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Pin Piles^{SM} for Building Foundations

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Pin Piles for Building Foundations

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ABSTRACT

Pin Piles are small-diameter high-capacity drilled and grouted piles. They are ideal for building foundations on sites with poor ground conditions, sensitive surroundings, restricted vertical clearance, or difficult access. They are also well suited to foundation underpinning and increasing the capacity of existing foundations. Building projects using Pin Pile foundations are summarized and two major case histories are presented. Practical constraints and design data are given for considering the use of Pin Piles.

INTRODUCTION

Many cases exist where it is not practical or economical to install more traditional deep foundation elements such as driven piles or drilled shafts. In these cases, such as in ground where obstructions, boulders and solution cavities are present, Pin Piles have been selected. Pin Piles are drilled-in elements typically ranging from 5 to 12 inches in diameter, which consist of steel casing, steel reinforcement, and cement grout. They derive capacity in the ground from side friction and work equally well in both compression and tension.

These piles were developed in Europe in a simpler form, typically using only a central rebar core encased with cement grout placed into a small diameter drilled hole. These minipiles or micropiles were installed as individual elements or groups with cumulative benefit.

In the United States, particularly when considered for building applications, it was realized that traditional mini or micro piles were limited by their structural capacity. That is, the rebar core with virtually unconfined grout surrounding it was not very ductile against high compressive loads or any manner of lateral bending or eccentric loading.

Since these elements are most often installed using a steel drill casing, it was the innovation of the American contracting community to incorporate the steel casing into the pile designs. This ductile steel casing pile, Pin Pile, provides a high degree of structural resistance in the soft upper soils, and allows for the full optimization of the underlying competent geology.

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It is often the physical constraints that act as a trigger for use of Pin Pile technology. Such situations may be:

- subsurface obstructions or difficult ground,
- limited overhead clearance,
- vibration or noise sensitivity,
- settlement sensitivity,
- limited plan access,
- the need to install elements in close proximity to or through existing footings, columns, walls, or other structures.

Geotechnical complications may act as a single driving force for Pin Pile selection, or may complement the already difficult physical limitations of a project. The geotechnical situations other than what might be called "conventional" which Pin Piles may be conveniently installed are:

- karstic limestone geology (that includes voids or soil-filled solution cavities),
- bouldery ground or glacial till,
- variable and/or random fill,
- underlying existing foundations or man-made obstructions,
- rock formations with variable weathering,
- or soils under a high water table.

Due to their diverse and flexible capabilities, the use of Pin Piles has dramatically increased in recent years. Most of the projects described in this paper have been constructed since 1993 and there is great potential for further use.

GEOTECHNICAL ASPECTS:

Pin Piles derive their load carrying capacity from side friction in suitable ground stratum, either soil or rock. Ground types that are capable include:

- stiff or hard non-plastic clays or silts,
- sands and gravels,
- rock formations,
- combination materials such as glacial tills or residual soil formations with variably weathered rock inclusions.

Since the primary load carrying capacity in the ground is derived from frictional bond in soil or rock, the Pin Piles can develop high capacity in both compression and tension. In compression, Pin Piles typically range in working load from 50 to 200 tons. In tension, their capacity is nearly identical geotechnically, and is primarily limited by the amount and detailing of the core reinforcement and casing joints used in the elements.

When subjected to lateral loadings, the piles derive resistance from the horizontal response of the adjacent soils and can sustain significant lateral deflection within the available structural pile capacity. Seven-inch diameter Pin Piles have been laterally tested in variable urban fills, with a free head condition, to up to 19 kips with 0.75 inch deflection. On a site with stiff alluvial soils, in a free head condition, a seven-inch Pin Pile was tested to 24 kips with 0.3 inch deflection. Where significant bending capacity is desired due to lateral loads, a larger upper casing can be installed to provide a pile with a two-part cross-section.

