Composite document highlighting proposed code changes submitted to the International Code Council (ICC) and approved by the Structural Code Committee at the ICC Code Development Hearings, February, 2008

Prepared by Philip Brazil, P.E., S.E., Chapter 18 Ad Hoc Committee, March 25, 2008

The code change proposals included in this document, and the colors used to highlight their proposed changes, are as follows:

1. S47-07/08-AM, proposed changes illustrated in blue.
2. S60-07/08-AM, proposed changes illustrated in green.
3. S61-07/08-AM, proposed changes illustrated in red.
4. S122-07/08-AM, proposed changes illustrated in red.
5. S123-07/08-AS, proposed changes illustrated in green.
6. S145-07/08-AS, proposed changes illustrated in violet.
7. S146-07/08-AM, proposed changes illustrated in purple.
8. S147-07/08-AM, proposed changes illustrated in red.
9. S149-07/08-AM, proposed changes illustrated in violet.
10. S150-07/08-AM, proposed changes illustrated in blue.
11. S151-07/08-AS, proposed changes illustrated in violet.
12. S152-07/08-AM, proposed changes illustrated in blue.
13. S153-07/08-AS, proposed changes illustrated in purple.
14. S154-07/08-AS, proposed changes illustrated in green.
15. S155-07/08-AS, proposed changes illustrated in red.
16. S156-07/08-AM, proposed changes illustrated in blue.
17. S157-07/08-AS, proposed changes illustrated in green.
18. S158-07/08-AM, proposed changes illustrated in blue.
19. S159-07/08-AS, proposed changes illustrated in red.
20. S160-07/08-AM, proposed changes illustrated in red.
21. S161-07/08-AS, proposed changes illustrated in purple.
22. S162-07/08-AM, proposed changes illustrated in green.
23. S163-07/08-AS, proposed changes illustrated in green.
24. S164-07/08-AS, proposed changes illustrated in purple.
25. S165-07/08-AS, proposed changes illustrated in green.
26. S166-07/08-AS, proposed changes illustrated in purple.
27. S167-07/08-AS, proposed changes illustrated in green.
28. S168-07/08-AS, proposed changes illustrated in purple.
29. S169-07/08-AS, proposed changes illustrated in violet.
30. S170-07/08-AS, proposed changes illustrated in green.
31. S172-07/08-AM, correlative changes for compatibility with ACI 318-08 illustrated in green.

"AS" means approval as submitted. "AM" means approval as modified (by the Committee).

The proponent for the proposals above is Edwin T. Huston, Smith & Huston, Inc., representing National council of Structural Engineering Associations, except for the following proposals:

1. S61-07/08-AM: William Sherman, CH2M Hill, representing himself
2. S152-07/08-AM: Philip Brazil, PE, SE, Reid Middleton, Inc., representing himself
3. S154-07/08-AS: David P. Tyree, PE, CBO and Dennis Pitts, American Forest & Paper Association
4. S155-07/08-AS: Philip Brazil, PE, SE, Reid Middleton, Inc., representing himself
5. S156-07/08-AM: William Sherman, CH2M Hill, representing himself
6. S157-07/08-AS: William Sherman, CH2M Hill, representing himself
7. S159-07/08-AS: Rebecca C. Quinn, RC Quinn Consulting, Inc., representing US Department of Homeland Security, Federal Emergency Management Agency
8. S172-07/08-AM: Joseph J. Messersmith, Jr PE, Portland Cement Association; Daniel Falconer, PE, American Concrete Institute

The code changes in this document should be considered as tentative, pending publication of the ICC "Report of Public Hearings," tentatively scheduled by the ICC for April 3, 2008.

The underlying text in which the proposed changes are highlighted is from the 2006 International Building Code (IBC) as modified by code changes approved during the 2006/2007 code development cycle of the ICC. Refer to the "2007 Supplement to the International Building Code" for further information. These approved changes are incorporated into this

document as current text. The code sections with changes that were approved during the 2006/2007 code development cycle are identified by "[Suppl]" in their titles. The additional text is highlighted in yellow for reference. The deleted text is not shown.

Included in this document is the text from Chapter 18 in its entirety plus code sections from other chapters of the IBC where the code change proposals listed above contain them. Note that current Section 1801.2.1 follows proposed Section 1808.3.

The code change proposals are presented in four parts:

1. Part 1 contains proposed revisions to code sections preceding Chapter 18.
2. Part 2 contains proposed revisions to code sections in Chapter 18.
3. Part 3 contains proposed revisions to code sections following Chapter 18.
4. Part 4 contains code sections from Chapter 18 that are proposed for deletion without substitution.

In the development of the code change proposals, it was necessary to show text as lined out or underlined where changes were not proposed. Part 5 contains excerpts from three such code sections where this was necessary and is intended for reference only.

1. Revise code sections preceding Chapter 18 as follows:

106.1 [Suppl] General. Submittal documents consisting of construction documents, statement of special inspections, geotechnical report and other data shall be submitted in one or more sets with each application for a permit. The construction documents shall be prepared by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed. Where special conditions exist, the building official is authorized to require additional construction documents to be prepared by a registered design professional.

Exception: The building official is authorized to waive the submission of construction documents and other data not required to be prepared by a registered design professional if it is found that the nature of the work applied for is such that review of construction documents is not necessary to obtain compliance with this code.

1603.1 General. Construction documents shall show the size, section and relative locations of structural members with floor levels, column centers and offsets dimensioned. The design loads and other information pertinent to the structural design required by Sections 1603.1.1 through ~~1603.1.8~~ 1603.1.9 shall be indicated on the construction documents.

Exception: Construction documents for buildings constructed in accordance with the conventional light-frame construction provisions of Section 2308 shall indicate the following structural design information:

1. Floor and roof live loads.
2. Ground snow load, P_g.
3. Basic wind speed (3-second gust), miles per hour (mph) (km/hr) and wind exposure.
4. Seismic design category and site class.
5. Flood design data, if located in flood hazard areas established in Section 1612.3.
6. Design load-bearing values of soils.

1603.1.6 Geotechnical information. The design load-bearing values of soils shall be shown on the construction documents.

(renumber subsequent sections)

1605.1 General. Buildings and other structures and portions thereof shall be designed to resist:

1. The load combinations specified in Sections 1605.2, 1605.3.1 or 1605.3.2,
2. The load combinations specified in Chapters 18 through 23, and
3. The load combinations with overstrength factor specified in Section 12.4.3.2 of ASCE 7 where required by Section 12.2.5.2, 12.3.3.3 or 12.10.2.1 of ASCE 7. With the simplified procedure of ASCE 7 Section 12.14, the load combinations with overstrength factor of Section 12.14.3.2 of ASCE 7 shall be used.

~~With the simplified procedure of ASCE 7 Section 12.14, the overstrength factor load combinations of Section 12.14.3.2 of ASCE 7 shall be used.~~ Applicable loads shall be considered, including both earthquake and wind, in accordance with the specified load combinations. Each load combination shall also be investigated with one or more of the variable loads set to zero.

Where the load combinations with overstrength factor in Section 12.4.3.2 of ASCE 7 apply, they shall be used as follows ~~in lieu of the following~~:

1. The ~~load~~ Basic Combinations for Strength Design with Overstrength Factor in lieu of Equations 16-5 and 16-7 in Section 1605.2.1.
2. The ~~load~~ Basic Combinations for Allowable Stress Design with Overstrength Factor in lieu of Equations 16-12, 16-13 and 16-15 in Section 1605.3.1.
3. The ~~load~~ Basic Combinations for Allowable Stress Design with Overstrength Factor in lieu of Equations 16-20 and 16-21 in Section 1605.3.2.

1605.1.1 Stability. Regardless of which load combinations are used to design for strength, where overall structure stability (such as stability against overturning, sliding, or buoyancy) is being verified, use of the load combinations specified in Section 1605.2 or 1605.3 shall be permitted. Where the load combinations specified in Section 1605.2 are used, strength reduction factors applicable to soil resistance shall be provided by a registered design professional. The stability of retaining walls shall be verified in accordance with Section 1807.2.3.

SECTION 1610
SOIL LATERAL LOAD

1610.1 General. ~~Basement,~~ Foundation walls and retaining walls shall be designed to resist lateral soil loads. Soil loads specified in Table 1610.1 shall be used as the minimum design lateral soil loads unless ~~specified~~ determined otherwise ~~in~~ by a ~~soil~~ geotechnical investigation ~~report approved by the building official~~ in accordance with Section 1803. ~~Basement~~ Foundation walls and other walls in which horizontal movement is restricted at the top shall be designed for at-rest pressure. Retaining walls free to move and rotate at the top ~~are~~ shall be permitted to be designed for active pressure. Design lateral pressure from surcharge loads shall be added to the lateral earth pressure load. Design lateral pressure shall be increased if soils ~~with expansion potential are present at the site~~ at the site are expansive. Foundation walls shall be designed to support the weight of the full hydrostatic pressure of undrained backfill unless a drainage system is installed in accordance with Sections 1805.4.2 and 1805.4.3.

Exception: ~~Basement~~ Foundation walls extending not more than 8 feet (2438 mm) below grade and ~~supporting~~ laterally supported at the top by flexible ~~floor systems~~ diaphragms shall be permitted to be designed for active pressure.

TABLE 1610.1
~~SOIL~~ LATERAL SOIL LOAD

DESCRIPTION OF BACKFILL MATERIAL [c]	UNIFIED SOIL CLASSIFICATION	DESIGN LATERAL SOIL LOAD [a] (pounds per square foot per foot of depth)	
		Active pressure	At-rest pressure
Well-graded, clean gravels; gravel-sand mixes	GW	30	60
Poorly graded clean gravels; gravel-sand mixes	GP	30	60
Silty gravels, poorly graded gravel-sand mixes	GM	40	60
Clayey gravels, poorly graded gravel-and-clay mixes	GC	45	60
Well-graded, clean sands; gravelly sand mixes	SW	30	60
Poorly graded clean sands; sand-gravel mixes	SP	30	60
Silty sands, poorly graded sand-silt mixes	SM	45	60
Sand-silt clay mix with plastic fines	SM-SC	45	100
Clayey sands, poorly graded sand-clay mixes	SC	60	100
Inorganic silts and clayey silts	ML	45	100
Mixture of inorganic silt and clay	ML-CL	60	100
Inorganic clays of low to medium plasticity	CL	60	100
Organic silts and silt clays, low plasticity	OL	Note b	Note b
Inorganic clayey silts, elastic silts	MH	Note b	Note b
Inorganic clays of high plasticity	CH	Note b	Note b
Organic clays and silty clays	OH	Note b	Note b

For SI: 1 pound per square foot per foot of depth = 0.157 kPa/m, 1 foot = 304.8 mm.

a. Design lateral soil loads are given for moist conditions for the specified soils at their optimum densities. Actual field conditions shall govern. Submerged or saturated soil pressures shall include the weight of the buoyant soil plus the hydrostatic loads.
b. Unsuitable as backfill material.
c. The definition and classification of soil materials shall be in accordance with ASTM D 2487.

1704.7 [Suppl] Soils. Special inspections for existing site soil conditions, fill placement and load-bearing requirements shall be as required by this section and Table 1704.7. The approved ~~soils~~ geotechnical report~~, required by Section 1802.2,~~ and the documents prepared by the registered design professional shall be used to determine compliance. During fill placement, the special inspector shall determine that proper materials and procedures are used in accordance with the provisions of the approved ~~soils~~ geotechnical report~~, as specified in Section 1803.5~~.

Exception: ~~Special inspection is not required during placement of controlled fill having a total depth of 12 inches (305 mm) or less~~ Where Section 1803 does not require reporting of materials and procedures for fill placement, the special inspector shall verify that the in-place dry density of the compacted fill is not less than 90 percent of the maximum dry density at optimum moisture content determined in accordance with ASTM D 1557.

TABLE 1704.7
REQUIRED VERIFICATION AND INSPECTION OF SOILS

VERIFICATION AND INSPECTION TASK	CONTINUOUS DURING TASK LISTED	PERIODICALLY DURING TASK LISTED
1. Verify materials below ~~footings~~ shallow foundations are adequate to achieve the design bearing capacity.	—	X
2. Verify excavations are extended to proper depth and have reached proper material.	—	X
3. Perform classification and testing of ~~controlled~~ compacted fill materials.	—	X
4. Verify use of proper materials, densities and lift thicknesses during placement and compaction of ~~controlled~~ compacted fill.	X	—
5. Prior to placement of ~~controlled~~ compacted fill, observe subgrade and verify that site has been prepared properly.	—	X

1704.8 [Suppl] ~~Pile~~ Driven deep foundations. Special inspections shall be performed during installation and testing of ~~pile~~ driven deep foundation~~s~~ elements as required by Table 1704.8. The approved ~~soils~~ geotechnical report~~, required by Section 1802.2,~~ and the documents prepared by the registered design professional shall be used to determine compliance.

