

# 2021 Virginia Construction Code

## CHAPTER 18 SOILS AND FOUNDATIONS

### SECTION 1810 DEEP FOUNDATIONS

#### 1810.1 General.

*Deep foundations* shall be analyzed, designed, detailed and installed in accordance with [Sections 1810.1](#) through [1810.4](#).

##### 1810.1.1 Geotechnical investigation.

*Deep foundations* shall be designed and installed on the basis of a geotechnical investigation as set forth in [Section 1803](#).

##### 1810.1.2 Use of existing deep foundation elements.

*Deep foundation* elements left in place where a structure has been demolished shall not be used for the support of new construction unless satisfactory evidence is submitted to the *building official*, which indicates that the elements are sound and meet the requirements of this code. Such elements shall be load tested or redriven to verify their capacities. The design *load* applied to such elements shall be the lowest allowable *load* as determined by tests or redriving data.

##### 1810.1.3 Deep foundation elements classified as columns.

*Deep foundation* elements standing unbraced in air, water or fluid soils shall be classified as columns and designed as such in accordance with the provisions of this code from their top down to the point where adequate lateral support is provided in accordance with [Section 1810.2.1](#).

**Exception:** Where the unsupported height to least horizontal dimension of a cast-in-place *deep foundation* element does not exceed three, it shall be permitted to design and construct such an element as a pedestal in accordance with [ACI 318](#).

##### 1810.1.4 Special types of deep foundations.

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.

#### 1810.2 Analysis.

The analysis of *deep foundations* for design shall be in accordance with [Sections 1810.2.1](#) through [1810.2.5](#).

##### 1810.2.1 Lateral support.

Any soil other than fluid soil shall be deemed to afford sufficient lateral support to prevent buckling of *deep foundation* elements and to permit the design of the elements in accordance with accepted engineering practice and the applicable provisions of this code.

Where *deep foundation* elements stand unbraced in air, water or fluid soils, it shall be permitted to consider them laterally supported at a point 5 feet (1524 mm) into stiff soil or 10 feet (3048 mm) into soft soil unless otherwise approved by the *building official* on the basis of a geotechnical investigation by a *registered design professional*.

##### 1810.2.2 Stability.

*Deep foundation* elements shall be braced to provide lateral stability in all directions. Three or more elements connected by a rigid cap shall be considered to be braced, provided that the elements are located in radial directions from the centroid of the group not less than 60 degrees (1 rad) apart. A two-element group in a rigid cap shall be considered to be braced along the axis connecting the two elements. Methods used to brace *deep foundation* elements shall be subject to the approval of the *building official*.

*Deep foundation* elements supporting walls shall be placed alternately in lines spaced not less than 1 foot (305 mm) apart and located symmetrically under the center of gravity of the wall load carried, unless effective measures are taken to provide for eccentricity and lateral forces, or the foundation elements are adequately braced to provide for lateral stability.

#### Exceptions:

1. Isolated cast-in-place *deep foundation* elements without lateral bracing shall be permitted where the least horizontal dimension is not less than 2 feet (610 mm), adequate lateral support in accordance with [Section 1810.2.1](#) is provided for the entire height and the height does not exceed 12 times the least horizontal dimension.
2. A single row of *deep foundation* elements without lateral bracing is permitted for one- and two-family dwellings and lightweight construction not exceeding two *stories above grade plane* or 35 feet (10 668 mm) in *building height*, provided that the centers of the elements are located within the width of the supported wall.

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### 1810.2.3 Settlement.

The settlement of a single *deep foundation* element or group thereof shall be estimated based on *approved* methods of analysis. The predicted settlement shall cause neither harmful distortion of, nor instability in, the structure, nor cause any element to be loaded beyond its capacity.

### 1810.2.4 Lateral loads.

The moments, shears and lateral deflections used for design of *deep foundation* elements shall be established considering the nonlinear interaction of the shaft and soil, as determined by a *registered design professional*. Where the ratio of the depth of embedment of the element to its least horizontal dimension is less than or equal to six, it shall be permitted to assume the element is rigid.

#### 1810.2.4.1 Seismic Design Categories D through F.

For structures assigned to *Seismic Design Category* D, E or F, *deep foundation* elements on *Site Class* E or F sites, as determined in [Section 1613.2.2](#), shall be designed and constructed to withstand maximum imposed curvatures from earthquake ground motions and structure response. Curvatures shall include free-field soil strains modified for soil-foundation-structure interaction coupled with foundation element deformations associated with earthquake *loads* imparted to the foundation by the structure.

**Exception:** *Deep foundation* elements that satisfy the following additional detailing requirements shall be deemed to comply with the curvature capacity requirements of this section.

1. Precast prestressed concrete piles detailed in accordance with [Section 1810.3.8](#).
2. Cast-in-place *deep foundation* elements with a minimum longitudinal reinforcement ratio of 0.005 extending the full length of the element and detailed in accordance with Sections 18.7.5.2, 18.7.5.3 and 18.7.5.4 of [ACI 318](#) as required by [Section 1810.3.9.4.2.2](#).

### 1810.2.5 Group effects.

The analysis shall include group effects on lateral behavior where the center-to-center spacing of *deep foundation* elements in the direction of lateral force is less than eight times the least horizontal dimension of an element. The analysis shall include group effects on axial behavior where the center-to-center spacing of *deep foundation* elements is less than three times the least horizontal dimension of an element. Group effects shall be evaluated using a generally accepted method of analysis; the analysis for uplift of grouped elements with center-to-center spacing less than three times the least horizontal dimension of an element shall be evaluated in accordance with [Section 1810.3.3.1.6](#).

### 1810.3 Design and detailing.

*Deep foundations* shall be designed and detailed in accordance with [Sections 1810.3.1](#) through [1810.3.13](#).

#### 1810.3.1 Design conditions.

Design of *deep foundations* shall include the design conditions specified in [Sections 1810.3.1.1](#) through [1810.3.1.6](#), as applicable.

##### 1810.3.1.1 Design methods for concrete elements.

Where concrete *deep foundations* are laterally supported in accordance with [Section 1810.2.1](#) for the entire height and applied forces cause bending moments not greater than those resulting from accidental eccentricities, structural design of the element using the allowable stress design load combinations specified in [ASCE 7, Section 2.4](#) or the [alternative allowable stress design load combinations of Section 1605.2](#) and the allowable stresses specified in this chapter shall be permitted. Otherwise, the structural design of concrete *deep foundation* elements shall use the [strength load combinations specified in ASCE 7, Section 2.3](#) and *approved* strength design methods.

##### 1810.3.1.2 Composite elements.

Where a single *deep foundation* element comprises two or more sections of different materials or different types spliced together, each section of the composite assembly shall satisfy the applicable requirements of this code, and the maximum allowable *load* in each section shall be limited by the structural capacity of that section.