INSTALLATION METHODS

The ability to install Pin Piles in the most difficult and problematic geotechnical situations is a major advantage in their use for building foundations. This capability is gained principally by the optimal selection of drilling and grouting techniques. Through proper selection and experienced execution, good results are obtained.

Pin Piles are installed using rotary drilling techniques similar to those used in the oil and gas industry. The piles develop their geotechnical capacity through grout to ground adhesion in the bond zone. In soils this bond is typically developed using pressure grouting, and in rock, tremie grouting. The principle types of drilling and grouting techniques used by the writers are described below:

DRILLING METHODS:

Positive Circulation or External Flush Drilling: This method entails rotating a pipe or drill casing into the ground while applying a vertical load or down pressure. The soil inside the casing is cleaned or flushed out by a drilling fluid. The drilling fluid is injected into the casing at the drill head and returns upward along the outside of the drill casing. Water is the most commonly used drilling fluid, although compressed air and drilling mud are also used in some circumstances. External flush drilling is the easiest and most cost effective drilling method for installing Pin Piles in soil and is generally used when obstructions are not present and some ground loss can be tolerated.

Duplex Drilling: Duplex drilling is a method of progressing and cleaning out the drill casing where the outer drill casing is advanced simultaneously with an inner drill rod tipped with a roller bit. The drilling fluid is circulated down through the center of the inner drill rod and returns upward through the annular space between the drill rod and drill casing. Water is again the most common drilling fluid used for this technique. One of the major advantages of duplex drilling is that intimate contact is maintained between the drill casing and the soil during drilling. This is important for situations where ground loss is a concern, or where the soil is so open, that fluid return is not possible with external flush. Duplex drilling is also used to penetrate through obstructions or to maintain an open hole in fractured rock formations. The disadvantage of this method is that it is slower and more labor intensive than external flush drilling and therefore more costly.

Rotary Eccentric Percussive Duplex Drilling: This method is similar to the duplex method except that the roller bit on the inner drill rod is replaced with a down-the-hole hammer. The hammer bit is specially designed to open up during drilling to a diameter slightly larger than the outside diameter of the drill casing. This bit provides a slightly oversized hole through obstructions or rock and thereby allows the casing to simultaneously follow it down. Compressed air is used to drive the hammer and also acts as the drilling fluid to lift the cuttings. This drilling method is used in soils containing large amounts of obstructions such as cobbles, boulders or demolition waste and is also very effective in advancing a drill casing through highly fractured rock zones in karst. The drill tooling required is more costly than that required for external flush or normal duplex drilling, but in special situations, the method is very effective.

GROUTING METHODS:

Tremie Grouting: This is a method used to place grout in a wet hole. A grout tube is lowered to the bottom of the drill casing and/or open hole or rock socket. Grout is pumped through the tube as it is slowly removed from the hole. As the grout fills the drill casing or hole, it displaces the drilling fluid. Tremie grouting is primarily used where the Pin Pile bond zone is founded in rock. When working in highly broken or fractured rock or in voided, karstic situations, grout loss is possible and may warrant testing for a sealed bond zone. When this is done it is typical to perform water testing and seal grouting as required, then redrill, and test again. This potentially repetitive process requires commercial compensation using unit prices for these variable and unpredictable quantities.

Pressure Grouting: Pressure grouting is a method used to develop enhanced pile capacity in soils. This is done by applying pressure to the top of the fluid grout column through the drill head as the drill casing is withdrawn from the bond zone. The pressure forces the grout into the surrounding soil to create a "grout bulb". The pile capacity is derived from the friction and bond developed between the surrounding soil and the grout bulb.

STRUCTURAL CONFIGURATIONS:

The elegance of the Pin Pile system is the intelligent mating of the drilling and grouting methods to develop an optimal design for the Piles. The authors typically use four configurations as described below and shown in Figures 1 and 2. The combined drilling and grouting methods for each type are as follows.