TABLE 1704.8
REQUIRED VERIFICATION AND INSPECTION OF ~~PILE~~ DRIVEN DEEP FOUNDATION~~S~~ ELEMENTS

VERIFICATION AND INSPECTION TASK	CONTINUOUS DURING TASK LISTED	PERIODICALLY DURING TASK LISTED
1. Verify ~~pile~~ element materials, sizes and lengths comply with the requirements.	X	—
2. Determine capacities of test ~~piles~~ elements and conduct additional load tests, as required.	X	—
3. Observe driving operations and maintain complete and accurate records for each ~~pile~~ element.	X	—
4. Verify placement locations and plumbness, confirm type and size of hammer, record number of blows per foot of penetration, determine required penetrations to achieve design capacity, record tip and butt elevations and document any ~~pile~~ damage to foundation elements.	X	—
5. For steel ~~piles~~ elements, perform additional inspections in accordance with Section 1704.3.	—	—
6. For concrete ~~piles~~ elements and concrete-filled ~~piles~~ elements, perform additional inspections in accordance with Section 1704.4.	—	—
7. For specialty ~~piles~~ elements, perform additional inspections as determined by the registered design professional in responsible charge.	—	—
~~8. For augered uncased piles and caisson piles, perform inspections in accordance with Section 1704.9.~~	—	—

1704.9 [Suppl] ~~Pier~~ Cast-in-place deep foundations. Special inspections shall be performed during installation and testing of ~~pier~~ cast-in-place deep foundation~~s~~ elements as required by Table 1704.9. The approved ~~soils~~ geotechnical report~~, required by Section 1802.2,~~ and the documents prepared by the registered design professional shall be used to determine compliance.

TABLE 1704.9
REQUIRED VERIFICATION AND INSPECTION OF ~~PIER~~ CAST-IN-PLACE DEEP FOUNDATION~~S~~ ELEMENTS

VERIFICATION AND INSPECTION TASK	CONTINUOUS DURING TASK LISTED	PERIODICALLY DURING TASK LISTED
1. Observe drilling operations and maintain complete and accurate records for each ~~pier~~ element.	X	—
2. Verify placement locations and plumbness, confirm ~~pier~~ element diameters, bell diameters (if applicable), lengths, embedment into bedrock (if applicable) and adequate end bearing strata capacity. Record concrete or grout volumes.	X	—
3. For concrete ~~piers~~ elements, perform additional inspections in accordance with Section 1704.4.	—	—
~~4. For masonry piers, perform additional inspections in accordance with Section 1704.5.~~	—	—

1704.10 Vertical masonry foundation elements. Special inspection shall be performed in accordance with Section 1704.5 for vertical masonry foundation elements.

(renumber subsequent sections)

~~**1707.5 Pier foundations.** Special inspection is required for pier foundations for buildings assigned to Seismic Design Category C, D, E or F in accordance with Section 1613. Periodic special inspection is required during placement of reinforcement and continuous special inspection is required during placement of the concrete.~~

(renumber subsequent sections)

2. Revise Chapter 18 as follows:

SECTION 1801
GENERAL

1801.1 Scope. The provisions of this chapter shall apply to building and foundation systems in those areas not subject to scour or water pressure by wind and wave action. Buildings and foundations subject to such scour or water pressure loads shall be designed in accordance with Chapter 16.

1801.2 Design basis. Allowable bearing pressures, allowable stresses and design formulas provided in this chapter shall be used with the allowable stress design load combinations specified in Section 1605.3. The quality and design of materials used structurally in excavations~~, footings~~ and foundations shall ~~conform to~~ comply with the requirements specified in Chapters 16, 19, 21, 22 and 23 of this code. Excavations and fills shall also comply with Chapter 33.

SECTION ~~1808~~ 1802
~~PIER AND PILE~~ DEFINITIONS

~~**1808.1**~~ **1802.1 Definitions.** The following words and terms shall, for the purposes of this ~~section~~ chapter, have the meanings shown herein.

DEEP FOUNDATION. A deep foundation is a foundation element that does not satisfy the definition of a shallow foundation.

DRILLED SHAFT. A drilled shaft is a cast-in-place deep foundation element constructed by drilling a hole (with or without permanent casing) into soil or rock and filling it with fluid concrete.

Socketed drilled shaft A socketed drilled shaft is a drilled shaft with a permanent pipe or tube casing that extends down to bedrock and an uncased socket drilled into the bedrock.

MICROPILES. ~~Micropiles are 12 inch (305 mm) diameter or less,~~ A micropile is a bored, grouted-in-place ~~piles incorporating steel pipe (casing) and/or steel reinforcement~~ deep foundation element that develops its load-carrying capacity by means of a bond zone in soil, bedrock, or a combination of soil and bedrock.

SHALLOW FOUNDATION. A shallow foundation is an individual or strip footing, a mat foundation, a slab on grade foundation, or a similar foundation element.

~~**FLEXURAL LENGTH.** Flexural length is the length of the pile from the first point of zero lateral deflection to the underside of the pile cap or grade beam.~~

~~**PIER FOUNDATIONS.** Pier foundations consist of isolated masonry or cast-in-place concrete structural elements extending into firm materials. Piers are relatively short in comparison to their width, with lengths less than or equal to 12 times the least horizontal dimension of the pier. Piers derive their load-carrying capacity through skin friction, through end bearing, or a combination of both.~~

~~**Belled piers.** Belled piers are cast-in-place concrete piers constructed with a base that is larger than the diameter of the remainder of the pier. The belled base is designed to increase the load-bearing area of the pier in end bearing.~~

~~**PILE FOUNDATIONS.** Pile foundations consist of concrete, wood or steel structural elements either driven into the ground or cast in place. Piles are relatively slender in comparison to their length, with lengths exceeding 12 times the least horizontal dimension. Piles derive their load-carrying capacity through skin friction, through end bearing, or a combination of both.~~

~~**Augered uncased piles.** Augered uncased piles are constructed by depositing concrete into an uncased augered hole, either during or after the withdrawal of the auger.~~

~~**Caisson piles.** Caisson piles are cast-in-place concrete piles extending into bedrock. The upper portion of a caisson pile consists of a cased pile that extends to the bedrock. The lower portion of the caisson pile consists of an uncased socket drilled into the bedrock.~~

~~**Concrete-filled steel pipe and tube piles.** Concrete-filled steel pipe and tube piles are constructed by driving a steel pipe or tube section into the soil and filling the pipe or tube section with concrete. The steel pipe or tube section is left in place during and after the deposition of the concrete.~~

~~**Driven uncased piles.** Driven uncased piles are constructed by driving a steel shell into the soil to shore an unexcavated hole that is later filled with concrete. The steel casing is lifted out of the hole during the deposition of the concrete.~~

~~**Enlarged base piles.** Enlarged base piles are cast-in-place concrete piles constructed with a base that is larger than the diameter of the remainder of the pile. The enlarged base is designed to increase the load-bearing area of the pile in end bearing.~~

~~**Steel-cased piles.** Steel-cased piles are constructed by driving a steel shell into the soil to shore an unexcavated hole. The steel casing is left permanently in place and filled with concrete.~~

~~**Timber piles.** Timber piles are round, tapered timbers with small (tip) end embedded into the soil.~~

SECTION ~~1802~~ 1803
~~FOUNDATION AND SOILS~~ GEOTECHNICAL INVESTIGATIONS

~~**1802.1**~~ **1803.1 General.** ~~Foundation and soils~~ Geotechnical investigations shall be conducted in ~~conformance~~ accordance with ~~Sections 1802.2 through 1802.6~~ Section 1803.2 and reported in accordance with Section 1803.6. Where required by the building official ~~the classification and investigation of the soil~~ or where geotechnical investigations involve in-situ testing, laboratory testing, or engineering calculations, such investigations shall be ~~made~~ conducted by a registered design professional.

~~**1802.2**~~ **1803.2 ~~Where~~ Investigations required**. ~~The owner or applicant shall submit a foundation and soils investigation to the building official where required in~~ Geotechnical investigations shall be conducted in accordance with Sections ~~1802.2.1~~ 1803.3 through ~~1802.2.7~~ 1803.5.

Exception: The building official ~~need not require~~ shall be permitted to waive the requirement for a ~~foundation or soils~~ geotechnical investigation where satisfactory data from adjacent areas is available that demonstrates an investigation is not necessary for any of the conditions in Sections ~~1802.2.1~~ 1803.5.1 through ~~1802.2.6~~ 1803.5.6 and Sections 1803.5.10 and 1803.5.11.

~~1802.4~~ **1803.3 Basis of investigation.** Soil classification shall be based on observation and any necessary tests of the materials disclosed by borings, test pits or other subsurface exploration made in appropriate locations. Additional studies shall be made as necessary to evaluate slope stability, soil strength, position and adequacy of load-bearing soils, the effect of moisture variation on soil-bearing capacity, compressibility, liquefaction and expansiveness.

~~1802.4.1~~ **1803.3.1 ~~Exploratory boring~~ Scope of investigation.** The scope of the ~~soil~~ geotechnical investigation including the number and types of borings or soundings, the equipment used to drill ~~and~~ or sample, the in-situ testing equipment and the laboratory testing program shall be determined by a registered design professional.

~~1802.5~~ **1803.4 ~~Soil boring and sampling~~ Qualified representative.** The ~~soil boring and sampling~~ investigation procedure and apparatus shall be in accordance with generally accepted engineering practice. The registered design professional shall have a fully qualified representative on the site during all boring ~~and~~ or sampling operations.

1803.5 Investigated conditions. Geotechnical investigations shall be conducted as indicated in Sections 1803.5.1 through 1803.5.12.

~~1802.3.1~~ **1803.5.1 ~~General~~ Classification.** ~~For the purposes of this chapter, the definition and classification of~~ Soil materials ~~for use in Table 1804.2~~ shall be classified in accordance with ASTM D 2487.

~~1802.2.1~~ **1803.5.2 Questionable soil.** Where the classification, strength or compressibility of the soil is in doubt or where a load-bearing value superior to that specified in this code is claimed, the building official shall be permitted to require that ~~the necessary~~ a geotechnical investigation be ~~made~~ conducted. ~~Such investigation shall comply with the provisions of Sections 1802.4 through 1802.6~~.

~~1802.2.2~~ **1803.5.3 Expansive ~~soils~~ soil.** In areas likely to have expansive soil, the building official shall require soil tests to determine where such soils do exist.

~~1802.3.2 Expansive soils.~~ Soils meeting all four of the following provisions shall be considered expansive, except that tests to show compliance with Items 1, 2 and 3 shall not be required if the test prescribed in Item 4 is conducted:

1. Plasticity index (PI) of 15 or greater, determined in accordance with ASTM D 4318.
2. More than 10 percent of the soil particles pass a No. 200 sieve (75 µm), determined in accordance with ASTM D 422.
3. More than 10 percent of the soil particles are less than 5 micrometers in size, determined in accordance with ASTM D 422.
4. Expansion index greater than 20, determined in accordance with ASTM D 4829.

~~1802.2.3~~ **1803.5.4 Ground-water table.** A subsurface soil investigation shall be performed to determine whether the existing ground-water table is above or within 5 feet (1524 mm) below the elevation of the lowest floor level where such floor is located below the finished ground level adjacent to the foundation.

Exception: A subsurface soil investigation to determine the location of the ground-water table shall not be required where waterproofing is provided in accordance with Section ~~1807~~ 1805.

~~1802.2.4~~ **1803.5.5 ~~Pile and pier~~ Deep foundations.** ~~Pile and pier foundations shall be designed and installed on the basis of a foundation investigation and report as specified in Sections 1802.4 through 1802.6 and Section 1808.2.1.~~ Where deep foundations will be used, a geotechnical investigation shall be conducted and shall include all of the following, unless sufficient data upon which to base the design and installation is otherwise available:

1. Recommended deep foundation types and installed capacities.
2. Recommended center-to-center spacing of deep foundation elements.
3. Driving criteria.

4. Installation procedures.
5. Field inspection and reporting procedures (to include procedures for verification of the installed bearing capacity where required).
6. Load test requirements.
7. Suitability of deep foundation materials for the intended environment.
8. Designation of bearing stratum or strata.
9. Reductions for group action, where necessary.

~~1802.2.5~~ **1803.5.6 Rock strata.** Where subsurface explorations at the project site indicate variations or doubtful characteristics in the structure of the rock upon which foundations are to be constructed, a sufficient number of borings shall be made to a depth of not less than 10 feet (3048 mm) below the level of the foundations to provide assurance of the soundness of the foundation bed and its load-bearing capacity.

1803.5.7 Excavation near foundations. Where excavation will remove lateral support from any foundation, an investigation shall be conducted to assess the potential consequences and address mitigation measures.

1803.5.8 Compacted fill material. Where shallow foundations will bear on compacted fill material more than 12 inches (305 mm) in depth, a geotechnical investigation shall be conducted and shall include all of the following:

1. Specifications for the preparation of the site prior to placement of compacted fill material.
2. Specifications for material to be used as compacted fill.
3. Test methods to be used to determine the maximum dry density and optimum moisture content of the material to be used as compacted fill.
4. Maximum allowable thickness of each lift of compacted fill material.
5. Field test method for determining the in-place dry density of the compacted fill.
6. Minimum acceptable in-place dry density expressed as a percentage of the maximum dry density determined in accordance with Item 3.
7. Number and frequency of field tests required to determine compliance with Item 6.