##### 1810.3.1.3 Mislocation.

The foundation or superstructure shall be designed to resist the effects of the mislocation of any *deep foundation* element by not less than 3 inches (76 mm). To resist the effects of mislocation, compressive overload of *deep foundation* elements to 110 percent of the allowable design load shall be permitted.

##### 1810.3.1.4 Driven piles.

Driven piles shall be designed and manufactured in accordance with accepted engineering practice to resist all stresses induced by handling, driving and service loads.

##### 1810.3.1.5 Helical piles.

*Helical piles* shall be designed and manufactured in accordance with accepted engineering practice to resist all stresses induced by installation into the ground and service loads.

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#### 1810.3.1.6 Casings.

Temporary and permanent casings shall be of steel and shall be sufficiently strong to resist collapse and sufficiently watertight to exclude any foreign materials during the placing of concrete. Where a permanent casing is considered reinforcing steel, the steel shall be protected under the conditions specified in [Section 1810.3.2.5](#). Horizontal joints in the casing shall be spliced in accordance with [Section 1810.3.6](#).

#### 1810.3.2 Materials.

The materials used in *deep foundation* elements shall satisfy the requirements of [Sections 1810.3.2.1](#) through [1810.3.2.8](#), as applicable.

##### 1810.3.2.1 Concrete.

Where concrete is cast in a steel pipe or where an enlarged base is formed by compacting concrete, the maximum size for coarse aggregate shall be  $\frac{3}{4}$  inch (19.1 mm). Concrete to be compacted shall have a zero slump.

##### 1810.3.2.1.1 Seismic hooks.

For structures assigned to *Seismic Design Category* C, D, E or F, the ends of hoops, spirals and ties used in concrete *deep foundation* elements shall be terminated with seismic hooks, as defined in [ACI 318](#), and shall be turned into the confined concrete core.

##### 1810.3.2.1.2 ACI 318 Equation (25.7.3.3).

Where this chapter requires detailing of concrete *deep foundation* elements in accordance with Section 18.7.5.4 of [ACI 318](#), compliance with Equation (25.7.3.3) of [ACI 318](#) shall not be required.

##### 1810.3.2.2 Prestressing steel.

Prestressing steel shall conform to [ASTM A416](#).

##### 1810.3.2.3 Steel.

Structural steel H-piles and structural steel sheet piling shall conform to the material requirements in [ASTM A6](#). Steel pipe piles shall conform to the material requirements in [ASTM A252](#). Fully welded steel piles shall be fabricated from plates that conform to the material requirements in [ASTM A36](#), [ASTM A283](#), [ASTM A572](#), [ASTM A588](#) or [ASTM A690](#).

##### 1810.3.2.4 Timber.

Timber *deep foundation* elements shall be designed as piles or poles in accordance with [ANSI/AWC NDS](#). Round timber elements shall conform to [ASTM D25](#). Sawn timber elements shall conform to [DOC PS-20](#).

##### 1810.3.2.4.1 Preservative treatment.

Timber *deep foundation* elements used to support permanent structures shall be treated in accordance with this section unless it is established that the tops of the untreated timber elements will be below the lowest ground-water level assumed to exist during the life of the structure. Preservative and minimum final retention shall be in accordance with [AWPA U1](#) (Commodity Specification E, Use Category 4C) for round timber elements and [AWPA U1](#) (Commodity Specification A, Use Category 4B) for sawn timber elements. Preservative-treated timber elements shall be subject to a quality control program administered by an *approved* agency. Element cutoffs shall be treated in accordance with [AWPA M4](#).

##### 1810.3.2.5 Protection of materials.

Where boring records or site conditions indicate possible deleterious action on the materials used in deep foundation elements because of soil constituents, changing water levels or other factors, the elements shall be adequately protected by materials, methods or processes *approved* by the *building official*. Protective materials shall be applied to the elements so as not to be rendered ineffective by installation. The effectiveness of such protective measures for the particular purpose shall have been thoroughly established by satisfactory service records or other evidence.

##### 1810.3.2.6 Allowable stresses.

The allowable stresses for materials used in deep foundation elements shall not exceed those specified in [Table 1810.3.2.6](#).

**TABLE 1810.3.2.6**  
**ALLOWABLE STRESSES FOR MATERIALS USED IN DEEP FOUNDATION ELEMENTS**

MATERIAL TYPE AND CONDITION	MAXIMUM ALLOWABLE STRESS <sup>a</sup>
1. Concrete or grout in compression <sup>b</sup>	
Cast-in-place with a permanent casing in accordance with <a href="#">Section 1810.3.2.7</a> or <a href="#">Section 1810.3.5.3.4</a>	$0.4 f_c$
Cast-in-place in other permanent casing or rock	$0.33 f_c$
Cast-in-place without a permanent casing	$0.3 f_c$

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Precast nonprestressed	$0.33 f'_c$
Precast prestressed	$0.33 f'_c - 0.27 f_{pc}$
2. Nonprestressed reinforcement in compression	$0.4 f_y \leq 30,000$ psi
3. Steel in compression	
Cores within concrete-filled pipes or tubes	$0.5 F_y \leq 32,000$ psi
Pipes, tubes or H-piles, where justified in accordance with <a href="#">Section 1810.3.2.8</a>	$0.5 F_y \leq 32,000$ psi
Pipes or tubes for micropiles	$0.4 F_y \leq 32,000$ psi
Other pipes, tubes or H-piles	$0.35 F_y \leq 24,000$ psi
Helical piles	$0.6 F_y \leq 0.5 F_u$
4. Nonprestressed reinforcement in tension	
Within micropiles	$0.6 f_y$
Other conditions	
For load combinations that do not include wind or seismic loads	$0.5 f_y \leq 30,000$ psi
For load combinations that include wind or seismic loads	$0.5 f_y \leq 40,000$ psi
5. Steel in tension	
Pipes, tubes or H-piles, where justified in accordance with <a href="#">Section 1810.3.2.8</a>	$0.5 F_y \leq 32,000$ psi
Other pipes, tubes or H-piles	$0.35 F_y \leq 24,000$ psi
Helical piles	$0.6 F_y \leq 0.5 F_u$
6. Timber	In accordance with the <a href="#">ANSI/AWC NDS</a>

a.  $f'_c$  is the specified compressive strength of the concrete or grout;  $f_{pc}$  is the compressive stress on the gross concrete section due to effective prestress forces only;  $f_y$  is the specified yield strength of reinforcement;  $F_y$  is the specified minimum yield stress of steel;  $F_u$  is the specified minimum tensile stress of structural steel.

b. The stresses specified apply to the gross cross-sectional area of the concrete for precast prestressed piles and to the net cross-sectional area for all other piles. Where a temporary or permanent casing is used, the inside face of the casing shall be considered the outer edge of the concrete cross-section.

