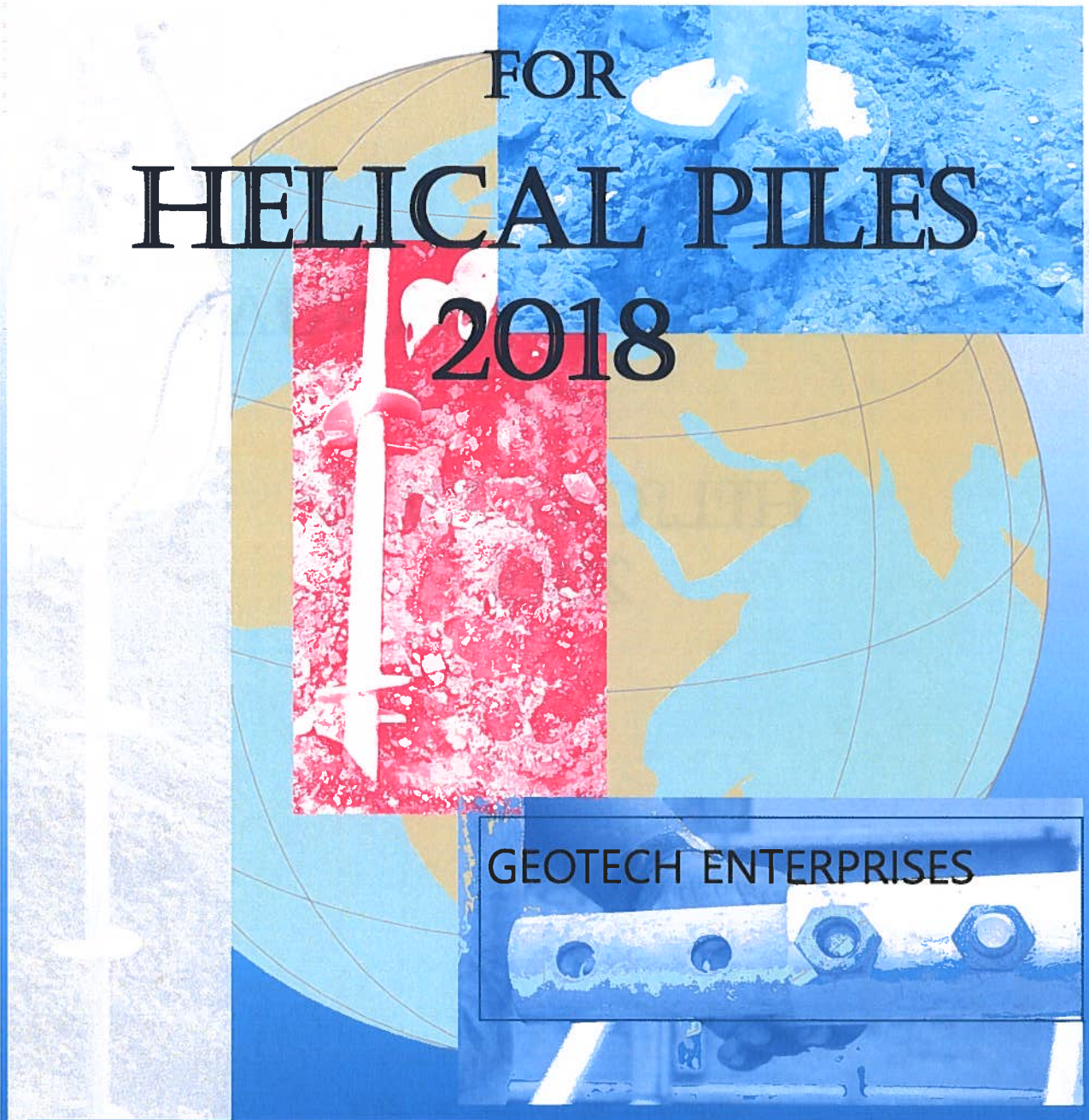


TECHNICAL MANUAL FOR HELICAL PILES 2018



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TECHNICAL MANUAL FOR HELICAL PILES 2018

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HELICAL PILES

Design

Furnish

Inspect

Certify

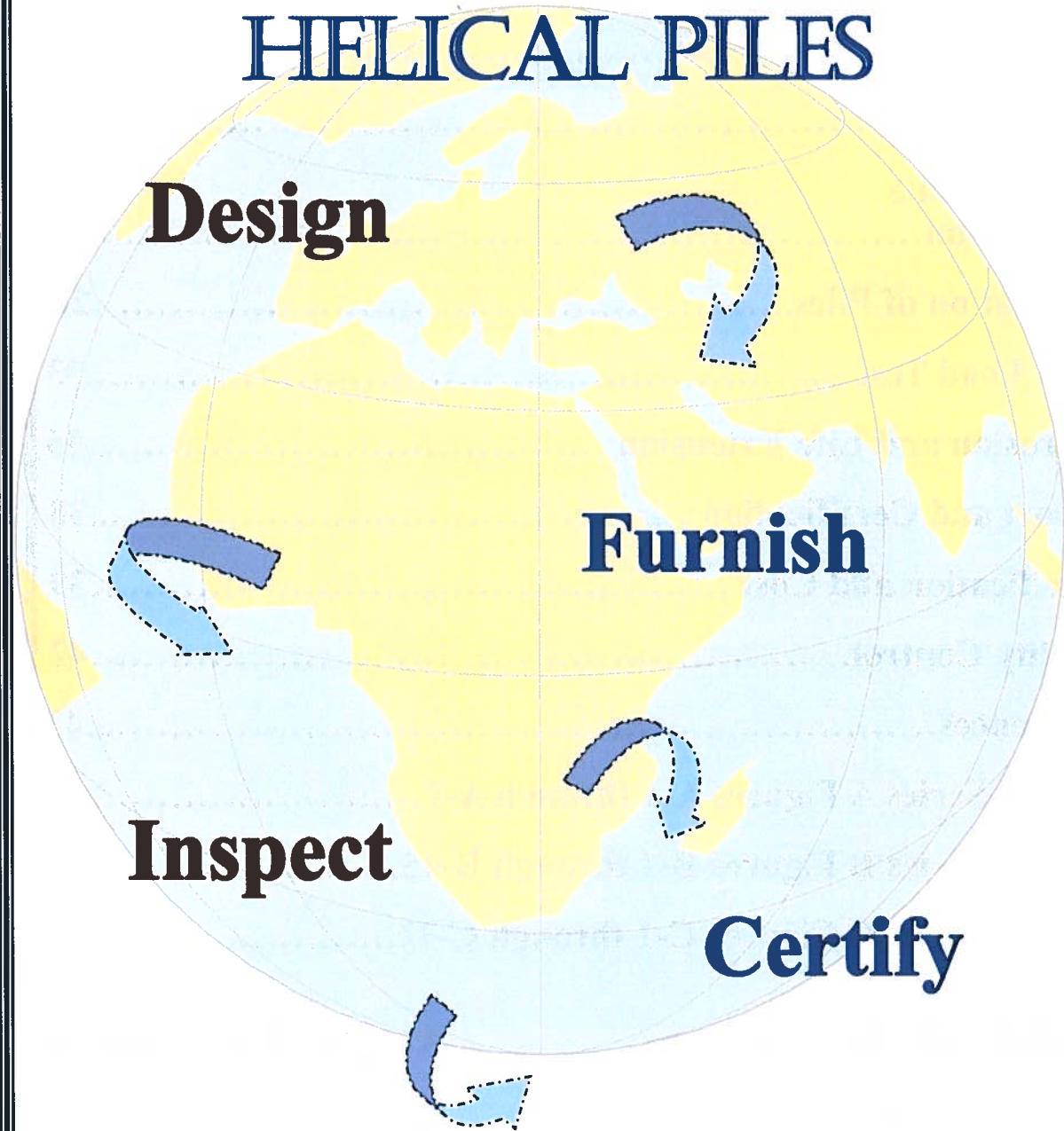


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INTRODUCTION

Helical piles have been in use both in the USA and abroad in various designs for over a century. Due to their unique design, helical piles can take tension as well as compression loads even in poor soil. The ease of installation makes helical piles popular for light and medium-heavy structures. Vibration-free installation makes them suitable in densely built areas where impact-driven piles are avoided for fear of damaging adjacent buildings or structures. Helical piles often turn out to be cost-effective compared to other forms of non-driven piles. They are known by various names in the industry, such as, screw piles, screw anchors, anchor piles, helical piers and so on. For consistency, we will use the term “helical pile” throughout this manual. The helical pile consists of one or more steel helices mounted on a steel pipe or shaft and is inserted into the ground by application of manual or mechanical torque on top.

We at Geotech Enterprises deal directly with the owner, architect, engineer, general contractor and/or construction management, and offer a wide range of services related to helical pile foundations. Since 2005, working in one or more aspects of helical pile projects including designing, manufacturing, installing and testing, our personnel have gained comprehensive expertise in helical piles. Currently, we concentrate on manufacturing and supplying helical piles and offer supporting services in other aspects if and as needed by the clients, specifically, design, field testing and inspection. Our pile installation equipment is also available for possible use by others. All tasks are conducted under the supervision of licensed professional engineers registered in New York State.

The products and services that we offer are further elaborated in the following chapters. Some technical background regarding helical piles is included in order to assist the reader. Both engineering processes and regulatory requirements are also described. For the purpose of quick review and decision-making, a set of one-page summary of technical data for each pile size is included in the manual right after this introduction page.

Conveniently located in Long Island City, Queens we serve all five boroughs in New York City as well as Long Island, Westchester and its vicinity.

Michael Karantinidis, P.E., President
Efthalia Boulias, General Manager
Kalipso Magoulas, Marketing Manager
Miro Bazac, R.A., Quality Control Manager

HELICAL: spiral-shaped: in the shape of a helix or spiral

PILE: sunken support for building: a vertical support, for a building or another structure, that is inserted into the ground.

PHSYICAL DESCRIPTION OF PILES

The helical pile is a long round tubular shaft with helices welded on it. A helix (plural: helices) is made from a circular plate with a round opening at the center that matches the outer diameter of the pile shaft. The plate is pressed in order to form the twisted shape, the helix. Typically, three helices with increasing diameters are mounted on the pile shaft although more helices can be accommodated if the design requires so. Various components of a helical pile are schematically shown in the previous pages and further pictorially presented in the enclosed Exhibit A.

The standard shaft length is 10'-6". If the pile depth exceeds the standard length, an additional section (called extension) is attached to the first section (called lead or starter section) through a coupling system (also called coupler). The coupler is a short long pipe section (sleeve) that fits tightly outside or inside of two adjacent pile shafts and is connected to both of them by either welds or bolts (see Figure A-5 through A-7 in Exhibit A).

We furnish helical piles of three different shaft diameters: 2 $\frac{7}{8}$ ", 3 $\frac{1}{2}$ ", and 4 $\frac{1}{2}$ ". The pipe wall thicknesses are 0.203" (schedule 40) and 0.276" (schedule 80) for 2 $\frac{7}{8}$ ", 0.300" (schedule 80) for 3 $\frac{1}{2}$ " and 0.337" (schedule 80) for 4 $\frac{1}{2}$ " diameter shafts. Helices are selected from a repertoire of five different diameters: 8", 10", 12", 14" and 16". The pitch of a helix is about 3" (see Figure 1) and plate thickness for helices is $\frac{3}{8}$ " for 2 $\frac{7}{8}$ " diameter shafts and $\frac{1}{2}$ " for the rest. The first (bottom-most) helix is mounted slightly above the tip of the lead section and other helices are welded on the same section at a spacing of about 3 feet but not less than three times the diameter of the lower helix. (This is to ensure independent transmittal of bearing load from each helix).

We also furnish the metal cap (also called bracket) assembly that sits atop each pile and ultimately becomes embedded in the concrete foundation. The cap consists of 6"x6"x $\frac{1}{2}$ " (for 2 $\frac{7}{8}$ " diameter shafts), an 8"x8"x $\frac{3}{4}$ " (for 3 $\frac{1}{2}$ " diameter shafts) or 10"x10"x $\frac{3}{4}$ " (for 4 $\frac{1}{2}$ " diameter shafts) plate welded on top of a pipe sleeve whose inner diameter matches the outer diameter of the pile shaft. Upon completion of installation of the pile to the required depth, the exposed upper-most shaft is cut to the desired elevation, the metal cap is placed on it so that the head of the shaft is enclosed by the cap, and then the two (shaft and cap) are connected with through bolts or welds, especially if the pile carries tension load. For piles that need to support existing foundation, we supply eccentric brackets instead of the metal caps as shown in Figure 6. The eccentric brackets are fabricated from $\frac{3}{8}$ " thick steel plates and matching pipe sleeves and square tubes.

In summary, the package for each helical pile that we supply includes the lead section with the specified helices mounted on it, the necessary extensions, the couplings, the cap or bracket and the connecting nuts and through bolts. All these components are made of carbon steel. We can also furnish the entire package galvanized. The standard size of each component and the corresponding metal grades and mechanical properties are presented in Table 1.

PHYSICAL DESCRIPTION OF PILES (Cont.)

TABLE 1
Pile Components, Steel Grades and Mechanical Properties

ITEM	ASTM GRADE	MINIMUM YIELD STRESS KSI	MINIMUM TENSILE STRENGTH KSI	REMARKS
PILE SHAFT				
3 1/2" Diameter Schedule 80	A53 TYPE E Grade B	64	71	
2 7/8" Diameter Schedule 40 and 80	A500 Grade B	42	58	
3 1/2" Diameter Schedule 80				
4 1/2" Diameter Schedule 80				
HELIX				
Diameter: 8", 10", 12", 14", 16": Thickness: 3/8" for 2 7/8" shafts 1/2" for 3 1/2" & 4 1/2" shafts	A36	36	58	
ECCENTRIC BRACKET				
3/8" Plate	A36	36	58	
2 7/8", 3 1/2", 4 1/2" pipe sleeves	A500	42	58	
Matching square tubes				
CAPPING PLATE	A36	36	58	
6"x6"x1/2" for 2 7/8" shafts 8"x8"x3/4" for 3 1/2" shafts 10"x10"x3/4" for 4 1/2" shafts				
COUPLER				
For 3 1/2" ASTM A53 shafts	A513, Types Grade 1026	84	94	Drawn over a mandrel
For 2 7/8", 3 1/2", 4 1/2", ASTM A500 shafts	A500 Grade B	42	58	
BOLTS				
3/4"-1" DIAMETER	A354 Grade BD (SAE J429 Grade 8)	130	150	
NUTS				
3/4"-1" DIAMETER	A563 Grade DH			

Approval has been obtained from ICC-ES Evaluation Service:
 ESR-3741 for 2 7/8-inch pile
 ESR-3723 for 3 1/2-inch pile
 ESR-3742 for 4 1/2-inch pile

