vinyl Walls with Wood Framing on Basement or Crawlspace and Footing	DL 1,250 – 1,500 lb/ft LL 300 – 475 lb/ft
One Story Masonry Walls with Wood Framing – Footing with Slab	DL 1,000 – 1,200 lb/ft LL 100 – 200 lb/ft	**One Story** Masonry Walls with Wood Framing on Basement or Crawlspace and Footing	DL 1,500 – 2,000 lb/ft LL 300 – 475 lb/ft
Two Story Wood/Metal/Vinyl Walls with Wood Framing – Footing with Slab	DL 1,050 – 1,550 lb/ft LL 300 – 475 lb/ft	**Two Story** Wood/Metal/Vinyl Walls with Wood Framing on Basement or Crawlspace and Footing	DL 1,400 – 1,900 lb/ft LL 600 – 950 lb/ft
Two Story 1st Floor Masonry, 2nd Wood/Metal/Vinyl with Wood Framing – Footing with Slab	DL 1,300 – 2,000 lb/ft LL 300 – 475 lb/ft	**Two Story** 1st Masonry, 2nd Wood/Metal/Vinyl – Wood Framing, Basement or Crawlspace & Footing	DL 1,650 – 2,200 lb/ft LL 600 – 950 lb/ft
Two Story Masonry Walls with Wood Framing – Footing with Slab	DL 1,600 – 2,250 lb/ft LL 300 – 475 lb/ft	**Two Story** Masonry Walls with Wood Framing on Basement or Crawlspace and Footing	DL 1,900 – 2,500 lb/ft LL 600 – 950 lb/ft

*** Table 10 load estimates DO NOT Include Snow Loads.**

Estimating Commercial Building Loads

Because commercial construction and building use is so varied, it is not practical to produce tables similar to Table 2 through Table 7 for commercial structures, but using the typical weights of common building materials provided in Table 11, the designer may be able to determine perimeter and footing loads from knowledge about the construction materials and techniques used to construct the building needing repair; simply use the component weights below to create weights for the structural elements to the building.

Table 11. Weights of Building Materials

Materials	Weight lb/sq. ft.	Materials	Weight lb/sq. ft.	Materials	Weight lb/sq. ft.
Brick Masonry:		**Wood Framing:**		**Roof:**	
4" Brick	40	2x4 @ 12 – 16" o.c.	2	Asphalt	3
8" Brick	80	2x6 @ 12 – 16" o.c.	3	Wood	2
12" Brick	120	2x8 @ 12 – 16" o.c.	4	3-ply Felt & Gravel	5-1/2
Concrete: (per inch thick)		**Sheathing:**		**Insulation** (per inch)	
Standard Concrete	12.5	1/2" Wood	2	Blown	1/2
Slag Concrete	11.5	3/4" Wood	3	Batts	3/4
Lightweight Concrete	6 to 10	1/2" Gypsum	2	Rigid	1-1/2
Soil:	**lb/cu. ft.**	**Floors:**		**Hollow Conc. Block:**	
Clay (Dry)	63	Vinyl	1	4" Light Wt	21
Clay (Damp)	110	7/8" Hardwood	4	4" Heavy Wt	30
Sand, Gravel (Dry, Loose)	90 - 105	3/4" Softwood	2-1/2	6" Light Wt	30
Sand, Gravel (Dry, Packed)	100 - 120			6" Heavy Wt	43
Sand, Gravel (Wet)	118 - 120	Carpet & Pad	2	8" Light Wt	38
Earth (Dry, Loose)	76			8" Heavy Wt	55
Earth (Dry / Wet, Packed)	95 - 96	3/4" Ceramic Tile	10	12" Light Wt	55
Earth (Mud, Packed)	115	1" Terrazzo	13	4" Stone	55

Reference: Excerpts from American Institute of Steel Construction, "Manual of Steel Construction" - 1989

Determining Pier Spacing

When locating piers on a structure, two factors must be considered that can limit the center-to-center distance between piers. The spacing between piers cannot be so large such that:

- **The spacing between piers exceeds the pier capacity. (*Pier Strength Spacing*)**
- **The spacing between piers overloads the footing. (*Footing Strength Spacing*)**

Equation 1: Pier Spacing

$$\text{"X"} = P_{DSL} / P_L \quad \text{or} \quad P_{DSL} = \text{"X"} \times P_L$$

Where:

"X" = Pier Spacing (ft)

P_{DSL} = Recommended Design / Service Load (Table 1)

P_L = Estimated Lifting Load

Pier Spacing Based Upon *Pier Strength*

The strength of the pier system is usually of concern when supporting and restoring a heavy structure such as a commercial building or a heavy, two-story residence with a full basement. **"Safe Design" dictates that the designer applies a suitable factor of safety.** Table 1 provides a quick reference to selecting a *Recommended Design / Service Load*. In other cases the Factor of Safety may be dictated by the project. Equation 1 is used to determine the pier spacing relative to pier capacity.