Type S1: A steel pipe is rotated into the soil using external flush or either duplex technique. Neat cement grout is tremied from the bottom of the hole to displace the drilling fluid. The reinforcing element is then placed to the bottom of the hole. As the pipe is withdrawn over the length of the bond zone, additional grout is pumped under sufficient excess pressure to create the bond zone. The pipe is then plunged back into the grouted bond zone for 5 to 10 feet. In granular soils, a certain amount of permeation and replacement of loosened soils takes place. In cohesive soils, a certain amount of lateral displacement or localized improvement of the soil around the bond zone is accomplished with the pressure grouting. To attain an even greater

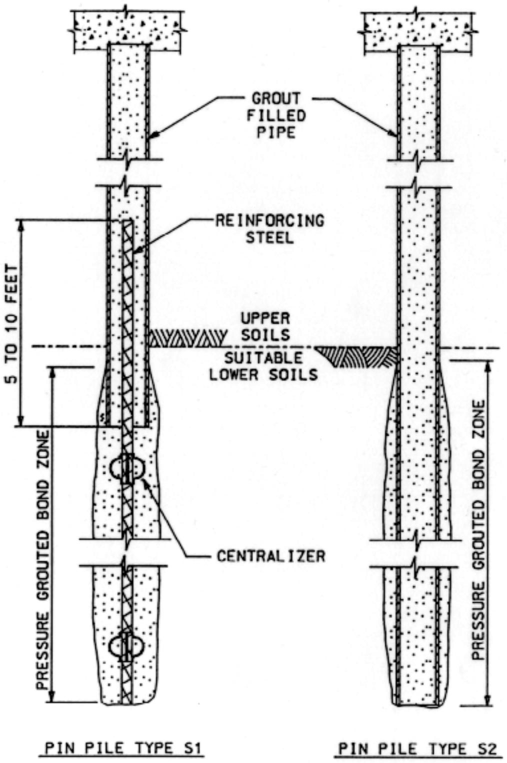

FIGURE 1
PIN PILE TYPES IN SOIL

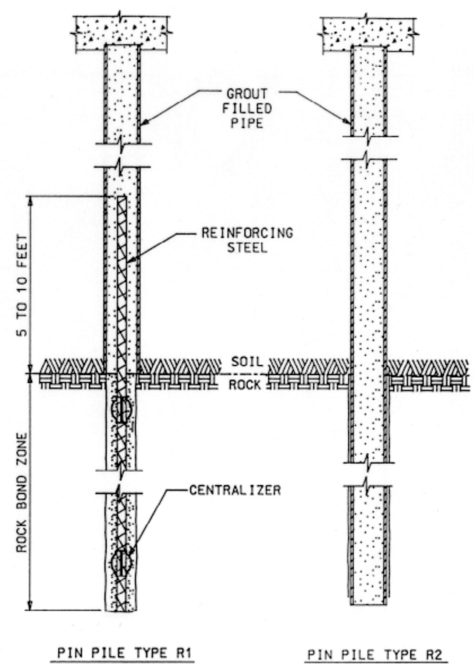

FIGURE 2
PIN PILE TYPES IN ROCK

displacement effect around the bond zone, a special technique called post-grouting (Figure 3) is used with S1 type Pin Piles. In this process, a slotted plastic tube with drilled holes covered by a rubber sleeve (sleeved-port pipe) is placed into the pile with the reinforcement. After the initial grout has partially cured, a packer is used to place controlled quantities of grout at high pressures through individual sleeve ports. This process breaks the initial grout, injects additional grout, and may create higher in-situ lateral stresses around the bond zone while enlarging the bond zone.