2 7/8" SHAFT, SCHEDULE 40

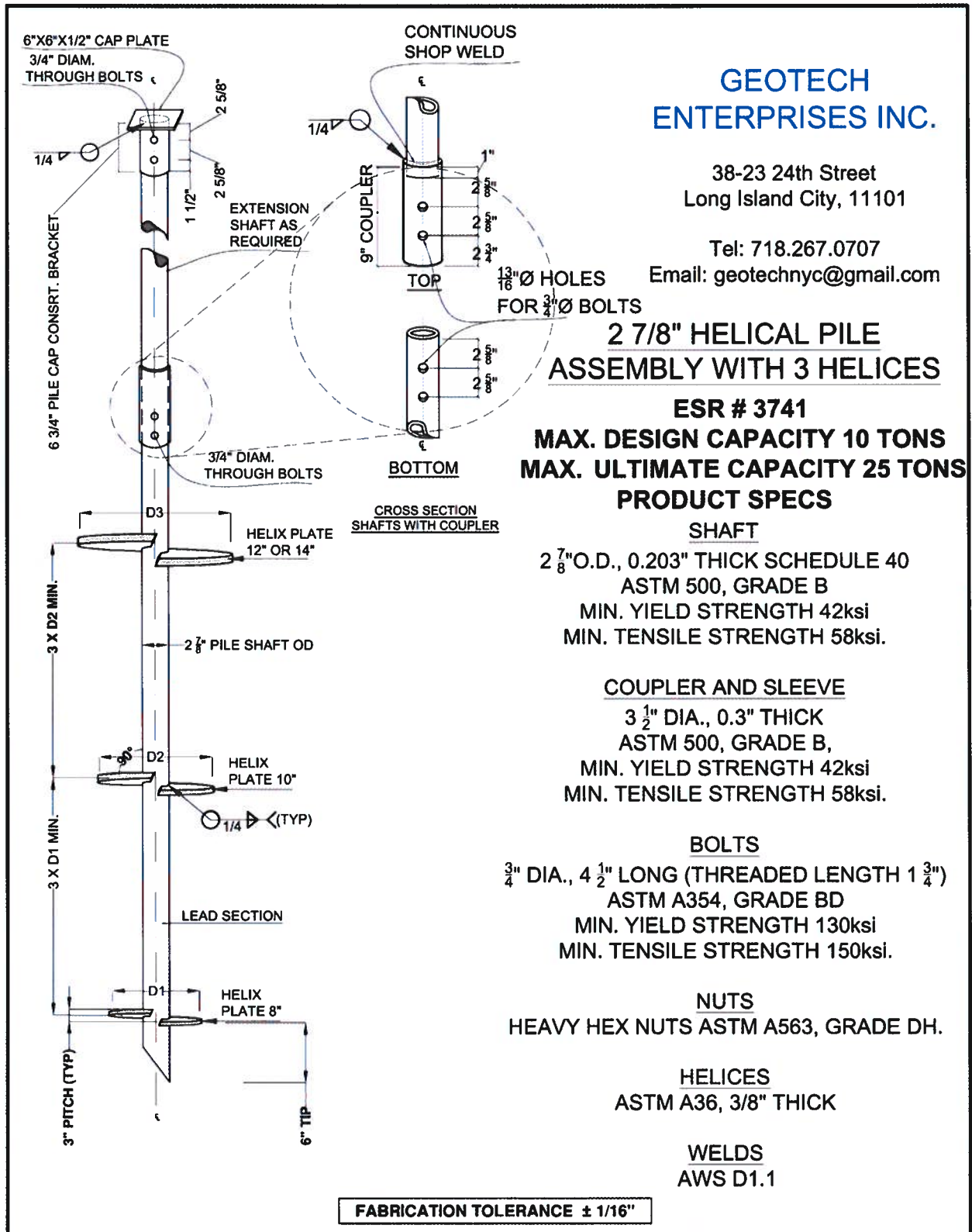


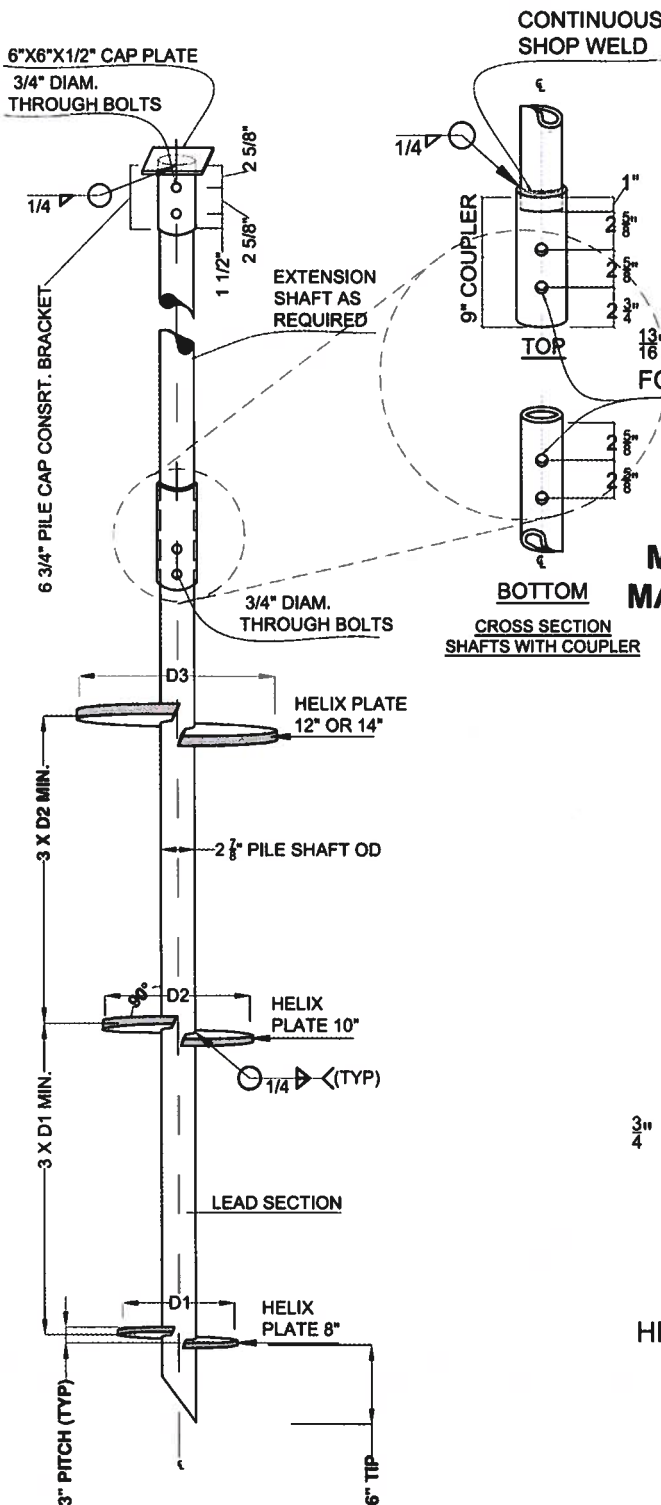
Fig. 1 2 7/8" Shaft, Schedule 40

2 7/8" SHAFT, SCHEDULE 80

GEOTECH ENTERPRISES INC.

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2 7/8" HELICAL PILE ASSEMBLY WITH 3 HELICES

ESR # 3741

MAX. DESIGN CAPACITY 15 TONS
MAX. ULTIMATE CAPACITY 30 TONS
PRODUCT SPECS

SHAFT

2 7/8" O.D., 0.276" THICK, SCHEDULE 80
ASTM 500, GRADE B
MIN. YIELD STRENGTH 42ksi
MIN. TENSILE STRENGTH 58ksi.

COUPLER AND SLEEVE

3 1/2" DIA., 0.3" THICK
ASTM 500, GRADE B
MIN. YIELD STRENGTH 42ksi
MIN. TENSILE STRENGTH 58ksi.

BOLTS

3/4" DIA., 4 1/2" LONG (THREADED LENGTH 1 3/4")
ASTM A354, GRADE BD
MIN. YIELD STRENGTH 130ksi
MIN. TENSILE STRENGTH 150ksi.

NUTS

HEAVY HEX NUTS ASTM A563, GRADE DH.

HELICES

ASTM A36, 3/8" THICK

WELDS

AWS D1.1

FABRICATION TOLERANCE $\pm 1/16"$

Fig. 2 Shaft 2 7/8" Schedule 80

3 1/2" SHAFT, COUPLING INSIDE

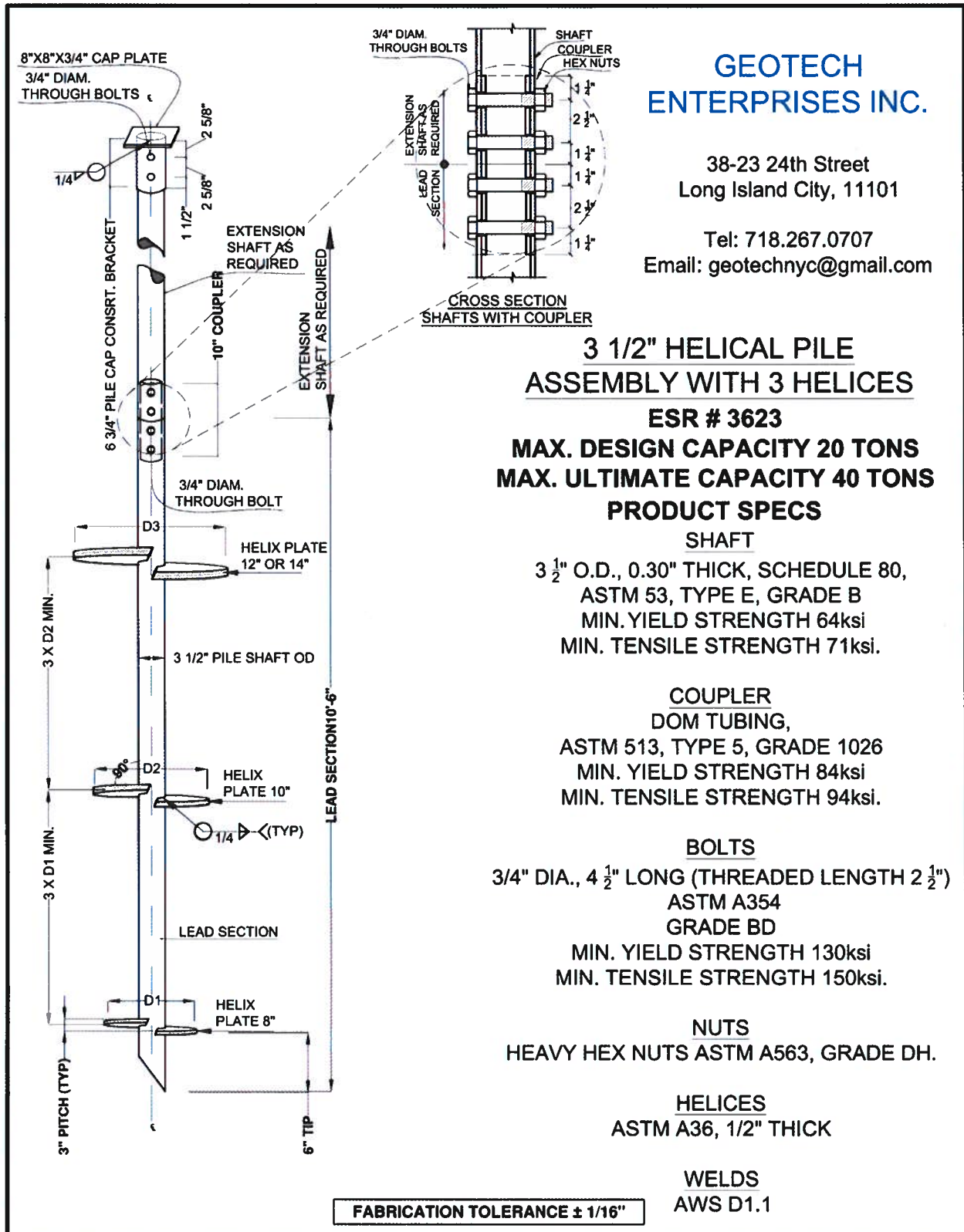


Fig. 3 3 1/2" Shaft, Coupling inside

4 1/2" SHAFT

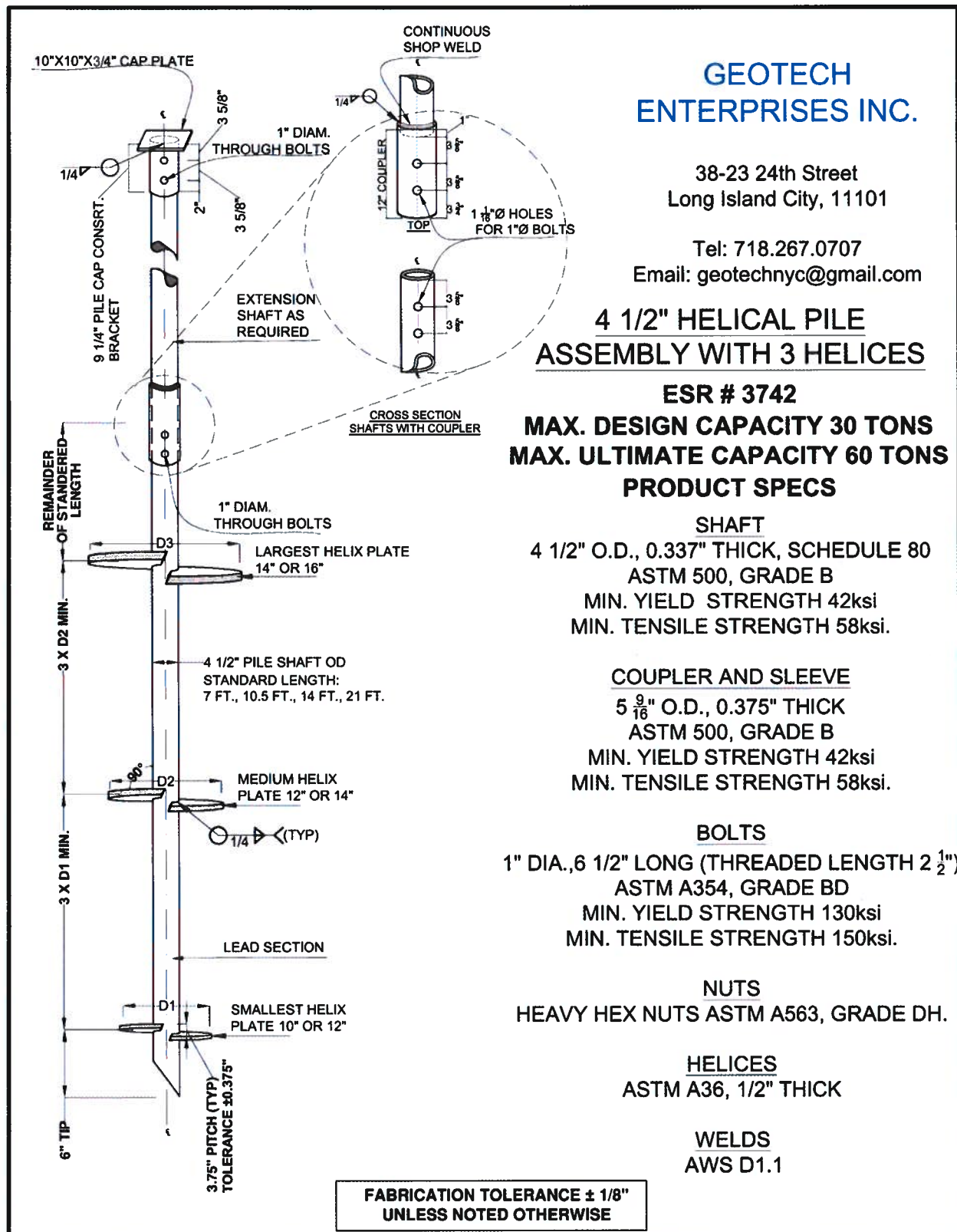


Fig. 5 4 1/2" Shaft

SOIL BEARING UNDER & ECCENTRIC BRACKET

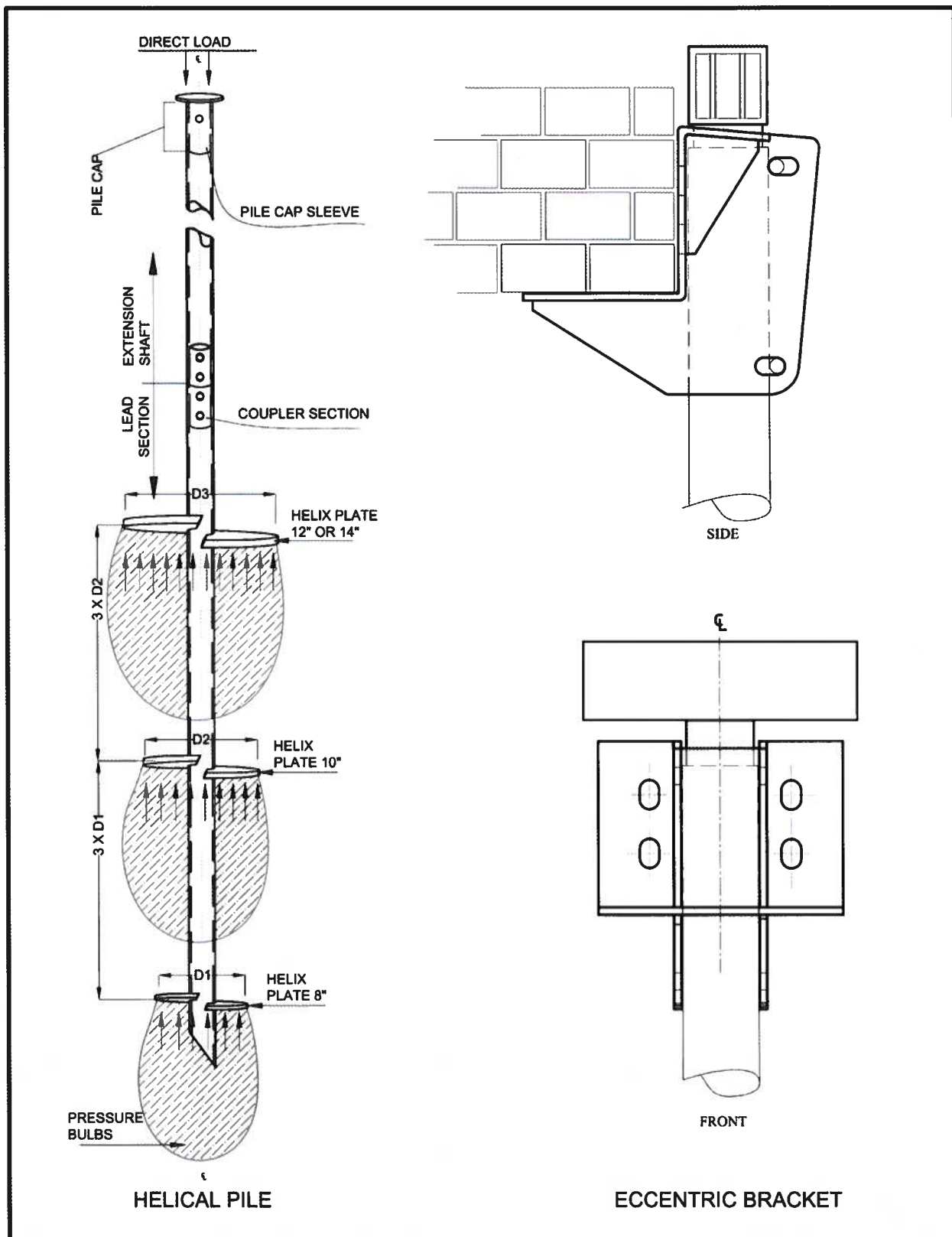


Fig. 6 Soil Bearing Under Helices And Eccentric Bracket

WHERE DO WE NEED HELICAL PILES?

Buildings and structures transfer load to soil, in general, through footing foundation that rests on competent soil. However, for certain sites, the soil at the foundation level may not be strong enough or the structural load may be high enough that it becomes necessary to transfer load to deeper, stronger soil strata through piles. For example, in New York City, class 3B soil (sand) or stronger is usually considered competent soil. An allowable bearing pressure of 2 tons per square foot is generally adequate for light or medium-heavy structures. An allowable bearing pressure for class 4 soil (silt) could be less than 2 tons per square foot which may be too low to carry structural load for certain applications. Class 5 soil (clay) may require further testing in order to verify adequacy. Soil Classes 6 (organic or loose) and 7 (fills) may not be suitable for structural load bearing purposes. Thus, for soil classes 4 through 7, or otherwise weak soil, a pile foundation may be the solution.