Pier Spacing Based Upon *Footing Strength*

The strength of the footing is of great importance in lighter structures. These structures generally have small footings with little or no rigid stem wall for strength. If Equation 1 were used to estimate the spacing for a single story with slab on grade, the result would suggest pier spacing at a distance that the footing cannot span. In Design Examples 3 in Chapter 6, a typical light structure is shown. Using Equation 1 to estimate the pier spacing for the structure in Design Example 3 would suggest 27 foot pier spacing, but the concrete slab foundation simply cannot support such a long span between piers. Therefore, in this case, **the foundation strength determines the maximum pier spacing**.

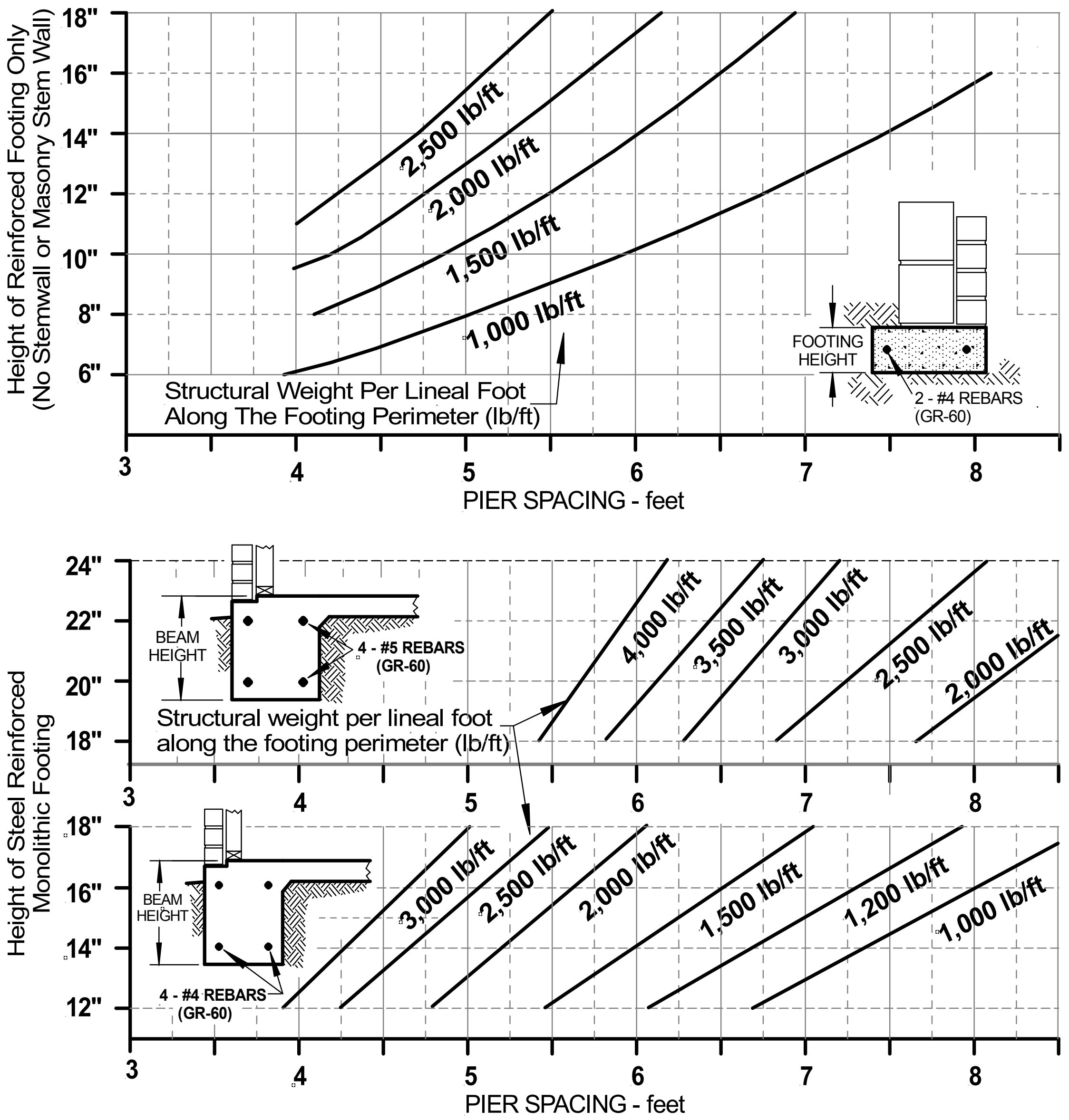
Graph 2 is provided to assist with estimating pier spacing when dealing with:

1. Monolithic ("turned down") footings and/or,
2. Steel reinforced spread footings with no stem wall or,
3. When hollow masonry stem walls are present.

