DESIGN, MANUFACTURE, AND INSTALLATION GUIDELINES

OF

PRECAST CONCRETE SEGMENTED PILES

FOR

FOUNDATION UNDERPINNING

by

The Structural Committee

of

The Foundation Performance Association

Houston, Texas

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PREFACE

This document was written by the Structural Committee and has been peer reviewed by the Foundation Performance Association (FPA). This document was initially published 17 July 2005 as FPA-SC-08 as Revision 0 (FPA-SC-08-0) and then again as this Revision 1 (FPA-SC-08-1), superseding the Revision 0 issue, and is made freely available to the public at www.foundationperformance.org so all may have access to the information. To ensure this document remains as current as possible, it may be periodically updated under the same document number but with higher revision numbers such as 2, 3, 4, etc.

The Structural Committee is a standing committee of the Foundation Performance Association. At the time of writing Revision 0 of this document, the Structural Committee was chaired by Ron Kelm, P.E. and 20 to 25 members were active on the committee. During the writing of this Revision 1, the Structural Committee was again chaired by Ron Kelm, P.E. and 45 to 55 members were active on the committee. The committee sanctioned the Rev. 0 version of this paper in January 2001 and the Rev. 1 version in May 2012, and in each case formed an ad hoc subcommittee to write or revise the document. The subcommittee chair(s) and members are listed on the cover sheet of this document and are considered these document's co-authors.

Suggestions for improvement of this document shall be directed to the current chair of the Structural Committee. If sufficient comments are received to warrant a revision, the committee may form a new subcommittee to revise this document. If the revised document successfully passes FPA peer review, it will be published on the FPA website, superseding the previous revision.

The intended audiences for the use of this document are engineers, foundation repair contractors, segmented pile manufacturers, builders, property owners, property managers, and others that may be involved in the design, manufacture, and installation of foundation underpinning and underpinning components.

This document was created with generously donated time in an effort to advance the knowledge, performance, and standards of engineering, construction, and repairs related to foundations, soils, and structures. The text in this document represents the opinions of a majority of the subcommittee members and may not necessarily reflect the opinions of every subcommittee member or FPA member at the time of, or since this document’s publication. The FPA and its members make no warranty regarding the accuracy of the information contained herein and will not be liable for any damages, including consequential damages, resulting from the use of this document. Each project should be investigated for its individual characteristics to permit appropriate application of the material contained herein. Please refer to the FPA’s website at www.foundationperformance.org for other information pertaining to this publication and other FPA publications.

1.0 INTRODUCTION

The scope of this document is to provide guidance and information for projects that use Precast Concrete Segmented Piles for underpinning foundations in the repair of existing residential and other low-rise structures. This type of Foundation Underpinning system is usually not suitable for high-rise buildings or other similarly heavily loaded structures due to the limited load capacity of the Pile sizes commonly used and the driving depths typically achieved. Most applications involve lifting existing foundations with the intent to mitigate future downward movement.

This Foundation Underpinning system is also known by generic names such as precast concrete Piles, Precast Pilings, hydraulically driven concrete Pilings, pressed Piles, pressed Pilings, driven cylinders, and others. Most of the available Segmented Pile systems utilize cylindrical concrete Segments, but rectangular and other shapes may be used.

Piles addressed in this paper consist of Precast Concrete Segments, usually manufactured cylinders, which are installed one by one on top of one another and are pressed into the ground by hydraulically jacking against the underside of the existing structure. Typically the weight of the structure is used to create the reactive force that allows the Pile Segments to be driven into the soil. These Piles may be categorized as “driven displacement Piles”, which displace and force aside the surrounding soil as they are driven. The Piles transfer load to the foundation soil primarily through skin friction along the length of the Pile, although some end-bearing load transfer also occurs.

This system is mainly utilized in clay soils where the driving resistance is small enough to allow the weight of the structure to be used to develop the driving force necessary to obtain sufficient Pile penetration. Dense granular soils may offer too much driving resistance, making the Piles more difficult to install with the available weight of the structure as the driving force. For similar reasons, Precast Concrete Segmented Piles are also difficult to install in clay soils with stiff sandy clay or clayey sand layers. However, a high-pressure water injection technique, called jetting, or other methods, such as pre-drilling, may be used to break up the soil and allow additional Pile penetration.

