Earth
Engineers,
Inc.

IAS ACCREDITED DIAMOND PIER ®
UPLIFT AND LATERAL FIELD LOAD TEST REPORT

Prepared for

PIN FOUNDATIONS, INC.
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Prepared by

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REPORT TEXT ONLY

EEI REPORT NO. 07-020-11

JANUARY 23, 2017

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January 23, 2017

Pin Foundations, Inc.
4810 Pt. Fosdick Drive Northwest, PMB 60
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Attention: Rick Gagliano

Phone: 253-858-8809
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Subject: IAS Accredited Diamond Pier Uplift and Lateral Field Load Test Report
EEI Report No. 07-020-11

Dear Mr. Gagliano:

Earth Engineers, Inc. (EEI) is pleased to transmit our test report for Diamond Piers, which have been developed and marketed by Pin Foundations, Inc. (PFI). Our services were completed in accordance with EEI Proposal No. 15-P093 dated April 2, 2015, which you authorized by signing on April 6, 2015.

PROJECT BACKGROUND

EEI has been involved in load testing the Diamond Pier product dating back to 2006. In 2006, EEI was engaged by Professional Services Industries, Inc. (PSI) of Portland, Oregon to conduct axial compressive pile load testing on DP-50 Diamond Piers with 36-inch long steel pins (reference PSI Report No. 704-25035-1, dated November 26, 2006). This current report expands on the knowledge base of load carrying capacity of Diamond Piers by testing both DP-50 and DP-75 Diamond Piers with 50-inch pin lengths for both lateral and uplift load carrying capacity (see Appendix A for pier dimensions).

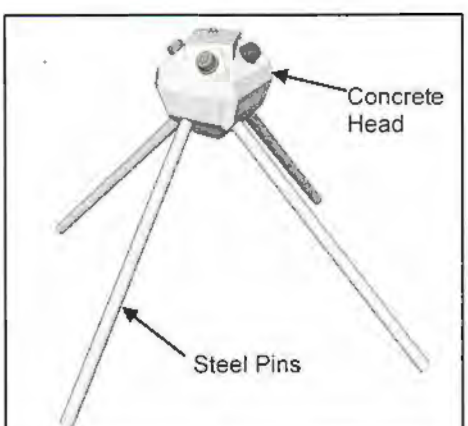

FIGURE 1: Typical schematic drawing for Diamond Pier DP-50 or DP-75.

SCOPE OF SERVICES

EEI's scope of services included a number of tasks related to evaluating the uplift and lateral load carrying capacity of DP-50 and DP-75 Diamond Piers with four 50-inch long bearing pins and concrete heads installed at a site with a 1,500 pounds per square foot (psf) presumptive allowable soil bearing capacity per Table R401.4.1 of the International Residential Code (IRC). These tasks were completed under the direction of EEI Principal Geotechnical Engineer Troy Hull, P.E.

The scope of services included the following:

1. Qualify the load test site. Site qualification included performing 5 soil test borings (B-1 through B-5), laboratory testing, and geotechnical engineering analyses to confirm that the site met the requirements of IRC Table 401.4.1.
2. Select load test samples of the DP-50 and DP-75 Diamond Pier concrete heads at PFI's Gig Harbor facility, as well as the steel pins at the load test site in Washougal, Washington.
3. Perform 6 uplift pile load tests (3 DP-50 Diamond Piers and 3 DP-75 Diamond Piers) in general accordance with ASTM D3689/D3689M – 07 (Reapproved 2013).
4. Perform 6 lateral load tests (3 DP-50 Diamond Piers and 3 DP-75 Diamond Piers) in general accordance with ASTM D3966/D3966M – 07 (Reapproved 2013).
5. Provide a final typed report summarizing the site qualification and load test results.

Note that EEI is an International Accreditation Service (IAS) approved testing agency for conducting the requested load testing services in accordance with the ASTM standards listed above. See the accreditation certificate attached in Appendix N.