1803.5.9 Controlled low-strength material (CLSM). Where shallow foundations will bear on controlled low-strength material (CLSM), a geotechnical investigation shall be conducted and shall include all of the following:

1. Specifications for the preparation of the site prior to placement of the CLSM.
2. Specifications for the CLSM.
3. Laboratory or field test method(s) to be used to determine the compressive strength or bearing capacity of the CLSM.
4. Test methods for determining the acceptance of the CLSM in the field.
5. Number and frequency of field tests required to determine compliance with Item 4.

1803.5.10 Alternate setback and clearance. Where setbacks or clearances other than those required in Section 1808.7 are desired, the building official shall be permitted to require a geotechnical investigation by a registered design professional to demonstrate that the intent of Section 1808.7 would be satisfied. Such an investigation shall include consideration of material, height of slope, slope gradient, load intensity and erosion characteristics of slope material.

~~1802.2.6~~ **1803.5.11 Seismic Design ~~Category~~ Categories C through F.** ~~Where a~~ For structures ~~is determined~~ assigned to ~~be in~~ Seismic Design Category C, D, E, or F in accordance with Section 1613, ~~an~~ a geotechnical investigation shall be conducted, and shall include an evaluation of all the following potential geologic and seismic hazards ~~resulting from earthquake motions~~:

1. Slope instability.
2. Liquefaction.
3. Differential settlement. ~~and~~
4. Surface ~~rupture~~ displacement due to faulting or lateral spreading.

~~1802.2.7~~ **1803.5.12 Seismic Design ~~Category~~ Categories D~~, E or~~ through F.** ~~Where the~~ For structures ~~is determined~~ assigned to ~~be in~~ Seismic Design Category D, E or F~~,~~ in accordance with Section 1613, the ~~soils~~ geotechnical investigation ~~requirements for Seismic Design Category C, given in~~ required by Section ~~1802.2.6~~ 1803.5.11~~, shall be met, in addition to the following. The investigation~~ shall also include:

1. ~~A~~ The determination of lateral pressures on ~~basement~~ foundation walls and retaining walls due to earthquake motions.
2. The potential for liquefaction and soil strength loss evaluated for site peak ground accelerations, magnitudes, and source characteristics consistent with the design earthquake ground motions. Peak ground acceleration shall be permitted to be determined based on a site-specific study taking into account soil amplification effects, as specified in Chapter 21 of ASCE 7, or, in the absence of such a study, peak ground accelerations shall be assumed equal to S_{DS} / 2.5, where S_{DS} is determined in accordance with Section 11.4 of ASCE 7.
3. An assessment of potential consequences of ~~any~~ liquefaction and soil strength loss, including estimation of differential settlement, lateral movement ~~or~~, lateral loads on foundations, reduction in foundation soil-bearing capacity, increases in lateral pressures on retaining walls and flotation of buried structures.
4. ~~and shall address~~ Discussion of mitigation measures~~. Such measures shall be given consideration in the design of the structure and can include, but are~~ such as, but not limited to, ground stabilization, selection of appropriate foundation type and depths, selection of appropriate structural systems to accommodate anticipated displacements and forces, or any combination of these measures and how they shall be considered in the design of the structure. ~~The potential for liquefaction and soil strength loss shall be evaluated for site peak ground acceleration magnitudes and source characteristics consistent with the design earthquake ground motions. Peak ground acceleration shall be determined from a site-specific study taking into account soil amplification effects, as specified in Chapter 21 of ASCE 7.~~

   ~~**Exception:** A site-specific study need not be performed provided that peak ground acceleration equal to S_{DS} / 2.5 is used, where S_{DS} is determined in accordance with Section 21.2.1 of ASCE 7.~~

~~**1802.6**~~ **1803.6** ~~**Reports**~~ **Reporting.** ~~The soil classification and design load-bearing capacity shall be shown on the construction document.~~ Where geotechnical investigations are required ~~by the building official~~, a written report of the investigations shall be submitted ~~that includes~~ to the building official by the owner or authorized agent at the time of permit application. This geotechnical report shall include, but need not be limited to, the following information:

1. A plot showing the location of ~~test borings and/or excavations~~ the soil investigations.
2. A complete record of the soil boring and penetration test logs and soil samples.
3. A record of the soil profile.
4. Elevation of the water table, if encountered.
5. Recommendations for foundation type and design criteria, including but not limited to: bearing capacity of natural or compacted soil; provisions to mitigate the effects of expansive soils; mitigation of the effects of liquefaction, differential settlement and varying soil strength; and the effects of adjacent loads.
6. Expected total and differential settlement.
7. ~~Pile and pier~~ Deep foundation information in accordance with Section ~~1808.2.2~~ 1803.5.5.
8. Special design and construction provisions for ~~footings or~~ foundations of structures founded on expansive soils, as necessary.
9. Compacted fill material properties and testing in accordance with Section ~~1803.5~~ 1803.5.8.
10. Controlled low-strength material properties and testing in accordance with Section 1803.5.9.

SECTION ~~1803~~ 1804
EXCAVATION, GRADING AND FILL

~~**1803.1**~~ **1804.1** ~~**Excavations**~~ **Excavation near** ~~**footings or**~~ **foundations.** ~~Excavations~~ Excavation for any purpose shall not remove lateral support from any ~~footing or~~ foundation without first underpinning or protecting the ~~footing or~~ foundation against settlement or lateral translation.

~~**1803.2**~~ **1804.2 Placement of backfill.** The excavation outside the foundation shall be backfilled with soil that is free of organic material, construction debris, cobbles and boulders or with a controlled low-strength material (CLSM). The backfill shall be placed in lifts and compacted, in a manner that does not damage the foundation or the waterproofing or dampproofing material.

Exception: Controlled low-strength material need not be compacted.

~~**1803.3**~~ **1804.3 Site grading.** The ground immediately adjacent to the foundation shall be sloped away from the building at a slope of not less than one unit vertical in 20 units horizontal (5-percent slope) for a minimum distance of 10 feet (3048 mm) measured perpendicular to the face of the wall. If physical obstructions or lot lines prohibit 10 feet (3048 mm) of horizontal

distance, a 5-percent slope shall be provided to an approved alternate method of diverting water away from the foundation. Swales used for this purpose shall be sloped a minimum of 2 percent where located within 10 feet (3048 mm) of the building foundation. Impervious surfaces within 10 feet (3048 mm) of the building foundation shall be sloped a minimum of 2 percent away from the building.

Exception: Where climatic or soil conditions warrant, the slope of the ground away from the building foundation ~~is~~ shall be permitted to be reduced to not less than one unit vertical in 48 units horizontal (2-percent slope).

The procedure used to establish the final ground level adjacent to the foundation shall account for additional settlement of the backfill.

~~1803.4~~ 1804.4 **Grading and fill in flood hazard areas**. In flood hazard areas established in Section 1612.3, grading and/or fill shall not be approved:

1. Unless such fill is placed, compacted and sloped to minimize shifting, slumping and erosion during the rise and fall of floor water and, as applicable, wave action.
2. In floodways, unless it has been demonstrated through hydrologic and hydraulic analyses performed by a registered design professional in accordance with standard engineering practice that the proposed grading or fill, or both, will not result in any increase in flood levels during the occurrence of the design flood.
3. In flood hazard areas subject to high-velocity wave action, unless such fill is conducted and/or placed to avoid diversion of water and waves toward any building or structure.
4. Where design flood elevations are specified but floodways have not been designated, unless it has been demonstrated that the cumulative effect of the proposed floor hazard area encroachment, when combined with all other existing and anticipated floor hazard area encroachment, will not increase the design flood elevation more than one foot (305 mm) at any point.

~~1803.5~~ 1804.5 **Compacted fill material.** Where ~~footings~~ shallow foundations will bear on compacted fill material, the compacted fill shall comply with the provisions of an approved geotechnical report~~, which shall contain the following:~~ as set forth in Section 1803.

~~1. Specifications for the preparation of the site prior to placement of compacted fill material.~~
~~2. Specifications for material to be used as compacted fill.~~
~~3. Test method to be used to determine the maximum dry density and optimum moisture content of the material to be used as compacted fill.~~
~~4. Maximum allowable thickness of each lift of compacted fill material.~~
~~5. Field test method for determining the in-place dry density of the compacted fill.~~
~~6. Minimum acceptable in-place dry density expressed as a percentage of the maximum dry density determined in accordance with Item 3.~~
~~7. Number and frequency of field tests required to determine compliance with Item 6.~~

Exception: Compacted fill material ~~less than~~ 12 inches (305 mm) in depth or less need not comply with an approved report, provided ~~it has been compacted to a minimum of~~ the in-place dry density is not less than 90 percent of ~~Modified Proctor~~ the maximum dry density at optimum moisture content determined in accordance with ASTM D 1557. The compaction shall be verified by ~~a qualified inspector approved by the building official~~ special inspection in accordance with Section 1704.7.

~~1803.6~~ 1804.6 **Controlled low-strength material (CLSM).** Where ~~footings~~ shallow foundations will bear on controlled low-strength material (CLSM), the CLSM shall comply with the provisions of an approved geotechnical report, ~~which shall contain the following:~~ as set forth in Section 1803.

~~1. Specifications for the preparation of the site prior to placement of the CLSM.~~
~~2. Specifications for the CLSM.~~
~~3. Laboratory or field test method(s) to be used to determine the compressive strength or bearing capacity of the CLSM.~~
~~4. Test methods for determining the acceptance of the CLSM in the field.~~
~~5. Number and frequency of field tests required to determine compliance with Item 4.~~

SECTION ~~1807~~ 1805
DAMPPROOFING AND WATERPROOFING

~~**1807.1**~~ **1805.1** ~~**Where required**~~ **General.** Walls or portions thereof that retain earth and enclose interior spaces and floors below grade shall be waterproofed and dampproofed in accordance with this section, with the exception of those spaces containing groups other than residential and institutional where such omission is not detrimental to the building or occupancy.

Ventilation for crawl spaces shall comply with Section 1203.4.

~~**1807.1.1**~~ **1805.1.1 Story above grade plane.** Where a basement is considered a story above grade plane and the finished ground level adjacent to the basement wall is below the basement floor elevation for 25 percent or more of the perimeter, the floor and walls shall be dampproofed in accordance with Section ~~1807.2~~ 1805.2 and a foundation drain shall be installed in accordance with Section ~~1807.4.2~~ 1805.4.2. The foundation drain shall be installed around the portion of the perimeter where the basement floor is below ground level. The provisions of Sections ~~1802.2.3~~ 1803.5.4, ~~1807.3~~ 1805.3 and ~~1807.4.1~~ 1805.4.1 shall not apply in this case.

~~**1807.1.2**~~ **1805.1.2 Under-floor space.** The finished ground level of an under-floor space such as a crawl space shall not be located below the bottom of the footings. Where there is evidence that the ground-water table rises to within 6 inches (152 mm) of the ground level at the outside building perimeter, or that the surface water does not readily drain from the building site, the ground level of the under-floor space shall be as high as the outside finished ground level, unless an approved drainage system is provided. The provisions of Sections ~~1802.2.3~~ 1803.5.4, ~~1807.2~~ 1805.2, ~~1807.3~~ 1805.3 and ~~1807.4~~ 1805.4 shall not apply in this case.

~~**1807.1.2.1**~~ **1805.1.2.1 Flood hazard areas.** For buildings and structures in flood hazard areas as established in Section 1612.3, the finished ground level of an under-floor space such as a crawl space shall be equal to or higher than the outside finished ground level on at least one side.

Exception: Under-floor spaces of Group R-3 buildings that meet the requirements of FEMA/FIA-TB-11.

~~**1807.1.3**~~ **1805.1.3 Ground-water control.** Where the ground-water table is lowered and maintained at an elevation not less than 6 inches (152 mm) below the bottom of the lowest floor, the floor and walls shall be dampproofed in accordance with Section ~~1807.2~~ 1805.2. The design of the system to lower the ground-water table shall be based on accepted principles of engineering that shall consider, but not necessarily be limited to, permeability of the soil, rate at which water enters the drainage system, rated capacity of pumps, head against which pumps are to operate and the rated capacity of the disposal area of the system.

~~**1807.2**~~ **1805.2 Dampproofing ~~required~~.** Where hydrostatic pressure will not occur as determined by Section ~~1802.2.3~~ 1803.5.4, floors and walls for other than wood foundation systems shall be dampproofed in accordance with this section. Wood foundation systems shall be constructed in accordance with AF&PA ~~Technical Report No. 7~~ PWF.

~~**1807.2.1**~~ **1805.2.1 Floors.** Dampproofing materials for floors shall be installed between the floor and the base course required by Section 1805.4.1 ~~1807.4.1~~, except where a separate floor is provided above a concrete slab.