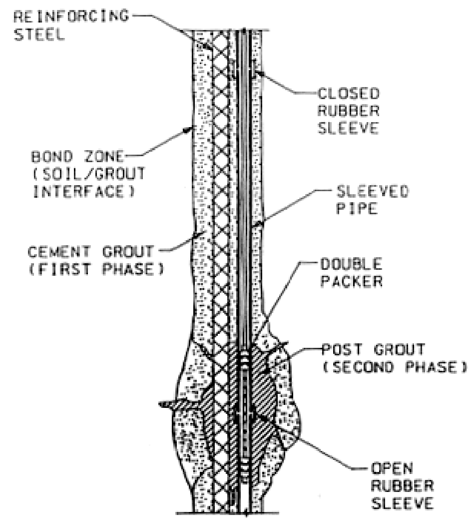

FIGURE 3
REPRESENTATION OF TYPE S1 PIN PILE DURING POST GROUTING PROCEDURE

Type S2: The Type S2 pile may be installed two ways. The first is similar to the methods used for the Type S1 pile, except that the pipe reinforcement must be plunged back down over the full depth of the bond zone.

A second approach for soils with sufficient cohesion has been developed using external flush and maintaining an open borehole. Grout is first tremied inside the pipe, then pumped from the filled center of the pipe and forced to flow up the annulus. This encapsulates and bonds the pipe to the soil. There is no pressure grouting here, just tremie flow, however, the entire pipe is engaged in frictional bond.

Type R1: The Type R1 pile uses the same techniques for advancing a steel pipe as described for Type S1, except that the depth of penetration is limited to the top of the rock bond zone. Once the pipe is seated into the rock, a smaller diameter drill string is advanced through the center of the pipe to drill the rock bond zone to a diameter slightly less than the inside diameter of the pipe. Once cleaned out, neat cement grout is tremied from the bottom, and a reinforcing element is placed in the rock bond zone to complete the pile installation. A minimum transfer length is required for the reinforcing to develop inside the pipe (typically 5 to 10 feet).

Alternatively, in poor quality rock formations, such as karst, the rotary eccentric percussive drilling tool is used to advance the casing into rock until the hammer response indicates that rock of sufficient quality is penetrated. Then the casing is withdrawn over the length of the bond zone, the pile is grouted, and the reinforcement is placed.

Type R2: The Type R2 pile differs from the R1 pile in that it uses a full length steel pipe. Centralized reinforcement is optional. In order to advance the pipe through both the overburden and the rock, a permanent drill bit is used on the end of the pipe with a diameter somewhat greater than that of the outside diameter, or the eccentric percussive system is used as described above.

Once the hole is advanced to the desired depth, grout is tremied from the bottom, and additional grout is pumped to assure full grouting of the rock bond zone. This grout may not flow completely to the surface in some conditions. However, once the level inside the pile has stabilized, the final grout level on the outside of the pile can be verified.

DESIGN

MATERIALS:

Pin Piles are typically constructed using steel casing with special machined flush jointed threads. The casing meets the physical properties of ASTM A-252 Grade 3, except that the minimum yield strength is typically 80 ksi. This material is most often mill secondary API drill casing. As such, material certifications are not available. The physical properties are confirmed by cut coupons from representative pieces of casing.

The core reinforcing steel is Grade 60 or 75 reinforcing bar (ASTM A615, A616 or A617) or Grade 150 prestressing bar (ASTM A722).

The grout typically consists of neat cement and water mixed with a high shear colloidal type mixer. This grout has a fluid consistency, a water/cement ratio of about 0.45, and a typical minimum unconfined compressive strength (from cubes) of 4,000 psi in 28 days.

STRUCTURAL DESIGN:

The structural design of Pin Piles for building foundations is typically not found in local building codes. However, based on our experience in conjunction with some applicable codes, the following equation can be used.

$$P_{all} = (0.40 \text{ to } 0.50)F_yA_s + (0.35 \text{ to } 0.45)f'_cA_c$$

where: F_y = Yield Stress of either the casing or rebar
A_s = Cross-sectional area of casing or rebar
f'_c = Unconfined Compressive Strength of the grout at 28 days
A_c = Cross-sectional area of the grout