In addition to the consideration of soil characteristics, there may exist other concerns specific for certain sites that would require a pile foundation. For example, in flood plain areas, sudden erosion of soil around and beneath footing foundations may be a potential threat to the stability of the supporting structure. A pile foundation, especially helical piles, can anchor the structure to deeper, competent soil layers thereby protecting its stability.

Helical piles are suitable for light-weight and medium-weight structures and buildings because of their design features and ease of mobilization of installation equipment. These piles are uniquely qualified for projects in crowded city blocks since the installation of helical piles does not require impacting with hammers and thus produces no vibration which could otherwise create cracks in existing adjacent or nearby buildings. Another unique feature of helical piles is that the helices also provide substantial resistance against tensile loads thus making them suitable for anchoring structures with the potential for uplifting such as control and transmission towers subject to wind loads.

As an illustration for selection of helical piles based on soil characteristics, consider the following project of a new building in Brooklyn, New York. The footing foundation initially planned for the building with a cellar would rest seven (7) feet below the ground level. As the boring log (Figure 7) shows, the soil underlying the planned foundation level consists of organic material (peat), designated as class 6 and is not suitable for bearing structural load. The option for extending the foundation deeper has been considered but rejected for two reasons: First, the competent soil stratum (i.e., class 3b) starts at a depth of 20 feet requiring additional 13 feet of excavation. Second, the footing of an adjacent building is at about the same level as the new one (i.e., 7 feet) and extends along the property line. Thus, the additional excavation would require underpinning the existing foundation by 13 feet making the option prohibitively expensive as well as dangerous. Therefore, a pile foundation became the choice by necessity. Since vibration could crack the adjacent existing building, the owner opted for helical piles.

Regarding local regulations, the Department of Buildings of the City of New York first issued a bulletin (Reference 22) to specify the conditions for the use of helical piles and has subsequently superseded that with the provisions in the latest Building Code (Reference 23).

LOAD TRANSFER MECHANISM

Helical piles transfer load from the structure to the soil through the helices. The load-carrying mechanism of helical piles has been extensively studied in the literature by both analysis and testing (References 1-20). In compression, each helix may be considered to act separately to transfer load by bearing as shown in Figure 6. The shaft acts as a structural member in carrying the load from the structure and delivering it to the helices. The shaft can also transfer load to the soil directly by friction. But, typically this contribution comes out to be much smaller than the combined bearing capacity of the helices. As a structural member in compression, the shaft must have adequate resistance against buckling since the intermediate soil stratum through which the shaft extends to transfer the load from the structure to the helices contains usually poor soil (e.g., peat) that offers little lateral support. The shafts of the piles we furnish have adequate diameter and thickness for their designated capacity so that they are stiff enough against lateral buckling. This has been demonstrated through numerous field load tests that we have performed to demonstrate pile capacity (see Section on Field Load Test). By geometry, tubular shafts are much stiffer than the solid ones for the same cross sectional area. For example, a 3½" diameter tubular shaft with a 0.3" thick wall is about 3 times as stiff as a 2" square solid shaft even though the tubular shaft requires 25% less material. Consequently, the tubular shafts we furnish are preferable to the solid ones. In any event, the Building Code (Reference 23) requires buckling analysis for piles embedded in fill (class 7) and loose soil (class 6), and allows a compressive strength not greater than $\frac{2}{3}$ of the calculated buckling load.

In tension, although the load transfer mechanism is different, the helices again play the key role. For a pile installed at a depth greater than five times the diameter of the largest helix, the pullout capacity has been attributed to the bearing resistance of the top helix, the shear resistance acting along the wall of a cylinder of soil, formed between the helices, and the friction on the shaft wall above the top helix (Reference 1). For clayey soil, the failure surface changes to some extent. Bearing and friction of the shaft along its length and the shear resistance of the soil cylinder around helices can also transfer a small amount of lateral load from the structure to the soil.

In summary, a helical pile supports both tensile and compressive loads, and the load-carrying capacity can be calculated using formulas available in the literature (References 1-20). However, due to many assumptions inherent in derivation of these formulas including variability of the soil conditions, the as-installed pile capacity may vary significantly from the computed value. Given the background of the general load transfer mechanism of helical piles described above, we will discuss in the next Section how the pile capacity is determined and what the regulations are to this end.

SOIL BORING LOG

Project Address: QUEENS, NY						
Block: 0			CLIENT NAME:			
Lot: 0			Address: QUEENS, NY			
Boring No.: B-2			Tel. & FAX:			
Report No.: ITL-XXX			Report Date: XXX			
Drilling Date: XXX			ENGINEER: XXX			
			P.E. Lic. : XXX			
GROUND WATER OBSERVATION:				METHOD OF ADVANCED BORING	DEPTH OF BORING	
Depth of low face ft	DEPTH	HOUR	DATE			
	12ft	5:30	XXX			
	DEPTH SURFACE	SAMPLE 4	BLOWS PER 6" ON SAMPLES OF 24" LONG			
					DESCRIPTION	
					REMARKS	
1		S - 1			Backfill	Class 7
			8	5		
5			4	4		
		S - 2			Loose Fill, Silt/Clay and Fine Sand	Class 6
			4	3		
10			1	2		
		S - 3			Loose Fill, Peat with Silt/Clay and Fine Sand	Class 6
			1	2		
15			1	1		
		S - 4			Loose Fill, Grayish Brown, Fine Sand	Class 6
			4	3		
20			4	7		
		S - 5			Light Brown, Fine Sand	Class 3b
			10	12		
25			8	8		
		S - 6			Brown, Fine and Medium Sand	Class 3b
			10	11		
30			15	10		
		S - 7			Brown, Fine and Medium Sand	Class 3b
			10	10		
35			12	11		
		S - 8			Brown, Medium and Fine Sand	Class 3b
			9	13		
40			10	12		
	Weight of Hammer	Drop of Hammer	signature		Seal P.E.	
	140.0 lbs.	30 inches				

Fig. 7 Soil Boring Log at Pile Site

PILE CAPACITY

The load bearing capacity of a helical pile in the field depends on three parameters: pile design, soil characteristics, and the interaction between the two (piles and soil). Pile design includes consideration of geometry and material of each component of the pile including the mechanical connections. Soil characteristics including ground water level are available in geotechnical reports. The soil-pile interaction accounts for the effect of the pile on soil as it is screwed into the ground and as such depends on the pile geometry, the depth of the pile, and the installation process. Since for a particular site, soil characteristics are given and cannot be altered, the pile capacity is varied and determined by the use of the other two parameters, namely pile design and interaction between the pile and the soil.

In the design of the pile itself, the major components that can be varied in order to alter the pile capacity are the shaft and the helices. A larger shaft increases pile capacity and larger helices increase soil bearing area, that in turn, also increases pile capacity. For a given geometry and given material properties, the load a pile shaft can carry can be calculated using standard engineering principles as are normally done for other structural members. Samples of the piles that we furnish have been tested and analyzed by an independent laboratory (References 24-29) and the entire pile assemblies have been evaluated by another independent body, a subsidiary of the International Code Council (References 30-32). The allowable, rated or reported capacities of the pile components based only on material strengths under various loading conditions are presented in Tables 2, 3 and 4. The weakest component governs the capacity of the assembly that includes the shaft, helices, couplings and cap. Thus for a 3½" diameter pile assembly with a minimum of two helices, the governing allowable loads are 60 kips in compression, 18 kips intension, 4.7 ft-kips in bending, and 1.4 kips in lateral shear. The rated torsional capacity is 12,500 ft-lb. The capacities in tension and lateral shear can be substantially increased by redesigning the pile cap (e.g., provide two bolts).

The above capacity values have been established from the pile design only without consideration of the soil properties that are expected to vary from site to site. In other words, the pile-design capacities are upper-bound values of the respective actual capacities in the field. For the actual capacities, we need to consider the next parameter: interaction between the pile and the soil. This can be achieved in three different ways: computing soil bearing capacity under helices, using an empirical formula, and performing a load test on a pile in the field.

Helix Bearing Capacity

In the first method, the load that can safely be transmitted from a helix to the soil is calculated by multiplying the allowable soil bearing pressure with the area of the helix (see Figure 6). This is repeated for all the helices and the sum of the products provides an estimate of the total compressive load that the soil can safely carry under the helices. This load becomes an estimate of the pile capacity in compression. The estimation ignores the soil bearing at the pile tip and the soil friction along the shaft wall, both of which are conservative assumptions in the sense that the true pile capacity will be greater than the estimated value. The estimation also ignores possible interaction of the soil bearing areas, i.e., the possibility that a part of the load from one helix could reach the area underneath the next lower helix and appreciably reduce the bearing capacity of the soil below the second helix.

PILE CAPACITY (Cont.)

Table 2
Capacity of Pile Components Based on Material
Strength for 2½-inch Diameter Shaft, Schedule 40

Component	Allowable Axial Compression	Allowable Axial Tension	Allowable Bend- ing Moment	Allowable Lat- eral Shear	Torsion
Shaft with Couplings	32,400 lbs.	22,900 lbs.	2,310 ft-lb	9,100 lbs.	5,744 ft-lb (Rated)
Helix: 8" Diameter	34,460 lbs.	34,460 lbs.			
Helix: 10" Diameter	29,906 lbs.	29,906 lbs.			
Helix: 12" Diameter	36,704 lbs.	36,704 lbs.			
Helix: 14" Diameter	43,168 lbs.	43,168 lbs.			
Cap (Bracket)	32,490 lbs.	30,410 lbs.		1,980 lbs.	

PILE CAPACITY (Cont.)

Table 3
Capacity of Pile Components Based on Material
Strength for 3½-inch Diameter Shaft

Component	Allowable Axial Compression	Allowable Axial Tension	Allowable Bend- ing Moment	Allowable Lat- eral Shear	Torsion
Shaft with Couplings	60,000 lbs.	47,400 lbs.	4,740 ft-lb	28,300 lbs.	12,500 ft-lb (Rated)
Helix: 8" Diameter	47,355 lbs.	47,355 lbs.			>15,000 ft-lb (Reported)
Helix: 10" Diameter	47,172 lbs.	47,172 lbs.			>15,000 ft-lb (Reported)
Helix: 12" Diameter	39,890 lbs.	39,890 lbs.			>16,000 ft-lb (Reported)
Helix: 14" Diameter	39,472 lbs.	39,472 lbs.			>14,000 ft-lb (Reported)
Cap (Bracket)	60,000 lbs.	18,350 lbs.		1,430 lbs.	

PILE CAPACITY (Cont.)

Table 4
Capacity of Pile Components Based on Material
Strength for 4½-inch Diameter Shaft

Component	Allowable Axial Compression	Allowable Axial Tension	Allowable Bend- ing Moment	Allowable Lat- eral Shear	Torsion
Shaft with Couplings	60,000 lbs.	42,400 lbs.	10,210 ft-lb	26,600 lbs.	21,900 ft-lb (Rated)
Helix: 10" Diameter	49,200 lbs.	49,200 lbs.			
Helix: 12" Diameter	48,226 lbs.	48,226 lbs.			
Helix: 14" Diameter	41,936 lbs.	41,936 lbs.			
Helix: 16" Diameter	45,293 lbs.	45,293 lbs.			
Cap (Bracket)	60,000 lbs.	60,000 lbs.		3,100 lbs.	

PILE CAPACITY (Cont.)

The possibility of such interaction is avoided by placing the helices sufficiently apart so that the load from an upper helix is distributed over a wide area without appreciably affecting the load-transfer capability of a lower helix. For example, our pile design specifies a spacing of three times the diameter of the lower helix as mentioned earlier in the Section on physical description of piles.

In any event, the reliability of this method for estimation of the pile capacity from helices depends on the degree of knowledge we have of the actual bearing pressure of soil at the levels of the helices. The soil bearing pressure available from a geotechnical exploration is typically based on the number of blow counts from standard penetration tests in the field and sieve analysis for particle size in the laboratory. These tests provide an indirect and rough estimate of the bearing pressure which could be far from the actual soil capacity. Since such estimations usually follow the guidelines of national standards and local codes (e.g., New York City Building Code), they are usually conservative and thus serve the purpose of designing foundation for direct load bearing but not necessarily reflect the actual soil capacity. For example, the New York City Building Code specifies a maximum allowable bearing pressure of 3 tons per square foot for sandy soil up to a blow count number of 30. (This is usually considered to be competent soil). Considering a 3½" diameter pile with three helices of diameters 8, 10, and 12 inches, the net bearing area is 1.5 square feet which translates to an allowable pile capacity for the sandy soil as $(1.5 \times 3 =) 4.5$ tons. This is far lower than the allowable capacity of 30 tons in compression based on the shaft strength (see Table 2) or a similar value confirmed by field testing. Even if we double the soil bearing pressure to consider the embedment effect (Reference 23), the capacity based on helix bearing becomes $(2 \times 4.5 =) 9$ tons which is still very low. Such a wide discrepancy arises because the actual soil bearing pressure at the level of the helices is much higher than what is usually provided in geotechnical reports. Our inability to estimate the real soil bearing capacity at the helix level is further complicated due to the fact that the insertion of the pile itself alters the soil bearing capacity. As the pile shaft progressively becomes embedded in the competent soil, the twisting of the pile and rotation of the helices press the soil underneath helices thereby enhancing its compaction which, in turn, increases the soil bearing capacity. Furthermore, when the installation torque causes a firm grip of the pile, the compacted soil underneath helices likely acts as a bulb of a higher bearing capacity than on natural soil around. Thus, in summary, the pile capacity estimated using the method of soil bearing of helix areas ignores such soil-structure interaction and renders an unrealistically low value.

Empirical Formula

In the second method, the pile capacity is estimated by using an empirical formula that relates the capacity to the installation torque. As a helical pile is screwed into the soil, the torque needed to rotate the pile head usually increases. At a certain depth (e.g., with competent soil) the helices form a "firm grip" on soil and the corresponding torque can be used for an indirect estimate of the pile bearing capacity in compression using the following empirical formula:

$$\text{Ultimate capacity} = A \text{ factor} \times \text{torque.}$$

PILE CAPACITY (Cont.)

The factor in the formula reflects the soil interaction with the pile geometry at the ultimate installation torque level and is estimated from past experiences. For our pile design with a 3½-inch diameter shaft, the ICC review group recommends a factor of 7 where the torque is expressed in foot-pound yielding the ultimate capacity in pound (Reference 31). Using a factor of safety of 2 (as required by the New York City Department of Buildings, Reference 23), the allowable pile capacity would be 3½ times the installation torque. If the pile is installed with the rated shaft torque capacity of 12,500 ft.lb (see Table 3), the allowable pile capacity in compression would be $(3.5 \times 12,500 =)$ 44,000 lb or 22 tons which is a realistic estimate. The torque multiplying factors recommended by the ICC review group for 2⅞" and 4½" diameter shafts are 9 and 5.5, respectively (References 30 and 32).

The strength of this approach is that the installation torque is a good measure of the "grip" between the pile (including helices) and the soil, thus representing a more realistic interaction between the two than the first method in which only the soil bearing pressure has been considered ignoring the installation process thus capturing the effect of a mere action rather than an interaction. The weakness of this approach is that torsional shear is a force component different from the actual compression which is the target force component so that the installation torque can at most indicate an indirect estimate of the pile capacity in compression. This weakness is addressed by using an empirical factor to relate the torque with the capacity of a pile for a particular size. As we have noted above, for the 3 1/2" diameter pile, the recommended value of the factor is 7. However, this value is generic, and its applicability to a particular site with specific soil characteristics and ground water condition may be questioned. Thus, in summary, this empirical method represents to a good extent the soil-pile interaction during installation but the value of the relational factor may need to be determined on a site-specific basis by performing a load test in the field. The NYC Department of Buildings acknowledges this weakness and requires a factor of safety of 2.5 and limits the pile capacity to 10 tons if the site-specific correlation by load test is not performed (Reference 23).

Field Load Test

In the third method, a minimum of one pile is tested in the field by applying a load to which it is expected to be qualified. According to New York Building Code, the allowable capacity of the pile can be taken as one half of the qualification load (e.g., maximum test load, Reference 23). This method is more direct than the other two and provides a realistic characterization of the pile for the test conditions. Since such pile tests are proof tests, the load bearing capacity of the pile may not be reached within the predetermined loading level. The weakness of this method is how to qualify the remainder of the piles that would not be tested. Here comes the utility of the second method (i.e., empirical formula), as a complementary procedure. The factor relating the installation torque to the pile resistance discussed above can be determined for the tested pile and the same factor may be used to qualify the rest of the piles as long as the pile design and soil characteristics are comparable. More discussions on pile testing are included in a subsequent Section.

PILE CAPACITY (Cont.)

Summary

In summary, the first method (computing load bearing capacity of soil underneath helices) provides usually a poor and ultra-conservative estimate of the pile capacity. The second method (empirical formula) is too generic and the applicability of a predetermined relational factor is questionable. The third method (field load test) provides the most realistic measure of resistance of the tested pile up to the qualification load level but applicability of the test results to the other piles requires a load-torque relational factor similar to the second method (empirical formula). The relational factor can be better established from the load test results by comparing the qualification load with the installation torque, (rather than assuming a generic value as Method 2 does). In any event, the pile capacity obtained by any of the three soil-pile interaction methods is expected to be bounded by the corresponding capacity determined earlier based only on material strength as presented in Tables 2, 3 and 4. Thus, for example, the upper-bound allowable capacity of our 3½-inch diameter pile assembly in compression is 30 tons based on material strength and about 20 tons based on expected generic soil-pile interaction. In any event, the actual capacity or a qualification-level load is to be established by a load test in the field. The upper-bound allowable capacity for 3½-inch diameter piles in tension is 9 tons (see Table 3). Since the weak link for the tensile capacity is the pile cap with one bolt, the capacity can be substantially increased by redesigning the cap (e.g., by providing two bolts).