Where installed beneath the slab, dampproofing shall consist of not less than 6-mil (0.006 inch; 0.152 mm) polyethylene with joints lapped not less than 6 inches (152 mm), or other approved methods or materials. Where permitted to be installed on top of the slab, dampproofing shall consist of mopped-on bitumen, not less than 4-mil (0.004 inch; 0.102 mm) polyethylene, or other approved methods or materials. Joints in the membrane shall be lapped and sealed in accordance with the manufacturer's installation instructions.

~~**1807.2.2**~~ **1805.2.2 Walls**. Dampproofing materials for walls shall be installed on the exterior surface of the wall, and shall extend from the top of the footing to above ground level.

Dampproofing shall consist of a bituminous material, 3 pounds per square yard (16 N/m^2) of acrylic modified cement, 0.125 inch (3.2 mm) coat of surface-bonding mortar complying with ASTM C 887, any of the materials permitted for waterproofing by Section ~~1807.3.2~~ 1805.3.2 or other approved methods or materials.

~~**1807.2.2.1**~~ **1805.2.2.1 Surface preparation of walls.** Prior to application of dampproofing materials on concrete walls, holes and recesses resulting from the removal of form ties shall be sealed with a bituminous material or other approved methods or materials. Unit masonry walls shall be parged on the exterior surface belowground level with not less than 0.375 inch (9.5 mm) of portland cement mortar. The parging shall be coved at the footing.

Exception: Parging of unit masonry walls is not required where a material is approved for direct application to the masonry.

~~1807.3~~ 1805.3 **Waterproofing ~~required~~.** Where the ground-water investigation required by Section ~~1802.2.3~~ 1803.5.4 indicates that a hydrostatic pressure condition exists, and the design does not include a ground-water control system as described in Section ~~1807.1.3~~ 1805.1.3, walls and floors shall be waterproofed in accordance with this section.

~~1807.3.1~~ 1805.3.1 **Floors.** Floors required to be waterproofed shall be of concrete, designed and constructed to withstand the hydrostatic pressures to which the floors will be subjected.

Waterproofing shall be accomplished by placing a membrane of rubberized asphalt, butyl rubber, fully adhered/fully bonded HDPE or polyolefin composite membrane, or not less than 6-mil [0.006 inch (0.152 mm)] polyvinyl chloride with joints lapped not less than 6 inches (152 mm) or other approved materials under the slab. Joints in the membrane shall be lapped and sealed in accordance with the manufacturer's installation instructions.

~~1807.3.2~~ 1805.3.2 **Walls.** Walls required to be waterproofed shall be of concrete or masonry and shall be designed and constructed to withstand the hydrostatic pressures and other lateral loads to which the walls will be subjected.

Waterproofing shall be applied from the bottom of the wall to not less than 12 inches (305 mm) above the maximum elevation of the ground-water table. The remainder of the wall shall be dampproofed in accordance with Section ~~1807.2.2~~ 1805.2.2. Waterproofing shall consist of two-ply hot-mopped felts, not less than 6-mil (0.006 inch; 0.152 mm) polyvinyl chloride, 40-mil (0.040 inch; 1.02 mm) polymer-modified asphalt, 6-mil (0.006 inch; 0.152 mm) polyethylene or other approved methods or materials capable of bridging nonstructural cracks. Joints in the membrane shall be lapped and sealed in accordance with the manufacturer's installation instructions.

~~1807.3.2.1~~ 1805.3.2.1 **Surface preparation of walls.** Prior to the application of waterproofing materials on concrete or masonry walls, the walls shall be prepared in accordance with Section ~~1807.2.2.1~~ 1805.2.2.1.

~~1807.3.3~~ 1805.3.3 **Joints and penetrations.** Joints in walls and floors, joints between the wall and floor and penetrations of the wall and floor shall be made water-tight utilizing approved methods and materials.

~~1807.4~~ 1805.4 **Subsoil drainage system.** Where a hydrostatic pressure condition does not exist, dampproofing shall be provided and a base shall be installed under the floor and a drain installed around the foundation perimeter. A subsoil drainage system designed and constructed in accordance with Section ~~1807.1.3~~ 1805.1.3 shall be deemed adequate for lowering the ground-water table.

~~1807.4.1~~ 1805.4.1 **Floor base course.** Floors of basements, except as provided for in Section ~~1807.1.1~~ 1805.1.1, shall be placed over a floor base course not less than 4 inches (102 mm) in thickness that consists of gravel or crushed stone containing not more than 10 percent of material that passes through a No. 4 (4.75 mm) sieve.

Exception: Where a site is located in well-drained gravel or sand/gravel mixture soils, a floor base course is not required.

~~1807.4.2~~ 1805.4.2 **Foundation drain**. A drain shall be placed around the perimeter of a foundation that consists of gravel or crushed stone containing not more than 10-percent material that passes through a No. 4 (4.75 mm) sieve. The drain shall extend a minimum of 12 inches (305 mm) beyond the outside edge of the footing. The thickness shall be such that the bottom of the drain is not higher than the bottom of the base under the floor, and that the top of the drain is not less than 6 inches (152 mm) above the top of the footing. The top of the drain shall be covered with an approved filter membrane material. Where a drain tile or perforated pipe is used, the invert of the pipe or tile shall not be higher than the floor elevation. The top of joints or the top of perforations shall be protected with an approved filter membrane material. The pipe or tile shall be placed on not less than 2 inches (51 mm) of gravel or crushed stone complying with Section ~~1807.4.1~~ 1805.4.1, and shall be covered with not less than 6 inches (152 mm) of the same material.

~~1807.4.3~~ 1805.4.3 **Drainage discharge.** The floor base and foundation perimeter drain shall discharge by gravity or mechanical means into an approved drainage system that complies with the *International Plumbing Code*.

Exception: Where a site is located in well-drained gravel or sand/gravel mixture soils, a dedicated drainage system is not required.

SECTION ~~1804~~ 1806
~~ALLOWABLE~~ PRESUMPTIVE LOAD-BEARING VALUES OF SOILS

~~1804.1~~ **1806.1 ~~Design~~ Load combinations.** The presumptive load-bearing values provided in Table ~~1804.2~~ 1806.2 shall be used with the allowable stress design load combinations specified in Section 1605.3. The values of vertical foundation pressure and lateral bearing pressure given in Table 1806.2 shall be permitted to be increased by one-third where used with the alternative basic load combinations of Section 1605.3.2 that include wind or earthquake loads.

~~1804.2~~ **1806.2 Presumptive load-bearing values.** The ~~maximum allowable foundation pressure, lateral pressure or lateral sliding resistance~~ load-bearing values used in design for supporting soils near the surface shall not exceed the values specified in Table ~~1804.2~~ 1806.2 unless data to substantiate the use of ~~a~~ higher ~~value~~ values are submitted and approved. Where the building official has reason to doubt the classification, strength, or compressibility of the soil, the requirements of Section 1803.5.2 shall be satisfied.

Presumptive load-bearing values shall apply to materials with similar physical characteristics and dispositions.

Mud, organic silt, organic clays, peat or unprepared fill shall not be assumed to have a presumptive load-bearing capacity unless data to substantiate the use of such a value are submitted.

Exception: A presumptive load-bearing capacity ~~is~~ shall be permitted to be used where the building official deems the load-bearing capacity of mud, organic silt or unprepared fill is adequate for the support of lightweight ~~and~~ or temporary structures.

TABLE ~~1804.2~~ 1806.2
~~ALLOWABLE FOUNDATION AND LATERAL PRESSURE~~ PRESUMPTIVE LOAD-BEARING VALUES

CLASS OF MATERIALS	~~ALLOWABLE~~ VERTICAL FOUNDATION PRESSURE (psf) [d]	LATERAL BEARING PRESSURE (psf/f below natural grade) [d]	LATERAL SLIDING RESISTANCE	
			Coefficient of friction [a]	~~Resistance~~ Cohesion (psf) [b]
1. Crystalline bedrock	12,000	1,200	0.70	—
2. Sedimentary and foliated rock	4,000	400	0.35	—
3. Sandy gravel and/or gravel (GW and GP)	3,000	200	0.35	—
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	2,000	150	0.25	—
5. Clay, sandy clay, silty clay, clayey silt, silt and sandy silt (CL, ML, MH and CH)	1,500 [e]	100	—	130

For SI: 1 pound per square foot = 0.0479 kPa, 1 pound per square foot per foot = 0.157 kPa/m.

a. Coefficient to be multiplied by the dead load.

b. ~~Lateral sliding resistance~~ Cohesion value to be multiplied by the contact area, as limited by Section ~~1804.3~~ 1806.3.2.

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

~~d. An increase of one-third is permitted when using the alternate load combinations in Section 1605.3.2 that include wind or earthquake loads.~~

~~1804.3~~ **1806.3 Lateral ~~sliding~~ load resistance.** Where the presumptive values of Table 1806.2 are used to determine resistance to lateral loads, the calculations shall be in accordance with Sections 1806.3.1 through 1806.3.4.

1806.3.1 Combined resistance. The total resistance ~~of structural walls~~ to lateral loads ~~sliding~~ shall be permitted to be determined ~~calculated~~ by combining the values derived from the lateral bearing pressure and the lateral sliding resistance specified ~~shown~~ in Table ~~1804.2~~ 1806.2 ~~unless data to substantiate the use of higher values are submitted for approval~~.

1806.3.2 Lateral sliding resistance limit. For clay, sandy clay, silty clay, ~~and~~ clayey silt, silt and sandy silt, in no case shall the lateral sliding resistance exceed one-half the dead load.

~~**1804.3.1**~~ **1806.3.3** ~~**Increases in allowable lateral sliding resistance**~~ **Increase for depth.** ~~The resistance values derived from the table~~ The lateral bearing pressures specified in Table 1806.2 shall be ~~are~~ permitted to be increased by the tabular value for each additional foot (305 mm) of depth to a maximum of 15 times the tabular value.

1806.3.4 Increase for poles. Isolated poles for uses such as flagpoles or signs and poles used to support buildings that are not adversely affected by a 0.5 inch (12.7 mm) motion at the ground surface due to short-term lateral loads ~~are~~ shall be permitted to be designed using ~~lateral-bearing values~~ lateral bearing pressures equal to two times the tabular values.

SECTION 1807
FOUNDATION WALLS, RETAINING WALLS, AND EMBEDDED POSTS AND POLES

1807.1 Foundation walls. Foundation walls shall be designed and constructed in accordance with Sections 1807.1.1 through 1807.1.6. Foundation walls shall be supported by foundations designed in accordance with Section 1808.

1807.1.1 Design lateral soil loads. Foundation walls shall be designed for the lateral soil loads set forth in Section 1610.

1807.1.2 Unbalanced backfill height. Unbalanced backfill height is the difference in height between the exterior finish ground level and the lower of the top of the concrete footing that supports the foundation wall or the interior finish ground level. Where an interior concrete slab on grade is provided and is in contact with the interior surface of the foundation wall, the unbalanced backfill height shall be permitted to be measured from the exterior finish ground level to the top of the interior concrete slab.

~~**1805.5.1.3**~~ **1807.1.3 Rubble stone foundation walls.** Foundation walls of rough or random rubble stone shall not be less than 16 inches (406 mm) thick. Rubble stone shall not be used for foundation~~s~~ walls for structures ~~in~~ assigned to Seismic Design Category C, D, E or F.

~~**1805.4.6**~~ **1807.1.4 Permanent wood foundation~~s~~ systems.** Permanent wood foundation systems shall be designed and installed in accordance with AF&PA ~~Technical Report No. 7~~ PWF. Lumber and plywood shall be treated in accordance with AWPA U1 (Commodity Specification A, Use Category 4B and Section 5.2) and shall be identified in accordance with Section 2303.1.8.1.

~~**1805.5**~~ **1807.1.5 Concrete and masonry foundation walls.** Concrete and masonry foundation walls shall be designed in accordance with Chapter 19 or 21, ~~respectively~~ as applicable.

Exception: Concrete and masonry foundation walls ~~that are laterally supported at the top and bottom within the parameters of Tables 1805.5(1) through 1805.5(5) are~~ shall be permitted to be designed and constructed in accordance with ~~Sections 1805.5.1 through 1805.5.5~~ Section 1807.1.6.

1807.1.6 Prescriptive design of concrete and masonry foundation walls. Concrete and masonry foundation walls that are laterally supported at the top and bottom shall be permitted to be designed and constructed in accordance with this section.