The factors that are most appropriate depend upon the experience of the contractor, the experience of the structural engineer, and the observed performance of the test piles. Full scale sections of the 7 inch steel pipe were tested (Kenny), which show that the full yield strength of the pipe can be developed in compression, along with a calculated stress in the grout filled center far in excess of the unconfined compressive strength. The equation above is conservative as long as the pile is structurally configured to take advantage of confinement. That is, in soft soils, the grout needs to be confined inside the pipe casing, and in dense soil or rock bond zones, the grout receives lateral confinement from the ground. This effect has been confirmed many times through load test performance at ultimate loading, with stresses far in excess of typical values. More research and modeling is needed in this area to further quantify this benefit so that further economy of design is possible.

GEOTECHNICAL DESIGN:

The bond length is determined by experience and by previous load tests in similar ground. If the ground conditions vary considerably, then more load tests should be planned. The bond zone capacity is calculated as a typical friction pile. Tip resistance is usually neglected. The following calculation can be used.

$$P_{all} = \sigma \pi d L$$

where: σ = Allowable bond stress of soil/rock in bond zone
d = Diameter of bond zone
L = Length of bond zone

LOAD TESTS:

All projects of any significance justify full scale testing (ASTM D1143) of at least one pile unless there is significant confidence and prior experience with the founding stratum. The purpose of the testing is to verify both the geotechnical capacity of the bond zone and the structural performance of the pile. Many tests have been run on the Pin Pile configurations as is illustrated in Table 1. As more highly loaded Pin Piles are installed and tested, the experience and confidence with this technique expands.

COMMERCIAL RECOMMENDATIONS:

It is the authors' opinion that the detailed design of the piles should be performed by the contractor's engineer, while the owner's engineer should specify the appropriate constraints.

CASE HISTORIES

This paper summarizes two building projects that used Pin Piles as foundation constructed by Nicholson Construction Company since 1998. The introduction, design and installation discussions, summary Table 1, and the specific expanded case histories, which follow, are intended to provide designers with a practical set of constraints for which to consider the use of Pin Piles.

EXTON MALL AND GARAGE
EXTON, PENNSYLVANIA

Project Background: Exton is a city located approximately 20 miles west of Philadelphia. The owner of the Exton Square Mall was constructing a second-story addition and a new parking garage. The initial foundation contractor encountered difficulty in drilling through the karstic limestone underlying the site. This contractor's method of installation resulted in several pile failures during the load test program. Nicholson was called in on short notice to take over the construction. Two contracts were awarded: one for the support of the addition to the existing mall, and one for the new foundation for the parking garage.

The construction for the addition to the mall was completed in two areas: drilling from inside the mall itself, and drilling at close proximity to the perimeter of the building. The work on the inside of the mall took place during hours when the mall was non-operational. This meant construction crews would work night shift, ensuring the stores were cleaned and functional for normal business during the day. Special piping was used to remove the spoils from the drilling up through the roof of the mall, and down into refuse containers on the ground. Drilling conditions inside the mall involved tight access and limited headroom (12' feet). Crews moved merchandise and protected it where necessary.

All Pin Pile installation and testing was completed in 6 months, in the fall of 1998.

<u>Geotechnical Considerations:</u> Bedrock at the site consisted of karstic limestone with voids and clayseams. The top of competent bedrock ranged from 20 feet to 150 feet below the existing ground surface.

<u>Design:</u> The maximum design working load was 300 kips in compression. A total of 294 Pin Piles were installed in the interior of the mall and 111 Pin Piles were installed around the perimeter. The average pile lengths were approximately 34 feet, ranging from 20 to 150 feet below the existing slab elevation. A total of 355 piles were installed for the new parking garage, with pile lengths averaging 43 feet, ranging from 25 to 85 feet.