#### 1810.3.2.7 Increased allowable compressive stress for cased mandrel-driven cast-in-place elements.

The allowable compressive stress in the concrete shall be permitted to be increased as specified in [Table 1810.3.2.6](#) for those portions of permanently cased cast-in-place elements that satisfy all of the following conditions:

1. The design shall not use the casing to resist any portion of the axial load imposed.
2. The casing shall have a sealed tip and be mandrel driven.
3. The thickness of the casing shall be not less than manufacturer's standard gage No.14 (0.068 inch) (1.75 mm).
4. The casing shall be seamless or provided with seams of strength equal to the basic material and be of a configuration that will provide confinement to the cast-in-place concrete.
5. The ratio of steel yield strength ( $F_y$ ) to specified compressive strength ( $f'_c$ ) shall be not less than six.
6. The nominal diameter of the element shall not be greater than 16 inches (406 mm).

#### 1810.3.2.8 Justification of higher allowable stresses.

Use of allowable stresses greater than those specified in [Section 1810.3.2.6](#) shall be permitted where supporting data justifying such higher stresses is filed with the *building official*. Such substantiating data shall include the following:

1. A geotechnical investigation in accordance with [Section 1803](#).
2. Load tests in accordance with [Section 1810.3.3.1.2](#), regardless of the load supported by the element.

The design and installation of the deep foundation elements shall be under the direct supervision of a registered design professional knowledgeable in the field of soil mechanics and deep foundations who shall submit a report to the *building official* stating that the elements as installed satisfy the design criteria.

#### 1810.3.3 Determination of allowable loads.

The allowable axial and lateral loads on deep foundation elements shall be determined by an approved formula, load tests or method of analysis.

##### 1810.3.3.1 Allowable axial load.

The allowable axial load on a deep foundation element shall be determined in accordance with [Sections 1810.3.3.1.1](#)

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through [1810.3.3.1.9](#).

**Exception:** Where approved by the *building official*, load testing is not required.

#### **1810.3.3.1.1 Driving criteria.**

The allowable compressive load on any driven deep foundation element where determined by the application of an *approved* driving formula shall not exceed 40 tons (356 kN). For allowable loads above 40 tons (356 kN), the wave equation method of analysis shall be used to estimate driveability for both driving stresses and net displacement per blow at the ultimate load. Allowable loads shall be verified by load tests in accordance with [Section 1810.3.3.1.2](#). The formula or wave equation load shall be determined for gravity-drop or power-actuated hammers and the hammer energy used shall be the maximum consistent with the size, strength and weight of the driven elements. The use of a follower is permitted only with the approval of the *building official*. The introduction of fresh hammer cushion or pile cushion material just prior to final penetration is not permitted.

#### **1810.3.3.1.2 Load tests.**

Where design compressive *loads* are greater than those determined using the allowable stresses specified in [Section 1810.3.2.6](#), where the design *load* for any deep foundation element is in doubt, or where cast-in-place deep foundation elements have an enlarged base formed either by compacting concrete or by driving a precast base, control test elements shall be tested in accordance with [ASTM D1143](#) or [ASTM D4945](#). One element or more shall be load tested in each area of uniform subsoil conditions. Where required by the *building official*, additional elements shall be load tested where necessary to establish the safe design capacity. The resulting allowable *loads* shall not be more than one-half of the ultimate axial load capacity of the test element as assessed by one of the published methods listed in [Section 1810.3.3.1.3](#) with consideration for the test type, duration and subsoil. The ultimate axial load capacity shall be determined by a *registered design professional* with consideration given to tolerable total and differential settlements at design *load* in accordance with [Section 1810.2.3](#). In subsequent installation of the balance of deep foundation elements, all elements shall be deemed to have a supporting capacity equal to that of the control element where such elements are of the same type, size and relative length as the test element; are installed using the same or comparable methods and equipment as the test element; are installed in similar subsoil conditions as the test element; and, for driven elements, where the rate of penetration (for example, net displacement per blow) of such elements is equal to or less than that of the test element driven with the same hammer through a comparable driving distance.

#### **1810.3.3.1.3 Load test evaluation methods.**

It shall be permitted to evaluate load tests of *deep foundation* elements using any of the following methods:

1. Davisson Offset Limit.
2. Brinch-Hansen 90-percent Criterion.
3. Butler-Hoy Criterion.
4. Other methods *approved* by the *building official*.

#### **1810.3.3.1.4 Allowable shaft resistance.**

The assumed shaft resistance developed by any uncased cast-in-place *deep foundation* element shall not exceed one-sixth of the bearing value of the soil material at minimum depth as set forth in [Table 1806.2](#), up to 500 psf (24 kPa), unless a greater value is allowed by the *building official* on the basis of a geotechnical investigation as specified in [Section 1803](#) or a greater value is substantiated by a load test in accordance with [Section 1810.3.3.1.2](#). Shaft resistance and end-bearing resistance shall not be assumed to act simultaneously unless determined by a geotechnical investigation in accordance with [Section 1803](#).

#### **1810.3.3.1.5 Uplift capacity of a single deep foundation element.**

Where required by the design, the uplift capacity of a single deep foundation element shall be determined by an *approved* method of analysis based on a minimum factor of safety of three or by load tests conducted in accordance with [ASTM D3689](#). The maximum allowable uplift *load* shall not exceed the ultimate load capacity as determined in [Section 1810.3.3.1.2](#), using the results of load tests conducted in accordance with [ASTM D3689](#), divided by a factor of safety of two.

**Exception:** Where uplift is due to wind or seismic loading, the minimum factor of safety shall be two where capacity is determined by an analysis and one and one-half where capacity is determined by load tests.

#### **1810.3.3.1.6 Allowable uplift load of grouped deep foundation elements.**

For grouped *deep foundation* elements subjected to uplift, the allowable uplift *load* for the group shall be calculated by a generally accepted method of analysis. Where the *deep foundation* elements in the group are placed at a center-to-center spacing less than three times the least horizontal dimension of the largest single element, the allowable uplift *load* for the group is permitted to be calculated as the lesser of:

1. The proposed individual allowable uplift *load* times the number of elements in the group.
2. Two-thirds of the effective weight of the group and the soil contained within a block defined by the perimeter of

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the group and the length of the element, plus two-thirds of the ultimate shear resistance along the soil block.

#### **1810.3.3.1.7 Load-bearing capacity.**

*Deep foundation* elements shall develop ultimate load capacities of not less than twice the design working loads in the designated load-bearing layers. Analysis shall show that soil layers underlying the designated load-bearing layers do not cause the load-bearing capacity safety factor to be less than two.