Graph 3 is provided to help estimate pier spacing when estimating footings with steel reinforced footings with integral short concrete stem walls.

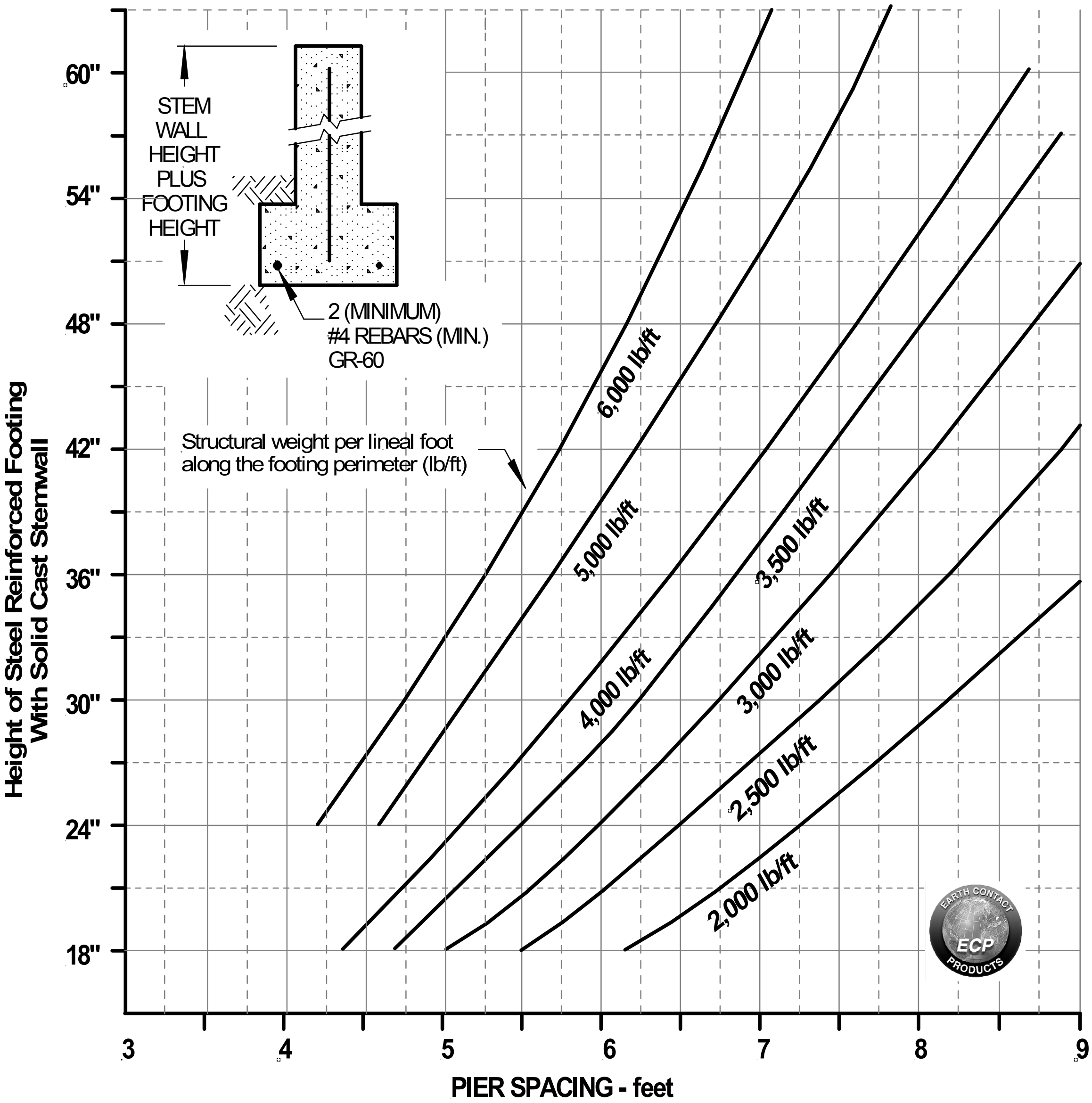
These graphs assume generally accepted construction techniques, adequate steel reinforcement that is properly embedded into the concrete, and concrete with a compressive strength of 3,000 psi or more after 28 days.