<u>Pile Description:</u> The Pin Piles consisted of a 7 inch O.D. by 0.50 inch wall outer steel casing above the competent rock bond zone and two #18 Grade 75 all-thread bars from the bottom of the 10-foot bond zone overlapping 5 feet into steel casing. The casing had physical properties equal to or exceeding ASTM A252, Grade 3, except that the minimum yield strength was equal to or greater than 80 ksi. Physical properties of the steel casing were determined by coupon tests on random samples. Pile grout consisted of Type I Portland cement grout (w/c = 0.45), with a nominal 28 day strength of 4,000 psi.

<u>Installation:</u> The piles outside the existing mall were installed with a large track-mounted Casagrande C12 drill rig, and the piles inside the facility were installed with both Davey Kent DK-50 or Klemm mini drill rigs. All drills utilized rotary eccentric percussive drilling techniques. For the outside piles, the casing was advanced in twenty foot, flush joint threaded sections to the bottom of the bond zone. Piles drilled inside were advanced with five foot, flush joint threaded casing due to overhead limitations. Once the bottom of the bond zone was established, the casing in all piles was retracted to the top of bond zone elevation. Consolidation grouting of the bond zone was then performed using a 1.5-inch diameter steel tremie tube.

<u>Testing:</u> Three production Pin Piles installed were tested in accordance with the Standard Test Method for Piles Under Static Axial Compressive Load (ASTM D1143-81, Reapproved 1994). In particular, the Quick Load Test Method for Individual Piles (section 5.6) was used. The maximum test load applied was 600 kips equal to twice the design load.

<u>Summary:</u> This project was ideally suited for the use of Pin Piles due to the difficult ground conditions and tight access requirements inside the mall. Because various drilling techniques can

be utilized to advance small diameter casing through virtually any material encountered, there are many times when Pin Piles are an attractive alternative to other types of deep foundations.

PENN STATE FOOTBALL TRAINING FACILITY
STATE COLLEGE, PENNSYLVANIA

Project Background: The Football Training Facility for Penn State University in State College, Pennsylvania is a two-story building with interior columns and grade beams around the perimeter. Column loads range from 80 kips to 320 kips. The exterior of the structure is designed primarily with architectural block and glass veneer. Therefore, the structure is very sensitive to differential settlements. Originally, drilled shafts were recommended for foundation support of the building. One geotechnical consultant designed the shafts to carry load in skin friction in rock sockets, ignoring the tip resistance of the shaft. This design resulted in construction that was very costly due to the amount of drilling in very hard limestone to develop the frictional resistance in the shafts. Another consultant designed the shafts to bear on rock, using a high end bearing capacity. This design eliminated the rock sockets, therefore reducing construction costs. However, due to the geology of the site, both designs included probing beyond the tip elevation of the shafts to verify existence of competent bedrock below the shafts. It was decided that if competent bedrock was not found (i.e. the presence of voids, clayseams, etc.), the shafts would be drilled to greater depths until competent bedrock was encountered. This would require drilling the shafts through varying amounts of very hard bedrock, voids, clayseams and artesian conditions. This situation is ideal for Pin Pile Construction. The Pin Piles acted as support of the structural loads and also as individual probes for each foundation.

Geotechnical Conditions: The project site is underlain by Karst geology, consisting of very hard dolomitic limestone (unconfined compressive strengths up to 18,000 psi). The hard bedrock is pinnacled, with almost vertical bedding planes. This geologic formation is prone to voids, clayseams, varying water levels and greatly varying overburden depths. The top of bedrock at the project site ranged from 6 feet to 90 feet below the floor slab elevation.

Design: Two pile designs were used, supporting four different loading conditions. The column loads were separated into four groups: 80 kips, 160 kips, 240 kips, and 320 kips. The two different piles used were 80 kips and 160 kips. At the 80 kip locations, obviously a single 80 kip pile was used to support the load. At the 160 kip locations, a single 160 kip pile was installed. At the 240 and 320 kip locations, two 160 kip piles were installed. All of the piles were installed vertically and consisted of three distinct components. The first was the outer casing that provided additional bending capacity and lateral stiffness. The second component was the centralized reinforcement bar that extended to the tip of the pile and overlapped inside the outer casing. The third component was the grout which was tremied into the pile.