~~**1805.5.1**~~ **1807.1.6.1 Foundation wall thickness.** ~~The minimum thickness of concrete and masonry foundation walls shall comply with Sections 1805.5.1.1 through 1805.5.1.3.~~

~~**1805.5.1.1 Thickness at top of foundation wall.**~~ The thickness of prescriptively designed foundation walls shall not be less than the thickness of the wall supported, except that foundation walls of at least 8 inch (203 mm) nominal width ~~are~~ shall be permitted to support brick-veneered frame walls and 10-inch-wide (254 mm) cavity walls provided the requirements of Section ~~1805.5.1.2~~ 1807.1.6.2 or 1807.1.6.3 are met. ~~Corbeling of masonry shall be in accordance with Section 2104.2. Where an 8-inch (203 mm) wall is corbeled, the top corbel shall not extend higher than the bottom of the floor framing and shall be a full course of headers at least 6 inches (152 mm) in length or the top course bed joint shall be tied to the vertical wall projection. The tie shall be W2.8 (4.8 mm) and spaced at a maximum horizontal distance of 36 inches (914 mm). The hollow space behind the corbelled masonry shall be filled with mortar or grout.~~

~~**1805.5.2.1**~~ **1807.1.6.2 Concrete foundation walls**. Concrete foundation walls shall comply with the following:

1. The thickness shall comply with the requirements of Table 1807.1.6.2.

2. The size and spacing of vertical reinforcement shown in Table ~~1805(5)~~ 1807.1.6.2 is based on the use of reinforcement with a minimum yield strength of 60,000 psi (414 Mpa). Vertical reinforcement with a minimum yield strength of 40,000 psi (276 Mpa) or 50,000 psi (345 Mpa) ~~is~~ shall be permitted, provided the same size bar is used and the spacing shown in the table is reduced by multiplying the spacing by 0.67 or 0.83, respectively.
3. Vertical reinforcement, when required, shall be placed nearest the inside face of the wall a distance, d, from the outside face (soil face) of the wall. The distance, d, is equal to the wall thickness, t, minus 1.25 inches (32 mm) plus one-half the bar diameter, d_b, [$d = t - (1.25 + d_b / 2)$]. The reinforcement shall be placed within a tolerance of ± 3/8 inch (9.5 mm) where d is less than or equal to 8 inches (203 mm) or ± 1/2 inch (12.7 mm) where d is greater than 8 inches (203 mm).
4. In lieu of the reinforcement shown in Table ~~1805.5(5)~~ 1807.1.6.2, smaller reinforcing bar sizes with closer spacings that provide an equivalent cross-sectional area of reinforcement per unit length ~~are~~ shall be permitted.
5. Concrete cover for reinforcement measured from the inside face of the wall shall not be less than 3/4 inch (19.1 mm). Concrete cover for reinforcement measured from the outside face of the wall shall not be less than 1.5 inches (38 mm) for No. 5 bars and smaller, and not less than 2 inches (51 mm) for larger bars.
6. Concrete shall have a specified compressive strength, f_c', of not less than 2,500 psi (17.2 MPa) ~~at 28 days~~.
7. The unfactored axial load per linear foot of wall shall not exceed $1.2\, t\, f_c'$ where t is the specified wall thickness in inches.

~~1805.5.5.1~~ 1807.1.6.2.1 Seismic requirements ~~for concrete foundation walls~~. Based on the seismic design category assigned to the structure in accordance with Section 1613, concrete foundation walls designed using Table ~~1805.5(5)~~ 1807.1.6.2 shall be subject to the following limitations:

1. Seismic Design Categories A and B. No additional seismic requirements, except provide ~~not less than two No. 5 bars around window and door openings. Such bars shall extend at least 24 inches (610 mm) beyond the corners of the openings~~ reinforcement around openings in accordance with Section 1909.6.3.
2. Seismic Design Categories C, D, E and F. Tables shall not be used except as allowed for plain concrete members in Section ~~1908.1.15~~ 1908.1.8.

TABLE ~~1805.5(5)~~ 1807.1.6.2
CONCRETE FOUNDATION WALLS [b, c]

MAXIMUM WALL HEIGHT (feet)	MAXIMUM UNBALANCED BACKFILL HEIGHT[e] (feet)	VERTICAL REINFORCEMENT AND SPACING (inches)								
		Design lateral soil load[a] (psf per foot of depth)								
		30[d]			45[d]			60		
		Minimum wall thickness (inches)								
		7.5	9.5	11.5	7.5	9.5	11.5	7.5	9.5	11.5
5	4	PC	PC	PC	PC	PC	PC	PC	PC	PC
	5	PC	PC	PC	PC	PC	PC	PC	PC	PC
6	4	PC	PC	PC	PC	PC	PC	PC	PC	PC
	5	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	PC	PC	PC	PC	PC	PC	PC	PC	PC
7	4	PC	PC	PC	PC	PC	PC	PC	PC	PC
	5	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	PC	PC	PC	PC	PC	PC	#5 at 48"	PC	PC
	7	PC	PC	PC	#5 at 46"	PC	PC	#6 at 48"	PC	PC
8	4	PC	PC	PC	PC	PC	PC	PC	PC	PC
	5	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	PC	PC	PC	PC	PC	PC	#5 at 43"	PC	PC
	7	PC	PC	PC	#5 at 41"	PC	PC	#6 at 43"	PC	PC
	8	#5 at 47"	PC	PC	#6 at 43"	PC	PC	#6 at 32"	#6 at 44"	PC
9	4	PC	PC	PC	PC	PC	PC	PC	PC	PC
	5	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	PC	PC	PC	PC	PC	PC	#5 at 39"	PC	PC
	7	PC	PC	PC	#5 at 37"	PC	PC	#6 at 38"	#5 at 37"	PC
	8	#5 at 41"	PC	PC	#6 at 38"	#5 at 37"	PC	#7 at 39"	#6 at 39"	#4 at 48"
	9[d]	#6 at 46"	PC	PC	#7 at 41"	#6 at 41"	PC	#7 at 31"	#7 at 41"	#6 at 39"
10	4	PC	PC	PC	PC	PC	PC	PC	PC	PC
	5	PC	PC	PC	PC	PC	PC	PC	PC	PC
	6	PC	PC	PC	PC	PC	PC	#5 at 37"	PC	PC
	7	PC	PC	PC	#6 at 48"	PC	PC	#6 at 35"	#6 at 48"	PC
	8	#5 at 38"	PC	PC	#7 at 47"	#6 at 47"	PC	#7 at 35"	#7 at 47"	#6 at 45"
	9[d]	#6 at 41"	#4 at 48"	PC	#7 at 37"	#7 at 48"	#4 at 48"	#6 at 22"	#7 at 37"	#7 at 47"
	10[d]	#7 at 45"	#6 at 45"	PC	#7 at 31"	#7 at 40"	#6 at 38"	#6 at 22"	#7 at 30"	#7 at 38"

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot per foot = 0.157 kPa/m.

a. For design lateral soil loads ~~for different classes of soil~~, see Section 1610.
b. Provisions for this table are based on design and construction requirements specified in Section ~~1805.5.2.1~~ 1807.1.6.2.
c. "PC" means plain concrete.
d. Where unbalanced backfill height exceeds 8 feet and design lateral soil loads from Table 1610.1 are used, the requirements for 30 and 45 psf per foot of depth are not applicable. See Section 1610.
e. For height of unbalanced backfill, see Section ~~1805.5.1.2~~ 1807.1.2.

~~**1805.5.2.2**~~ **1807.1.6.3 Masonry foundation walls**. Masonry foundation walls shall comply with the following:

1. The thickness shall comply with the requirements of Table 1807.1.6.3(1) for plain masonry walls or Table 1807.1.6.3(2), 1807.1.6.3(3) or 1807.1.6.3(4) for masonry walls with reinforcement.
2. Vertical reinforcement shall have a minimum yield strength of 60,000 psi (414 Mpa).
3. The specified location of the reinforcement shall equal or exceed the effective depth distance, *d*, noted in Tables ~~1805.5(2), 1805.5(3) and 1805.5(4)~~ 1807.1.6.3(2), 1807.1.6.3(3) and 1807.1.6.3(4) and shall be measured from the face of the exterior (soil) side of the wall to the center of the vertical reinforcement. The reinforcement shall be placed within the tolerances specified in ACI 530.1/ASCE 6/TMS 402, Article 3.4 B7 of the specified location.
4. Grout shall comply with Section 2103.12.
5. Concrete masonry units shall comply with ASTM C 90.
6. Clay masonry units shall comply with ASTM C 652 for hollow brick, except compliance with ASTM C 62 or C 216 ~~is~~ shall be permitted ~~when~~ where solid masonry units are installed in accordance with Table ~~1805.5(1)~~ 1807.1.6.3(1) for plain masonry.
7. Masonry units shall be laid in running bond and installed with Type M or S mortar in accordance with Section 2103.8.
8. The unfactored axial load per linear foot of wall shall not exceed $1.2\,t\,f'_m$ where t is the specified wall thickness in inches and f'_m is the specified compressive strength of masonry in pounds per square inch.
9. At least 4 inches (102 mm) of solid masonry shall be provided at girder supports at the top of hollow masonry unit foundation walls.
10. Corbeling of masonry shall be in accordance with Section 2104.2. Where an 8-inch (203 mm) wall is corbeled, the top corbel shall not extend higher than the bottom of the floor framing and shall be a full course of headers at least 6 inches (152 mm) in length or the top course bed joint shall be tied to the vertical wall projection. The tie shall be W2.8 (4.8 mm) and spaced at a maximum horizontal distance of 36 inches (914 mm). The hollow space behind the corbelled masonry shall be filled with mortar or grout.

~~**1805.5.3**~~ **1807.1.6.3.1 Alternative foundation wall reinforcement.** In lieu of the reinforcement provisions for masonry foundation walls in Table ~~1805.5(2), 1805.5(3) or 1805.5(4)~~ 1807.1.6.3(2), 1807.1.6.3(3) or 1807.1.6.3(4), alternative reinforcing bar sizes and spacings having an equivalent cross-sectional area of reinforcement per linear foot (mm) of wall ~~are~~ shall be permitted to be used, provided the spacing of reinforcement does not exceed 72 inches (1829 mm) and reinforcing bar sizes do not exceed No. 11.

~~**1805.5.5.2**~~ **1807.1.6.3.2 Seismic requirements** ~~**for masonry foundation walls**~~**.** Based on the seismic design category assigned to the structure in accordance with Section 1613, masonry foundation walls designed using Tables ~~1805.5(1) through 1805.5(4)~~ 1807.1.6.3(1) through 1807.1.6.3(4) shall be subject to the following limitations:

1. Seismic Design Categories A and B. No additional seismic requirements.
2. Seismic Design Category C. A design using Tables ~~1805.5(1) through 1805.5(4)~~ 1807.1.6.3(1) through 1807.1.6.3(4) is subject to the seismic requirements of Section 2106.4.
3. Seismic Design Category D. A design using Tables ~~1805.2(2) through 1805.5(4)~~ 1807.1.6.3(2) through 1807.1.6.3(4) is subject to the seismic requirements of Section 2106.5.
4. Seismic Design Categories E and F. A design using Tables ~~1805.2(2) through 1805.5(4)~~ 1807.1.6.3(2) through 1807.1.6.3(4) is subject to the seismic requirements of Section 2106.6.

TABLE ~~1805.5(1)~~ 1807.1.6.3(1)
PLAIN MASONRY FOUNDATION WALLS [a, b, c]

MAXIMUM WALL HEIGHT (feet)	MAXIMUM UNBALANCED BACKFILL HEIGHT[e] (feet)	MINIMUM NOMINAL WALL THICKNESS (inches)		
		~~Soil classes and~~ Design lateral soil load[a] (psf per foot ~~below natural grade~~ of depth)		
		~~GW, GP, SW and SP soils~~ 30[f]	~~GM, GC, SM, SM-SC and ML soils~~ 45[f]	~~SC, ML-CL and Inorganic CL soils~~ 60
7	4 (or less)	8	8	8
	5	8	10	10
	6	10	12	10 (solid [c])
	7	12	10 (solid [c])	10 (solid [c])
8	4 (or less)	8	8	8
	5	8	10	12
	6	10	12	12 (solid [c])
	7	12	12 (solid [c])	Note d
	8	10 (solid [c])	12 (solid [c])	Note d
9	4 (or less)	8	8	8
	5	8	10	12
	6	12	12	12 (solid [c])
	7	12 (solid [c])	12 (solid [c])	Note d
	8	12 (solid [c])	Note d	Note d
	9[f]	Note d	Note d	Note d

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot per foot = 0.157 kPa/m.

a. For design lateral soil loads, see Section 1610. ~~Soil classes are in accordance with the Unified Soil Classification System and design lateral soil loads are for moist soil conditions without hydrostatic pressure.~~

b. Provisions for this table are based on design and construction requirements specified in Section ~~1805.5.2.2~~ 1807.1.6.3.

c. Solid grouted hollow units or solid masonry units.

d. A design in compliance with Chapter 21 or reinforcement in accordance with Table ~~1805.5(2)~~ 1807.1.6.3(2) is required.

e. For height of unbalanced backfill, see Section ~~1805.5.1.2~~ 1807.1.2.

f. Where unbalanced backfill height exceeds 8 feet and design lateral soil loads from Table 1610.1 are used, the requirements for 30 and 45 psf per foot of depth are not applicable. See Section 1610.