The committee reviewed the applicable sections of the 2006, 2009, and 2012 International Building Code (IBC) for code compliance of Precast Concrete Segmented Piles. The committee found that no unique definition or identifier within the IBC specifically addresses Segmented Piles. The physical aspects and application of Segmented Piles that make their installation and usage effective are contained in the IBC. The commonly accepted engineering principals of driven Piles, structural piers, helical Piles, etc. are applicable to Segmented Piles, as are the engineering factors such as Refusal, skin friction, concrete strength, bearing capacity, etc.

The committee found that the IBC permits the use of such technology as follows:

- Under IBC (2012) Section 104.11 Alternative materials, design and methods of construction and equipment, states "The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been *approved*. An alternative material, design or method of construction shall be *approved* where the *building official* finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, *fire resistance*, durability and safety."

- The IBC (2012) Commentary Section 104.11 states, "The code is not intended to inhibit innovative ideas or technological advances. A comprehensive regulatory document, such as a building code, cannot envision and then address all future innovations in the industry. As a result, a performance code must be applicable to and provide a basis for the approval of an increasing number of newly developed, innovative materials, systems and methods for which no code text or referenced standards yet exist. The fact that a material, product or method of construction is not addressed in the code is not an indication that such material, product or method is intended to be prohibited. The building official is expected to apply sound technical judgment in accepting materials, systems or methods that, while not anticipated by the drafters of the current code text, can be demonstrated to offer equivalent performance. By virtue of its text, the code regulates new and innovative construction practices while addressing the relative safety of building occupants. The building official is responsible for determining if a requested alternative provides the equivalent level of protection of public health, safety and welfare as required by the code."

- Under Chapter 18, Soils and Foundations, in Section 1810.1.4 Special types of deep foundations, IBC (2012) states, "The use of types of deep foundation elements not specifically mentioned herein is permitted, subject to the approval of the *building official*, upon the submission of acceptable test data, calculations and other information relating to the structural properties and load capacity of such elements. The allowable stresses for materials shall not in any case exceed the limitations specified herein." Because Precast Concrete Segmented Piles have not been specifically mentioned by IBC, this deep foundation system is allowed by IBC provided the building official approves the submission, if applicable.

Considering the information contained in the references above, it is the opinion of the committee that the use of Precast Concrete Segmented Piles for repair of foundations by underpinning are in compliance with the IBC.

2.0 GENERAL DESIGN CONSIDERATIONS

In deciding which type of Foundation Underpinning system to specify, consider the following in using Interconnected and Non-Interconnected Precast Concrete Segmented Piles:

1. Non-Interconnected Precast Concrete Segmented Piles without reinforcement are typically less expensive.

2. Precast Concrete Segmented Piles are typically not able to resist significant bending moments due to lateral loads. Therefore, when lateral loads exist (such as a structure on a slope) the Licensed Professional Engineer should take into consideration designing for lateral load resistance, if applicable.

3. Depending on the type of interconnecting system used and when the interconnecting element is installed, the interconnection may help to detect vertical misalignment of the pile while being driven.

4. A Pile will typically not resist the uplift forces to the foundation. In other words, depending upon the soil uplift forces, Interconnected Precast Concrete Segmented Piles that are supporting the existing foundation system will not be able to provide resistance against foundation uplift if the soil is in contact with the existing foundation system.

5. For most projects, the final depth of each Pile will vary from Pile to Pile. As a result of using only the weight of the structure to drive the Pile, the Precast Concrete Segmented Pile system has a depth of Refusal that varies depending upon the tributary weight, soil properties, Pile geometry, procedure and stiffness of the structure above the Pile being driven. If the Pile cannot attain sufficient penetration into stable soils, then it may not be resistant to potential movements that occur due to swelling or shrinking of the soils in the movement active zone.

6. Should a void exist under the slab subsequent to the lifting process, treatment of the void should be determined on an individual basis. The void should remain in a majority of the cases in order to mitigate the effects of potential soil swell causing heave of the foundation as a result of increased moisture content in the soils.

7. Geotechnical investigation and structural analysis is of value for the design of the foundation repair when raising the foundation above the potential vertical rise (PVR).

3.0 FOUNDATION UNDERPINNING GUIDELINES

The purpose of this section is to provide a guideline to specify Foundation Underpinning, utilizing Precast Concrete Segmented Piles for foundation repair, foundation raising, and Foundation Stabilization.

3.1 DEFINITIONS

Foundation Elevation Adjustment: The process of raising or lowering the foundation in order to obtain a new vertical position in an effort to reduce distress, deflection, and/or tilt to the foundation or superstructure.