TEST SITE QUALIFICATION

EEI conducted a geotechnical subsurface investigation on a select part of the Port of Camas-Washougal's 125-acre Steigerwald Commerce Center property at the east terminus of Grant Street, in Washougal, Clark County, Washington (see Site Location Plan in Appendix B attached). At the time of our subsurface investigation, the test site was a large, undeveloped grass field. The purpose of the subsurface investigation was to confirm the site meets the soil classification criteria outlined in 2015 IRC Table R401.4.1 for load-bearing pressures of 1,500 psf (see Table 1 below).

TABLE 1: IRC Table R401.4.1, Presumptive Load-Bearing Values of Foundation Materials[a]

CLASS OF MATERIAL	LOAD-BEARING PRESSURE (pounds per square foot)
Crystalline bedrock	12,000
Sedimentary and foliated rock	4,000
Sandy gravel and/or gravel (GW and GP)	3,000
Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	2,000
Clay, sandy clay, silty clay, clayey silt, silt, sandy silt, and sandy clay (CL, ML, MH and CH)	1,500[b]

a. When soil tests are required by Section 401.4, the allowable bearing capacities of the soil shall be part of the recommendations.

b. When the building official determines that in-place soils with an allowable bearing capacity of less than 1,500 psf are likely to be present at the site, the allowable bearing capacity shall be determined by a soils investigation.

Prior to the subsurface investigation, EEI reviewed available geologic references for the area. According to the "Geologic Map of the Vancouver Quadrangle, Washington and Oregon" (1987), the general area of the site consists of Holocene (the last 11,000 years) to upper Pleistocene (1.8 mya to 10,000 years) aged alluvium (Qal). These alluvial soils typically consist of sand, silt and clay on the floodplains of the Columbia River that are locally up to about 50 meters thick. This is generally consistent with the soil conditions encountered in our subsurface investigation.

On August 13, 2015, five Standard Penetration Test (SPT) soil borings (B-1 through B-5) were performed by PLi Systems of Hillsboro, Oregon using a Beretta T46 track drill rig outfitted with solid stem auger and a calibrated automatic SPT hammer. The SPT was performed by driving a 2-inch, O.D., split-spoon sampler into the undisturbed soil formation located at the bottom of the advanced auger with repeated blows of a 140-pound, pin-guided, automatic mechanical hammer falling a vertical distance of 30 inches. The number of blows required to drive the sampler one foot is a measure of the *consistency* for cohesive soils and *density* for granular soils.

SPT samples were obtained at 2 ½ foot intervals and all soil samples were identified in the field, placed in sealed containers, and transported to the laboratory for further classification, testing and storage. In addition to the SPT sampling, relatively undisturbed Shelby tube samples were obtained at depths selected by EEI Principal Geotechnical Engineer Troy Hull, P.E. The laboratory evaluation consisted of visual and textural examinations (ASTM D2487-00), moisture content tests (ASTM D2216-98), particle size analyses (ASTM D1140), Atterberg limits tests (ASTM D4318-10), unit weight tests (ASTM D2937), and direct shear tests (ASTM D3080). Results of the tests are shown on the attached boring logs.

The following is a summary of soil and groundwater conditions encountered in the 5 borings. All of the borings encountered approximately 12 inches of topsoil. Beneath the topsoil in B-1 through B-5 was sandy silt/clay and silty/clay with sand, which classifies as ML/CL in accordance with the Unified Soil Classification System (USCS). The stratum extended to the maximum depths of the borings (10 ½ feet). The one exception was a thin (approximately 6 inch) seam of silty sand in B-3 from a depth of 3 to 3 ½ feet below grade. Moisture contents of the ML/CL material tested ranged from 6 to 41 percent. In general, the moisture content increased with depth. The fines content (i.e. material passing a #200 sieve) ranged from 52 to 99 percent. Based on the soil conditions encountered in Borings B-1 through B-5, we consider these soils to be characterized as silt/clay soils typically associated with 1,500 psf bearing material.