Pile Description: All piles consisted of a 5-1/2 inch O.D. x 0.415 inch wall thickness threaded flush joint steel drill casing with a minimum yield of 80 ksi above the bond zone. The bond zone section was made up of either a #14 Grade 75 rebar (80 kip pile) or a #18 Grade 75 rebar (160 kip pile) in a 10 foot long tremie grouted bulb with the bar overlapping 5 feet into the casing. The neat cement grout had a minimum 28-day strength of 4,000 psi.

The 5-1/2 inch casing was made from mill secondary API drill casing. The piles were installed using rotary eccentric percussive duplex drilling with air as the flushing medium. The piles were installed prior to the excavation of the pile caps.

Testing: Two compressive pile load tests were conducted on piles with 160 kip capacity and one compressive pile load test was conducted on a pile with 80 kip capacity to verify the adequacy of the pile design and installation methods. To be acceptable, a test pile had to carry a test load equal to two times the design load and the slope of the load vs. deflection curve at this load had to be 0.05 inches / ton or less.

Summary: The Penn State Football Training Facility project involved installing 138 Pin Piles. The Pin Piles were successfully installed despite drilling in the very difficult karst geology that included pinnacled limestone, clayseams, voids and solution cavities.

Year Complete	Location	Description	Ground Conditions	Physical Constraints	Working Load (tons)	Test Load (tons)	No. of Load Tests	No. of Prod Piles	Typical Pile Length (ft)	Type-Structural Composition
1998	Penn State Football Training Facility State College, PA	Installed Pin Piles as an alternate to caisson foundations for new building.	Karstic limestone.	Unrestricted access. New building foundation.	40-80	160	3	138	18-110	R1 5½" Casing 5.78" Tubex Drill #18 or #14 GR 75 Bar
1998	Green Mill Building Addition New Madrid, MO	Support for storage tank and building addition.	Silty clay overburden. Bond in medium sand.	Drilling from inside existing facility.	100	200	1	74	56	S1 7" Casing #18 GR 60 Bar
1998	New Jersey Transit Matawan Station Matawan, NJ	Foundation for high-level train station loading platform.	Fill, brown coarse to fine sand with traces of silt. Bond zone in sand with traces of silt.	Tight access, working near the top of a slope along side a set of operating railroad tracks.	30	60	2	30	55	S1 5½" Casing x 0.415" Wall #11 GR 75 Bar
1998	Exton Square Mall Exton, PA	Foundation support to add a second-story structure above an operating mall, as well as foundation for new parking garage. Interior construction was performed during the night to keep mall operational.	Clay and sand with bond zones in Karstic limestone.	Interior construction involved tight access and limited headroom. Exterior work was performed around the perimeter of the mall close to the building	150	300	3	762	20-150	R1 7" Casing 7.44" Tubex Drill #18 GR 75 (2 each)
1997	Buyers Mart Pittsburgh, PA	Foundation support for renovations and addition to existing office complex.	Brick, sands, compacted sands/clay.	19' Headroom.	75	N/A	N/A	103	24	S1 7" Casing #11 Bar
1997	Jones Beach Marine Theater Wantagh, NY	Support for second tier addition. Pin Piles were used to minimize vibration and ground loss.	Loose, fine sands with some clay, dense sands.	30' Headroom and unlimited access.	60/120	120/240	2	97	65-85	S1 5½"/7" Casing 60T - #18 GR 75 (1 each) 120T - #18 GR 75 (2 each)
1997	Westvaco #9 Paper Mill Luke, MD	Pin Piles for building column support.	Boulders and sandstone.	Installed from inside building. 19' Headroom.	104	N/A	N/A	20	25-35	R1 12.75" Outer Casing 7" Casing in Bond Zone
1996	Embarcadero Lofts San Francisco, CA	Seismic foundation retrofit for conversion of warehouses to condominiums.	Sand/rubble fill over native soils.	8'-20' Headroom.	75-125	N/A	N/A	57	45	S1 7" Casing 7½" Drill #18 GR 60 Bar
1996	Kaiser Sunnyside Expansion Portland, OR	Support of new hospital wing and seismic retrofitting of pile caps in existing building.	Overburden/rock.	Limited and low headroom.	100	N/A	N/A	68	40-80	R1 7" Casing 7½" Drill #11 Bar