Foundation Stabilization: The process of underpinning the foundation to help minimize future downward movement without regard for Foundation Elevation Adjustment.

Foundation Underpinning: The process of adding remedial supporting elements, such as Piles, under an existing foundation system.

Interconnected Precast Concrete Segmented Pile: An assembly of Segments that are driven into the ground using an interconnection between the Segments. Examples of Interconnected Segments may include a center hole in the longitudinal axis, held together at the center hole by a central steel reinforcing bar, a steel rod or rods, threaded ends and coupling nuts, steel cable, or other similar reinforcement. Alternative methods of interconnection include but are not limited to, adhesives between the contact faces of the Segments or couplings.

Non-Interconnected Precast Concrete Segmented Pile: An assembly of Segments that are driven into the ground without any physical connecting elements.

Pile (Piling, Precast Concrete Segmented Pile): The remedial foundation support assembly consisting of the following elements: multiple Segments that are driven into the ground, Pile Cap, Shims, and Interconnections (if specified).

Pile Cap: A rectangular or trapezoidal shaped concrete block positioned above the last Segment and beneath the Shim Segment(s).

Refusal: The point when the driving force exerted on the Piling exceeds the load to be supported.

Reinforced Precast Concrete Segments: Precast concrete Pile Segments reinforced with steel, fiberglass, or other materials.

Segments: Precast concrete units that are typically cylindrical in shape and about one-foot long, although other shapes and lengths may be used. Some manufacturers offer a starter Segment that is smaller in diameter than the following Segments.

Shim: Metal or other material used to fill the space between the Shim Segment(s) and the bottom of the foundation system.

Shim Segments: Spacers that are placed above the Pile Cap and below the Shims.

3.2 REFERENCES AND STANDARDS

The contractor shall follow all applicable codes and standards. In addition, the contractor shall follow the current version of the applicable standards for materials from the American Society for Testing and Materials (ASTM) listed below:

ASCE, American Society of Civil Engineers, Guidelines for the Evaluation and Repair of Residential Foundations Version 2 (Adopted May 1, 2009) by the Texas Section American Society of Civil Engineers.
ASTM A29/A29M Steel Bars, Carbon and Alloy, Hot-Wrought and Cold Finished.
ASTM A36/A36M Carbon Structural Steel.
ASTM A153 Zinc Coating (Hot Dip) on Iron and Steel Hardware.
ASTM A416 Steel Strand, Uncoated Seven-Wire for Pre-stressed Concrete.
ASTM A615 Deformed and Plain Billet-Steel Bars for Concrete Reinforcement.
ASTM A706 Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement.
ASTM A767 Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement.
ASTM A775 Epoxy-Coated Reinforcing Steel Bars.
ASTM A992 Structural Steel.
ASTM C33 Concrete Aggregates.
ASTM C39 Test Method for Compressive Strength of Cylindrical Concrete Specimens.
ASTM C150 Portland Cement.
ASTM C494 Chemical Admixtures for Concrete.
IBC 2006, 2009, 2012, International Building Code, ICC International Code Council, Inc.

3.3 DESIGN REQUIREMENTS

The property owner and/or property manager shall have involvement in specifying the project objective. Design of the Precast Concrete Segmented Pile for commercial applications shall be prepared by a Licensed Professional Engineer (Engineer)**.** In residential projects, an Engineer should be engaged to prepare a design or certify a Pile layout that has been prepared by a contractor.

The scope of foundation repair can be divided into:

- Partial underpinning, which is defined as installing Pilings on only a portion of the structure, such as under a Segment of the exterior and/or interior.
- A complete underpinning which underpins the entire exterior and interior of the structure. A complete underpinning may be utilized to lift the structure above potential vertical rise (PVR).

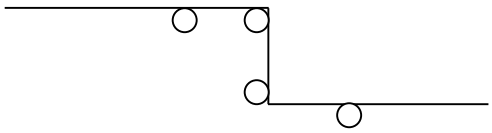
The following are general underpinning placement guidelines for use in the repair of lightly loaded structures. These prescriptive guidelines are based on reinforced foundations. Alternatively, the foundation repair plan can be determined by an Engineer.