Groundwater was not encountered in any of the borings at the time of the subsurface investigation. Based on our past experience working at the Steigerwald Commerce Center property, groundwater is typically greater than about 15 feet below the ground surface. It is possible that groundwater levels will vary by season, year, and location across the site.

EEI performed geotechnical engineering analyses based on soil strength characterization using the data from our subsurface investigation and laboratory test data. Our bearing capacity calculations were performed using the General Bearing Capacity Equation, originally developed by Karl Terzaghi and since modified by several researchers and practitioners (McCarthy, 1998). This method considers soil cohesion and internal friction, foundation size, total soil weight, and surcharge effects to determine bearing capacity. Soil cohesion and internal friction values were determined from Direct Shear lab testing. Table 2 is a brief summary of the calculation results.

TABLE 2: SUMMARY OF SITE BEARING CAPACITY CALCULATIONS

	REQUIRED BEARING CAPACITY PER 2015 IRC TABLE R401.4.1 (psf)	**GENERAL BEARING CAPACITY EQUATION NET ALLOWABLE BEARING RESULTS (psf)**
Site #1 (Silt/Clay)	1,500	1,610

In our professional opinion, the engineering analyses confirm that the soil within the zone of influence for Site #1 (i.e. in the area of borings B-1 through B-5) meets the requirement for soil with a load-bearing value of 1,500 psf as outlined in IRC Table R401.4.1.

LOAD TEST PROGRAM

Once the test site at the Port of Camas-Washougal was qualified, the test area was cordoned off with stakes and safety tape (see Photo 3 below). This was done to prevent vehicles or equipment from driving over the site and compacting (improving) the near-surface soils. The approximate size of the cordoned off test site was approximately 75 feet (north-south direction) by 350 feet (east-west direction).

EEI Principal Geotechnical Engineer Troy Hull, P.E. traveled to PFI's Gig Harbor, Washington facility on April 1, 2016 and randomly sampled the precast concrete heads for the DP-50 and DP-75 Diamond Piers to be used for load testing.

PHOTO 1: Pallet of DP-75 precast concrete heads sampled at PFI's Gig Harbor, Washington facility.

Upon arrival at the PFI facility at 2105 34th Avenue Northwest in Gig Harbor, Washington, EEI rep. Troy Hull noted there were 4 pallets of precast concrete heads (2 pallets of DP-50s and 2 pallets of DP-75s).

The concrete heads were precast by PFI supplier Stoneworks of Elk River, Minnesota. Concrete test cylinders were molded by Stoneworks at the time the precast concrete heads were poured. The concrete used to fabricate the load test assemblies was also tested in accordance with ASTM C231 to verify the total air content (percent by volume of concrete) was not less than 5 percent nor more than 7 percent. The cylinders and heads were then shipped to PFI by truck and cured in accordance with Section 9.2 of ASTM C31, except they were cured in the same temperature and moisture environment as the precast concrete heads to be field load tested (uplift and lateral). The concrete test cylinders were subsequently tested by PSI, Inc. of Tacoma, Washington in accordance with ASTM C39. Test results are found in the Compressive Strength Test Reports attached in Appendix J. Note that the concrete compressive strength of the precast concrete heads load tested per ASTM D1143/D1143M cannot exceed 5,500 psi as that is the minimum concrete strength specified in PFI's Quality Control Manual for production heads.

The steel bearing pins for the DP-50 were 1-inch nominal diameter, schedule 40, galvanized steel pipe (1.315-inch actual outside diameter). The pipe wall thickness was 0.133 inches with a tolerance of +/- 1 percent. Each pin had a length of 50 inches +/- ½ inch. The pin corrosion resistance coating consisted of hot dip galvanizing in accordance with ASTM A53-02.

The steel bearing pins for the DP-75 were 1 ¼-inch nominal diameter, schedule 40, galvanized steel pipe (1.660-inch actual outside diameter). The pipe wall thickness was 0.140 inches with a tolerance of +/- 1 percent. Each pin had a length of 50 inches +/- 1/2 inch. The pin corrosion resistance coating consisted of hot dip galvanizing in accordance with ASTM A53-02.