The maximum allowable compressive load for our piles are as follows:

2⅞-inch diameter, schedule 40	10 tons
2⅞-inch diameter, schedule 80	15 tons
3½-inch diameter, schedule 80	20 tons
4½-inch diameter, schedule 80	30 tons

The maximum allowable loads for any helical piles permitted by the Building Code (Reference 23) are as follows:

30 tons in compression
30 tons in tension
3 tons for lateral load

DESIGN OF PILE FOUNDATION

In addition to furnishing the pile assemblies, we also offer the services of designing the pile foundation for our clients. If on the other hand, the structural engineers for a project decide to perform the design themselves, we offer our assistance and provide them with necessary technical information about our products.

If we perform the pile foundation design, we do it in two steps: calculate the load that each pile is supposed to carry and select a pile configuration that would provide the strength necessary to support the load. In order to calculate the pile load, we use the building/structure data that the client can provide, such as conceptual plan, soil exploration data, architectural drawings and engineering calculations, if available. The more information the client can furnish, the better estimate we can make of the pile load. Depending on the structural members, such as columns and walls, the pile load and spacing can be obtained individually or as a group.

The next step is the selection of the shaft diameter. If the pile design load is relatively small (e.g., 10 tons), 2 $\frac{7}{8}$ " diameter pile may be adequate. On the other hand, if the demand is higher (say, 20 to 30 tons), 3 $\frac{1}{2}$ " or 4 $\frac{1}{2}$ " diameter shafts would be required. A larger shaft diameter makes the pile more stable.

The remaining physical parameters are the helices and pile depth. By varying either of the two, the pile capacity can be changed for a given soil profile. The soil boring data is very important at this stage of the design. We study the soil data of both the load-bearing stratum and intermediate layers. The soil classification, blow-counts and water table data are crucial for judging the competent soil layer where the helices can seat for good bearing. Based on experience, a set of helices is selected as a starting point and the load bearing capacity of the proposed pile configuration is estimated by use of the methods and data presented in the previous section on pile capacity. If the estimated pile capacity is comparable to the demand load, the proposed pile configuration can be considered to be optimum. If not, the diameters, and possibly also the numbers of the helices, can be changed to achieve the desired strength.

The theoretical design as described above will provide an approximate depth of the pile. The actual depth needed to attain the desired strength will be determined in the field during pile installation as described in the next section. This happens due primarily to the variation of soil strength across the site as well as to the approximation inherent in the theoretical formulas. In extreme cases, the helix configuration may also be altered in order to provide a cost-effective, custom-made design.

If the engineers intend to perform the design themselves (instead of using our design services), they may find the following quick method based on our experience to be useful.

DESIGN OF PILE FOUNDATION (Cont.)

QUICK METHOD

Use the following steps:

- A) Compute the load that needs to be transferred to the piles.
- B) Select a pile diameter and desired pile strength in terms of allowable (design) load (see Table 5 as a guide).

Table 5

Type of Structure	Pile Diameter (Inches)	Desired pile strength allowable (Design) Load (Tons)
One- or Two-Family Buildings	2½ Schedule 40 2½ Schedule 80	5-10 10-15
Two- to Ten-Story Buildings or Medium Heavy Structures	3½ Schedule 40 4½ Schedule 80	10-20 20-30

C) Prepare a pile layout plan. Use a spacing of 4 feet between piles for individual footings (e.g., column footings). For wall footings, Table 6 may be used as a guide.

D) Design concrete foundation including pile caps, tie beams, etc. for the pile layout plan.

E) Compute final load on each pile including the weight of concrete foundation and verify adequacy of pile diameter. Repeat Steps (B) through (E) as necessary.

F) Provide us with the final pile layout plan including the demand pile capacity (the ultimate capacity is usually twice the design allowable load). Specify if you would like the piles to be galvanized (see Section on Life Extension). Also, specify how many load tests you would require (none for pile load less than 10 Tons; otherwise, minimum one).

DESIGN OF PILE FOUNDATION (Cont.)

Table 6
SPACING OF PILES FOR A LINEAR LOAD (e.g., Wall)

Linear Load (Kips/ft)	Demand Pile Capacity in terms of Design (Working) Load (Tons)										
	5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30
1.0	10'-0	15'-0	20'-0	25'-0	30'-0						
1.5	6'-8	10'-0	13'-4	16'-8	20'-0	23'-4	26'-8				
2.0	5'-0	7'-6	10'-0	12'-6	15'-0	17'-6	20'-0	22'-6	25'-0		
2.5	4'-0	6'-0	8'-0	10'-0	12'-0	14'-0	16'-0	18'-0	20'-0	22'-0	24'-0
3.0		5'-0	6'-8	8'-4	10'-0	11'-8	13'-4	15'-0	16'-8	18'-4	20'-0
3.5	-	4'-3	5'-8	7'-1	8'-7	10'-0	11'-5	12'-10	14'-3	15'-8	17'-1
4.0	-		5'-0	6'-3	7'-6	8'-9	10'-0	11'-3	12'-6	13'-9	15'-0
4.5	-		4'-5	5'-6	6'-8	7'-9	8'-10	10'-0	11'-1	12'-2	13'-4
5.0	-	-	4'-0	5'-0	6'-0	7'-0	8'-0	9'-0	10'-0	11'-0	12'-0
5.5	-	-		4'-6	5'-5	6'-4	7'-3	8'-2	9'-1	10'-0	10'-11
6.0	-	-	-	4'-2	5'-0	5'-10	7'-8	9'-6	10'-4	11'-2	12'-0
6.5	-	-	-		4'-7	5'-4	6'-1	6'-11	7'-8	8'-5	9'-2
7.0	-	-	-		4'-3	5'-0	5'-8	6'-5	7'-1	7'-10	8'-6
7.5	-	-	-	-	4'-0	4'-8	5'-4	6'-0	6'-8	7'-4	8'-0
8.0	-	-	-	-		4'-4	5'-0	5'-7	6'-3	6'-10	7'-6
8.5	-	-	-	-		4'-1	4'-8	5'-3	5'-10	6'-5	7'-0
9.0	-	-	-	-	-		4'-5	5'-0	5'-6	6'-1	6'-8
9.5	-	-	-	-	-		4'-2	4'-8	5'-3	5'-9	6'-3
10.0	-	-	-	-	-		4'-0	4'-6	5'-0	5'-6	6'-0
10.5	-	-	-	-	-	-		4'-3	4'-9	5'-2	5'-8
11.0	-	-	-	-	-	-		4'-1	4'-6	5'-0	5'-5
11.5	-	-	-	-	-	-			4'-4	4'-9	5'-2
12.0	-	-	-	-	-	-	-		4'-2	4'-7	5'-0

DESIGN OF PILE FOUNDATION (Cont.)

NOTE

The depth of pile required for the specified demand load will be determined in the field. If an approximate idea is needed (e.g., for estimating cost), review the soil boring data and find a competent, compact soil layer (e.g., medium sand). Compute the depth assuming that at least 10 feet of the pile should be embedded inside this compact soil layer. Again, this is an approximate estimate.

Never specify the pile depth as an installation requirement since the pile strength dictates the actual depth. Specifying both is a contradiction.

Never specify the torque as an installation requirement since the pile strength again dictates the installation torque. The torque needed to achieve the desired pile strength is calibrated through the load test.

Two examples of pile foundation design - one for wall footing and another for column footing - are provided in the subsequent pages to illustrate the use of the design steps suggested above.

DESIGN OF PILE FOUNDATION (Cont.)

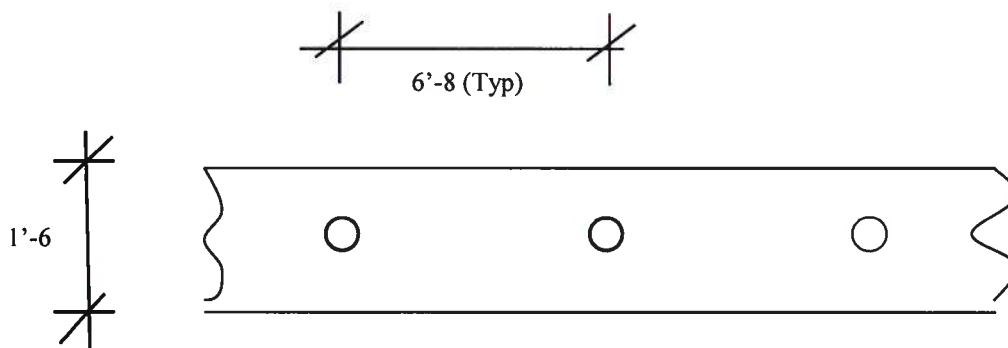
Example 1

The load-bearing wall of a two-family house carries a design load of 2.5 Kips/ft including its own weight. Design a pile foundation for the wall.

Select 27/8" diameter piles and assume each pile can carry a maximum design load of 10 Tons (Table 5). Assuming 1'-6" wide and 2'-0" deep continuous pile cap, the actual line load = $1.5 \times 2.0 \times 0.15 + 2.5 = 2.95 \text{ K/ft}$.

From Table 6, the spacing of 10-Ton piles required to carry 2.95 K/ft is approximately 6'-8" which is greater than the minimum spacing of 4'-0". Therefore, the specification for the given project would be as follows:

Furnish steel helical piles with 27/8" diameter, 0.276" thick shafts and three helices with a minimum thickness of 3/8". The piles as installed shall have a minimum allowable load capacity of 10Tons in compression. The piles including the couplings shall be hot-dip galvanized and installed at 6'-8" O.C. as shown on the drawing.

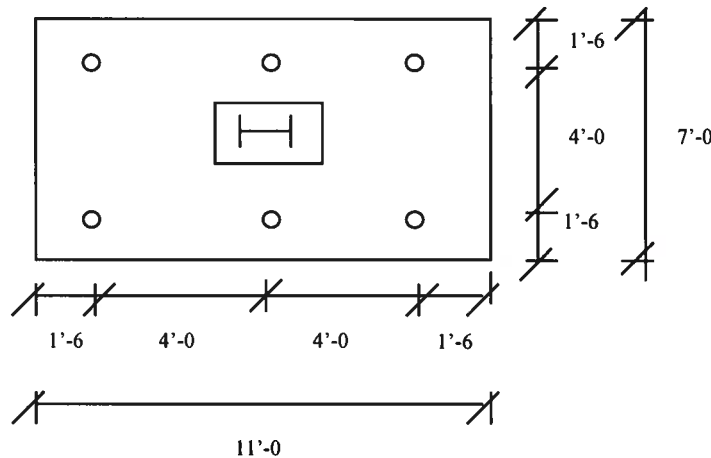


DESIGN OF PILE FOUNDATION (Cont.)

Example 2

An interior column of a six-story steel-framed building carries a design load of 210 Kips. Design a helical pile foundation for the column.

Use Table 5 and select 3½" diameter piles. Assume a capacity of 20 Tons design load. The number of piles needed will be $210/(20 \times 2) = 5.25$, say 6. Using a minimum spacing of 4'-0", the following pile cap can be considered:



Assuming a 2-foot thick pile cap, the total design load = $210 + 2 \times 7 \times 11 \times 0.15 = 233$ Kips
Actual load per pile = $233/6 = 39$ Kips < 40 Kips, OK

The piles can be specified as follows:

Furnish steel helical piles with 3½" diameter, 0.3" thick shafts and three helices with a minimum thickness of ½". The piles including the couplings shall be hot-dip galvanized and installed as shown on the drawing. The piles shall have a minimum ultimate load capacity of 40 Tons each in compression. The pile strength shall be demonstrated by a load test during which load vs. settlement data will be recorded. Upon completion of the project, a report including field installation data (e.g., depth and torque) and load test data (load vs. settlement) shall be provided.

DISCLAIMER

The contents of the above quick method and the accompanied illustrations are intended to assist the engineers in designing a pile foundation and writing their own specifications. The final design of any helical pile system requires knowledge of the specific soil properties and the structural conditions of each project. The design of any helical pile system is the full and complete responsibility of the design engineers.

INSTALLATION OF PILES

Unlike many other structural components, the reliability of a pile foundation depends to a great extent on the field process. The appropriate soil-pile interaction necessary to assure the desired pile capacity as discussed in a previous Section is achieved on a real-time basis during installation. Minor departures from proper installation techniques could substantially reduce the load-carrying capability of a pile. Therefore, it is of paramount importance that piles are installed by trained technicians and the process is supervised by engineers well experienced in this field. It is no wonder that the regulatory authorities such as the New York City Department of Buildings place enormous emphasis on inspection and documentation of the installation process as further elaborated at the end of this Section.

Helical piles are screwed into the ground by applying torque. A small amount of continuous push is also necessary for forward movement of the pile. Every turn of the pile advances it by a length equal to the pitch of the helices.

Equipment such as skid steer and excavator with high-flow hydraulic pressure is used to generate the necessary forces (See Exhibit D for photos). (We review the pile installation equipment on a project-specific basis and advise the installer accordingly.) The in-flow and out-flow hydraulic pressures of the drive head are monitored continuously. The difference between the two pressures is a measure of the torque being applied. The torque can also be measured directly by an electronic torque indicator. Initially, the required torque is very low and remains low as the pile penetrates through poor soil, such as peat. The torque increases sharply as the helices become embedded in competent soil, such as dense sand (See Figure D-14). Thus the installation torque is an indirect measure of the pile capacity. However, the exact relation between the two is typically not known aprioré. The literature shows a wide range of values of the multiplier that can be used to obtain the pile capacity from the torque. The interaction between the pile geometry and the site soil condition determines the appropriate multiplication factor. Thus, field load test data serve the need to correlate the torque with the actual pile capacity (see next Section).

Once the relation between the torque and pile capacity has been established through a load test, the remaining piles are installed to the necessary torque. Thus, the exact depth of a pile required to achieve the desired strength is established in the field during installation, although an approximate depth can be estimated before installation based on soil data. Frequently the two depths, i.e., estimated vs. actual, vary significantly. Furthermore, two adjacent piles of an identical design for the same project may require different depths to achieve the same desired strength.

The installation starts with the starter section that contains the helices and more sections (called “extensions”) are added as the pile depth increases. Strong couplings with bolts are used to connect two adjacent sections and the operation continues until the desired torque has been reached. The required torque may be reached gradually or suddenly depending on the soil as can be observed from the attached installation logs.

PILE INSTALLATION LOG

PILE INSTALLATION LOG							
				Machinery Used Hydraulic Equipment: CASE SHI SHAW 85X Digger Drive: Mako 88 Model : Eshridge/77 (One-Gear) Rate: 12,000 ft-lb Cone Factor(p): 5			
PROJECT XXXX-PL			CLIENT NAME: XXX				
Pile No. 13			Address: BROOKLYN, NY				
Pile Diameter: 12"			Installed by: HENRY				
			Pile Diameter: 10/12/14"		Date: XXX		
Depth ft	In-Pressure		Head-Pressure	Factor	Differential Pressure	Torque	REMARKS
	p1 psi	p2 psi	q		$\Delta p = p1 - p2$ psi	$T = q \Delta p$ ft-lbs	
1	900	350	5		550	2,750	
2	.	.	.	.	.	.	
3	.	.	.	.	.	.	
4	.	.	.	.	.	.	
5	.	.	.	.	.	.	
6	.	.	.	.	.	.	
7	.	.	.	.	.	.	
8	.	.	.	.	.	.	
9	.	.	.	.	.	.	
10	800	280	5		450	2,750	
11	.	.	.	.	.	.	
12	1,100	350	5		750	3,750	
13	.	.	.	.	.	.	
14	1,200	300	5		900	4,500	
15	.	.	.	.	.	.	
16	1,500	300	5		1200	6,000	
17	.	.	.	.	.	.	
18	1,000	300	5		1300	6,500	
19	.	.	.	.	.	.	
20	1,700	250	5		1450	7,250	
21							
22							
23							
24							
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PILE INSTALLATION LOG

PILE INSTALLATION LOG						
				Machinery Used Hydraulic Equipment: CASE 816D Steer 85X Digger Drive: Make 81 Model : Echridge/77(One Gear) Rated: 12,000 ft-lb Const. Factor(q): 5		
PROJECT XXXX-PL			CLIENT NAME: XXX			
File No. 103			Address: BROOKLYN, NY			
Shaft Diameter: 3.6"			Installed by: JOSE		Date: XXX	
Head Diameter: 10712"14"						
Depth ft	In-Pressure p1 psi	Back-Pressure p2 psi	Factor q	Differential Pressure $\Delta p = p1 - p2$ psi	Torque $T = q \Delta p$ ft-lbs	REMARKS
1	900	400	5	500	2,500	
2	"	"	"	"	"	
3	"	"	"	"	"	
4	"	"	"	"	"	
5	"	"	"	"	"	
6	"	"	"	"	"	
7	"	"	"	"	"	
8	"	"	"	"	"	
9	"	"	"	"	"	
10	1,000	400	5	600	3,000	
11	"	"	"	"	"	
12	900	400	5	500	2,500	
13	"	"	"	"	"	
14	1,100	400	5	700	3,500	
15	"	"	"	"	"	
16	1,000	400	5	600	3,000	
17	"	"	"	"	"	
18	800	300	5	500	2,500	
19	"	"	"	"	"	
20	1,000	300	5	700	3,500	
21	"	"	"	"	"	
22	1,400	300	5	1100	5,500	
23	"	"	"	"	"	
24	1,500	300	5	1200	6,000	
25	"	"	"	"	"	
26	1,600	300	5	1300	6,500	
27	"	"	"	"	"	
28	1,700	250	5	1400	7,000	
29	"	"	"	"	"	
30	1,700	250	5	1450	7,250	
31	"	"	"	"	"	
32	1,700	200	5	1500	7,500	
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PILE INSTALLATION LOG