1. **Exterior Pilings** - Exterior Piling supports shall have a maximum spacing as follows (porches and garages see Nos. 5 and 8 below):
    a. 8 feet center to center on a 1-story wood or brick structure.

b. 7 feet center to center on a 2-story with brick on the 1st story only and 1-1/2 story when the wall supports the second floor joists.
c. 6 feet center to center on 2-story brick structures.
d. 3 or more stories should have an engineered underpinning design.
e. If the foundation does not have a structurally adequate exterior grade beam to span between the Pilings, then a structural member designed by an Engineer shall be installed at the Pile under the foundation in order to reduce the point load on the foundation and to increase the Pile driving force.

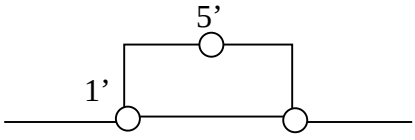
2. **Interior Pilings** - Interior Pilings shall have a maximum spacing as follows:
   a. In a stiffened slab foundation, Piles will be placed at beam intersections, and along beams at a maximum of 10 feet center to center.
   b. 8 feet center to center under walls of 1-story structures.
   c. 7 feet center to center under walls of 2-story structures.
   d. 3 or more stories should have an engineered underpinning design.
   e. When the measurement across a room is 12 feet or more, a Pile / Piles will be placed near the middle of the room. The location of the Piles will be no greater than 8 feet from a Pile-supported wall or adjacent Pile.
   f. If there is no interior grade beam present, then a structural member designed by an Engineer shall be installed at the Pile under the foundation in order to reduce the point load on the foundation and to increase the Pile driving force.

3. **Corners** - Piling supports shall be placed at each corner where an exterior wall changes direction. At corners provide at least one Piling support on each side of the corner Pile spaced in accordance with these guidelines as depicted below. If an existing pier is encountered at the corner, provide a Piling within 2 feet of each side of the corner.

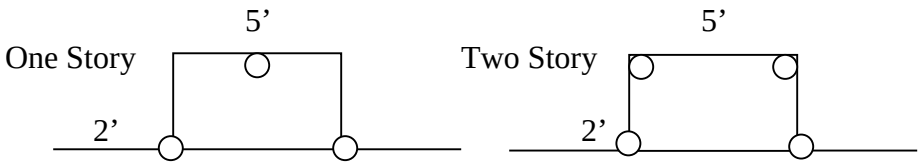


4. **Fireplaces** - The following are examples of Piling support placement for fireplaces:

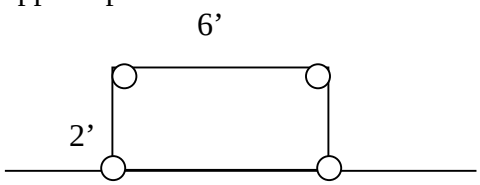
   a. 1 foot by 5 feet prefabricated fireplace should have a minimum of 3 Piling supports placed as shown below.



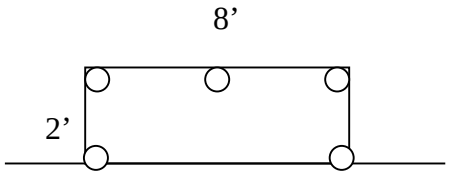
   b. 2 feet by 5 feet fireplace with brick veneer exterior should have a minimum of 3 Piling supports placed as shown below for a 1-story and 4 Piling supports shall be used on a 2-story.



c. 2 feet by 6 feet fireplace with brick exterior should have a minimum of 4 Piling supports placed as shown below.

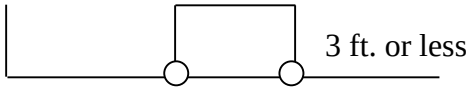


d. A fireplace 8 feet or greater in length should have an additional Piling placed at the center on the exterior wall as depicted below.

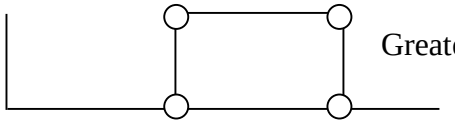


5. **Porches** - The following are examples of Piling support placement for porches:

a. If the inset walls of a monolithic foundation with a covered porch are 3 feet or less then a minimum of 2 Piling supports should be placed as illustrated below.