The steel bearing pins consisted of Type E, Grade A (electric-resistance-welded), galvanized steel pipe complying with ASTM A53-02. See the mill test report attached in Appendices M and N.

The galvanized steel anchor bolts precast in the top of each concrete head were 1/2 inch in diameter by 5 inches long for the Diamond Pier DP-50 and 5/8 inch diameter by 5 1/2 inches long for the DP-75. See the certification report attached as Appendices O and P.

On April 4 and 5, 2016, PFI staff installed six DP-50 and six DP-75 Diamond Piers at Site #1 (silt/clay soil with a presumptive load bearing capacity of 1,500 psf). The installation was witnessed by EEI Principal Geotechnical Engineer Troy Hull, P.E. At that time, it was visually confirmed that the ground surface had not been disturbed by any heavy equipment since the August 2015 subsurface investigation was completed. Additionally, all of the steel bearing pins were randomly sampled by Mr. Hull from large bundles of pre-cut lengths of pipe brought to the site by PFI. The manufacturer's markings were checked against the product certification paperwork and the pins were inspected by Mr. Hull for straightness prior to installation. The selected pins were marked with a black felt pen and separated out for installation with the individual concrete heads. The concrete heads were inspected for any cracking after installation. No discontinuities were observed in any of the pins or heads used for load testing.

The Diamond Pier foundation assemblies were installed in a manner as recommended by the manufacturer for construction. A small amount of grass sod was removed with a shovel to seat the concrete head (see Photo 2 below).

PHOTO 2: Sod removed in conical shape of concrete head.

PHOTO 3: Typical concrete head seated and ready for bearing pin installation. Note caution tape in the background to ensure test site was not impacted by vehicular traffic surcharge loads.

Once the concrete head was seated, a small bubble level was used to level the top of the concrete head. The 4 steel bearing pins were placed through precast holes in the concrete head. Each steel bearing pin was driven a few inches with a 3-pound sledge. The steel bearing pins were then installed the rest of the way using a Bosch GSH 16 jackhammer with a pipe driving bit (see Photo 4 below). The levelness of the top of the concrete head was continuously checked when driving the steel bearing pins into the ground. This same procedure was repeated for the other 11 Diamond Pier installations.

PHOTO 4: Typical driving of the steel bearing pins.

PHOTO 5: Typical Diamond Pier after the bearing pins were driven.

After installation, 1 to 2 inches of soil was removed from around the base and sides of the precast concrete head to ensure that the entire test load was carried by the steel bearing pins and not the precast concrete head. Additionally, the soil removal allowed EEI to inspect the base of the concrete head where the steel bearing pins exit the head both before and after load testing was completed.

PHOTO 6: Typical Diamond Pier after 1 to 2 inches of soil was removed from around the bottom and sides.

The following is a summary of the test program for each of these test locations.

TABLE 3: Summary of Diamond Piers installed April 4-5, 2016 on the 1,500 psf Silt Site #1

Test Pier #	Diamond Pier Description	Test Program
CL-U-DP50-1	DP-50 precast concrete head with (4) 1" nominal diameter by 50" long steel pins	Uplift
CL-U-DP50-2	DP-50 precast concrete head with (4) 1" nominal diameter by 50" long steel pins	Uplift
CL-U-DP50-3	DP-50 precast concrete head with (4) 1" nominal diameter by 50" long steel pins	Uplift
CL-U-DP75-1	DP-75 precast concrete head with (4) 1 ¼" nominal diameter by 50" long steel pins	Uplift
CL-U-DP75-2	DP-75 precast concrete head with (4) 1 ¼" nominal diameter by 50" long steel pins	Uplift
CL-U-DP75-3	DP-75 precast concrete head with (4) 1 ¼" nominal diameter by 50" long steel pins	Uplift
CL-L-DP50-1	DP-50 precast concrete head with (4) 1" nominal diameter by 50" long steel pins	Lateral
CL-L-DP50-2	DP-50 precast concrete head with (4) 1" nominal diameter by 50" long steel pins	Lateral
CL-L-DP50-3	DP-50 precast concrete head with (4) 1" nominal diameter by 50" long steel pins	Lateral
CL-L-DP75-1	DP-75 precast concrete head with (4) 1 ¼" nominal diameter by 50" long steel pins	Lateral
CL-L-DP75-2	DP-75 precast concrete head with (4) 1 ¼" nominal diameter by 50" long steel pins	Lateral
CL-L-DP75-3	DP-75 precast concrete head with (4) 1 ¼" nominal diameter by 50" long steel pins	Lateral