#### **1810.3.3.1.8 Bent deep foundation elements.**

The load-bearing capacity of *deep foundation* elements discovered to have a sharp or sweeping bend shall be determined by an *approved* method of analysis or by load testing a representative element.

#### **1810.3.3.1.9 Helical piles.**

The allowable axial design load,  $P_a$ , of *helical piles* shall be determined as follows:

$$P_a = 0.5 P_u$$

where  $P_u$  is the least value of:

(Equation 18-4)

1. **Base capacity plus shaft resistance of the helical pile.** The base capacity is equal to the sum of the areas of the helical bearing plates times the ultimate bearing capacity of the soil or rock comprising the bearing stratum. The shaft resistance is equal to the area of the shaft above the uppermost helical bearing plate times the ultimate skin resistance.
2. Ultimate capacity determined from well-documented correlations with installation torque.
3. Ultimate capacity determined from load tests where required by Section 1810.3.3.1.2.
4. Ultimate axial capacity of pile shaft.
5. Ultimate axial capacity of pile shaft couplings.
6. Sum of the ultimate axial capacity of helical bearing plates affixed to pile.

#### **1810.3.3.2 Allowable lateral load.**

Where required by the design, the lateral load capacity of a single *deep foundation* element or a group thereof shall be determined by an *approved* method of analysis or by lateral load tests to not less than twice the proposed design working load. The resulting allowable load shall not be more than one-half of the load that produces a gross lateral movement of 1 inch (25 mm) at the lower of the top of foundation element and the ground surface, unless it can be shown that the predicted lateral movement shall cause neither harmful distortion of, nor instability in, the structure, nor cause any element to be loaded beyond its capacity.

#### **1810.3.4 Subsiding soils or strata.**

Where *deep foundation* elements are installed through subsiding soils or other subsiding strata and derive support from underlying firmer materials, consideration shall be given to the downward frictional forces potentially imposed on the elements by the subsiding upper strata.

Where the influence of subsiding soils or strata is considered as imposing loads on the element, the allowable stresses specified in this chapter shall be permitted to be increased where satisfactory substantiating data are submitted.

#### **1810.3.5 Dimensions of deep foundation elements.**

The dimensions of *deep foundation* elements shall be in accordance with Sections 1810.3.5.1 through 1810.3.5.3, as applicable.

##### **1810.3.5.1 Precast.**

The minimum lateral dimension of precast concrete *deep foundation* elements shall be 8 inches (203 mm). Corners of square elements shall be chamfered.

##### **1810.3.5.2 Cast-in-place or grouted-in-place.**

Cast-in-place and grouted-in-place *deep foundation* elements shall satisfy the requirements of this section.

##### **1810.3.5.2.1 Cased.**

Cast-in-place or grouted-in-place *deep foundation* elements with a permanent casing shall have a nominal outside diameter of not less than 8 inches (203 mm).

##### **1810.3.5.2.2 Uncased.**

Cast-in-place or grouted-in-place *deep foundation* elements without a permanent casing shall have a specified diameter of not less than 12 inches (305 mm). The element length shall not exceed 30 times the specified diameter.

**Exception:** The length of the element is permitted to exceed 30 times the specified diameter, provided that the design and installation of the deep foundations are under the direct supervision of a *registered design professional* knowledgeable in the field of soil mechanics and deep foundations. The *registered design professional* shall submit a report to the *building official* stating that the elements were installed in compliance with the *approved construction*

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### **1810.3.5.2.3 Micropiles.**

Micropiles shall have a nominal diameter of 12 inches (305 mm) or less. The minimum diameter set forth elsewhere in [Section 1810.3.5](#) shall not apply to micropiles.

### **1810.3.5.3 Steel.**

Steel *deep foundation* elements shall satisfy the requirements of this section.

#### **1810.3.5.3.1 Structural steel H-piles.**

Sections of structural steel H-piles shall comply with the requirements for HP shapes in [ASTM A6](#), or the following:

1. The flange projections shall not exceed 14 times the minimum thickness of metal in either the flange or the web and the flange widths shall be not less than 80 percent of the depth of the section.
2. The nominal depth in the direction of the web shall be not less than 8 inches (203 mm).
3. Flanges and web shall have a minimum nominal thickness of  $\frac{3}{8}$  inch (9.5 mm).

For structures assigned to *Seismic Design Category D, E or F*, design and detailing of H-piles shall also conform to the requirements of [AISC 341](#).

#### **1810.3.5.3.2 Fully welded steel piles fabricated from plates.**

Sections of fully welded steel piles fabricated from plates shall comply with the following:

1. The flange projections shall not exceed 14 times the minimum thickness of metal in either the flange or the web and the flange widths shall be not less than 80 percent of the depth of the section.
2. The nominal depth in the direction of the web shall be not less than 8 inches (203 mm).
3. Flanges and web shall have a minimum nominal thickness of  $\frac{3}{8}$  inch (9.5 mm).

#### **1810.3.5.3.3 Structural steel sheet piling.**

Individual sections of structural steel sheet piling shall conform to the profile indicated by the manufacturer, and shall conform to the general requirements specified by [ASTM A6](#).

#### **1810.3.5.3.4 Steel pipes and tubes.**

Steel pipes and tubes used as *deep foundation* elements shall have a nominal outside diameter of not less than 8 inches (203 mm). Where steel pipes or tubes are driven open ended, they shall have not less than 0.34 square inch (219 mm<sup>2</sup>) of steel in cross section to resist each 1,000 foot-pounds (1356 Nm) of pile hammer energy, or shall have the equivalent strength for steels having a yield strength greater than 35,000 psi (241 MPa) or the wave equation analysis shall be permitted to be used to assess compression stresses induced by driving to evaluate if the pile section is appropriate for the selected hammer. Where a pipe or tube with wall thickness less than 0.179 inch (4.6 mm) is driven open ended, a suitable cutting shoe shall be provided. Concrete-filled steel pipes or tubes in structures assigned to *Seismic Design Category C, D, E or F* shall have a wall thickness of not less than  $\frac{3}{16}$  inch (5 mm). The pipe or tube casing for socketed *drilled shafts* shall have a nominal outside diameter of not less than 18 inches (457 mm), a wall thickness of not less than  $\frac{3}{8}$  inch (9.5 mm) and a suitable steel driving shoe welded to the bottom; the diameter of the rock socket shall be approximately equal to the inside diameter of the casing.

#### **Exceptions:**

1. There is no minimum diameter for steel pipes or tubes used in micropiles.
2. For mandrel-driven pipes or tubes, the minimum wall thickness shall be  $\frac{1}{10}$  inch (2.5 mm).