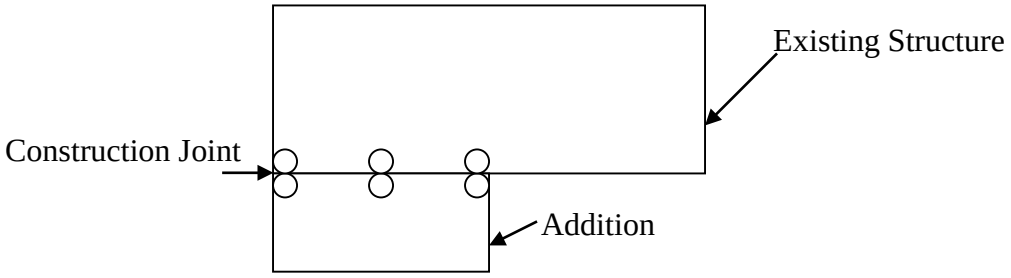
b. If the inset walls of the monolithic foundation with a covered porch are greater than 3 feet then a minimum of 4 Piling supports should be placed as illustrated below.



c. On open porches, Piling supports should be placed directly underneath the columns, and if columns are not present then at an appropriate spacing not to exceed 12 feet.

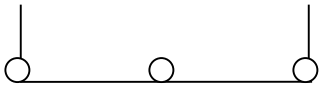
6. **Wing Walls** - If the wing wall is monolithic and greater than 3 foot in length then a Piling should be placed at the end of the wing wall.

7. **Additions** - At additions, the drawing shall show the concrete joint and separation dimensions. At the interface of the addition and the original structure double-Piling supports should be used and spaced per the exterior and/or interior requirements stated above.

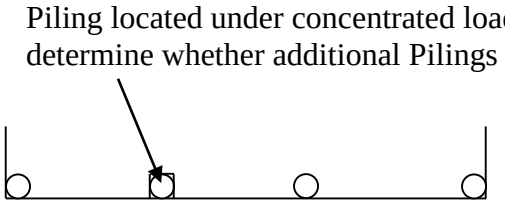


8. **Garages** - A minimum of one Piling support shall be used at the mid-point of a garage door opening for a 2-car garage. A Piling support should be placed under garage support columns. Examples are illustrated below.

   a. Two car garage with or without center support.



   b. Three car garage.



3.4 SUBMITTALS

The contractor shall submit the following items to the owner or his designated representative prior to beginning repair in accordance with conditions of the contract and the applicable submittal procedures in the above References and Standards (Section 3.2):

Pile Detail and Pile Layout Drawing: Drawing showing Pile configuration and proposed location(s), materials, and measurements. Specify size of Segments, reinforcement, interconnection method (if applicable), and Pile assembly. Drawings shall include date, address, and relative elevation survey information. The pre-repair foundation elevation survey should be corrected for floor coverings, show elevations units (preferably inch units) and clearly show the location of the reference datum. The elevation readings shall show (+/-) and be prepared by a licensed Engineer if required.

Initial Elevation Survey: Along with the Pile Layout Drawings, submit the initial (pre-repair) foundation elevation survey clearly showing the location of the reference datum. A symbol may be used to show the location of each elevation survey point.

Contract: The contract should include number of Piles, description of types of Piles such as interior and exterior, concrete breakouts, and price. Contract should include performance payment, and service agreement (warranty) terms.

The contractor should submit the following items to the owner or his designated representative after completing the repair:

Pile-Driving Records: Upon request, submit the pile-driving records. The pile-driving records shall indicate depths of exterior Piles from existing grade and depths of interior Piles from the top of the slab. If recorded, the submitted records shall include the force or pressure used to drive the Piles to Refusal. These records shall be forwarded to the Engineer for review.

Final Elevation Survey: The post-repair foundation elevation survey, corrected for floor coverings. The reference datum used in the initial elevation survey shall be used for the final elevation survey. The survey will include location of installed Piles, numbered to coordinate with the Pile-Driving Record, and any conditions which affected the repair, such as existing supports, and abandoned installations.

Engineering Certification: A Licensed Professional Engineer may certify the repair.

The contractor *may* be asked to submit the following items to the owner or his designated representative, or provide the following services:

Qualification Data: A reference list of completed projects to demonstrate contractor's capabilities and experience, and other information, such as insurance.

Engineering Analysis: A foundation analysis and a foundation repair design shall be prepared by an Engineer. When a design is submitted by the contractor for review, it should be analyzed by an Engineer.

Prequalification Test Reports: If a prequalification test is required to observe the behavior of the building's superstructure and the Pile under actual driving conditions, then a test Pile shall be driven at an outside corner of a building. If an outside corner is not available then the test Pile shall be driven in another area where the driving force (structure's weight and stiffness) is minimized. Test reports for prequalification test Piles shall be submitted to the Engineer for review and comment prior to the installation of additional Piles.