Uplift Load Testing

Uplift load testing was conducted on 6 Diamond Piers in general accordance with ASTM D3689/D3689M between April 15 and May 6, 2016. The load test reaction frame consisted of two W12x40 by 25 foot long (minimum) wide flange steel beams supported on either end by a single 2.5 by 2.5 by 5 foot, solid concrete block manufactured by Ultrablock Inc. of Vancouver, Washington. Each concrete block weight was about 4,320 pounds. The steel beams and concrete block reaction frame was assembled using an all-terrain forklift working from outside the taped off restricted area to prevent the equipment from compacting the ground in the area of the tests. For each individual load test, vertical tension load was applied using a single, calibrated Enerpac 12-ton hydraulic hollow core ram.

PHOTO 7: Typical uplift load test reaction frame setup.

PHOTO 8: Typical uplift load test setup.

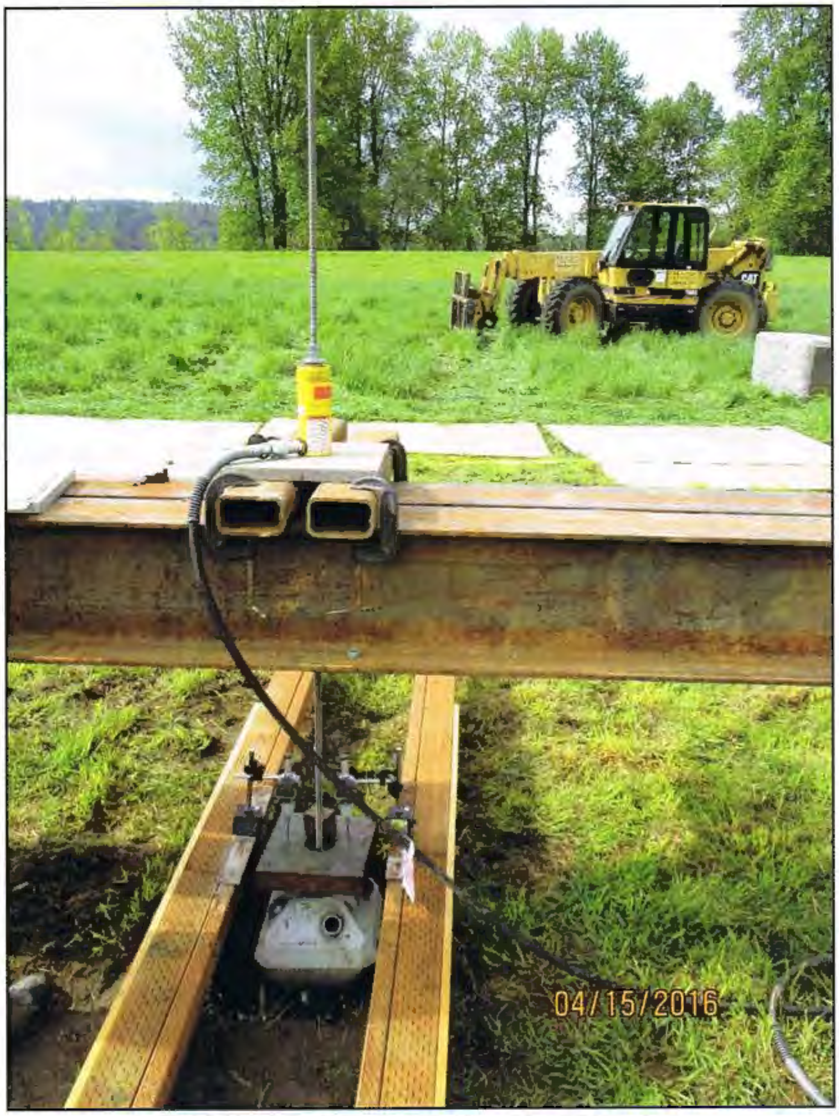

PHOTO 9: Typical uplift load test setup.