Graph 2. Graphs for Estimating Pier Spacing Based Upon Foundation Strength of Spread Footing or Monolithic Slab Only (No Stem Wall or Hollow Masonry Stem Walls)



Important: Building techniques and Building Codes vary across the country; the graphs presented here are to be used only as a general guide for spacing requirements, for preliminary designs, and for estimation purposes. It is recommended that a registered professional engineer conduct the final design and supervise the installation.

Graph 3. Graph for Estimating Pier Spacing Based Upon Foundation Strength of Spread Footing with Short Integrally Cast Concrete Stem Walls



Important: Building techniques and Building Codes vary across the country; the graphs presented here are to be used only as a general guide for spacing requirements, for preliminary designs, and for estimation purposes. It is recommended that a registered professional engineer conduct the final design and supervise the installation.

ECP Steel Pier™ Design

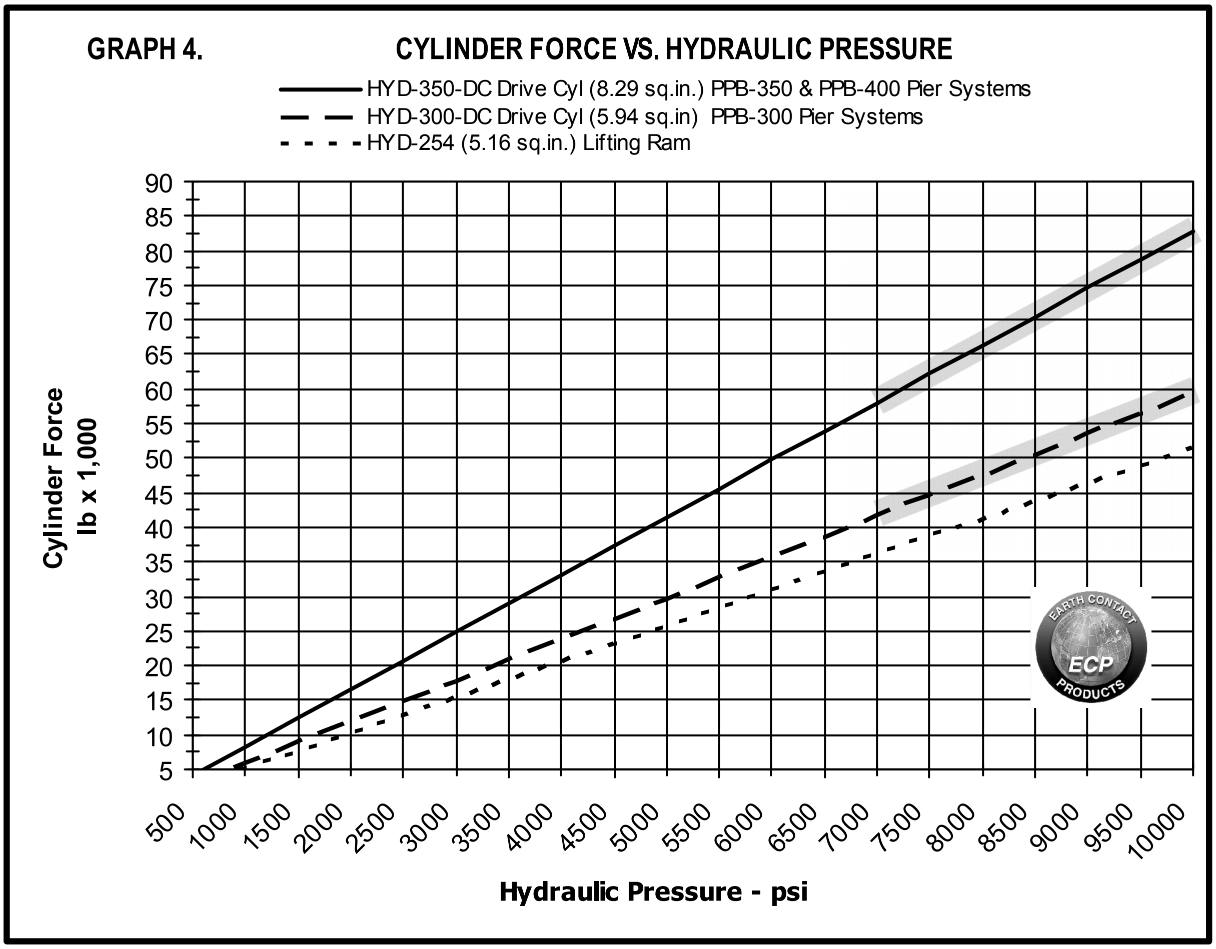
Technical Design Assistance

Earth Contact Products, LLC. has a knowledgeable staff that stands ready to help you with understanding how to design using ECP Steel Piers™, installation procedures, load testing, and documentation of each pier placement. If you have questions about structural weights, product selection or require engineering assistance in evaluating, designing, and/or specifying Earth Contact Products, please call 913 393-0007, Fax at 913 393-0008.

Pier Installation

Pier installation consists of forcing the pier pipe into the soil until end bearing resistance is encountered. Once this occurs, the strength of the bearing stratum is verified by load testing. The pier is subjected to a *proof load test* that is greater than the pier design (working) load.

Graph 4 below provides a quick reference to determine the actual downward force generated on the pier pipe at a various pressures on the drive cylinder.



GRAPH 4. CYLINDER FORCE VS. HYDRAULIC PRESSURE

When using other manufacturers drive cylinders, **Do Not Exceed 7,000 psi**. The shaded areas are restricted only for cylinders verified with the manufacturer to be rated above 7,000 psi. **All drive cylinders that ECP sells are rated to 10,000 psi.**

Caution!

Verify the manufacturer's recommended working pressure for the specific hydraulic drive cylinder to be used on a project prior to installing piers. When operating near the maximum cylinder pressure, the amount of actuator rod extension should be restricted to less than full length to prevent damage to the drive cylinder or actuator rod.

Equation 2: Hydraulic Cylinder Force

$$F_{Cyl} = A_{cyl} \times P_{cyl}$$

Where, F_{Cyl} = Cylinder force on pier – lb
P_{cyl} = Hydraulic Pressure -- psi
A_{cyl} = Effective Cylinder Area – in^2

- HYD-350-DC (3-1/2" & 4" dia)= 8.29 in^2
- HYD-300-DC (3" dia) = 5.94 in^2
- Lifting Ram = 5.16 in^2

Notice!