PILE INSTALLATION LOG						
				Machinery Used Hydraulic Equipment: CASE 544i Steer 95K Cylinder Drive: Make & Model : Exbridge/77 (One - Gear) Rate: 12,000 ft-lb Cone Factor(q): 5		
PROJECT XXXL-FL File No. 28 Shell Diameter: 3.6"			CLIENT NAME: XXX Address: BROOKLYN, NY Installed by : HENRY Head Diameter: 10712"14" Date: XXX			
Depth ft	In-Pressure p1 psi	Back-Pressure p2 psi	Factor q	Differential Pressure Ap = p1-p2 psi	Torque T=qAp ft-lbs	REMARKS
1	800	400	6	400	2,000	
2	.	.	.	.	.	
3	.	.	.	.	.	
4	800	400	6	400	2,000	
5	.	.	.	.	.	
6	800	400	6	400	2,000	
7	.	.	.	.	.	
8	800	300	6	500	2,500	
9	.	.	.	.	.	
10	800	300	6	500	2,500	
11	.	.	.	.	.	
12	800	300	6	500	2,500	
13	.	.	.	.	.	
14	800	300	6	500	3,000	
15	.	.	.	.	.	
16	1,100	300	6	800	4,000	
17	.	.	.	.	.	
18	1,200	300	6	900	4,500	
19	.	.	.	.	.	
20	1,400	300	6	1100	5,500	
21	.	.	.	.	.	
22	1,400	300	6	1100	5,500	
23	.	.	.	.	.	
24	1,500	300	6	1200	6,000	
25	.	.	.	.	.	
26	1,500	300	6	1200	6,000	
27	.	.	.	.	.	
28	1,600	250	6	1350	6,950	
29	.	.	.	.	.	
30	2,400	200	6	2200	11,000	
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PILE INSTALLATION LOG

PILE INSTALLATION LOG								
					Machinery Used Hydraulic Equipment: CASE Side Steer 95X Digger Drive: White 88 Model : Schirge/77 (One- Gear) Rated: 12,000 ft-lb Cons. Factor(q): 5			
PROJECT XXXX-FL			CLIENT NAME: XXX					
File No. 18			Address: FAR ROCKAWAY, NY					
Shaft Diameter: 3.5"			Installed by: PHILIP			Date: XXX		
Depth ft	In-Pressure		Back-Pressure		Factor	Differential Pressure	Torque	REMARKS
	p1 psi	psi	p2 psi	psi	q	$\Delta p = p1 - p2$ psi	$T = q \Delta p$ ft-lbs	
1	1000		400		5	600	3,000	
2	.		.		.	.	.	
3	.		.		.	.	.	
4	.		.		.	.	.	
5	.		.		.	.	.	
6	.		.		.	.	.	
7	.		.		.	.	.	
8	.		.		.	.	.	
9	.		.		.	.	.	
10	1,000		400		5	600	3,000	
11	.		.		.	.	.	
12	1,100		300		5	800	4,000	
13	.		.		.	.	.	
14	1,200		300		5	900	4,500	
15	.		.		.	.	.	
16	1,200		300		5	900	4,500	
17	.		.		.	.	.	
18	1,000		300		5	700	3,500	
19	.		.		.	.	.	
20	900		300		5	600	3,000	
21	.		.		.	.	.	
22	800		300		5	500	2,500	
23	.		.		.	.	.	
24	900		300		5	600	3,000	
25	.		.		.	.	.	
26	1,000		300		5	700	3,500	
27	.		.		.	.	.	
28	1,100		300		5	800	4,000	
29	.		.		.	.	.	
30	1,100		300		5	800	4,000	
31	.		.		.	.	.	
32	1,200		300		5	900	4,500	
33	.		.		.	.	.	
34	1,400		300		5	1,100	5,500	
35	1,500		300		5	1,200	6,000	
36	1,600		300		5	1,300	6,500	
37	1,700		250		5	1,450	7,250	
38	1,800		250		5	1,550	7,750	
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INSTALLATION OF PILES (Cont.)

At sites with loose backfill, it has been frequently observed that as the pile is twisted in, an inverted conical hole grows around it. Continuous filling in with grout as the installation proceeds has been found to be effective in restoring lateral stability.

Since the tubular shaft sections come with a standard length and since different depths are expected to be required for different piles, upon completion of installation of all piles, the site looks more like a winter forest with standing trees of varying heights, i.e., the piles extend above the ground by varying heights. At that point, the extended sections are cut to the desired elevations according to the design drawings and a matching steel cap placed on the top of each pile (See Figure B-13). Ultimately, concrete is poured to embed the steel cap including the pile top to form a pile foundation either individually or as a group.

The pile installation technique is principally the same regardless of whether the pile will carry compressive or tensile load in its service life. For a tensile pile, the minimum depth of the uppermost helix is 12 times the diameter of the largest helix (References 30-32). Piles can be installed vertically or battered to the desired slope if the design requires so.

For every pile, a field log shall be prepared during its installation. In particular, New York City Department of Buildings requires the following for installation of helical piles (Reference 23; see attached Installation Logs):

1. Equipment used for the installation of helical piles shall be as recommended by the helical piles manufacturer.
2. The installation of helical piles shall be subject to the special inspection requirements stated in section BC 1704.8.
3. The special inspector shall prepare a report summarizing all helical piles installed (e.g. TR-5 form). The following additional information shall be reported:
 - 3.1. Helical pile type and product specification sheet for each helical pile installed published by the manufacturer.
 - 3.2. Make and model of the equipment used for installation
 - 3.3. Make and model number of the torque indicator used to measure installation torque.
 - 3.4. Calibration records for the torque indicator used to measure installation torque.
 - 3.5. The installation speed (rpm) of the helical pile.

INSTALLATION OF PILES (Cont.)

3.6. From axial load tests and the site-specific torque-to-capacity relationship, the minimum torque required to achieve the allowable pile load in tension or compression

3.7. For each helical pile, measure and log the installation torque for each foot of depth and the final torque in the helices soil bearing zone. The shaft advancement shall equal or exceed 85% of helix pitch per revolution at time of final torque measurement.

As explained earlier, field load tests are necessary to establish the required installation torque. This topic is discussed in the next Section.

FIELD LOAD TEST

A field load test is performed to demonstrate the strength of an installed helical pile and thus to establish the required torque. Typically, the pile load test is a proof test in that the pile is subjected to a predetermined load rather than loading to failure. The test load must certainly be greater than the design load and is often equal to the so-called “ultimate pile capacity”, which is obtained by multiplying the design load with a factor of safety. As with any other structural members, the factor of safety for helical piles is introduced in order to take into account the randomness and uncertainties inherent in the entire design and construction process and to institute a high degree of confidence that the pile will perform its intended function during its service life in transferring safely the structural load to the soil. Settlement is used as the indicator for performance of a pile. An acceptable upper limit as well as the trend of settlement is used to judge performance of a pile. For example, a sudden increase of settlement with an increasing load may indicate failure.

A factor of safety between 2 and 3 against compressive load is common in the industry. Department of Buildings of the City of New York requires a minimum value of 2 (Reference 23; see below for exception) Thus, for example, if the allowable (design) load in compression for a helical pile is 15 tons, the ultimate capacity that one should target for installation is 30 tons. And, the test load is also 30 tons.

Test Procedures and Requirement

For a field test, a steel frame is anchored around the test pile and the loading jack is placed between the frame and the pile (see Exhibit C). Thus, as the load is applied through the hydraulic jack, the pile is pushed down at the expense of a reactionary upward force on the steel frame. (In a tension test, the situation is reverse). The reactionary force is resisted by four or six anchor piles depending the test load (Figure C-3)

A minimum of one load test is required for each set of “substantially similar” soil conditions and pile designs as determined by the engineer. Additional tests may need to be performed for nonconforming or questionable construction. Furthermore, a minimum of two load tests will be required for a site having a footprint (of a building or a group of buildings) between 5,000 and 30,000 square feet and one additional load test for each 20,000 square feet of added footprint area (Reference 23). In a load test, the pile to be tested is loaded incrementally until the full load is reached and then the load is reduced following a decremental unloading pattern. Exactly what the loading increments and decrements should be and how long the load should be sustained at any particular loading step may vary according to the regulatory codes and standards. The settlement of the pile is monitored at each load step and how much settlement will be permitted for qualification and at what point the pile will be considered to reach its capacity depends again on the regulations.

FIELD LOAD TEST (Cont.)

The New York City Department of Building endorses (Reference 23) national (also international) standards for testing of helical piles. The testing procedures for axial compressive load are embodied in ASTM (American Society of Testing Materials) standard D1143 (Reference 33). The quick load test method of the standard, which is particularly promulgated by the Department of Buildings (Reference 23), requires application of load in increments of 5% of the anticipated failure load (i.e., the intended maximum test load or proof load). Once the maximum load has been applied, the load is reduced in five (to ten) equal decrements. The load at each step, whether during increments or decrements, should be kept constant for a time interval not less than 4 minutes. After completing the application of each load increment and at 1 and 4 minutes settlement readings are taken at 0.5, 1, 2 and 4 minutes after completing each load decrement. The readings at the full load and at the removal of all load should be taken for a longer period (15 minutes).

The pile can also be tested in the field for axial tension and lateral load by use of the test procedures embodied in the respective ASTM Standards D3689 (Reference 34) and D3966 (Reference 35). The City of New York Building Department endorses these standards (Reference 23). Following the load test (whether compression, tension or lateral load), each test pile shall be removed by unscrewing and inspected for any deformations to the helices, and to verify the structural integrity of the shaft and its connections (Reference 23).

Acceptance Criteria

The load that can be allowed on the helical pile during its service life is computed from the load-settlement relationship obtained from the test. The Building Department of New York City requires computation of the allowable load as follows (Reference 23):

“The allowable pile load shall be the lesser of the two values computed as follows:

- (a) Fifty percent of the applied load causing a net settlement of the pile of not more than 1/100 of 1 inch per ton ... of applied load. Net settlement in this paragraph is defined as gross settlement due to the total test load minus the rebound after removing 100 per cent of the test load.
- (b) Fifty percent of the applied load causing a net settlement of the pile of $\frac{3}{4}$ inch. Net settlement in this paragraph is defined as the gross settlement due to the total test load less the amount of elastic shortening in the pile section due to total test load.”

FIELD LOAD TEST (Cont.)

Torque Correlation Factor and Settlement

As discussed earlier in the Section on pile capacity, a correlation factor is established by dividing the test load by the torque applied to install the test pile and then used to qualify the remainder of the piles provided they are “substantially similar”. Otherwise, additional testing may be required. Installation equipment, installation procedures, helical pile materials and configurations, installation depth and soil profile may be used for the purpose of comparison to judge similarity of the piles.

The City of New York exempts the load test provided the following conditions are met (Reference 23):

- (a) The pile torque-to-capacity ratio has been approved. (For our piles, the approved values are 9, 7, and 5.5 for 2 $\frac{7}{8}$ -, 3 $\frac{1}{2}$ - and 4 $\frac{1}{2}$ - inch diameter shafts, respectively, as per References 30-32).
- (b) The torque correlation shall demonstrate a factor of safety of 2.5 on the allowable load {i.e., the allowable load is $(9/2.5 =) 3.6$ times the installation torque for 2 $\frac{7}{8}$ -inch piles}; and
- (c) The maximum allowable axial compression load on the helical pile shall be 10 tons.

CORROSION AND LIFE EXTENSION

As with all other types of piles embedded in soil, helical piles also degrade with time. The primary degradation mechanism for the steel piles is corrosion. The rate of corrosion is generally governed by the flow of electricity in soil, and thus depends on the nature of soil, such as, soil type, moisture content, acidity and presence of dissolved salts. A measure of the resistance of the soil to the flow of electric current is called soil resistivity. A primary source of the soil-corrosivity data was the test programs conducted by the National Bureau of Standards (Reference 21). These and additional data have been studied and published in the literature. Due to the wide variation of the statistical data, there is a substantial uncertainty about the corrosion rate at a given site.

In summary, the soil in marine environments provides the least resistance (less than 2,000 ohm-cm) to electric flow and thus results in the highest rate of corrosion. On the other extreme is the dry soil containing gravel or sand which provides the most resistance (greater than 20,000 ohm-cm) and is least sensitive to corrosion. We measure the soil resistivity in the field and assess the soil corrosivity.

The New York City Building Code offers the following cautions and requirements for piles in general (Reference 23): “Where boring records or site conditions indicate possible deleterious action on pier or pile materials because of soil constituents, changing water levels or other factors, the pier or pile materials shall be adequately protected by materials, methods or processes approved by the engineer. Protective materials shall be applied to the piles so as not to be rendered ineffective by driving” (screwing in for helical piles).

The Code further identifies the following specific deleterious conditions:

“Piles installed in ash or garbage fills, cinder fills, and piles that are free-standing in or near a seawater environment, or that are used for the support of chemical plants, coal piles (plants) and piles under similar conditions of chemical seepage or aggressive action, or that are used for support of electrical generating plants, shall be investigated regarding the need for special protective treatment.”

Particularly for helical piles, the New York City Building Department adds the following requirements (Reference 23):

“Tests shall be performed for soil resistivity, soil pH, organic content, and sulfate concentration in each soil layer. The device or system shall not be used in conditions that are indicative of a potential pile corrosion situation, as defined by soil resistivity less than 1,000 ohm-cm, pH less than 5.5, soils with high organic content, sulfate concentrations greater than 1,000 ppm, landfills, or mine waste.”

CORROSION AND LIFE EXTENSION (Cont.)

The rate of soil corrosion can be reduced by providing a protective coating on the steel surfaces. This can be accomplished by galvanizing the entire pile assembly. Hot-dip galvanization is preferable to other forms of galvanization. Engineers often recommend that the piles be galvanized since this usually extends the life by about 100% at an approximate cost increase of 10% for the pile project.

Another method of life extension is cathodic protection. In a passive cathodic protection, a sacrificial anode is added and connected to the pile. The life of the pile is extended at the expense of the anode. More aggressive corrosion control is provided by active cathodic protection in which the piles are connected to an electric source and a small amount of electric current is maintained continuously.

REPORT AND CERTIFICATION

Upon completion of the project, a technical report should be prepared that presents the technical data for every pile on a separate form (see Installation Logs included in the Section on Pile Installation). The data includes the diameter of the shaft, number and diameters of helices, as-installed depth of the pile and torque used for installation. For hydraulic pressure gauges, the in- and out-pressures, are measured continuously as the pile is installed and reported every foot along the depth of the pile.

In addition to the technical report, certification is usually required by the local authorities for both the design and installation. The engineer stamps the drawings for submittal to the local authority, e.g., the Department of Buildings (DOB) in New York City. Upon completion of the installation and load test, the engineer will certify on an appropriate form. For example, DOB requires submittal of installation and test data on TR-5 form.

SPECIFICATION AND COST

In the previous Sections, we have described the services we provide. Now, the obvious questions you may have are: “How can I specify for your services? How much will your services cost?”

Regarding the specification, we would encourage you to contact us regardless of what your role is on the project or what stage of the project you are at, and we will explain to you how we can serve you best for your given project. Consultation with us on piles is free of cost. Depending on your role, you may choose one of the following paths.

If you are the *owner, contractor or construction manager*, let us review whatever you have, (as a minimum, a conceptual plan and soil data). We will perform a preliminary design of your piles for cost estimate purposes.

If you are the *architect*, you can specify our name on your drawings for furnishing steel helical piles. We will review your drawings and perform a preliminary design for cost estimate and proposal purposes. Upon your acceptance of the proposal, we will perform the final design and prepare the pile foundation drawings including concrete pile caps. We will give you the stamped drawings for incorporation to your package that can be submitted to the local authority, such as NYC Department of Buildings for approval.

If you are the *engineer* and have already calculated the foundation load, specify on your drawings the ultimate capacity of helical piles that would be required (e.g., 30 Tons) to support the structural load. You can also specify the shaft diameter, if you so choose. Alternatively, you can give us the load and we will design the piles and prepare the drawings.

Regardless of whether you are the owner, contractor, construction manager, architect or engineer, specify any special need such as galvanization, which we strongly recommend for a longer life. A sample specification, for retaining our services for design of helical piles are included at the end of this Section.

Regarding cost, we do not charge our client for the preliminary design that we perform. The preliminary design includes an approximate number of piles, pile capacity (demand), diameter of shaft, number and diameter of helices, and an approximate depth of pile. For the final design, we charge a very low fee (e.g., the drafting time) if the client purchases piles from us. In the final design, we refine the load calculations, that may in turn reduce the number of piles, and prepare the drawings showing pile spacings, locations, etc.

Regarding the piles themselves, we offer a highly competitive price that the client may wish to compare with that of others. Since we provide a customized, cost-effective design that varies from project to project, we will give you the cost estimate including cost break-down after you give us the opportunity to perform the preliminary design.

SPECIFICATION AND COST (Cont.)

In conclusion, unlike most suppliers and installers, we provide in-house professional engineering services to perform customized design and certify for the local authorities, such as, the Department of Buildings of the City of New York. Furthermore, our in-house engineering capability allows us to make cost-effective design changes even at the installation stage without affecting your tight scheduling.

SPECIFICATION AND COST (Cont.)