The load test was conducted in accordance with Procedure A (Quick Test) of the ASTM. The test intervals were applied in increments of approximately 5% of the anticipated failure load. During each interval, the load was held constant for a time interval not less than 4 minutes and not more than 15 minutes. After reaching the maximum test load, the pier was unloaded in at least 5 decrements and readings were taken for not less than 4 minutes and not more than 15 minutes.

Lateral Load Testing

Lateral load testing was conducted on 6 Diamond Piers in general accordance with Procedure A (Standard Loading) of ASTM D3966/D3966M between April 20 and May 24, 2016. The test load was applied by testing 2 Diamond Piers simultaneously. A calibrated Chief WC Welded hydraulic cylinder was placed in line between the 2 Diamond Piers and connected via a turnbuckle and chain.

Loading was monitored with a calibrated Central 5-ton tension load cell placed in line between the 2 Diamond Piers.

PHOTO 10: Typical lateral load test setup.

CONCLUSIONS

In order to develop the allowable load capacity recommendations for both lateral and uplift as shown in Table 4 below, we determined the average load at a deflection of 1 inch, and applied a safety factor of 2. The results are summarized in Tables 4 and 5 below

TABLE 4: Summary of Uplift Load Test Results in 1,500 psf Bearing (Silt) Soils

Test Pier #	Diamond Pier Description	Test Load @ 1" Deflection	Design Load (Test Load/2)
CL-U-DP50-1	DP-50 precast concrete head with (4) 1" nominal diameter by 50" long steel pins	2,900	1,450
CL-U-DP50-2	DP-50 precast concrete head with (4) 1" nominal diameter by 50" long steel pins	3,200	1,600
CL-U-DP50-3	DP-50 precast concrete head with (4) 1" nominal diameter by 50" long steel pins	3,100	1,550
		AVERAGE FOR DP-50:	**1,533**
CL-U-DP75-1	DP-75 precast concrete head with (4) 1-¼" nominal diameter by 50" long steel pins	3,100	1,550
CL-U-DP75-2	DP-75 precast concrete head with (4) 1-¼" nominal diameter by 50" long steel pins	3,700	1,850
CL-U-DP75-3	DP-75 precast concrete head with (4) 1-¼" nominal diameter by 50" long steel pins	3,500	1,750
		AVERAGE FOR DP-75:	**1,716**

TABLE 5: Summary of Lateral Load Test Results in 1,500 psf Bearing (Silt) Soils

Test Pier #	Diamond Pier Description	Test Load @ 1" Deflection	Design Load (Test Load/2)
CL-L-DP50-1	DP-50 precast concrete head with (4) 1" nominal diameter by 50" long steel pins	1,600	800
CL-L-DP50-2	DP-50 precast concrete head with (4) 1" nominal diameter by 50" long steel pins	1,200	600
CL-L-DP50-3	DP-50 precast concrete head with (4) 1" nominal diameter by 50" long steel pins	1,050	525
		AVERAGE FOR DP-50:	**641**
CL-L-DP75-1	DP-75 precast concrete head with (4) 1-¼" nominal diameter by 50" long steel pins	1,250	625
CL-L-DP75-2	DP-75 precast concrete head with (4) 1-¼" nominal diameter by 50" long steel pins	1,100	550
CL-L-DP75-3	DP-75 precast concrete head with (4) 1-¼" nominal diameter by 50" long steel pins	1,700	850
		AVERAGE FOR DP-75:	**675**

As part of the testing procedure, the integrity of each Diamond Pier was visually inspected at the test load when at 1 inch deflection. The anchor bolts were straight and intact, with no radial concrete cracking around the anchor bolts. For the uplift tests, there was some minor concrete spalling on the underside of the concrete heads, but no other observed cracking of the concrete heads. We observed no cracking of the concrete heads tested for lateral load.