Earth Contact Products, LLC does not condone or recommend exceeding maximum working pressure ratings of hydraulic cylinders. Graph 4 shows maximum pressure allowed on ECP cylinders. Contact the cylinder manufacturer when in doubt about a pressure rating of other cylinders.

Proof Testing and Project Documentation

The big advantage when using hydraulically installed ECP Steel Piers™ is that each pier is field *Proof Tested* to a load that is greater than force that is required to restore and support the structure. This *Proof Testing* of each and every pier placement verifies that firm bearing stratum or rock upon which the pier pipe is founded is sufficient to support the working load requirement plus a factor of safety.

It is recommended that the installer document the following data for each pier placement:

1. The installation force used to drive each 3-1/2 foot long section of pier pipe into the soil.
2. The *Proof Test* force that was applied against the bearing stratum. This force shall be either the force required to slightly lift the structure using just the drive cylinder or the application of the maximum allowable test load shown in Table 1, whichever is less.
3. The length of time the pier was subjected to the *Proof Test* loading.
4. The depth to load bearing
5. After all pier placements have been installed and *Proof Tested*, the force required at each placement to recover lost elevation to restore the structure shall be recorded.
6. The amount of lift at each placement.

At the end of the project, this data shall be compiled into a project report and retained by the installer for future reference. The installer should provide a copy of the project report to the engineer of record or owner's representative upon request.

Buckling Loads on the Pier Shaft in Weak Soil

Whenever a slender column (Pier Pipe) does not have adequate lateral support from the surrounding soil, the load carrying capacity of the column is reduced as buckling of the pipe column becomes a risk. In the case of ECP Steel Piers™, the full ultimate-limit capacity shown in Table 1 is available provided the soil through which the pier penetrates maintains a Standard Penetration Test value "N" $\geq$ 5 blows per foot through the entire depth of the pier installation. The pier must also be firmly secured to a foundation bracket at the footing.

The most accurate way to determine the buckling load of a pier shaft in weak soil is by performing a buckling analysis by finite differences. There are several specialized computer programs that can perform this analysis and allow the introduction of shaft properties and soil conditions that can vary with depth. Another, less accurate method of estimating critical buckling is by Davisson Method, "*Estimating Buckling Loads for Piles"* (1963). In this method, Davisson assumes various combinations of pile head and tip boundary conditions with a constant modulus of sub-grade reaction, "k_H". Load transfer to the soil due to skin friction is assumed negligible and the pile is assumed straight. Equation 3 is Davisson's formula.