TABLE ~~1805.5(2)~~ 1807.1.6.3(2)
8-INCH MASONRY FOUNDATION WALLS WITH REINFORCEMENT WHERE d ≥ 5 INCHES [a, b, c]

MAXIMUM WALL HEIGHT (feet-inches)	MAXIMUM UNBALANCED BACKFILL HEIGHT[d] (feet-inches)	VERTICAL REINFORCEMENT		
		~~Soil classes and~~ Design lateral soil load[a] (psf per foot ~~below natural grade~~ of depth)		
		~~GW, GP, SW and SP soils~~ 30[e]	~~GM, GC, SM, SM-SC and ML soils~~ 45[e]	~~SC, ML-CL and Inorganic CL soils~~ 60
7-4	4-0 (or less)	#4 at 48" o.c.	#4 at 48" o.c.	#4 at 48" o.c.
	5-0	#4 at 48" o.c.	#4 at 48" o.c.	#4 at 48" o.c.
	6-0	#4 at 48" o.c.	#5 at 48" o.c.	#5 at 48" o.c.
	7-4	#5 at 48" o.c.	#6 at 48" o.c.	#7 at 48" o.c.
8-0	4-0 (or less)	#4 at 48" o.c.	#4 at 48" o.c.	#4 at 48" o.c.
	5-0	#4 at 48" o.c.	#4 at 48" o.c.	#4 at 48" o.c.
	6-0	#4 at 48" o.c.	#5 at 48" o.c.	#5 at 48" o.c.
	7-0	#5 at 48" o.c.	#6 at 48" o.c.	#7 at 48" o.c.
	8-0	#5 at 48" o.c.	#6 at 48" o.c.	#7 at 48" o.c.
8-8	4-0 (or less)	#4 at 48" o.c.	#4 at 48" o.c.	#4 at 48" o.c.
	5-0	#4 at 48" o.c.	#4 at 48" o.c.	#5 at 48" o.c.
	6-0	#4 at 48" o.c.	#5 at 48" o.c.	#6 at 48" o.c.
	7-0	#5 at 48" o.c.	#6 at 48" o.c.	#7 at 48" o.c.
	8-8[e]	#6 at 48" o.c.	#7 at 48" o.c.	#8 at 48" o.c.
9-4	4-0 (or less)	#4 at 48" o.c.	#4 at 48" o.c.	#4 at 48" o.c.
	5-0	#4 at 48" o.c.	#4 at 48" o.c.	#5 at 48" o.c.
	6-0	#4 at 48" o.c.	#5 at 48" o.c.	#6 at 48" o.c.
	7-0	#5 at 48" o.c.	#6 at 48" o.c.	#7 at 48" o.c.
	8-0	#6 at 48" o.c.	#7 at 48" o.c.	#8 at 48" o.c.
	9-4[e]	#7 at 48" o.c.	#8 at 48" o.c.	#9 at 48" o.c.
10-0	4-0 (or less)	#4 at 48" o.c.	#4 at 48" o.c.	#4 at 48" o.c.
	5-0	#4 at 48" o.c.	#4 at 48" o.c.	#5 at 48" o.c.
	6-0	#4 at 48" o.c.	#5 at 48" o.c.	#6 at 48" o.c.
	7-0	#5 at 48" o.c.	#6 at 48" o.c.	#7 at 48" o.c.
	8-0	#6 at 48" o.c.	#7 at 48" o.c.	#8 at 48" o.c.
	9-0[e]	#7 at 48" o.c.	#8 at 48" o.c.	#9 at 48" o.c.
	10-0[e]	#7 at 48" o.c.	#9 at 48" o.c.	#9 at 48" o.c.

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot per foot = 0.157 kPa/m.

a. For design lateral soil loads, see Section 1610. ~~Soil classes are in accordance with the Unified Soil Classification System and design lateral soil loads are for moist soil conditions without hydrostatic pressure.~~

b. Provisions for this table are based on design and construction requirements specified in Section ~~1805.5.2.2~~ 1807.1.6.3.

c. For alternative reinforcement, see Section ~~1805.5.3~~ 1807.1.6.3.1.

d. For height of unbalanced backfill, see Section ~~1805.5.1.2~~ 1807.1.2.

e. Where unbalanced backfill height exceeds 8 feet and design lateral soil loads from Table 1610.1 are used, the requirements for 30 and 45 psf per foot of depth are not applicable. See Section 1610.

TABLE ~~1805.5(3)~~ 1807.1.6.3(3)
10-INCH MASONRY FOUNDATION WALLS WITH REINFORCEMENT WHERE d ≥ 6.75 INCHES [a, b, c]

MAXIMUM WALL HEIGHT (feet-inches)	MAXIMUM UNBALANCED BACKFILL HEIGHT[d] (feet-inches)	VERTICAL REINFORCEMENT		
		~~Soil classes and~~ Design lateral soil load[a] (psf per foot ~~below natural grade~~ of depth)		
		~~GW, GP, SW and SP soils~~ 30[e]	~~GM, GC, SM, SM-SC and ML soils~~ 45[e]	~~SC, ML-CL and Inorganic CL soils~~ 60
7-4	4-0 (or less)	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 56" o.c.
	5-0	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 56" o.c.
	6-0	#4 at 56" o.c.	#4 at 56" o.c.	#5 at 56" o.c.
	7-4	#4 at 56" o.c.	#5 at 56" o.c.	#6 at 56" o.c.
8-0	4-0 (or less)	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 56" o.c.
	5-0	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 56" o.c.
	6-0	#4 at 56" o.c.	#4 at 56" o.c.	#5 at 56" o.c.
	7-0	#4 at 56" o.c.	#5 at 56" o.c.	#6 at 56" o.c.
	8-0	#5 at 56" o.c.	#6 at 56" o.c.	#7 at 56" o.c.
8-8	4-0 (or less)	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 56" o.c.
	5-0	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 56" o.c.
	6-0	#4 at 56" o.c.	#4 at 56" o.c.	#5 at 56" o.c.
	7-0	#4 at 56" o.c.	#5 at 56" o.c.	#6 at 56" o.c.
	8-8[e]	#5 at 56" o.c.	#7 at 56" o.c.	#8 at 56" o.c.
9-4	4-0 (or less)	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 56" o.c.
	5-0	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 56" o.c.
	6-0	#4 at 56" o.c.	#5 at 56" o.c.	#5 at 56" o.c.
	7-0	#4 at 56" o.c.	#5 at 56" o.c.	#6 at 56" o.c.
	8-0	#5 at 56" o.c.	#6 at 56" o.c.	#7 at 56" o.c.
	9-4[e]	#6 at 56" o.c.	#7 at 56" o.c.	#8 at 56" o.c.
10-0	4-0 (or less)	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 56" o.c.
	5-0	#4 at 56" o.c.	#4 at 56" o.c.	#4 at 56" o.c.
	6-0	#4 at 56" o.c.	#5 at 56" o.c.	#5 at 56" o.c.
	7-0	#5 at 56" o.c.	#6 at 56" o.c.	#7 at 56" o.c.
	8-0	#5 at 56" o.c.	#7 at 56" o.c.	#8 at 56" o.c.
	9-0[e]	#6 at 56" o.c.	#7 at 56" o.c.	#9 at 56" o.c.
	10-0[e]	#7 at 56" o.c.	#8 at 56" o.c.	#9 at 56" o.c.

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot per foot = 0.157 kPa/m.

a. For design lateral soil loads, see Section 1610. ~~Soil classes are in accordance with the Unified Soil Classification System and design lateral soil loads are for moist soil conditions without hydrostatic pressure.~~

b. Provisions for this table are based on design and construction requirements specified in Section ~~1805.5.2.2~~ 1807.1.6.3.

c. For alternative reinforcement, see Section ~~1805.5.3~~ 1807.1.6.3.1.

d. For height of unbalanced backfill, see Section ~~1805.5.1.2~~ 1807.1.2.

e. Where unbalanced backfill height exceeds 8 feet and design lateral soil loads from Table 1610.1 are used, the requirements for 30 and 45 psf per foot of depth are not applicable. See Section 1610.

TABLE ~~1805.5(4)~~ 1807.1.6.3(4)
12-INCH MASONRY FOUNDATION WALLS WITH REINFORCEMENT WHERE d ≥ 8.75 INCHES [a, b, c]

MAXIMUM WALL HEIGHT (feet-inches)	MAXIMUM UNBALANCED BACKFILL HEIGHT[d] (feet-inches)	VERTICAL REINFORCEMENT		
		~~Soil classes and~~ Design lateral soil load[a] (psf per foot ~~below natural grade~~ of depth)		
		~~GW, GP, SW and SP soils~~ 30[e]	~~GM, GC, SM, SM-SC and ML soils~~ 45[e]	~~SC, ML-CL and Inorganic CL soils~~ 60
7-4	4-0 (or less)	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	5-0	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	6-0	#4 at 72" o.c.	#4 at 72" o.c.	#5 at 72" o.c.
	7-4	#4 at 72" o.c.	#5 at 72" o.c.	#6 at 72" o.c.
8-0	4-0 (or less)	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	5-0	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	6-0	#4 at 72" o.c.	#4 at 72" o.c.	#5 at 72" o.c.
	7-0	#4 at 72" o.c.	#5 at 72" o.c.	#6 at 72" o.c.
	8-0	#5 at 72" o.c.	#6 at 72" o.c.	#7 at 72" o.c.
8-8	4-0 (or less)	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	5-0	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	6-0	#4 at 72" o.c.	#4 at 72" o.c.	#5 at 72" o.c.
	7-0	#4 at 72" o.c.	#5 at 72" o.c.	#6 at 72" o.c.
	8-8[e]	#5 at 72" o.c.	#7 at 72" o.c.	#8 at 72" o.c.
9-4	4-0 (or less)	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	5-0	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	6-0	#4 at 72" o.c.	#5 at 72" o.c.	#5 at 72" o.c.
	7-0	#4 at 72" o.c.	#5 at 72" o.c.	#6 at 72" o.c.
	8-0	#5 at 72" o.c.	#6 at 72" o.c.	#7 at 72" o.c.
	9-4[e]	#6 at 72" o.c.	#7 at 72" o.c.	#8 at 72" o.c.
10-0	4-0 (or less)	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	5-0	#4 at 72" o.c.	#4 at 72" o.c.	#4 at 72" o.c.
	6-0	#4 at 72" o.c.	#5 at 72" o.c.	#5 at 72" o.c.
	7-0	#4 at 72" o.c.	#6 at 72" o.c.	#6 at 72" o.c.
	8-0	#5 at 72" o.c.	#6 at 72" o.c.	#7 at 72" o.c.
	9-0[e]	#6 at 72" o.c.	#7 at 72" o.c.	#8 at 72" o.c.
	10-0[e]	#7 at 72" o.c.	#8 at 72" o.c.	#9 at 72" o.c.

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot per foot = 0.157 kPa/m.

a. For design lateral soil loads, see Section 1610. ~~Soil classes are in accordance with the Unified Soil Classification System and design lateral soil loads are for moist soil conditions without hydrostatic pressure.~~
b. Provisions for this table are based on design and construction requirements specified in Section ~~1805.5.2.2~~ 1807.1.6.3.
c. For alternative reinforcement, see Section ~~1805.5.3~~ 1807.1.6.3.1.
d. For height of unbalanced backfill, see Section ~~1805.5.1.2~~ 1807.1.2.
e. Where unbalanced backfill height exceeds 8 feet and design lateral soil loads from Table 1610.1 are used, the requirements for 30 and 45 psf per foot of depth are not applicable. See Section 1610.

1807.2 Retaining walls. Retaining walls shall be designed in accordance with Sections 1807.2.1 through 1807.2.3.

~~1806.1~~ **1807.2.1 General.** Retaining walls shall be designed to ensure stability against overturning, sliding, excessive foundation pressure and water uplift.

1807.2.2 Design lateral soil loads. Retaining walls shall be designed for the lateral soil loads set forth in Section 1610.

1807.2.3 Safety factor. Retaining walls shall be designed ~~for~~ to resist the lateral action of soil to produce sliding and overturning with a minimum safety factor of 1.5 ~~against lateral sliding and overturning~~ in each case. The load combinations of Section 1605 shall not apply to this requirement. Instead, design shall be based on 0.7 times nominal earthquake loads, 1.0 times other nominal loads, and investigation with one or more of the variable loads set to zero. The safety factor against lateral sliding shall be taken as the available soil resistance at the base of the retaining wall foundation divided by the net lateral force applied to the retaining wall.

Exception: Where earthquake loads are included, the minimum safety factor for retaining wall sliding and overturning shall be 1.1.

Where a keyway is extended below the wall base with the intent to engage passive pressure and enhance sliding stability, lateral soil pressures on both sides of the keyway shall be considered in the sliding analysis.

~~1805.7~~ 1807.3 ~~Designs employing lateral bearing~~ **Embedded posts and poles.** Designs to resist both axial and lateral loads employing posts or poles as columns embedded in earth or embedded in concrete footings in the earth shall ~~conform to the requirements of~~ be in accordance with Sections ~~1805.7.1~~ 1807.3.1 through ~~1805.7.3~~ 1807.3.3.

~~1805.7.1~~ 1807.3.1 **Limitations.** The design procedures outlined in this section are subject to the following limitations:

1. The frictional resistance for structural walls and slabs on silts and clays shall be limited to one-half of the normal force imposed on the soil by the weight of the footing or slab.
2. Posts embedded in earth shall not be used to provide lateral support for structural or nonstructural materials such as plaster, masonry or concrete unless bracing is provided that develops the limited deflection required.