After completion of the load testing program, the steel bearing pins and precast concrete heads were completely removed from the ground and visually inspected again. The lateral test steel pins showed no inelastic bending, and the anchor bolts were still straight and intact, with no concrete cracking around the anchor bolts.

For the uplift tests, the steel pins were not able to be removed without destroying the integrity of the pins and concrete heads. As such we were not able to check for pin straightness.

At least 3 concrete compression tests were conducted by PSI, Inc. (Pin Foundations' subcontracted testing lab) on 4 inch diameter by 8 inch tall cylinder samples cast in accordance with ASTM C39 from the same batch as the Diamond Piers that were load tested. Three concrete test cylinders were tested in accordance with ASTM C39 (see page 5). The cylinders were tested in the midst of the testing program covered by this report. The average of the three tests established the concrete compressive strength. See Appendix J for the test results. Note that the average of the 3 concrete compressive strength tests (5,330 psi) was less than 5,500 psi, which is the minimum compressive strength requirement in PFI's Quality Control Manual for production piers.

LIMITATIONS

The geotechnical recommendations presented in this report are based on the available project information, and the subsurface materials described in this report. If any of the noted information is incorrect, please inform EEI in writing so that we may amend the recommendations presented in this report if appropriate and if desired by the client. EEI will not be responsible for the implementation of its recommendations when it is not notified of any applicable changes.

The Geotechnical Engineer warrants that the findings, recommendations, specifications, or professional advice contained herein have been made in accordance with generally accepted professional geotechnical engineering practices in the local area. No other warranties are implied or expressed.

This report has been prepared for the exclusive use of Pin Foundations, Inc. for the specific application to the Diamond Pier load testing conducted in 2016 at the Port of Camas-Washougal's Steigerwald Commerce Center property in Washougal, Washington.

If you have any questions pertaining to this report, or if we may be of further service, please contact Troy Hull at 541-393-6340 (office) or 360-903-2784 (cell).

Sincerely,
Earth Engineers, Inc.

Reviewed by:

EXPIRES 09/06/17

Troy Hull, P.E.
Principal Geotechnical Engineer

Ray Aliperti
Technical Director

Attachments:	Appendix A:	Diamond Pier Dimensioned Drawing and Concrete Mix Design
	Appendix B:	Site Location Plan
	Appendix C:	Topographic Site Location Plan
	Appendix D:	Site Location Aerial Photo
	Appendix E:	Diamond Pier and Geotechnical Boring Location Plan
	Appendix F:	Boring Logs and Laboratory Test Results
	Appendix G:	Site Qualification Engineering Calculations
	Appendix H:	Load Test Setup Schematics
	Appendix I:	Load Test Equipment List and Hydraulic Ram Calibration Reports
	Appendix J:	Concrete Compressive Strength Test Report
	Appendix K:	Load Test Data
	Appendix L:	ASTM D3689
	Appendix M:	ASTM D3966
	Appendix N:	Earth Engineers Inc.'s IAS Certificate of Accreditation
	Appendix O:	Mill Test Report for 1-inch Diameter Nominal Steel Bearing Pin Pipe from Saha Thai Steel Pipe (Public) Company LTD
	Appendix P:	Mill Test Certificate for 1 1/4-inch Diameter Nominal Steel Bearing Pin Pipe from Al Jazeera Steel Products Company SAOG
	Appendix Q:	Material Certification Report for 1/2-inch Diameter Galvanized Anchor Bolt from Stoneworks Architectural
	Appendix R:	Material Certification Report for 5/8-inch Diameter Galvanized Anchor Bolt from Stoneworks Architectural
	Appendix S:	Bibliography