A SAMPLE SPECIFICATION FOR DESIGN OF HELICAL PILES

The engineer will review the architectural and structural drawings and soil exploration data provided herewith for the reference project, and design a helical pile foundation for the structure. The design will specify the shaft, number and diameters of the helices and ultimate capacity of the piles. The concrete pile cap will also be designed.

The engineer will prepare a set of drawings including the foundation plans and sections and showing the locations of the piles. The drawings will be signed and stamped by a professional engineer licensed and registered in the State of New York.

QUALITY CONTROL

In order to assure that the helical piles that we supply satisfy the material and strength requirements specified in this manual and serve the clients' engineering needs, we implement control (QC) using the documents prepared for us by an independent organization (Reference 36-38). The QC manuals have been prepared in conformance with an international standard (References 39 and 40) and reviewed and used by a subsidiary of the International Code Council (References 30-32).

In summary, we keep track of the steel materials that we procure for manufacturing of the pile assemblies (test reports or steel mill certificates). We inspect our manufacturing processes such as welding of helices to the shaft as required by the stated QC manual. We also follow the QC procedures for shipping out the customer's order.

Lastly, manufacturing, handling and shipping of our products are periodically inspected by the same independent laboratory that has initially tested and evaluated the products for conformance to the International Standard (Reference 39). We welcome comments and suggestions from the customers and are committed to furnishing quality products.