#### **1810.3.5.3.5 Helical piles.**

Dimensions of the central shaft and the number, size and thickness of helical bearing plates shall be sufficient to support the design loads.

### **1810.3.6 Splices.**

Splices shall be constructed so as to provide and maintain true alignment and position of the component parts of the *deep foundation* element during installation and subsequent thereto and shall be designed to resist the axial and shear forces and moments occurring at the location of the splice during driving and for design load combinations. Where *deep foundation* elements of the same type are being spliced, splices shall develop not less than 50 percent of the bending strength of the weaker section. Where *deep foundation* elements of different materials or different types are being spliced, splices shall develop the full compressive strength and not less than 50 percent of the tension and bending strength of the weaker section. Where structural steel cores are to be spliced, the ends shall be milled or ground to provide full contact and shall be full-depth welded.

**Exception:** For buildings assigned to *Seismic Design Category A or B*, splices need not comply with the 50-percent tension and bending strength requirements where justified by supporting data.

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Splices occurring in the upper 10 feet (3048 mm) of the embedded portion of an element shall be designed to resist at allowable stresses the moment and shear that would result from an assumed eccentricity of the axial load of 3 inches (76 mm), or the element shall be braced in accordance with [Section 1810.2.2](#) to other deep foundation elements that do not have splices in the upper 10 feet (3048 mm) of embedment.

#### 1810.3.6.1 Seismic Design Categories C through F.

For structures assigned to *Seismic Design Category C, D, E or F* splices of *deep foundation* elements shall develop the lesser of the following:

1. The nominal strength of the *deep foundation* element.
2. The axial and shear forces and moments from the seismic load effects including overstrength factor in accordance with Section 2.3.6 or 2.4.5 of [ASCE 7](#).

#### 1810.3.7 Top of element detailing at cutoffs.

Where a minimum length for reinforcement or the extent of closely spaced confinement reinforcement is specified at the top of a *deep foundation* element, provisions shall be made so that those specified lengths or extents are maintained after cutoff.

#### 1810.3.8 Precast concrete piles.

Precast concrete piles shall be designed and detailed in accordance with [ACI 318](#).

##### Exceptions:

1. For precast prestressed piles in *Seismic Design Category C*, the minimum volumetric ratio of spirals or circular hoops required by Section 18.13.5.10.4 of [ACI 318](#) shall not apply in cases where the design includes full consideration of load combinations specified in [ASCE 7](#), Section 2.3.6 or Section 2.4.5 and the applicable overstrength factor,  $\Omega_0$ . In such cases, minimum transverse reinforcement index shall be as specified in Section 13.4.5.6 of [ACI 318](#).
2. For precast prestressed piles in *Seismic Design Categories D through F*, the minimum volumetric ratio of spirals or circular hoops required by Section 18.13.5.10.5(c) of [ACI 318](#) shall not apply in cases where the design includes full consideration of load combinations specified in [ASCE 7](#), Section 2.3.6 or Section 2.4.5 and the applicable overstrength factor,  $\Omega_0$ . In such cases, minimum transverse reinforcement shall be as specified in Section 13.4.5.6 of [ACI 318](#).

#### 1810.3.9 Cast-in-place deep foundations.

Cast-in-place *deep foundation* elements shall be designed and detailed in accordance with [Sections 1810.3.9.1 through 1810.3.9.6](#).

##### 1810.3.9.1 Design cracking moment.

The design cracking moment ( $\phi M_n$ ) for a cast-in-place *deep foundation* element not enclosed by a structural steel pipe or tube shall be determined using the following equation:

$$\phi M_n = 3 \sqrt{f'_c} S_m$$

(Equation 18-5)

For SI:  $\phi M_n = 0.25 \sqrt{f'_c} S_m$

where:

$f'_c$  = Specified compressive strength of concrete or grout, psi (MPa).

$S_m$  = Elastic section modulus, neglecting reinforcement and casing, cubic inches (mm<sup>3</sup>).

##### 1810.3.9.2 Required reinforcement.

Where subject to uplift or where the required moment strength determined using the load combinations of [ASCE 7](#), [Section 2.3](#) exceeds the design cracking moment determined in accordance with [Section 1810.3.9.1](#), cast-in-place deep foundations not enclosed by a structural steel pipe or tube shall be reinforced.

##### 1810.3.9.3 Placement of reinforcement.

Reinforcement where required shall be assembled and tied together and shall be placed in the *deep foundation* element as a unit before the reinforced portion of the element is filled with concrete.

##### Exceptions:

1. Steel dowels embedded 5 feet (1524 mm) or less shall be permitted to be placed after concreting, while the concrete is still in a semifluid state.

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2. For *deep foundation* elements installed with a hollow-stem auger, tied reinforcement shall be placed after elements are concreted, while the concrete is still in a semifluid state. Longitudinal reinforcement without lateral ties shall be placed either through the hollow stem of the auger prior to concreting or after concreting, while the concrete is still in a semifluid state.
3. For Group R-3 and U occupancies not exceeding two stories of *light-frame construction*, reinforcement is permitted to be placed after concreting, while the concrete is still in a semifluid state, and the concrete cover requirement is permitted to be reduced to 2 inches (51 mm), provided that the construction method can be demonstrated to the satisfaction of the *building official*.

#### **1810.3.9.4 Seismic reinforcement.**

Where a structure is assigned to *Seismic Design Category C*, reinforcement shall be provided in accordance with [Section 1810.3.9.4.1](#). Where a structure is assigned to *Seismic Design Category D, E or F*, reinforcement shall be provided in accordance with [Section 1810.3.9.4.2](#).

##### **Exceptions:**

1. Isolated *deep foundation* elements supporting posts of Group R-3 and U occupancies not exceeding two stories of *light-frame construction* shall be permitted to be reinforced as required by rational analysis but with not less than one No. 4 bar, without ties or spirals, where detailed so the element is not subject to lateral loads and the soil provides adequate lateral support in accordance with [Section 1810.2.1](#).
2. Isolated *deep foundation* elements supporting posts and bracing from decks and patios appurtenant to Group R-3 and U occupancies not exceeding two stories of *light-frame construction* shall be permitted to be reinforced as required by rational analysis but with not less than one No. 4 bar, without ties or spirals, where the lateral load, *E*, to the top of the element does not exceed 200 pounds (890 N) and the soil provides adequate lateral support in accordance with [Section 1810.2.1](#).
3. *Deep foundation* elements supporting the concrete foundation wall of Group R-3 and U occupancies not exceeding two stories of *light-frame construction* shall be permitted to be reinforced as required by rational analysis but with not less than two No. 4 bars, without ties or spirals, where the design cracking moment determined in accordance with [Section 1810.3.9.1](#) exceeds the required moment strength determined using the *load* combinations with overstrength factor in Section 2.3.6 or 2.4.5 of [ASCE 7](#) and the soil provides adequate lateral support in accordance with [Section 1810.2.1](#).
4. Closed ties or spirals where required by [Section 1810.3.9.4.2](#) shall be permitted to be limited to the top 3 feet (914 mm) of *deep foundation* elements 10 feet (3048 mm) or less in depth supporting Group R-3 and U occupancies of *Seismic Design Category D*, not exceeding two stories of *light-frame construction*.