Safety Program: Submit Contractor's standard safety requirements for working in excavated trenches, tunnels, and confined spaces that meet the requirements of OSHA standards.

Pre-installation Meeting: Conduct a pre-installation meeting with owner or his designated representative to verify project requirements, soil conditions, contractor/manufacturer's installation plan, contractor/manufacturer's warranty, and other requirements of this document or contract.

Material Test Reports or Material Certificates: Submit material test results from a qualified testing agency, or material certificates from the manufacturer, indicating compliance with concrete and reinforcing (if applicable) material standards.

3.5 QUALITY ASSURANCE / QUALITY CONTROL

The following quality assurance / quality control requirements shall be submitted to the owner or his designated representative:

Manufacturing Segment Tolerances: Each Precast Concrete Segment shall conform to the following tolerances:

- Cylinder Diameter: Tolerance for the diameter of each Precast Concrete Segment cylinder shall be plus or minus (±) 1/4 inch.
- Segment Ends Concentricity: Tolerance for the concentricity of each of the Precast Concrete Segment ends about the central axis shall be plus or minus (±) 1/16 inch per foot of Segment length.
- Hole Location (if applicable): Tolerance for the location of the central hole through each Segment shall be plus or minus (±) 1/8 inch from true center, and measured at each end.
- Hole Diameter (if applicable): Tolerance for the diameter of the central hole through each Segment shall be plus or minus (±) 1/16 inch.
- End-Bearing Surface Flatness: Tolerance for flatness of end-bearing surfaces shall be plus or minus (±) 1/16 inch throughout the area of each end-bearing surface.
- End-Bearing Surface Cant: The cant of the end-bearing surface from a true perpendicular surface to the longitudinal axis of the cylinder shall be plus or minus (±) 1/2 degree.
- Compressive Strength: The minimum unconfined compressive strength shall not be less than the designated compressive strength.

Quality-Control Testing: Owner may employ, at owner's expense, an independent testing agency to evaluate the Precast Concrete Segment manufacturer's quality control and testing methods. Owner's testing agency shall have access to material storage areas, concrete production equipment, concrete placement, and curing facilities. Contractor shall cooperate with owner's testing agency and provide samples of materials and concrete mixes as may be requested for additional testing and evaluation. Owner's testing agency shall provide contractor a written report of findings.

Defective Materials: Precast Concrete Segments will be considered deficient if units fail to comply with requirements, including strength, manufacturing tolerances, damages such as but not limited to spalls and chips, and ASTM requirements.

Verification of Equipment Performance: Calibrate hydraulic ram using method and frequency in accordance with hydraulic jack manufacturer's recommendations.

3.6 DELIVERY, STORAGE, AND HANDLING

Deliver Pile materials and equipment to the project site in such quantities and at such times to ensure continuity of installation and to meet project schedule requirements. Handle and store materials at the project site so as to prevent breaks, chips, cracks, or other physical damage to the materials and to any protective coating that may be used on reinforcement, if applicable.

3.7 WARRANTY

Contractor typically provides a warranty for all work except as expressed in the contract. Typically, a contractor's warranty does not include damages to any architectural or landscaping finishes, such as, but not limited to, drywall, brick, plants, etc. Upward movement (heave) is also not typically covered unless specifically stated otherwise in the warranty / contract. The warranty period shall be defined in the contract.

3.8 PRODUCTS

Pilings: The concrete shall have a minimum 28-day compressive strength of 5,000 psi in accordance with ASTM C39.

Pile Caps: Pile Caps shall be precast concrete having the same strength and properties of the Precast Concrete Segments.

Reinforcement: The central longitudinal Segmented Pile reinforcement shall conform to the following, if applicable:

Reinforcing Bars: ASTM A615, Grade 60, deformed.
Low-Alloy-Steel Reinforcing Bars: ASTM A706.
Galvanized Reinforcing Bars: ASTM A767, Class II, hot-dip galvanized.
Epoxy-Coated Reinforcing Bars: ASTM A775.
Steel Cable: ASTM A416, Grade 250, galvanized, seven-wire, low-relaxation strand.
Steel Rods: ASTM F1554.

Reinforcement, Corrosion Protection: The reinforcement, if applicable, may be provided with corrosion protection as follows:

- Steel deformed bar reinforcement (rebar) shall be encased in epoxy or grout until the annulus fills.
- Steel cable reinforcement and threaded rods shall be galvanized.
- Smooth steel rod reinforcement shall be coated with epoxy paint.