Wood poles shall be treated in accordance with AWPA U1 for sawn timber posts (Commodity Specification A, Use Category 4B), and for round timber posts (Commodity Specification B, Use Category 4B).

~~1805.7.2~~ 1807.3.2 **Design criteria.** The depth to resist lateral loads shall be determined ~~by~~ using the design criteria established in Sections ~~1805.7.2.1~~ 1807.3.2.1 through ~~1805.7.2.3~~ 1807.3.2.3, or by other methods approved by the building official.

~~1805.7.2.1~~ 1807.3.2.1 **Nonconstrained.** The following formula shall be used in determining the depth of embedment required to resist lateral loads where no lateral constraint is provided at the ground surface, such as by a rigid floor or rigid ground surface pavement, and where no lateral constraint is provided above the ground surface, such as by a structural diaphragm.

$$d = 0.5\,A\,\{1 + [1 + (4.36\,h / A)]^{1/2}\} \qquad \textbf{(Equation 18-1)}$$

where:

A = $2.34\,P / S_1\,b$.
b = Diameter of round post or footing or diagonal dimension of square post or footing, feet (m).
d = Depth of embedment in earth in feet (m) but not over 12 feet (3658 mm) for purpose of computing lateral pressure.
h = Distance in feet (m) from ground surface to point of application of "P."
P = Applied lateral force in pounds (kN).
S_1 = Allowable lateral soil-bearing pressure as set forth in Section ~~1804.3~~ 1806.2 based on a depth of one-third the depth of embedment in pounds per square foot (psf) (kPa).

~~1805.7.2.2~~ 1807.3.2.2 **Constrained.** The following formula shall be used to determine the depth of embedment required to resist lateral loads where lateral constraint is provided at the ground surface, such as by a rigid floor or pavement.

$$d^2 = 4.25\,(P\,h / S_3\,b) \qquad \textbf{(Equation 18-2)}$$

or alternatively

$$d^2 = 4.25\,(M_g / S_3\,b) \qquad \textbf{(Equation 18-3)}$$

where:

M_g = Moment in the post at grade, in foot-pounds (kN-m).
S_3 = Allowable lateral soil-bearing pressure as set forth in Section ~~1804.3~~ 1806.2 based on a depth equal to the depth of embedment in pounds per square foot (kPa).

~~1805.7.2.3~~ 1807.3.2.3 **Vertical load.** The resistance to vertical loads shall be determined ~~by~~ using the ~~allowable soil bearing~~ vertical foundation pressure set forth in Table ~~1804.2~~ 1806.2.

~~1805.7.3~~ 1807.3.3 **Backfill.** The backfill in the annular space around columns not embedded in poured footings shall be by one of the following methods:

1. Backfill shall be of concrete with ~~an ultimate~~ a specified compressive strength of not less than 2,000 psi (13.8 MPa) ~~at 28 days~~. The hole shall not be less than 4 inches (102 mm) larger than the diameter of the column at its bottom or 4 inches (102 mm) larger than the diagonal dimension of a square or rectangular column.
2. Backfill shall be of clean sand. The sand shall be thoroughly compacted by tamping in layers not more than 8 inches (203 mm) in depth.
3. Backfill shall be of controlled low-strength material (CLSM).

SECTION ~~1805~~ 1808
~~FOOTINGS AND~~ FOUNDATIONS

1808.1 General. Foundations shall be designed and constructed in accordance with Sections 1808.2 through 1808.9. Shallow foundations shall also satisfy the requirements of Section 1809. Deep foundations shall also satisfy the requirements of Section 1810.

~~1805.4.1~~ **1808.2 Design for capacity and settlement.** ~~Footings~~ Foundations shall be so designed that the allowable bearing capacity of the soil is not exceeded, and that differential settlement is minimized. ~~The minimum width of footings shall be 12 inches (305 mm).~~ ~~Footings~~ Foundations in areas with expansive soils shall be designed in accordance with the provisions of Section ~~1805.8~~ 1808.6.

~~1805.4.1.1~~ **1808.3 Design loads.** ~~Footings~~ Foundations shall be designed for the most unfavorable effects due to the combinations of loads specified in Section 1605.2 or 1605.3. The dead load is permitted to include the weight of foundations~~,~~ ~~footings~~ and overlying fill. Reduced live loads, as specified in Sections 1607.9 and 1607.11, ~~are~~ shall be permitted to be used in the design of ~~footings~~ foundations.

~~1801.2.1~~ **1808.3.1 ~~Foundation design for~~ Seismic overturning.** Where ~~the foundation is~~ foundations are proportioned using the load combinations of Section 1605.2 or 1605.3.1, and the computation of seismic overturning ~~moment~~ effects is by ~~the~~ Equivalent Lateral Force ~~method~~ Analysis or ~~the~~ Modal Analysis ~~method~~, the proportioning shall be in accordance with Section 12.13.4 of ASCE 7.

~~1805.4.1.2~~ **1808.4 Vibratory loads.** Where machinery operations or other vibrations are transmitted through the foundation, consideration shall be given in the ~~footing~~ foundation design to prevent detrimental disturbances of the soil.

~~1805.2.3~~ **1808.5 Shifting or moving soils.** Where it is known that the shallow subsoils are of a shifting or moving character, ~~footings~~ foundations shall be carried to a sufficient depth to ensure stability.

~~1805.8~~ **1808.6 Design for expansive soils.** ~~Footings or~~ Foundations for buildings and structures founded on expansive soils shall be designed in accordance with Section ~~1805.8.1~~ 1808.6.1 or ~~1805.8.2~~ 1808.6.2.

Exception: ~~Footing or~~ Foundation design need not comply with Section ~~1805.8.1~~ 1808.6.1 or ~~1805.8.2~~ 1808.6.2 where one of the following conditions is satisfied:

1. The soil is removed in accordance with Section ~~1805.8.3, nor where~~ 1808.6.3; or
2. The building official approves stabilization of the soil in accordance with Section ~~1805.8.4~~ 1808.6.4.

~~1805.8.1~~ **1808.6.1 Foundations.** ~~Footings or~~ Foundations placed on or within the active zone of expansive soils shall be designed to resist differential volume changes and to prevent structural damage to the supported structure. Deflection and racking of the supported structure shall be limited to that which will not interfere with the usability and serviceability of the structure.

Foundations placed below where volume change occurs or below expansive soil shall comply with the following provisions:

1. Foundations extending into or penetrating expansive soils shall be designed to prevent uplift of the supported structure.
2. Foundations penetrating expansive soils shall be designed to resist forces exerted on the foundation due to soil volume changes or shall be isolated from the expansive soil.

~~1805.8.2~~ **1808.6.2 Slab-on-ground foundations.** Moments, shears and deflections for use in designing slab-on-ground, mat or raft foundations on expansive soils shall be determined in accordance with *WRI/CRSI Design of Slab-on-ground Foundations* or *PTI Standard Requirements for Analysis of Shallow Concrete Foundations on Expansive Soils*. Using the

moments, shears and deflections determined above, nonprestressed slabs-on-ground, mat or raft foundations on expansive soils shall be designed in accordance with *WRI/CRSI Design of Slab-on-ground Foundations* and post-tensioned slab-on-ground, mat or raft foundations on expansive soils shall be designed in accordance with *PTI Standard Requirements for Design of Shallow Post-tensioned Concrete Foundations on Expansive Soils*. It shall be permitted to analyze and design such slabs by other methods that account for soil-structure interaction, the deformed shape of the soil support, the plate or stiffened plate action of the slab, as well as both center lift and edge lift conditions. Such alternative methods shall be rational and the basis for all aspects and parameters of the method shall be available for peer review.

~~**1805.8.3**~~ **1808.6.3 Removal of expansive soil.** Where expansive soil is removed in lieu of designing ~~footings or~~ foundations in accordance with Section ~~1805.8.1 or 1805.8.2~~ 1808.6.1 or 1808.6.2, the soil shall be removed to a depth sufficient to ensure a constant moisture content in the remaining soil. Fill material shall not contain expansive soils and shall comply with Section ~~1803.5~~ 1804.5 or ~~1803.6~~ 1804.6.

Exception: Expansive soil need not be removed to the depth of constant moisture, provided the confining pressure in the expansive soil created by the fill and supported structure exceeds the swell pressure.

~~**1805.8.4**~~ **1808.6.4 Stabilization.** Where the active zone of expansive soils is stabilized in lieu of designing ~~footings or~~ foundations in accordance with Section ~~1805.8.1~~ 1808.6.1 or ~~1805.8.2~~ 1808.6.2, the soil shall be stabilized by chemical, dewatering, presaturation or equivalent techniques.

~~**1805.3**~~ **1808.7 ~~Footings~~ Foundations on or adjacent to slopes.** The placement of buildings and structures on or adjacent to slopes steeper than one unit vertical in three units horizontal (33.3-percent slope) shall ~~conform to~~ comply with Sections ~~1805.3.1~~ 1808.7.1 through ~~1805.3.5~~ 1808.7.5.

~~**1805.3.1**~~ **1808.7.1 Building clearance from ascending slopes.** In general, buildings below slopes shall be set a sufficient distance from the slope to provide protection from slope drainage, erosion and shallow failures. Except as provided ~~for~~ in Section ~~1805.3.5~~ 1808.7.5 and Figure ~~1805.3.1~~ 1808.7.1, the following criteria will be assumed to provide this protection. Where the existing slope is steeper than one unit vertical in one unit horizontal (100-percent slope), the toe of the slope shall be assumed to be at the intersection of a horizontal plane drawn from the top of the foundation and a plane drawn tangent to the slope at an angle of 45 degrees (0.79 rad) to the horizontal. Where a retaining wall is constructed at the toe of the slope, the height of the slope shall be measured from the top of the wall to the top of the slope.

FIGURE ~~1805.3.1~~ 1808.7.1
FOUNDATION CLEARANCES FROM SLOPES

AT LEAST THE SMALLER OF H/2 ~~BUT NEED NOT EXCEED~~ AND 15 ~~FT. MAX~~ FEET

AT LEAST THE SMALLER OF H/3 ~~BUT NEED NOT EXCEED~~ AND 40 ~~FT. MAX~~ FEET

(no further changes to Figure)

~~**1805.3.2**~~ **1808.7.2 ~~Footing~~ Foundation setback from descending slope surface**. ~~Footings~~ Foundations on or adjacent to slope surfaces shall be founded in firm material with an embedment and set back from the slope surface sufficient to provide vertical and lateral support for the ~~footing~~ foundation without detrimental settlement. Except as provided for in Section ~~1805.3.5~~ 1808.7.5 and Figure ~~1805.3.1~~ 1808.7.1, the following setback is deemed adequate to meet the criteria. Where the slope is steeper than 1 unit vertical in 1 unit horizontal (100-percent slope), the required setback shall be measured from an imaginary plane 45 degrees (0.79 rad) to the horizontal, projected upward from the toe of the slope.

~~**1805.3.3**~~ **1808.7.3 Pools.** The setback between pools regulated by this code and slopes shall be equal to one-half the building footing setback distance required by this section. That portion of the pool wall within a horizontal distance of 7 feet (2134 mm) from the top of the slope shall be capable of supporting the water in the pool without soil support.

~~**1805.3.4**~~ **1808.7.4 Foundation elevation.** On graded sites, the top of any exterior foundation shall extend above the elevation of the street gutter at point of discharge or the inlet of an approved drainage device a minimum of 12 inches (305 mm) plus 2 percent. Alternate elevations are permitted subject to the approval of the building official, provided it can be demonstrated that required drainage to the point of discharge and away from the structure is provided at all locations on the site.

~~1805.3.5~~ 1808.7.5 **Alternate setback and clearance.** Alternate setbacks and clearances are permitted, subject to the approval of the building official. The building official ~~is~~ shall be permitted to require ~~an~~ a geotechnical investigation ~~and recommendation of a registered design professional to demonstrate that the intent of this section has been satisfied. Such an investigation shall include consideration of material, height of slope, slope gradient, load intensity and erosion characteristics of slope material~~ as set forth in Section 1803.5.10.

~~1805.4.2~~ 1808.8 **Concrete ~~footings~~ foundations.** The design, materials and construction of concrete ~~footings~~ foundations shall comply with Sections ~~1805.4.2.1~~ 1808.8.1 through ~~1805.4.2.6~~ 1808.8.6 and the provisions of Chapter 19.

Exception: Where ~~a specific design is not provided,~~ concrete footings supporting walls of light-frame construction are ~~permitted to be~~ designed in accordance with Table ~~1805.4.2~~ 1809.7, a specific design in accordance with Chapter 19 is not required.

~~1805.4.2.1~~ 1808.8.1 **Concrete or grout strength and mix proportioning.** Concrete or grout in ~~footings~~ foundations shall have a specified compressive strength ($f'c$) ~~of~~ not less than ~~2,500 pounds per square inch (psi) (17 237 kPa) at 28 days~~ the largest applicable value indicated in Table 1808.8.1.