Equation 3: Critical Buckling

$$P_{cr} = U_{cr} E_p I_p / R^2$$

Where:

P_{cr} = Critical Buckling Load – lb
U_{cr} = Dimensionless ratio (Assume = 1)
E_p = Shaft Mod. of Elasticity = 30 x 10^6 psi
I_p = Shaft Moment of Inertia = in^4
$R = \sqrt[4]{E_p I_p / k_H d}$
d = Shaft Diameter – in

Computer analysis of shaft buckling is the recommended method to achieve the most accurate results. Many times, however, one must have general information to prepare a preliminary design or budget proposal. Table 13, Page 106 below provides conservative critical buckling load estimates for various shaft sizes penetrating through different types of homogeneous soils.

Graph 5 on the following page presents visual representation of Buckling Strength of various pier configurations when fully exposed in air, or water, when no lateral shaft support is present.

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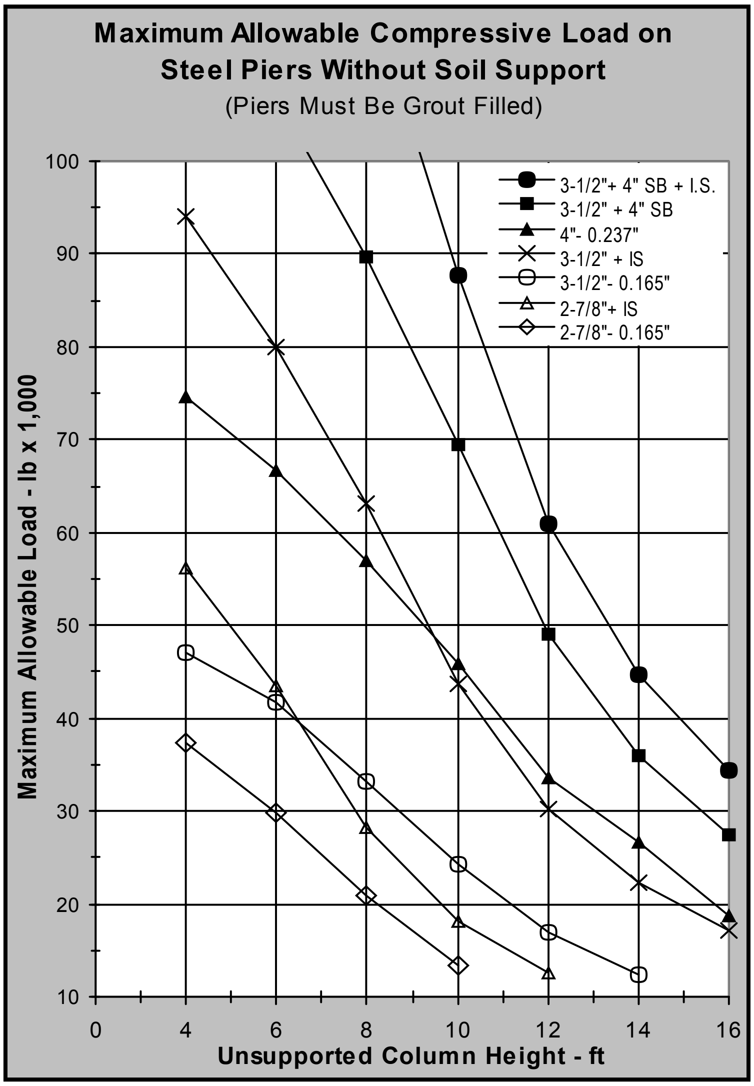
It is recommended that a Registered Professional Engineer conduct the design of ECP Steel Piers™ where the pipe column is likely to be in weak soil and shaft buckling may occur.

Allowable Compressive Loads - "P" in Air: Graph 5 shows the reduction in allowable axial compressive loading where the pier shaft has no lateral support.



Graph 5. Maximum Load* on piers with NO soil support

Table 12 illustrates demonstrates how the ECP PPB-400-EPS (4 inch diameter) pier pipe provides an axial stiffness of more than 3-1/2 times that of a PPB-300-EPS (2-7/8 inch diameter) pier pipe. In addition, Graph 5 demonstrates that the PPB-400-EPS pier pipe has a maximum compressive load capacity of more than three times that of the PPB-300-EPS pier pipe when each has ten feet of exposed column height without any lateral support.