##### **1810.3.9.4.1 Seismic reinforcement in Seismic Design Category C.**

For structures assigned to *Seismic Design Category C*, cast-in-place *deep foundation* elements shall be reinforced as specified in this section. Reinforcement shall be provided where required by analysis.

Not fewer than four longitudinal bars, with a minimum longitudinal reinforcement ratio of 0.0025, shall be provided throughout the minimum reinforced length of the element as defined in this section starting at the top of the element. The minimum reinforced length of the element shall be taken as the greatest of the following:

1. One-third of the element length.
2. A distance of 10 feet (3048 mm).
3. Three times the least element dimension.
4. The distance from the top of the element to the point where the design cracking moment determined in accordance with [Section 1810.3.9.1](#) exceeds the required moment strength determined using the load combinations of [ASCE 7, Section 2.3](#).

Transverse reinforcement shall consist of closed ties or spirals with a minimum  $\frac{3}{8}$  inch (9.5 mm) diameter. Spacing of transverse reinforcement shall not exceed the smaller of 6 inches (152 mm) or 8-longitudinal-bar diameters, within a distance of three times the least element dimension from the bottom of the pile cap. Spacing of transverse reinforcement shall not exceed 16 longitudinal bar diameters throughout the remainder of the reinforced length.

##### **Exceptions:**

1. The requirements of this section shall not apply to concrete cast in structural steel pipes or tubes.
2. A spiral-welded metal casing of a thickness not less than the manufacturer's standard No. 14 gage (0.068 inch) is permitted to provide concrete confinement in lieu of the closed ties or spirals. Where used as such, the metal casing shall be protected against possible deleterious action due to soil constituents, changing water levels or other factors indicated by boring records of site conditions.

##### **1810.3.9.4.2 Seismic reinforcement in Seismic Design Categories D through F.**

For structures assigned to *Seismic Design Category D, E or F*, cast-in-place *deep foundation* elements shall be reinforced

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as specified in this section. Reinforcement shall be provided where required by analysis.

Not fewer than four longitudinal bars, with a minimum longitudinal reinforcement ratio of 0.005, shall be provided throughout the minimum reinforced length of the element as defined in this section starting at the top of the element. The minimum reinforced length of the element shall be taken as the greatest of the following:

1. One-half of the element length.
2. A distance of 10 feet (3048 mm).
3. Three times the least element dimension.
4. The distance from the top of the element to the point where the design cracking moment determined in accordance with [Section 1810.3.9.1](#) exceeds the required moment strength determined using the load combinations of [ASCE 7, Section 2.3](#).

Transverse reinforcement shall consist of closed ties or spirals not smaller than No. 3 bars for elements with a least dimension up to 20 inches (508 mm), and No. 4 bars for larger elements. Throughout the remainder of the reinforced length outside the regions with transverse confinement reinforcement, as specified in [Section 1810.3.9.4.2.1](#) or [1810.3.9.4.2.2](#), the spacing of transverse reinforcement shall not exceed the least of the following:

1. 12 longitudinal bar diameters.
2. One-half the least dimension of the element.
3. 12 inches (305 mm).

**Exceptions:**

1. The requirements of this section shall not apply to concrete cast in structural steel pipes or tubes.
2. A spiral-welded metal casing of a thickness not less than manufacturer's standard No. 14 gage (0.068 inch) is permitted to provide concrete confinement in lieu of the closed ties or spirals. Where used as such, the metal casing shall be protected against possible deleterious action due to soil constituents, changing water levels or other factors indicated by boring records of site conditions.

**1810.3.9.4.2.1 Site Classes A through D.**

For *Site Class* A, B, C or D sites, transverse confinement reinforcement shall be provided in the element in accordance with Sections 18.7.5.2, 18.7.5.3 and 18.7.5.4 of [ACI 318](#) within three times the least element dimension of the bottom of the pile cap. A transverse spiral reinforcement ratio of not less than one-half of that required in Table 18.10.6.4(g) of [ACI 318](#) shall be permitted.

**1810.3.9.4.2.2 Site Classes E and F.**

For *Site Class* E or F sites, transverse confinement reinforcement shall be provided in the element in accordance with Sections 18.7.5.2, 18.7.5.3 and 18.7.5.4 of [ACI 318](#) within seven times the least element dimension of the pile cap and within seven times the least element dimension of the interfaces of strata that are hard or stiff and strata that are liquefiable or are composed of soft- to medium-stiff clay.

**1810.3.9.5 Belled drilled shafts.**

Where *drilled shafts* are belled at the bottom, the edge thickness of the bell shall be not less than that required for the edge of footings. Where the sides of the bell slope at an angle less than 60 degrees (1 rad) from the horizontal, the effects of vertical shear shall be considered.

**1810.3.9.6 Socketed drilled shafts.**

Socketed *drilled shafts* shall have a permanent pipe or tube casing that extends down to bedrock and an uncased socket drilled into the bedrock, both filled with concrete. Socketed *drilled shafts* shall have reinforcement or a structural steel core for the length as indicated by an *approved* method of analysis.

The depth of the rock socket shall be sufficient to develop the full load-bearing capacity of the element with a minimum safety factor of two, but the depth shall be not less than the outside diameter of the pipe or tube casing. The design of the rock socket is permitted to be predicated on the sum of the allowable load-bearing pressure on the bottom of the socket plus bond along the sides of the socket.

Where a structural steel core is used, the gross cross-sectional area of the core shall not exceed 25 percent of the gross area of the *drilled shaft*.

**1810.3.10 Micropiles.**

Micropiles shall be designed and detailed in accordance with [Sections 1810.3.10.1](#) through [1810.3.10.4](#).

**1810.3.10.1 Construction.**

Micropiles shall develop their load-carrying capacity by means of a bond zone in soil, bedrock or a combination of soil and bedrock. Micropiles shall be grouted and have either a steel pipe or tube or steel reinforcement at every section along the length. It shall be permitted to transition from deformed reinforcing bars to steel pipe or tube reinforcement by

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extending the bars into the pipe or tube section by not less than their development length in tension in accordance with [ACI 318](#).