Accessories: Shims shall have a minimum thickness of 1/8 inch. Shims and other accessories shall be of sufficient size, strength and durability to match the load capacity of the Precast Concrete Segments.

3.9 INSTALLATION

Install Precast Concrete Segmented Piles in accordance with the following procedures:

1. **Safety:** Meeting OSHA and other applicable work safety requirements is the responsibility of the contractor.

2. **Manufacturer's Product Data:** Contractor shall comply with manufacturer's usage instructions, including product technical bulletins.

3. **Site Examination:** Before installing any Piles, the contractor shall examine the site to verify the existing conditions are as indicated on the contract drawings. Notify the Engineer, owner or owner's designated representative of any discrepancies found between the existing site conditions and the contract drawings.

4. **Piling Placement:** Whenever possible, avoid damage to nearby structures. Remove concrete as required to create sufficiently sized access holes through existing concrete. Excavate soils as required at Pile locations to obtain clearance under existing foundation elements sufficient to install Piles. For workability, provide a flat bottom surface in the excavated pit at the Pile location under the existing foundation. Examine the underside of the existing foundation element, and, if required, chip concrete at bottom surface or add grout as required to provide a smooth bottom surface on the existing foundation at the Pile location.

5. **Plumbing Leak Test:** Contractor shall perform a hydrostatic leak detection test of the under-slab sanitary sewer lines and under-slab water supply lines after the work is performed. The contractor shall provide the results in a written report and this report shall be provided to the client, if requested.

6. **Utilities:** Obtain utility company line traces before digging, when required. When working near known buried utility lines, excavations shall be made using hand tools to avoid disturbing or damaging the utility lines.

7. **Groundwater Control:** If necessary, contractor shall provide groundwater control including dewatering of water-bearing soil layers to remove seepage water from excavations.

8. **Surface Water Control:** Contractor shall provide surface water control to divert water away from excavations through the use of dikes, ditches, curb walls, pipes, sumps, or other means. Water held within the excavations shall be pumped out as soon as practical.

9. **Access Holes:** Excavated holes (or pits) for installation of Piles shall not be larger than required for the safety and effectiveness of the Pile driving operation.

10. **Existing Drilled Piers:** If existing drilled piers are tied into the existing foundation, disconnect the existing drilled piers after driving new Piles. The connection may be

disconnected by chipping the concrete at the top of the pier in order to cut the reinforcement bars.

11. **Locate Piles:** Piles shall be positioned as indicated on the Pile Layout Drawing. Pilings shall be located not more than twelve (12) inches from design location on the Pile Layout Drawing, except for cause. Cause can consist of obstructions, location of interior grade beams, and unforeseen conditions discovered during the excavation process. Piles located more than 12 inches from the location shown on an Engineered plan requires approval by the Engineer.

12. **Obstructions:** Remove any encountered obstructions, or add/relocate Pile and adjacent Piles as required under direction of the Engineer, if applicable, or per approved plans and specifications.

13. **Stockpile Segments:** Stockpile a sufficient number of Segments at each Pile location to obtain the anticipated Pile depth, and have a sufficient number of extra Segments readily available to obtain the Pile length necessary to achieve the anticipated depth to Refusal. The stockpiling requirement is to ensure that the anticipated Pile depths can be obtained without having to stop the Pile driving process to obtain more Segments. Pausing the Pile driving process could potentially result in soil freeze up (thixotropy).

14. **Concrete Segment Size:** Unless approved otherwise, use the same Segment size for all Segments within each Pile. Contractors may use cylindrical Segments of varying diameters within a given single Pile, increasing the diameter in a step-wise fashion to effectively taper the Pile from bottom to top. An example would be to start driving with 4-inch diameter Segments, switching to 6-inch diameter Segments, and then switching again to 8-inch diameter Segments per approved design by Engineer, if applicable.

15. **Driving Records:** Maintain accurate driving records for each Pile recording, as a minimum, the information shown on the Segmented Repair Piles checklist of FPA-SC-10-1, *Quality Control Checklists for Foundation Inspection of Residential and Other Low-Rise Buildings*, current revision, found at www.foundationperformance.org.

16. **Axial Alignment:** Establish and maintain axial alignment of all cylinders within each Pile so that all cylinders remain concentric and vertical during the driving operation.

17. **Lubrication:** Water should be added to the bottom of the excavated hole (Pile pit) at the Pile location during Pile driving for lubrication purposes.