Table 1

Year Complete	Location	Description	Ground Conditions	Physical Constraints	Working Load (tons)	Test Load (tons)	No. of Load Tests	No. of Prod Piles	Typical Pile Length (ft)	Type-Structural Composition
1996	USX Clairton Works Clairton, PA	Repairs to existing motor/generator foundation.	Sandy clay soils to rock. Drilling under water table.	Low headroom – 8'. Limited access, tight schedule.	45	N/A	N/A	6	75	S2 7" Casing 7.9" Drill
1995	Koppers Tar Plant Follansbee, WV	Foundation support for new tar storage tanks.	Dense sands.	Unlimited overhead, no restrictions.	150	300	1	42	80	S1 7" Casing 7.75" Drill 3 each #10 GR 150 Bar
1995	Washington Steel Washington, PA	Increase column capacity of existing structure.	Soil/fill, highly fractured rock (shale).	Some limited overhead (8'). Steel mill was operational.	63	N/A	N/A	42	35-40	R2 5½" & 7" Casing 6"-8" Drill
1994	Vandenberg Air Force Base Lompoc, CA	Foundation support for rocket launch pad.	Beach sand.	Installation performed inside structure (10'-12' headroom), and outside.	225	550	12	202	55-70	S1 9.625" Casing x 0.542" Wall 7" Casing x 0.5" Wall #18 Bar
1993	United Grain Terminal Vancouver, WA	Designed and installed Pin Pile foundation for the largest grain terminal in the United States. Existing foundation began to fail as a result of deteriorated timber piling and the weight of the grain inside the silos.	Installation through existing timber pile foundation into dredged sand, silt, and dense sand and gravel.	Construction took place while terminal was operational. Special accommodations were made to drill rigs to allow for the very difficult access and low headroom (8½'-12').	150	300	3	840	65	S1 7" Casing x 0.5" Wall #18 Bar
1993	Williamson Service Center Williamson, WV	Stabilization of ongoing settlement at warehouse facility.	Mine spoil fill over rock.	Installation took place while facility was operational.		N/A	N/A	50	75-114	R2 7½" Casing x 0.3" Wall
1990	Bernstein Building Baltimore, MD	Underpinning and support of 5-story historic building adjacent to subway tunnel.	Loose fill, soil, sands & gravel. Pin Piles installed through existing timber pile foundation.	Installation through basement of building. 8' headroom.	70	140	1	120	30	S1 7" Casing #11 GR 60 Bar
1991	Postal Square Washington, DC	Underpinning of historic post office column and footer foundations.	Dense sands.	Drilling from inside building. 8' headroom.	75	150	4	700	60-80	S2 7" Casing
1989	Coney Island Maintenance Facility Coney Island, NY	Installation of Pin Piles for rehabilitation of existing repair shop.	Loose fill, swamp, sands.	Drilling from inside building. 8' headroom.	35	70	10	4,200	35-45	S1 7" Casing #6 Bar

Table 1 (Continued)

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OVERALL SUMMARY

The use of Pin Piles for building foundations is expanding while the technology is refined by gaining higher working loads. As more experience is gained, and disseminated, their usage will become more common. Numerous and successful tests accompanied by major projects have been installed which demonstrate the viability of their use. As the building industry continues to grow, rehabilitate, and expand, the benefits of using Pin Piles will be further realized.

ACKNOWLEDGMENTS

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