#### **1810.3.10.2 Materials.**

Reinforcement shall consist of deformed reinforcing bars in accordance with [ASTM A615](#) Grade 60 or 75 or [ASTM A722](#) Grade 150.

The steel pipe or tube shall have a minimum wall thickness of  $\frac{3}{16}$  inch (4.8 mm). Splices shall comply with [Section 1810.3.6](#). The steel pipe or tube shall have a minimum yield strength of 45,000 psi (310 MPa) and a minimum elongation of 15 percent as shown by mill certifications or two coupon test samples per 40,000 pounds (18 160 kg) of pipe or tube.

#### **1810.3.10.3 Reinforcement.**

For micropiles or portions thereof grouted inside a temporary or permanent casing or inside a hole drilled into bedrock or a hole drilled with grout, the steel pipe or tube or steel reinforcement shall be designed to carry not less than 40 percent of the design compression load. Micropiles or portions thereof grouted in an open hole in soil without temporary or permanent casing and without suitable means of verifying the hole diameter during grouting shall be designed to carry the entire compression *load* in the reinforcing steel. Where a steel pipe or tube is used for reinforcement, the portion of the grout enclosed within the pipe is permitted to be included in the determination of the allowable stress in the grout.

#### **1810.3.10.4 Seismic reinforcement.**

For structures assigned to *Seismic Design Category C*, a permanent steel casing shall be provided from the top of the *micropile* down to the point of zero curvature. For structures assigned to *Seismic Design Category D, E or F*, the *micropile* shall be considered as an alternative system in accordance with [Section 112.2](#). The alternative system design, supporting documentation and test data shall be submitted to the *building official* for review and approval.

#### **1810.3.11 Pile caps.**

[Pile caps shall conform with ACI 318 and this section.](#) Pile caps shall be of reinforced concrete, and shall include all elements to which vertical *deep foundation* elements are connected, including grade beams and mats. The soil immediately below the pile cap shall not be considered as carrying any vertical load, with the exception of a *combined pile raft*. The tops of vertical *deep foundation* elements shall be embedded not less than 3 inches (76 mm) into pile caps and the caps shall extend not less than 4 inches (102 mm) beyond the edges of the elements. The tops of elements shall be cut or chipped back to sound material before capping.

##### **1810.3.11.1 Seismic Design Categories C through F.**

For structures assigned to *Seismic Design Category C, D, E or F*, concrete *deep foundation* elements shall be connected to the pile cap in accordance with [ACI 318](#).

[For](#) resistance to uplift forces, anchorage of steel pipes, tubes or H-piles to the pile cap shall be made by means other than concrete bond to the bare steel section. Concrete-filled steel pipes or tubes shall have reinforcement of not less than 0.01 times the cross-sectional area of the concrete fill developed into the cap and extending into the fill a length equal to two times the required cap embedment, but not less than the development length in tension of the reinforcement.

##### **1810.3.11.2 Seismic Design Categories D through F.**

For structures assigned to *Seismic Design Category D, E or F*, *deep foundation* element resistance to uplift forces or rotational restraint shall be provided by anchorage into the pile cap, designed considering the combined effect of axial forces due to uplift and bending moments due to fixity to the pile cap. Anchorage shall develop not less than 25 percent of the strength of the element in tension. Anchorage into the pile cap shall comply with the following:

1. In the case of uplift, the anchorage shall be capable of developing the least of the following:

- 1.1. The nominal tensile strength of the longitudinal reinforcement in a concrete element.
- 1.2. The nominal tensile strength of a steel element.
- 1.3. The frictional force developed between the element and the soil multiplied by 1.3.

**Exception:** The anchorage is permitted to be designed to resist the axial tension force resulting from the seismic *load effects* including overstrength factor in accordance with Section 2.3.6 or 2.4.5 of [ASCE 7](#).

2. In the case of rotational restraint, the anchorage shall be designed to resist the axial and shear forces, and moments resulting from the seismic *load effects* including overstrength factor in accordance with Section 2.3.6 or 2.4.5 of [ASCE 7](#) or the anchorage shall be capable of developing the full axial, bending and shear nominal strength of the element.
3. [The connection between the pile cap and the steel H-piles or unfilled steel pipe piles in structures assigned to Seismic Design Category D, E or F shall be designed for a tensile force of not less than 10 percent of the pile compression capacity.](#)

#### **Exceptions:**

1. [Connection tensile capacity need not exceed the strength required to resist seismic load effects including](#)

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overstrength of ASCE 7 Section 12.4.3 or 12.14.3.2.

2. Connections need not be provided where the foundation or supported structure does not rely on the tensile capacity of the piles for stability under the design seismic force.

Where the vertical lateral-force-resisting elements are columns, the pile cap flexural strengths shall exceed the column flexural strength. The connection between batter piles and pile caps shall be designed to resist the nominal strength of the pile acting as a short column. Batter piles and their connection shall be designed to resist forces and moments that result from the application of seismic *load effects* including overstrength factor in accordance with Section 2.3.6 or 2.4.5 of ASCE 7.

#### **1810.3.12 Grade beams.**

Grade beams shall comply with the provisions of ACI 318.

**Exception:** Grade beams designed to resist the seismic load effects including overstrength factor in accordance with Section 2.3.6 or 2.4.5 of ASCE 7.

#### **1810.3.13 Seismic ties.**

Seismic ties shall comply with the provisions of ACI 318.

**Exception:** In Group R-3 and U occupancies of *light-frame construction*, *deep foundation* elements supporting foundation walls, isolated interior posts detailed so the element is not subject to lateral loads or exterior decks and patios are not subject to interconnection where the soils are of adequate stiffness, subject to the approval of the *building official*.

#### **1810.4 Installation.**

Deep foundations shall be installed in accordance with Section 1810.4. Where a single *deep foundation* element comprises two or more sections of different materials or different types spliced together, each section shall satisfy the applicable conditions of installation.

##### **1810.4.1 Structural integrity.**

*Deep foundation* elements shall be installed in such a manner and sequence as to prevent distortion or damage that would adversely affect the structural integrity of adjacent structures or of foundation elements being installed or already in place and as to avoid compacting the surrounding soil to the extent that other foundation elements cannot be installed properly.

##### **1810.4.1.1 Compressive strength of precast concrete piles.**

A precast concrete pile shall not be driven before the concrete has attained a compressive strength of not less than 75 percent of the specified compressive strength ( $f_c$ ), but not less than the strength sufficient to withstand handling and driving forces.

##### **1810.4.1.2 Shafts in unstable soils.**

Where cast-in-place *deep foundation* elements are formed through unstable soils **the open hole shall be stabilized by a casing, slurry, or other approved method** prior to placing the concrete. Where the casing is withdrawn during concreting, the level of concrete shall be maintained above the bottom of the casing at a sufficient height to offset any hydrostatic or lateral soil pressure. Driven casings shall be mandrel driven their full length in contact with the surrounding soil.