18. **Load Sharing:** Drive one Pile at a time to Refusal to maximize the load available to drive the Pile. If Piles are driven simultaneously the Piles being driven shall be a minimum of 25 feet apart.

19. **Reinforcing:** If applicable, install steel reinforcing bars, rods, or cable through the central hole in each Precast Concrete Segmented Pile during the Pile installation. If steel cables are used, ensure that the cable is tight.

20. **Reinforcement Splices:** Splices in the Pile's central steel reinforcing, if used, shall not be permitted except as approved by an Engineer.

21. **Epoxy:** If applicable, install epoxy or epoxy-grout to fill void around reinforcement. Some designs may also specify epoxy between the Pile Segments.

22. **Refusal:** At Refusal, maintain the pressure by shimming the Pile assembly before removing the jack, to mitigate the potential of the Pile assembly rebounding upward.

23. **Water Jetting:** Water jetting may be required in some soils to achieve minimum pile depth needed to embed pile below active soil zone.

24. **Pre-drilling:** Pre-drilling of holes may be required at some locations due to soil conditions such as a rock stratum.

25. **Hydraulic Jack Pressure:** Monitor the hydraulic jack pressure while driving each Pile Segment. A sudden significant loss of pressure occurring along with any abnormal sound from the Pile may indicate crushing of a Segment. Concrete crushing of a Pile Segment that occurs during the driving process is considered to result in a defective Pile since compressive load transfer between the Segments can no longer be assured and further driving of the Pile can result in misalignment of the Pile.

26. **Pile Depth:** Install Piles to the required minimum depth as specified by the plans, if applicable. The contractor shall provide Piles capable of withstanding the Pile driving stresses and design loads, and capable of being driven to Refusal at or below a minimum design depth, if specified by the Engineer. Piles that reach Refusal before attaining the minimum required depth as specified shall be subject to the following:

    - Terminate Pile at Refusal depth obtained with approval of Engineer, or
    - Replace Pile with Pile having a smaller cross sectional area, installed at a location at least 3 Pile diameters from the terminated Pile, or
    - Implement water jetting, or
    - Abandon the pile and pre-drill an adjacent pile at least 3 Pile diameters from the terminated Pile.

27. **Defective Pile:** Abandon damaged or defective Pile and install new Pile in alternate location (See "Locate Piles", No. 11 above). Record locations of abandoned Pile on the finished plan drawing.

28. **Cap Pile:** Immediately after removing the hydraulic ram, and after completion of the driving process, temporarily cap and shim the Pile utilizing the Pile Cap and pressure from the hydraulic jack to prevent Pile rebound.

29. **Adjacent Piles:** Proceed to drive adjacent Piles using the same steps as outlined above. Do not over-lift (See "Refusal", Section 3.1) the structure during the underpinning process since it may cause damage to the structure and / or architectural finishes.

30. **Adjust Pile Caps:** After all Piles are installed, adjust all Pile Caps and Shims as required to correct any Shims that may have been dislodged during the driving of adjacent Piles to provide full contact bearing at Pile locations. Maintain horizontal alignment of the Pile Cap on top of the driven Pile Segments.

31. **Foundation Elevation Adjustment:** Lift foundation system in a systematic manner using jacks, when applicable. Care shall be performed during the lifting process in a manner that limits damage to the structure. Attempt to close any masonry and/or drywall cracks as much as possible. Test doors and windows to ensure they operate as intended. If a primary structural member, such as a grade beam, is damaged during driving or lifting, an Engineer may be consulted for its repair and the member shall be repaired in accordance with the Engineer's repair specifications.

32. **Final Elevation Survey:** After the Foundation Elevation Adjustment process is complete, the contractor shall perform a final elevation survey of existing foundation floor. This will establish a baseline survey that may be used for warranty purposes. The results of the survey shall be documented on a sketch of the foundation repair plan, showing the location of the reference datum.

33. **Backfilling of Piling Access Holes:** Contractor shall fill excavations with soils that were removed from the excavations. The soil should be placed in eight-inch maximum loose lifts, and compacted using water as needed before the next placement. Fill should mound over the excavation to allow for settlement of the fill and be sloped away from the foundation for drainage.

34. **Restore Concrete:** Contractor shall restore holes and moisture retarder created in the foundation and flatwork, with concrete of the same or greater thickness, finished to match the existing concrete as much as practical.

35. **Excess Material:** Haul off excess excavated materials and clean finished surfaces.