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EXHIBIT SERIES A



FIG. A-1 Starter Section with Three Helices



FIG. A-2 Piles at The Job Site



FIG. A-3 Helix Welded to Shaft



FIG. A-4 Helix Welded to Shaft



FIG. A-5 Coupling Tube



FIG. A-6 Coupling Tube Connected to One Shaft



FIG. A-7 Coupling Tube Connecting Both Shafts

EXHIBIT SERIES B



*FIG. B-1 Pile Installation Equipment
Skid Steer*



*FIG. B-2 Pile Installation Equipment
Drive Head*



*FIG. B-3 Pile Installation Equipment
In-Flow and Out -Flow Hydraulic Hoses*

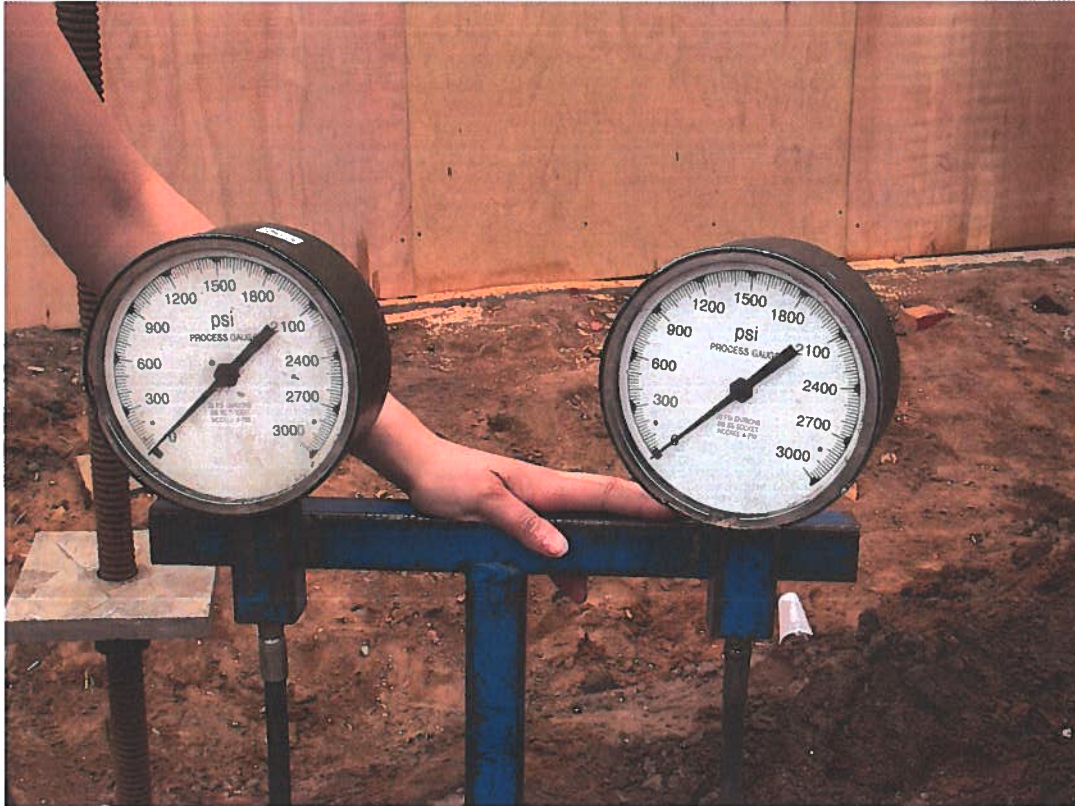


*FIG. B-4 Pile Installation Equipment
In-Flow and Out -Flow Pressure Gauges*



*FIG. B-5 Pile Installation
Driving Pile.*



*FIG. B-6 Pile Installation
Project 1*

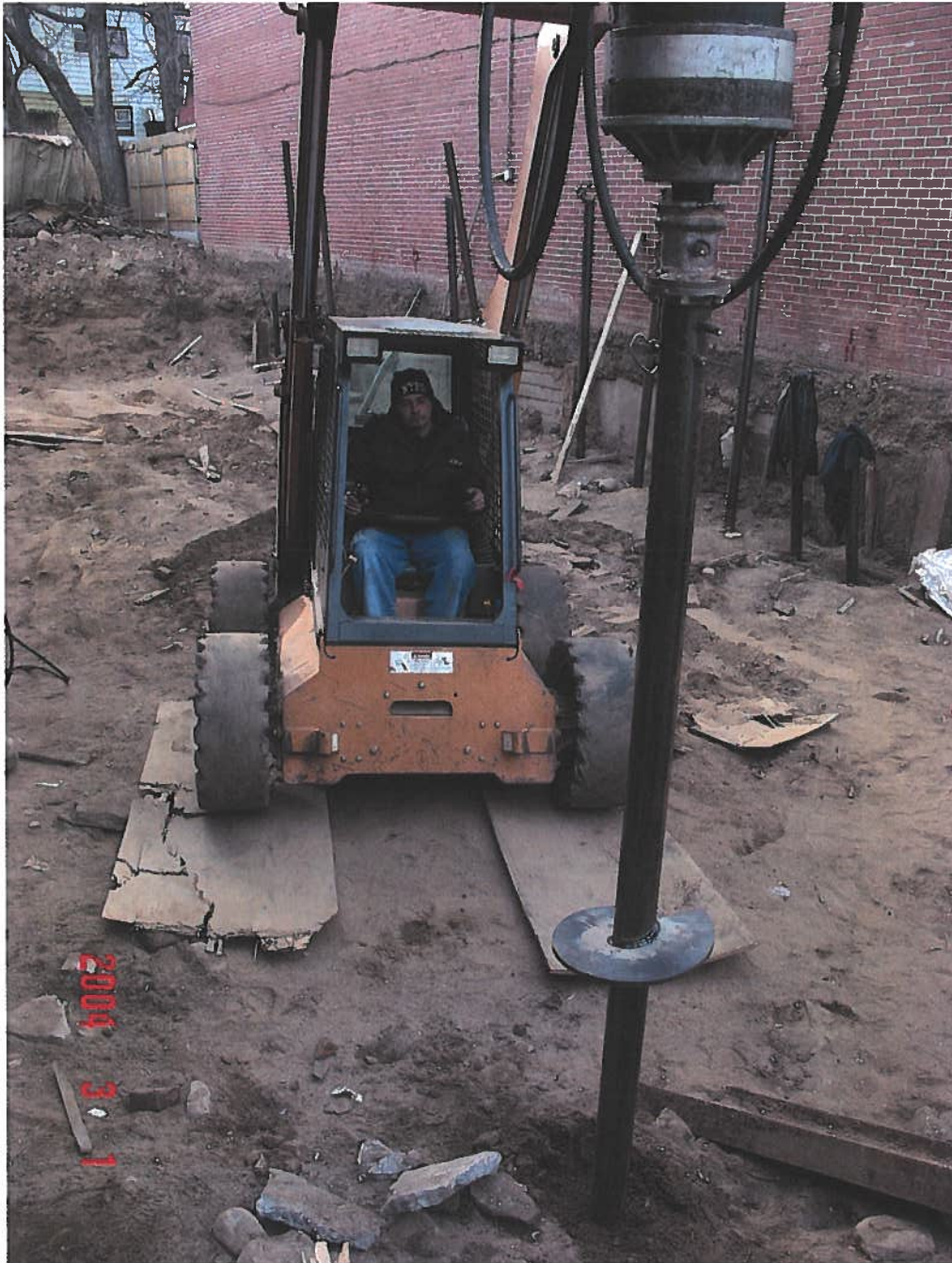


*FIG. B-7 Pile Installation
Project 2*



*FIG. B-8 Pile Installation
Project 3*



FIG. B-9 Intermediate Extension



*FIG. B-10 Pile Installation
Connecting Two Sections*



*FIG. B-11 Pile Installation
Last Extension*

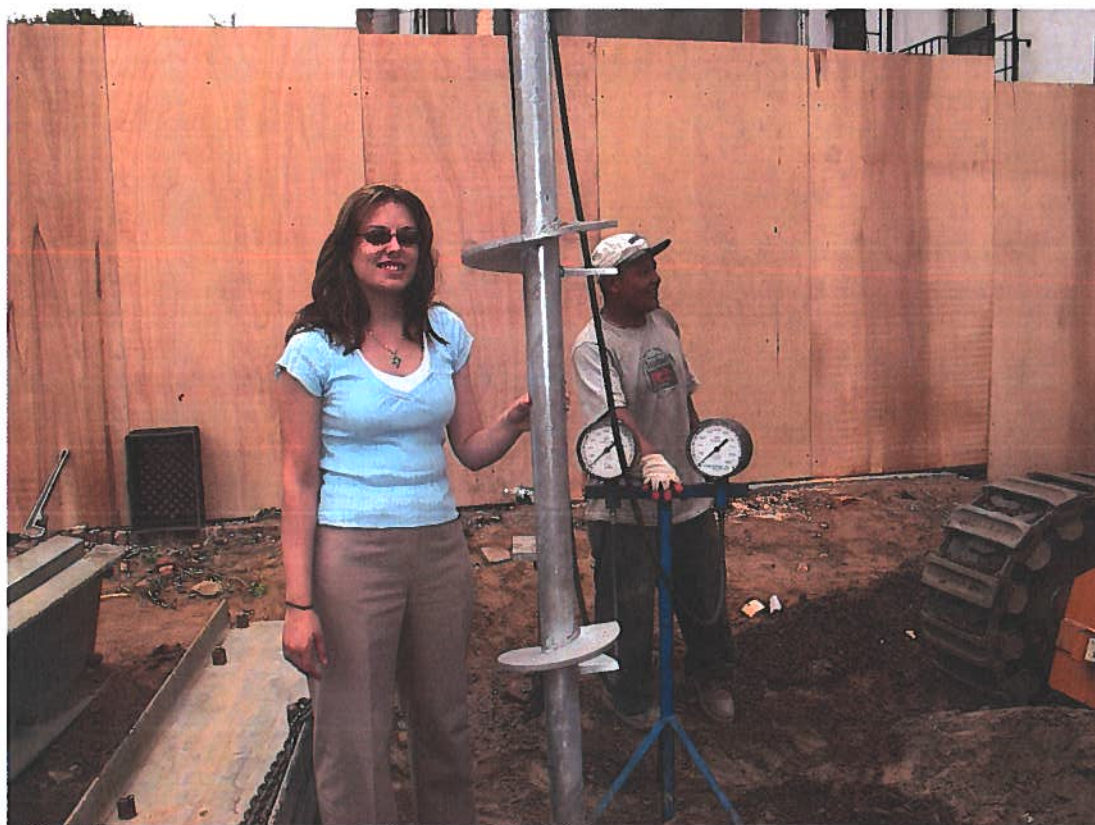


*FIG. B-12 Pile Installation
Pressure Gauges*



FIG. B-13 Installed Piles with Steel Caps



FIG. B-14 Engineers Inspecting Pile Installation



FIG. B-15 Aligning Drivehead



FIG. B-16 Driving Piles Around Shoring

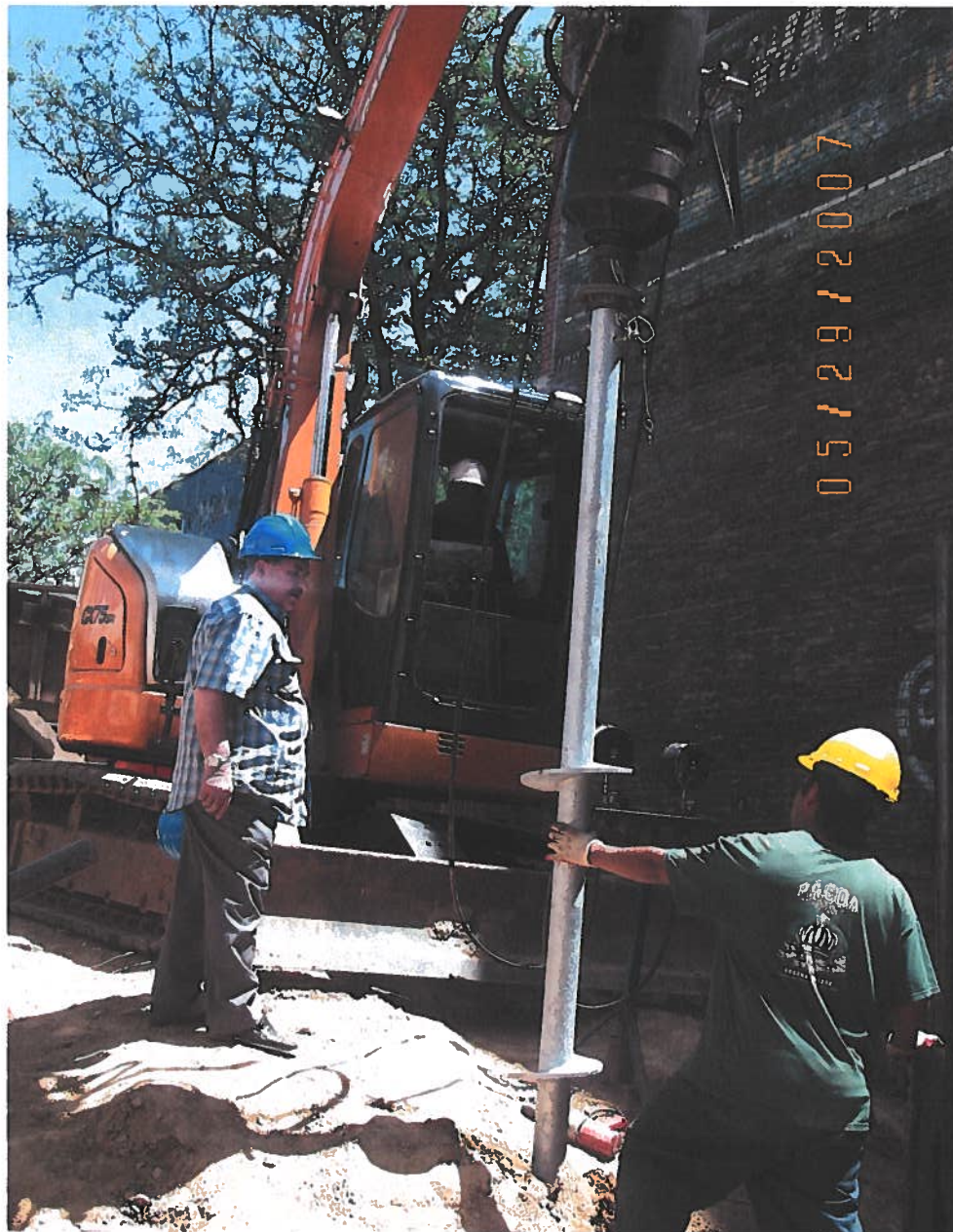


FIG. B-17 Aligning Pile during Installation

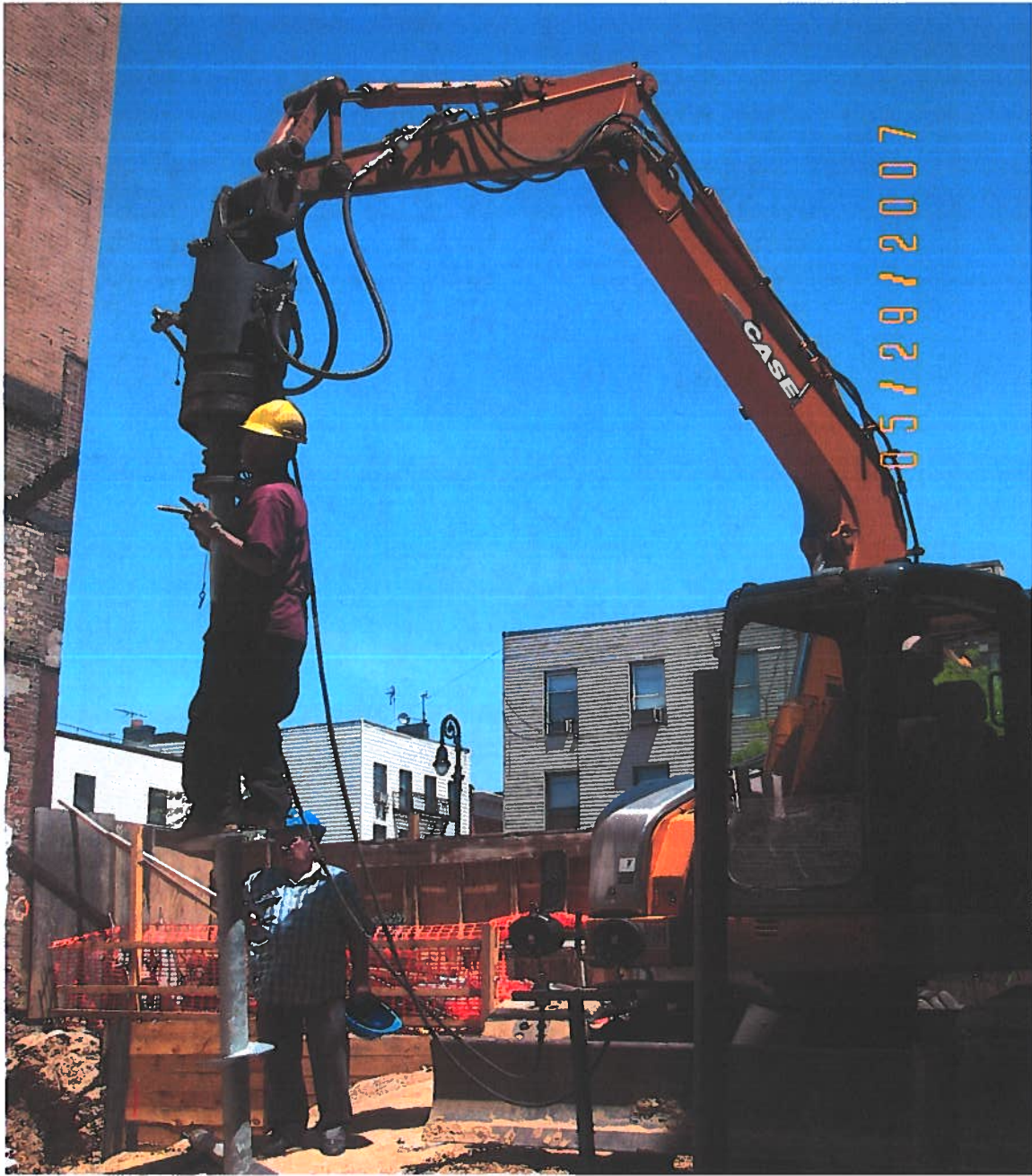


FIG. B-18 Connecting Pile to Drivehead

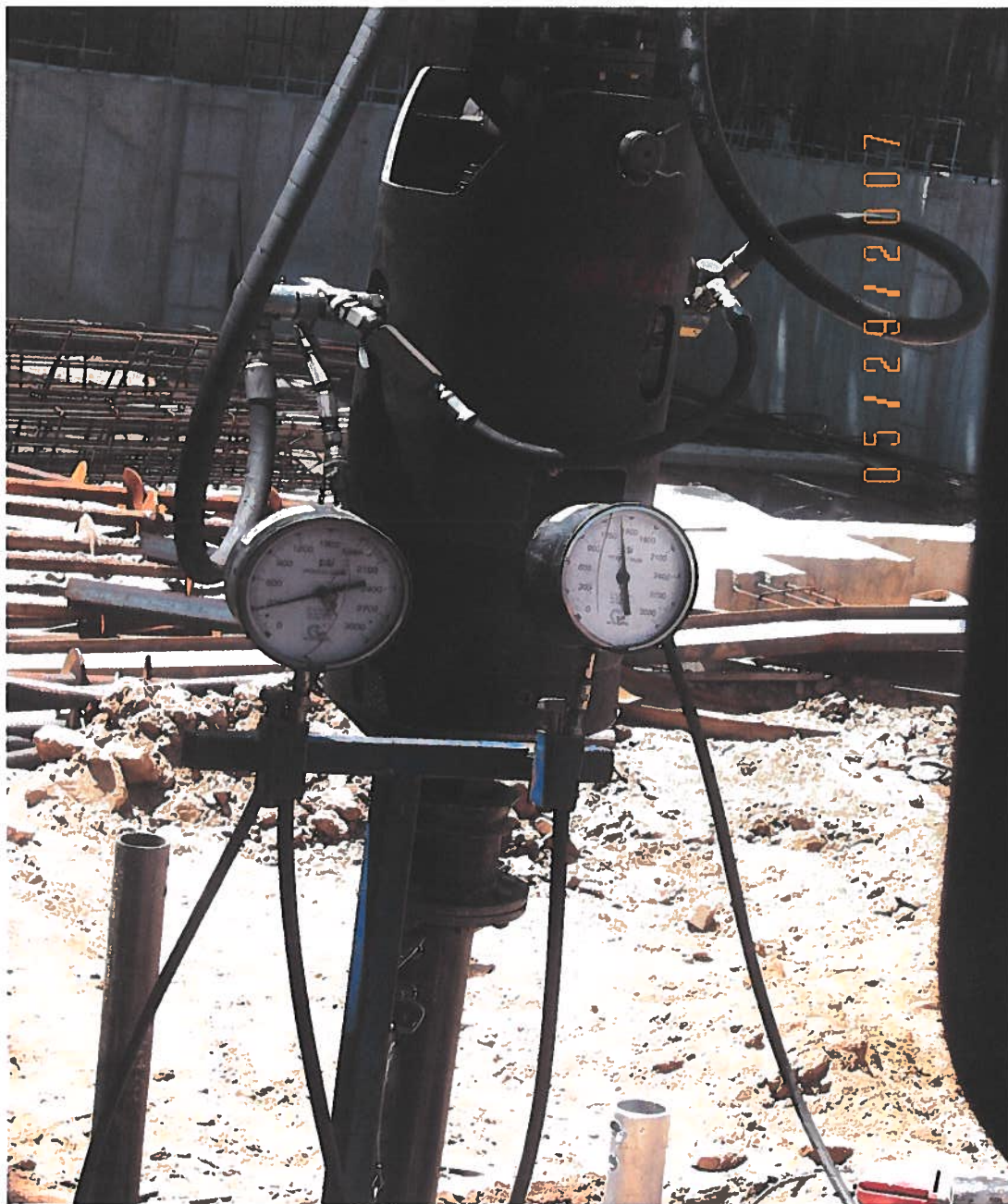


FIG. B-19 Preparing Monitoring Gauges



FIG. B-20 Piles in Line for Wall Foundation



FIG. B-21 A Pile Group for Column Footing.



*FIG. B-22 Excavated Trench to be Used for Pouring
Concrete Pile Cap. Piles to be Cut-off.*



FIG. B-23 Grouted Pile Driving Hole.



*FIG. B-24 Hooking up Lines for
Measuring Pressure during Pile Installation.*

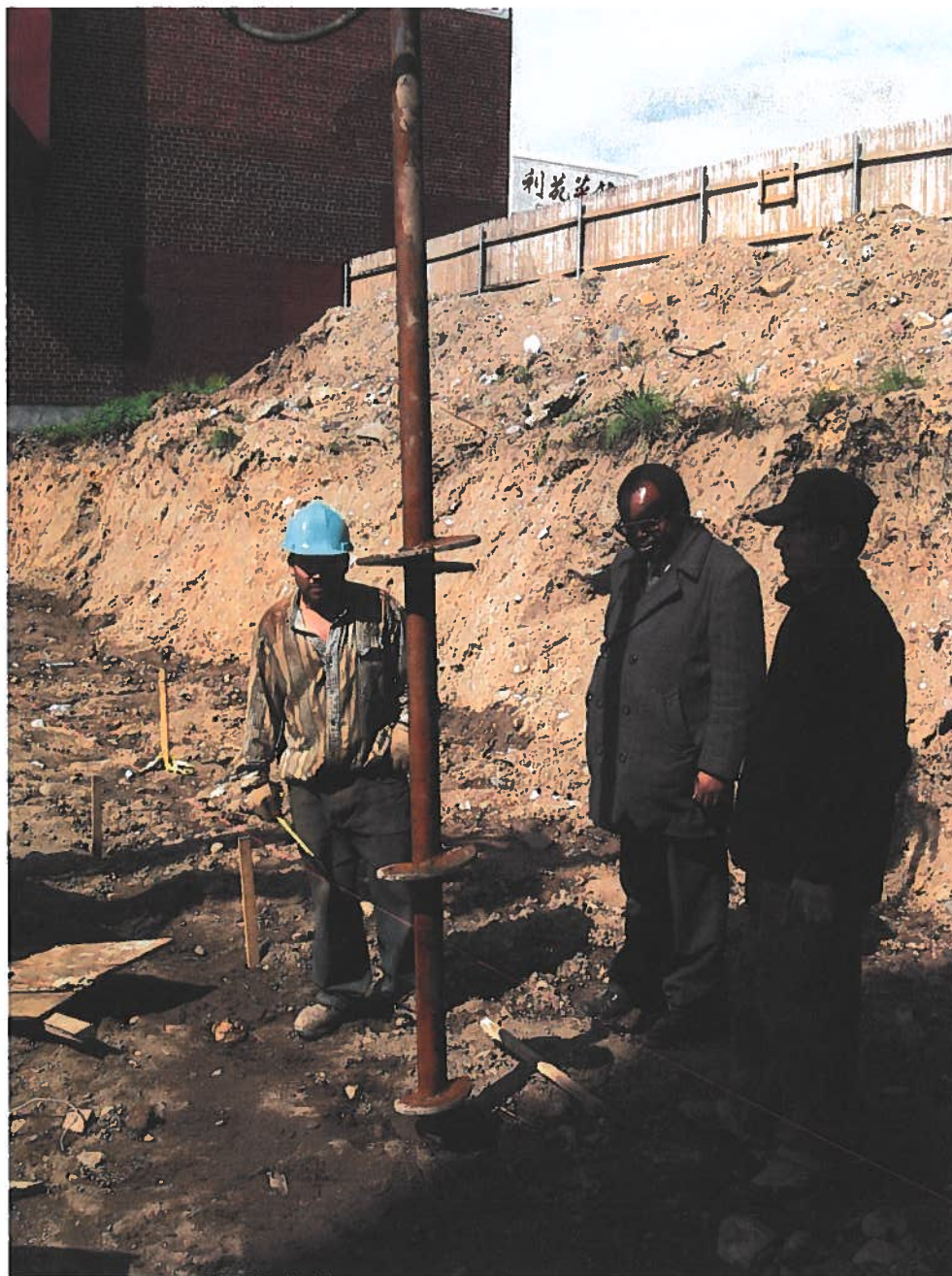


FIG. B-25 Engineer Inspecting Pile Location.

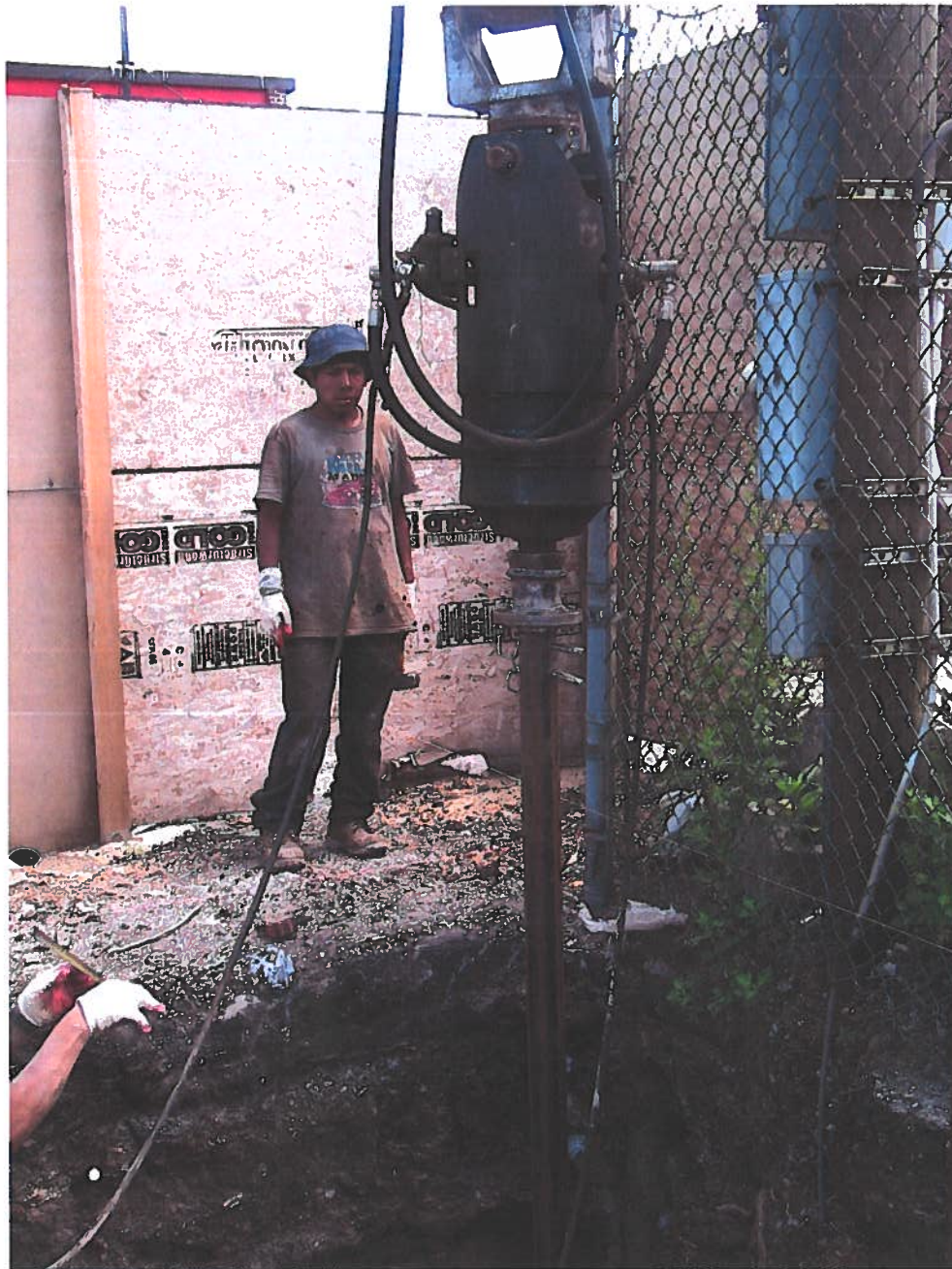


FIG. B-26 Minimum Space needed to Clear Drivehead from Existing Obstruction at Site Boundary.



FIG. B-27 Grouting Hole around Pile during Installation.



FIG. B-28 Pile Installation Pressure Monitoring.

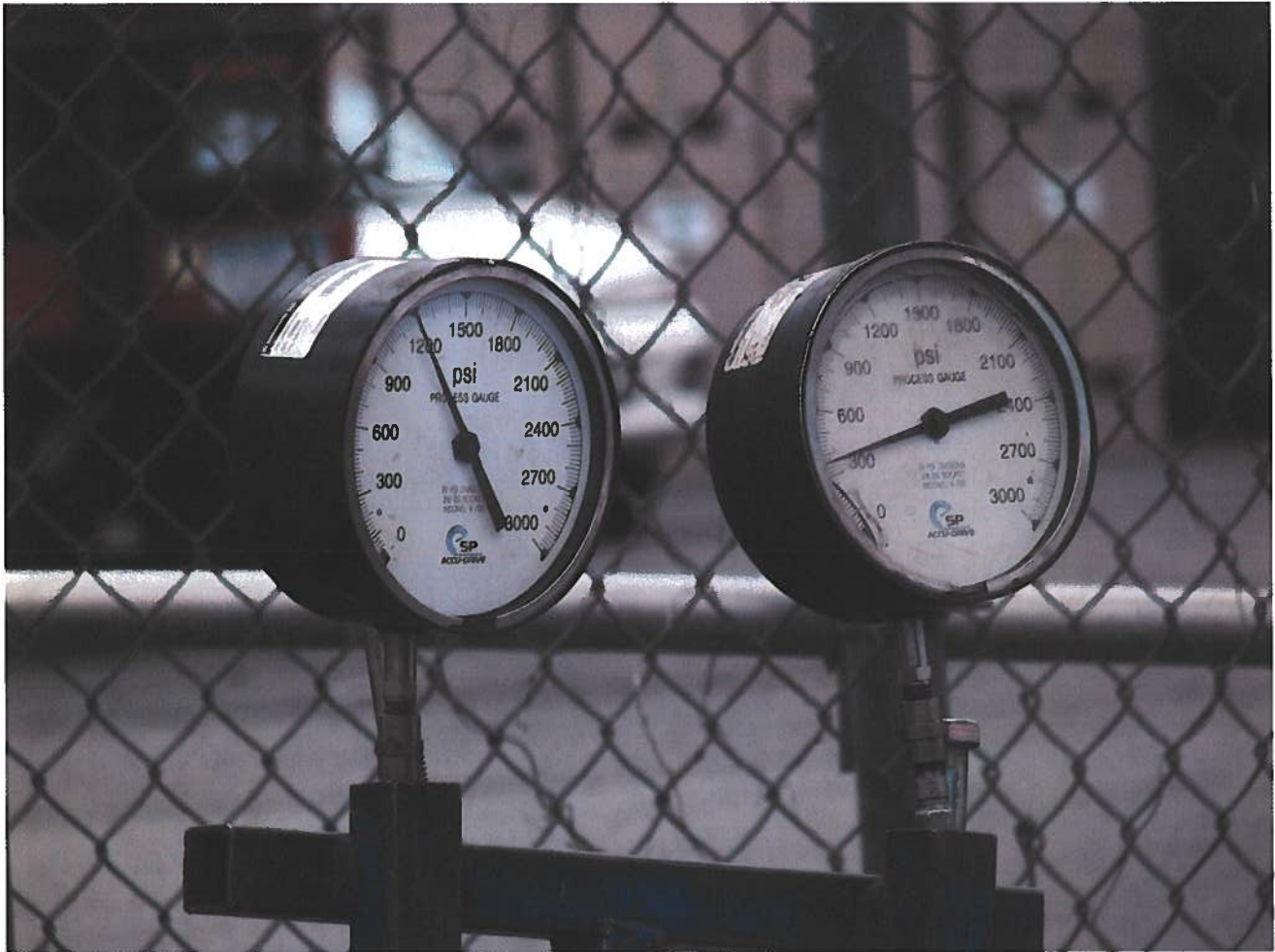


*FIG. B-29 Monitoring Pressure during Pile Installation
In- Flow (Higher Reading) and Out –Flow (Lower Reading).*



FIG. B-30 Pile Installation and Monitoring Operation.