Whenever weak soil is encountered such as peat or other organic soils, improperly consolidated soil, or a situation where a portion of the pier shaft may become fully exposed; consideration MUST be given to the reduction in capacity brought on by the lack of lateral support to the pier pipe.

In situations where insufficient lateral pier pipe support is provided by the soil, the pier is not able to support the full rated capacity. The length of pier pipe that is passing through the weak soil and the amount of stiffness provided by the pier pipe will affect the load capacity reduction that must be considered. **Pier pipe stiffness (Moment of Inertia) increases with increasing diameter.** Graph 5 shows reductions in allowable axial compressive loading relative to the exposed length of the pier pipe in air or water for various pier diameters and sleeved pier configurations. When ECP Steel Pier™ pipe is fully exposed or passes through very weak soils, we recommend installing sleeving over and/or inside the pier pipe to increase the bending strength of the pier; in addition, it is good practice for the designer to consider using a larger diameter pipe in weak soil applications.

Table 12 STEEL PIER SHAFT STIFFNESS COMPARISON

Steel Pier Pipe Configuration	Cross Section Area - in^2	Moment of Inertia - in^4 (Stiffness)	Pier Stiffness Relative to PPB-350-EPS
PPB-300-EPS (2-7/8" dia.)	1.41	1.29	0.55%
PPB-300-EPS + PPB-300-IP	2.65	1.81	0.77%
PPB-350-EPS (3-1/2" dia.)	1.68	2.35	100%
PPB-400-EPS (4" dia.)	2.60	4.66	198%
PPB-350-EPS + PPB-350-IP	3.46	4.22	180%
PPB-350-EPS + PPB-350-SB	4.27	7.01	298%
PPB-350-EPS + PPB-350-SB + PPB-350-IP	5.12	8.88	379%

EPS = Pier Pipe Section IP = Internal "Inertia" Sleeve SB = 4" External Sleeve

*** Caution: When selecting a pier configuration for a specific application, one must apply a factor of safety to the capacities shown on Graph 5 to insure "Safe Use" design.**

Pier Sleeves

In areas of poor soil, the stiffness (axial moment of inertia) of the pier pipe and the strength of the coupled joints are of concern. Installing a pier sleeve or changing to a larger diameter pier pipe is required to prevent buckling. Poor soil conditions are generally recognized as:

- Soil having Standard Penetration Blow Counts less than or equal to five blows per foot (“N” ≤ 5) or,
- On projects where the pier pipe is exposed, or may become exposed

There are several ways to reinforce pier pipe in such situations. One of the simplest to slightly improve pier stiffness and to strengthen the coupled joints is to grout the pier pipe after installation. Many designers also require that the contractor install a reinforcing bar in the center of the pier pipe along with the grouting to improve joint strength.

“Inertia Sleeve” – Earth Contact Products offers a patented product called the *Inertia Sleeve* to improve shaft stiffness. This unique product is shown in Figure 5, and is the most economical way to quickly enhance the axial moment of inertia (stiffness) of the pier system. The *Inertia Sleeve* is easy to install, but must be installed concurrent with driving the pier pipe. One simply allows an *Inertia Sleeve* section to drop by gravity into the most recently installed section of pier pipe. This must be done prior to coupling together and driving the next section of pier pipe.

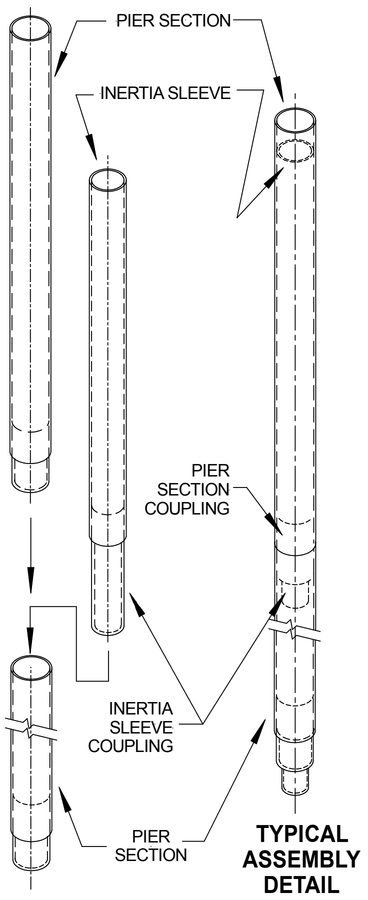


Figure 5. Details of ECP’s patented PPB-300-IP and PPB-350-IP Internal “Inertia Sleeve” Assembly

The low cost *Inertia Sleeve* takes nearly no labor to install and instantly increases the rigidity and strength of the pier shaft through weak soil. The unique design of the patented “Inertia Sleeve” also strengthens the coupled joints. The coupling connection of the *Inertia Sleeve* fully passes through the pier pipe coupling and engages with the previously installed section of *Inertia Sleeve*. The couplings are therefore doubled and staggered, providing a strengthened coupled joint.