##### **1810.4.1.3 Driving near uncased concrete.**

Deep foundation elements shall not be driven within six element diameters center to center in granular soils or within one-half the element length in cohesive soils of an uncased element filled with concrete less than 48 hours old unless *approved* by the *building official*. If **driving near uncased concrete elements causes** the concrete surface in any completed element **to rise or drop significantly or bleed additional water**, the **completed** element shall be replaced.

##### **1810.4.1.4 Driving near cased concrete.**

*Deep foundation* elements shall not be driven within four and one-half average diameters of a cased element filled with concrete less than 24 hours old unless *approved* by the *building official*. Concrete shall not be placed in casings within heave range of driving.

##### **1810.4.1.5 Defective timber piles.**

Any substantial sudden change in rate of penetration of a timber pile shall be investigated for possible damage. If the sudden change in rate of penetration cannot be correlated to soil strata, the pile shall be removed for inspection or rejected.

#### **1810.4.2 Identification.**

*Deep foundation* materials shall be identified for conformity to the specified grade with this identity maintained continuously from the point of manufacture to the point of installation or shall be tested by an *approved agency* to determine conformity to the specified grade. The *approved agency* shall furnish an affidavit of compliance to the *building*

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official.

#### **1810.4.3 Location plan.**

A plan showing the location and designation of *deep foundation* elements by an identification system shall be filed with the *building official* prior to installation of such elements. Detailed records for elements shall bear an identification corresponding to that shown on the plan.

#### **1810.4.4 Preexcavation.**

The use of jetting, augering or other methods of preexcavation shall be subject to the approval of the *building official*. Where permitted, preexcavation shall be carried out in the same manner as used for *deep foundation* elements subject to load tests and in such a manner that will not impair the carrying capacity of the elements already in place or damage adjacent structures. Element tips shall be advanced below the preexcavated depth until the required resistance or penetration is obtained.

#### **1810.4.5 Vibratory driving.**

Vibratory drivers shall only be used to install *deep foundation* elements where the element load capacity is verified by load tests in accordance with [Section 1810.3.3.1.2](#). The installation of production elements shall be controlled according to power consumption, rate of penetration or other *approved* means that ensure element capacities equal or exceed those of the test elements.

##### **Exceptions:**

1. The pile installation is completed by driving with an impact hammer in accordance with [Section 1810.3.3.1.1](#).
2. The pile is to be used only for lateral resistance.

#### **1810.4.6 Heaved elements.**

*Deep foundation* elements that have heaved during the driving of adjacent elements shall be redriven as necessary to develop the required capacity and penetration, or the capacity of the element shall be verified by load tests in accordance with [Section 1810.3.3.1.2](#).

#### **1810.4.7 Enlarged base cast-in-place elements.**

Enlarged bases for cast-in-place *deep foundation* elements formed by compacting concrete or by driving a precast base shall be formed in or driven into granular soils. Such elements shall be constructed in the same manner as successful prototype test elements driven for the project. Shafts extending through peat or other organic soil shall be encased in a permanent steel casing. Where a cased shaft is used, the shaft shall be adequately reinforced to resist column action or the *annular space* around the shaft shall be filled sufficiently to reestablish lateral support by the soil. Where heave occurs, the element shall be replaced unless it is demonstrated that the element is undamaged and capable of carrying twice its design *load*.

#### **1810.4.8 Hollow-stem augered, cast-in-place elements.**

Where concrete or grout is placed by pumping through a hollow-stem auger, the auger shall be permitted to rotate in a clockwise direction during withdrawal. As the auger is withdrawn at a steady rate or in increments not to exceed 1 foot (305 mm), concreting or grouting pumping pressures shall be measured and maintained high enough at all times to offset hydrostatic and lateral earth pressures. Concrete or grout volumes shall be measured to ensure that the volume of concrete or grout placed in each element is equal to or greater than the theoretical volume of the hole created by the auger. Where the installation process of any element is interrupted or a loss of concreting or grouting pressure occurs, the element shall be redrilled to 5 feet (1524 mm) below the elevation of the tip of the auger when the installation was interrupted or concrete or grout pressure was lost and reformed. Augered cast-in-place elements shall not be installed within six diameters center to center of an element filled with concrete or grout less than 12 hours old, unless *approved* by the *building official*. If the concrete or grout level in any completed element drops due to installation of an adjacent element, the element shall be replaced.

#### **1810.4.9 Socketed drilled shafts.**

The rock socket and pipe or tube casing of socketed *drilled shafts* shall be thoroughly cleaned of foreign materials before filling with concrete. Steel cores shall be bedded in cement grout at the base of the rock socket.

#### **1810.4.10 Micropiles.**

*Micropile deep foundation* elements shall be permitted to be formed in holes advanced by rotary or percussive drilling methods, with or without casing. The elements shall be grouted with a fluid cement grout. The grout shall be pumped through a tremie pipe extending to the bottom of the element until grout of suitable quality returns at the top of the element. The following requirements apply to specific installation methods:

1. For micropiles grouted inside a temporary casing, the reinforcing bars shall be inserted prior to withdrawal of the casing. The casing shall be withdrawn in a controlled manner with the grout level maintained at the top of the element to ensure that the grout completely fills the drill hole. During withdrawal of the casing, the grout level inside the casing shall be monitored to verify that the flow of grout inside the casing is not obstructed.

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2. For a *micropile* or portion thereof grouted in an open drill hole in soil without temporary casing, the minimum design diameter of the drill hole shall be verified by a suitable device during grouting.
3. For micropiles designed for end bearing, a suitable means shall be employed to verify that the bearing surface is properly cleaned prior to grouting.
4. Subsequent micropiles shall not be drilled near elements that have been grouted until the grout has had sufficient time to harden.
5. Micropiles shall be grouted as soon as possible after drilling is completed.
6. For micropiles designed with a full-length casing, the casing shall be pulled back to the top of the bond zone and reinserted or some other suitable means employed to ensure grout coverage outside the casing.

#### **1810.4.11 Helical piles.**

*Helical piles* shall be installed to specified embedment depth and torsional resistance criteria as determined by a *registered design professional*. The torque applied during installation shall not exceed the *manufacturer's rated* maximum installation torque *resistance* of the *helical pile*.

#### **1810.4.12 Special inspection.**

*Special inspections* in accordance with [Sections 1705.7](#) and [1705.8](#) shall be provided for driven and cast-in-place deep foundation elements, respectively. *Special inspections* in accordance with [Section 1705.9](#) shall be provided for *helical piles*.