FIG. B-31 Recording Pressure Gauge Readings.



FIG. B-32 Aligning Corner Pile.

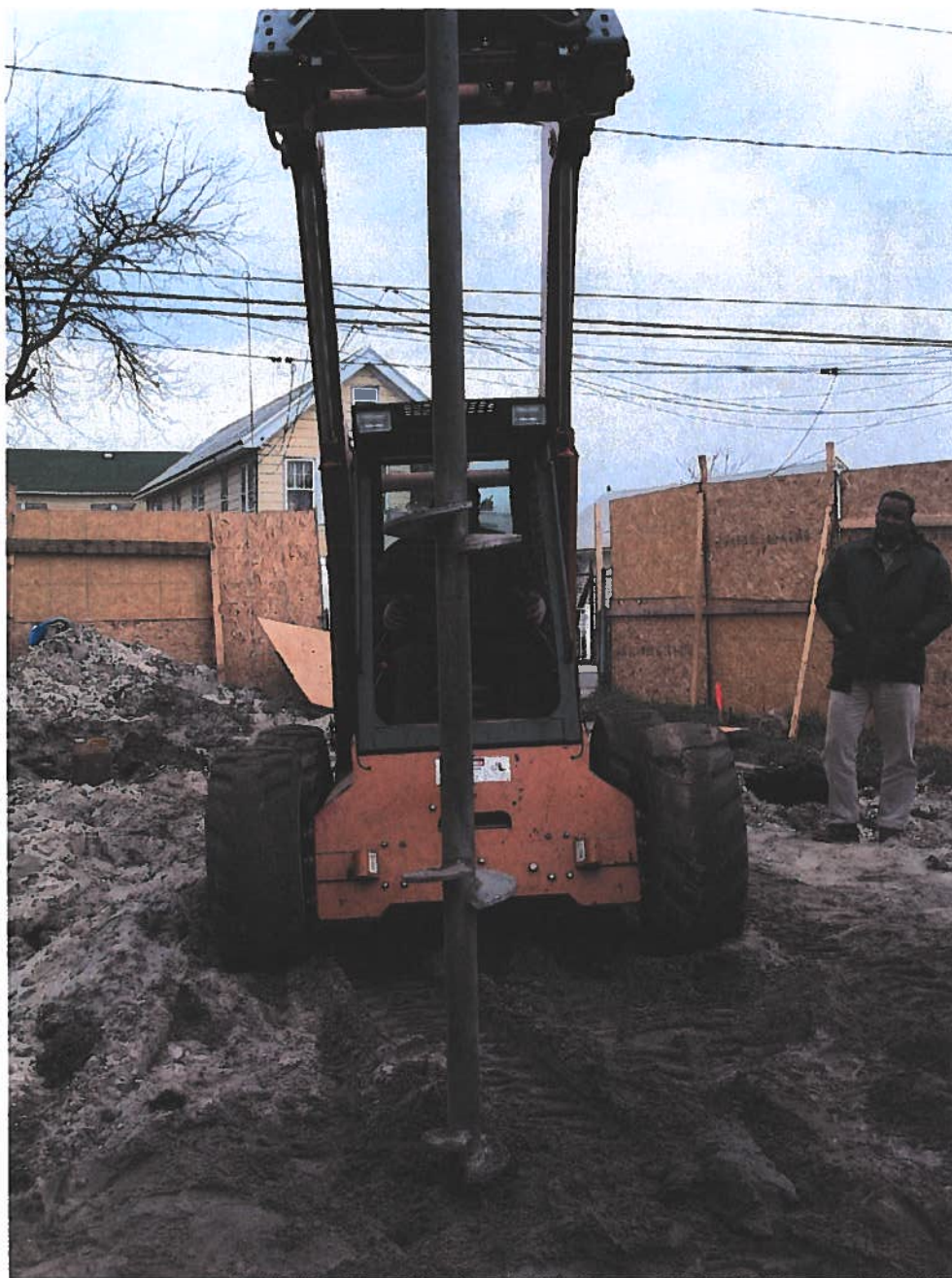


FIG. B-33 Owner Observes Vertical Alignment of Pile.



FIG. B-34 Vibration-free Helical Pile next to Shored Building.



*FIG. B-35 Tension Piles for a Control Tower.
Battered Piles*



FIG. B-36 Clearance for drivehead.(12"-18")



FIG. B-37 Muddy Field Condition.



*FIG. B-38 Obstruction Encountered in Driving
Piles through Backfill.*



FIG. B-39 Intermediate Extension



FIG. B-40 Intermediate Extension



FIG. B-41 Piles Installed



FIG. B-42 Piles Installed



FIG. B-43 Pile Installation Equipment



FIG. B-44 Pile Installation Equipment

EXHIBIT SERIES C



FIG. C-1 Pile Load Test Set Up



*FIG. C-2 Pile Load Test
Framing Beams*



*FIG. C-3 Pile Load Test
Framing Beams Held
by Four Anchor Piles*



*FIG. C-4 Pile Load Test
Load Frame
Test Pile and Hydraulic Jack*



*FIG. C-5 Pile Load Test
Settlement Gauge
Readings for Testing*



*FIG. C-6 Pile Load Test
Loading Frame
over Test Pile*



*FIG. C-7 Pile Load Test
Hydraulic Jack between Test Pile
and Loading Frame (for Compression Test)*

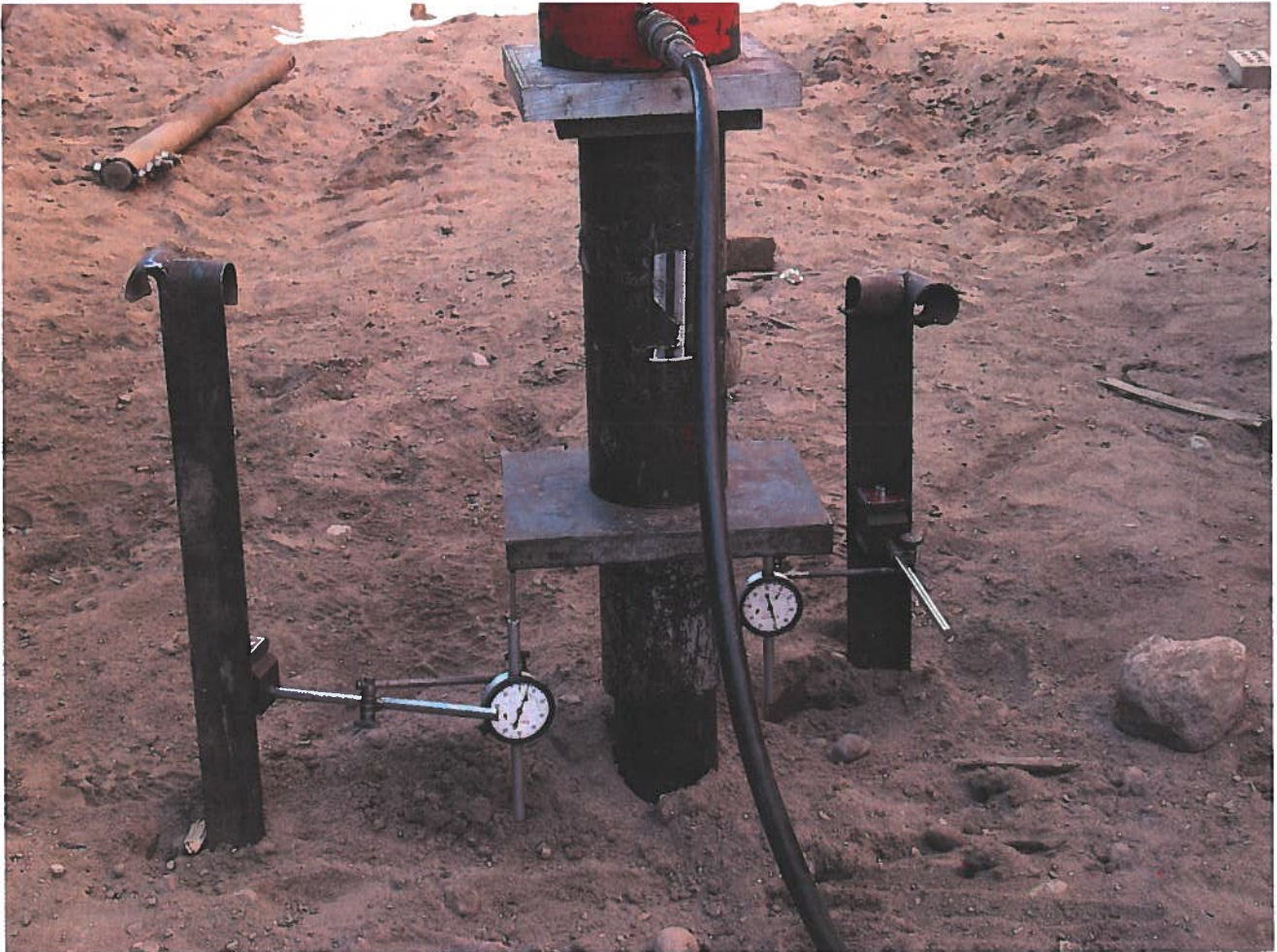


*FIG. C-8 Pile Load Test
Two Settlement Gauges*

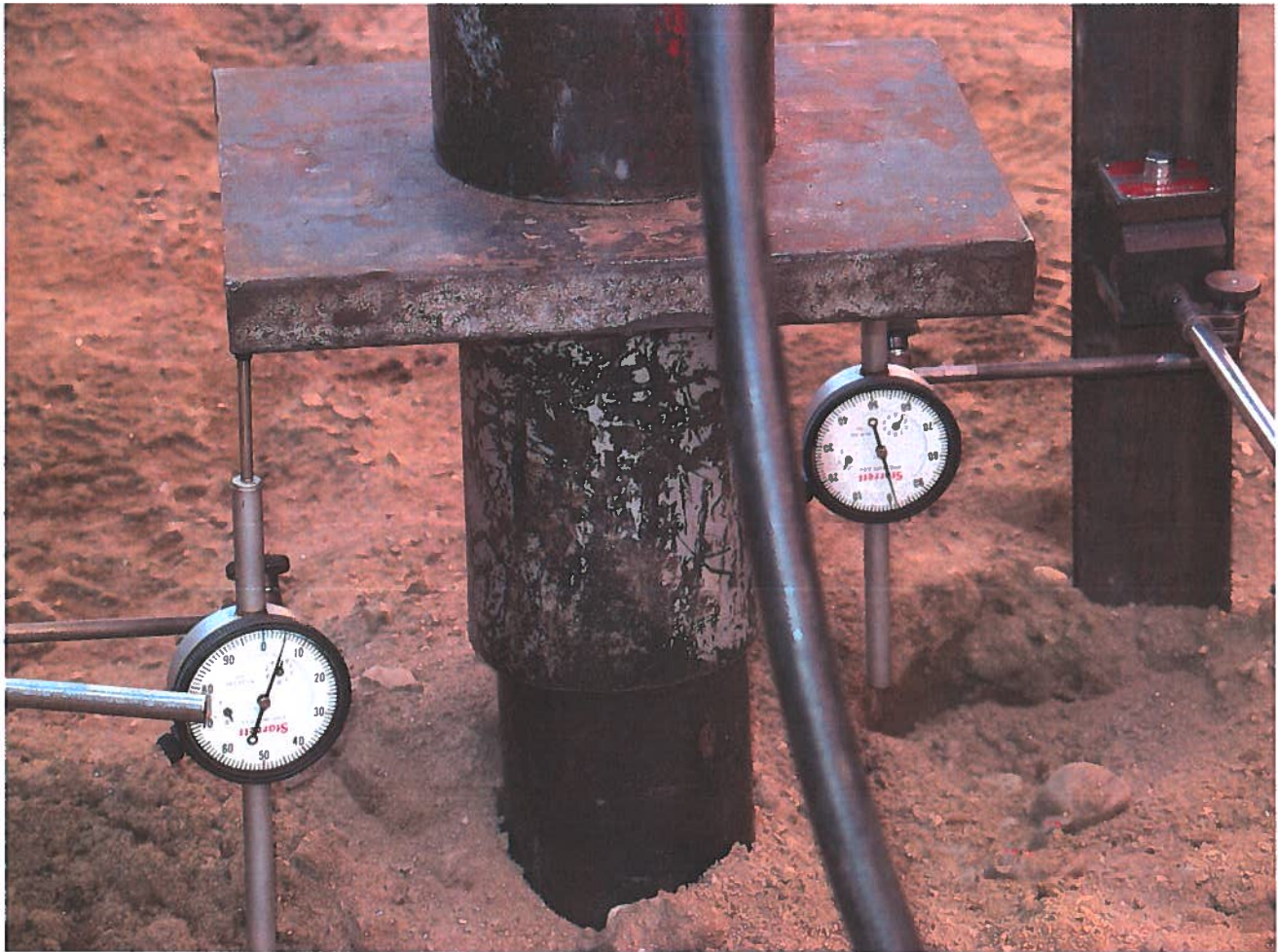


*FIG. C-9 Pile Load Test
Settlement Gauges
Close Up*

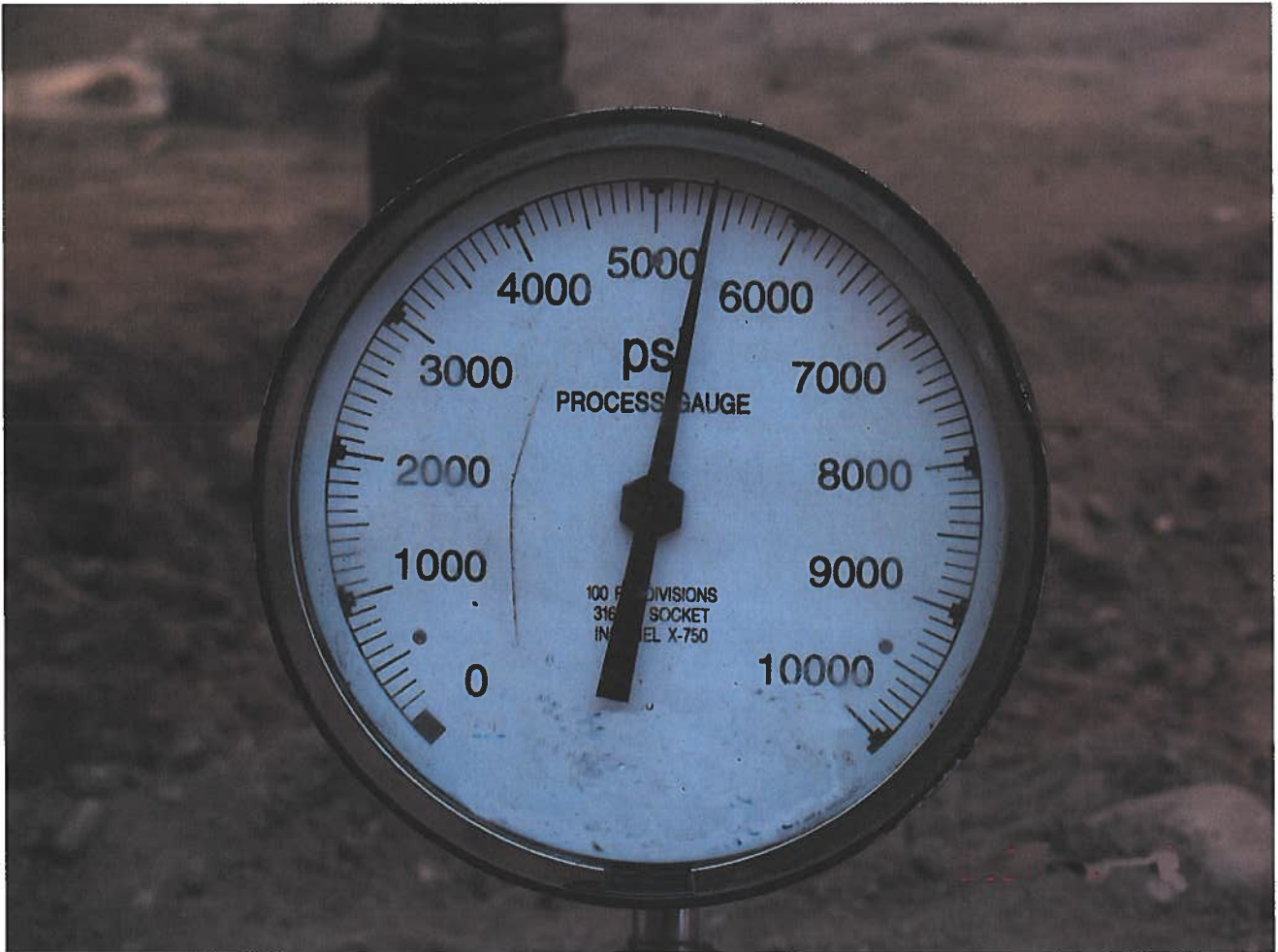


*FIG. C-10 Pile Load Test
Pressure Gauge
for Hydraulic Jack*



*FIG. C-11 Pile Load Test
Frame Beam Connected
to Anchor Pile*