External Sleeve – Another means of increasing the axial moment of inertia of the pier shaft is to install external pier sleeving. Many designers like this method because it provides a significantly larger increase in pier rigidity than other methods. This is because the external sleeve increases the diameter of the pier shaft.

When installed, each external sleeve must be positioned such that the joints on the external sleeving are staggered and are not near the pier pipe couplings. The external sleeving must be hydraulically driven over the installed pier pipe prior to field load testing. The time required to drive the external pier sleeving is generally equivalent to the time required to initially install the pier pipe. Keep in mind, however, that external sleeving is only required at locations where the pier pipe is exposed with no lateral support or where the pier pipe passes through weak soil with insufficient lateral support on the pipe shaft.

Table 12 on the previous page presents shaft stiffness relative to different pier pipe configurations. It is interesting to note that the combination of the PPB-350-EPS, 3-1/2” diameter pier pipe, plus the PPB-350-IP *Inertia Sleeve* provides axial stiffness equal to 91% of the of the PPB-400 system (4” diameter) system. If the designer chooses PPB-350-SP (4” diameter exterior sleeve) over the PPB-350-EPS (3-1/2 inch diameter) pier pipe and grout fills pier pipe, the allowable load on the system will be 151% that of a simple PPB-400 (4” diameter) pier

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system. The cost savings should be very evident especially on projects that require extra rigidity only in the upper several feet of soil.

When specifying either type of pipe sleeve, the designer must extend the sleeving a minimum depth of three feet beyond the zone of weak soil and into the competent material.

For example, if a site has 6 feet of peat with Standard Penetration Test (SPT), "N", from 0 bpf ("Weight of Hammer") to 2 bpf that is overlaying sand with a SPT, "N" > 5 blows per foot; the designer should specify sleeving to a depth of at least 9 feet in order to provide adequate sleeve embedment beyond the 6 foot zone of weak soil that contains peat.

"Quick and Rough" Buckling Load Estimates for Weak Soil Conditions

A method for instantly estimating **Maximum Conservative Working Loads in Weak Soil** can be found in Table 13 below. General soil types and SPT, "N", values are provided in four columns. On the left side of Table 13 are available pier pipe and sleeving configurations. Read horizontally until the column with soil that most closely matches the soil conditions at the job site. At the intersection of the product line and soil column is the maximum **Design Load** (Working Load) for that pier or pier combination. If the capacity is unsufficient, drop down to a stiffer pier for the job.

Please note that the values given in Table 13 are working loads. A Factor of Safety of 2.0 has been applied to the loads in Table 13.

Table 13 Working Loads Under Buckling Conditions For Budgetary Estimating (Factor of Safety = 2)

Shaft Size	Uniform Soil Condition			
	Organics N < 1	Very Soft Clay N = 1 - 2	Soft Clay N = 2 - 4	Loose Sand N = 2 - 4
PPB-300-EPS (2-7/8" dia.)	19,000 lb	22,000 lb	31,000 lb	26,000 lb
PPB-300-EPS + PPB-300-IP	23,000 lb	27,000 lb	39,000 lb	32,000 lb
PPB-350-EPS (3-1/2" dia.)	26,000 lb	30,000 lb	43,000 lb	35,000 lb
PPB-400-EPS (4" dia.)	34,000 lb	40,000 lb	57,000 lb	46,000 lb
PPB-350-EPS + PPB-350-IP	36,000 lb	42,000 lb	59,000 lb	48,000 lb
PPB-350-EPS + PPB-350-SB	50,000 lb	58,000 lb	82,000 lb	67,000 lb
PPB-350-EPS + PPB-350-SB + PPB-350-IP	56,000 lb	66,000 lb	93,000 lb	76,000 lb

EPS = Pier Pipe Section IP = Internal "Inertia" Sleeve SB = 4" Ext Sleeve

ECP Steel Pier™ PPB-350 Utility Bracket System, TAF-150 Torque Anchor™ Tieback and PPB-350-TA Tieback Adapter Assembly

The PPB-350 Steel Pier System may be connected to a Helical Torque Anchor™ to provide lateral stabilization to the pier system. The connection is made with a PPB-350-TA Adapter Assembly. Please contact ECP for full specifications for the installation. Configuration details are shown below.