~~**1810.1.1 Materials.** Concrete shall have a 28-day specified compressive strength (f'_c) of not less than 2,500 psi (17.24 MPa).~~ Where concrete is placed through a funnel hopper at the top of ~~the pile~~ a deep foundation element, the concrete mix shall be designed and proportioned so as to produce a cohesive workable mix having a slump of not less than 4 inches (102 mm) and not more than ~~6~~ 8 inches (~~152~~ 204 mm). Where concrete or grout is to be pumped, the mix design including slump shall be adjusted to produce a pumpable ~~concrete~~ mixture.

TABLE 1808.8.1
MINIMUM SPECIFIED COMPRESSIVE STRENGTH, f'_c, OF CONCRETE OR GROUT

FOUNDATION ELEMENT OR CONDITION	SPECIFIED COMPRESSIVE STRENGTH, $f'c$
1. Foundations for structures assigned to Seismic Design Category A, B, or C	2,500 psi (17.24 MPa)
2a. Foundations for Group R or U occupancies of light-frame construction, two stories or less in height, assigned to Seismic Design Category D, E, or F	2,500 psi (17.24 MPa)
2b. Foundations for other structures assigned to Seismic Design Category D, E, or F	3,000 psi (20.68 MPa)
3. Precast nonprestressed driven piles	3,000 psi (20.68 MPa)
5. Socketed drilled shafts	4,000 psi (27.58 MPa)
6. Micropiles	4,000 psi (27.58 MPa)
7. Precast prestressed driven piles	5,000 psi (34.48 MPa)

1808.8.2 Concrete cover. The concrete cover provided for prestressed and nonprestressed reinforcement in foundations shall be no less than the largest applicable value specified in Table 1808.8.2. Longitudinal bars spaced less than 1.5 inches (38 mm) clear distance apart shall be considered bundled bars for which the concrete cover provided shall also be no less than that required by Section 7.7.4 of ACI 318. Concrete cover shall be measured from the concrete surface to the outermost surface of the steel to which the cover requirement applies. Where concrete is placed in a temporary or permanent casing or a mandrel, the inside face of the casing or mandrel shall be considered the concrete surface.

TABLE 1808.8.2
MINIMUM CONCRETE COVER

FOUNDATION ELEMENT OR CONDITION	MINIMUM COVER
1. Shallow foundations	In accordance with Section 7.7 of ACI 318
2. Precast nonprestressed deep foundation elements[a] Exposed to seawater Not manufactured under plant conditions Manufactured under plant control conditions	 3 inches (76 mm) 2 inches (51 mm) In accordance with Section 7.7.3 of ACI 318
3. Precast prestressed deep foundation elements Exposed to seawater Other	 2.5 inches (64 mm) In accordance with Section 7.7.3 of ACI 318
4. Cast-in-place deep foundation elements not enclosed by a steel pipe, tube, or permanent casing	2.5 inches (64 mm)
5. Cast-in-place deep foundation elements enclosed by a steel pipe, tube, or permanent casing	1 inch (25 mm)
6. Structural steel core within a steel pipe, tube, or permanent casing	2 inches (51 mm)

~~1805.4.2.4~~ **1808.8.3 Placement of concrete.** Concrete shall be placed in such a manner as to ensure the exclusion of any foreign matter and to secure a full-sized foundation. Concrete ~~footings~~ shall not be placed through water unless a tremie or other method approved by the building official is used. Where placed under or in the presence of water, the concrete shall be deposited by approved means to ensure minimum segregation of the mix and negligible turbulence of the water. Where depositing concrete from the top of a deep foundation element, the concrete shall be chuted directly into smooth-sided pipes or tubes or placed in a rapid and continuous operation through a funnel hopper centered at the top of the element.

~~1805.4.2.5~~ **1808.8.4 Protection of concrete.** Concrete ~~footings~~ foundations shall be protected from freezing during depositing and for a period of not less than five days thereafter. Water shall not be allowed to flow through the deposited concrete.

~~1805.4.2.6~~ **1808.8.5 Forming of concrete.** Concrete ~~footings~~ foundations are permitted to be cast against the earth where, in the opinion of the building official, soil conditions do not require ~~forming~~ form work. Where ~~forming~~ form work is required, it shall be in accordance with Chapter 6 of ACI 318.

~~1805.9~~ **1808.8.6 Seismic requirements.** See Section 1908 for additional requirements for ~~footings and~~ foundations of structures assigned to Seismic Design Category C, D, E or F.

For structures assigned to Seismic Design Category D, E or F, provisions of ACI 318, Sections ~~21.10.1~~ 21.12.1 ~~to~~ through ~~21.10.3~~ 21.12.4, shall apply ~~when~~ where not in conflict with the provisions of ~~Section~~ Sections ~~1805~~ 1808 through 1810. ~~Concrete shall have a specified compressive strength of not less than 3,000 psi (20.68 MPa) at 28 days.~~

Exceptions:

~~1. Group R or U occupancies of light-framed construction and two stories or less above grade plane are permitted to use concrete with a specified compressive strength of not less than 2,500 psi (17.2 MPa) at 28 days.~~

1. Detached one- and two-family dwellings of ~~light-framed~~ light-frame construction and two stories or less above grade plane are not required to comply with the provisions of ACI 318, Sections ~~21.10.1~~ 21.12.1 ~~to~~ through ~~21.10.3~~ 21.12.4.
2. Section 21.12.4.4(a) of ACI 318 shall not apply.

~~1812.7~~ **1808.9 Vertical masonry foundation elements.** ~~Where the unsupported height of foundation piers exceeds six times the least dimension, the allowable working stress on piers of unit masonry shall be reduced~~ Vertical masonry foundation elements that are not foundation piers as defined in Section 2102.1 shall be designed as piers, walls, or columns, as applicable, in accordance with ACI 530/ASCE 5/TMS 402.

1809
SHALLOW FOUNDATIONS

~~1805.1~~ **1809.1 [Suppl] General.** ~~Footings and~~ Shallow foundations shall be designed and constructed in accordance with Sections ~~1805.1~~ 1809.2 through ~~1805.9~~ 1809.13.

1809.2 Supporting soils. ~~Footings and~~ Shallow foundations shall be built on undisturbed soil, compacted fill material or controlled low-strength material (CLSM). Compacted fill material shall be placed in accordance with Section ~~1803.5~~ 1804.5. CLSM shall be placed in accordance with Section ~~1803.6~~ 1804.6.

1809.3 Stepped footings. The top surface of footings shall be level. The bottom surface of footings ~~is~~ shall be permitted to have a slope not exceeding one unit vertical in 10 units horizontal (10-percent slope). Footings shall be stepped where it is necessary to change the elevation of the top surface of the footing or where the surface of the ground slopes more than one unit vertical in 10 units horizontal (10-percent slope).

~~1805.2~~ **1809.4 Depth and width of footings.** The minimum depth of footings below the undisturbed ground surface shall be 12 inches (305 mm). Where applicable, the ~~depth of footings~~ requirements of Section 1809.5 shall also ~~conform to Sections 1805.2.1 through 1805.2.3~~ be satisfied. The minimum width of footings shall be 12 inches (305 mm).

~~1805.2.1~~ **1809.5 Frost protection.** Except where otherwise protected from frost, foundations ~~walls, piers~~ and other permanent supports of buildings and structures shall be protected from frost by one or more of the following methods:

1. Extending below the frost line of the locality;
2. Constructing in accordance with ASCE-32; or
3. Erecting on solid rock.

Exception: Free-standing buildings meeting all of the following conditions shall not be required to be protected:
1. ~~Classified in~~ Assigned to Occupancy Category I, in accordance with Section 1604.5;
2. Area of 600 square feet (56 m^2) or less for light-frame construction or 400 square feet (37 m^2) or less for other than light-frame construction; and
3. Eave height of 10 feet (3048 mm) or less.

~~Footings~~ Shallow foundations shall not bear on frozen soil unless such frozen condition is of a permanent character.

~~1805.2.2~~ **1809.6 ~~Isolated~~ Location of footings.** Footings on granular soil shall be so located that the line drawn between the lower edges of adjoining footings shall not have a slope steeper than 30 degrees (0.52 rad) with the horizontal, unless the material supporting the higher footing is braced or retained or otherwise laterally supported in an approved manner or a greater slope has been properly established by engineering analysis.

1809.7 Prescriptive footings for light-frame construction. Where a specific design is not provided, concrete or masonry-unit footings supporting walls of light-frame construction shall be permitted to be designed in accordance with Table 1809.7.

TABLE ~~1805.4.2~~ 1809.7
PRESCRIPTIVE FOOTINGS SUPPORTING WALLS OF LIGHT-FRAME CONSTRUCTION [a, b, c, d, e]

NUMBER OF FLOORS SUPPORTED BY THE FOOTING [f]	WIDTH OF FOOTING (inches)	THICKNESS OF FOOTING (inches)
1	12	6
2	15	6
3	18	8 [g]

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

a. Depth of footings shall be in accordance with Section ~~1805.2~~ 1809.4.
b. The ground under the floor ~~is~~ shall be permitted to be excavated to the elevation of the top of the footing.
c. Interior-stud-bearing walls ~~are~~ shall be permitted to be supported by isolated footings. The footing width and length shall be twice the width shown in this table, and footings shall be spaced not more than 6 feet on center.
d. See Section 1908 for additional requirements for concrete footings of structures assigned to Seismic Design Category C, D, E or F.

e. For thickness of foundation walls, see Section ~~1805.5~~ 1807.1.6.
f. Footings ~~are~~ shall be permitted to support a roof in addition to the stipulated number of floors. Footings supporting roof only shall be as required for supporting one floor.
g. Plain concrete footings for Group R-3 occupancies ~~are~~ shall be permitted to be 6 inches thick.

~~1805.4.2.3~~ **1809.8 Plain concrete footings.** The edge thickness of plain concrete footings supporting walls of other than light-frame construction shall not be less than 8 inches (203 mm) where placed on soil or rock.

Exception: For plain concrete footings supporting Group R-3 occupancies, the edge thickness is permitted to be 6 inches (152 mm), provided that the footing does not extend beyond a distance greater than the thickness of the footing on either side of the supported wall.

~~1805.4.3~~ **1809.9 Masonry-unit footings.** The design, materials and construction of masonry-unit footings shall comply with Sections ~~1805.4.3.1~~ 1809.9.1 and ~~1805.4.3.2~~ 1809.9.2, and the provisions of Chapter 21.

Exception: Where a specific design is not provided, masonry-unit footings supporting walls of light-frame construction ~~are~~ shall be permitted to be designed in accordance with Table ~~1805.4.2~~ 1809.7.

~~1805.4.3.1~~ **1809.9.1 Dimensions.** Masonry-unit footings shall be laid in Type M or S mortar complying with Section 2103.8 and the depth shall not be less than twice the projection beyond the wall, pier or column. The width shall not be less than 8 inches (203 mm) wider than the wall supported thereon.

~~1805.4.3.2~~ **1809.9.2 Offsets.** The maximum offset of each course in brick foundation walls stepped up from the footings shall be 1.5 inches (38 mm) where laid in single courses, and 3 inches (76 mm) where laid in double courses.

~~1805.5.7~~ **1809.10 Pier and curtain wall foundations.** Except in Seismic Design Categories D, E and F, pier and curtain wall foundations ~~are~~ shall be permitted to be used to support light-frame construction not more than two stories above grade plane, provided the following requirements are met:

1. All load-bearing walls shall be placed on continuous concrete footings bonded integrally with the exterior wall footings.
2. The minimum actual thickness of a load-bearing masonry wall shall not be less than 4 inches (102 mm) nominal or 3.625 inches (92 mm) actual thickness, and shall be bonded integrally with piers spaced 6 feet (1829 mm) on center (o.c.).
3. Piers shall be constructed in accordance with Chapter 21 and the following:
   3.1. The unsupported height of the masonry piers shall not exceed 10 times their least dimension.
   3.2. Where structural clay tile or hollow concrete masonry units are used for piers supporting beams and girders, the cellular spaces shall be filled solidly with concrete or Type M or S mortar.
      Exception: Unfilled hollow piers ~~are~~ shall be permitted where the unsupported height of the pier is not more than four times its least dimension.
   3.3. Hollow piers shall be capped with 4 inches (102 mm) of solid masonry or concrete or the cavities of the top course shall be filled with concrete or grout.
4. The maximum height of a 4-inch (102mm) load-bearing masonry foundation wall supporting wood frame walls and floors shall not be more than 4 feet (1219 mm) in height.
5. The unbalanced fill for 4-inch (102 mm) foundation walls shall not exceed 24 inches (610 mm) for solid masonry, nor 12 inches (305mm) for hollow masonry.

~~1805.4.4~~ **1809.11 Steel grillage footings.** Grillage footings of structural steel shapes shall be separated with approved steel spacers and be entirely encased in concrete with at least 6 inches (152 mm) on the bottom and at least 4 inches (102 mm) at all other points. The spaces between the shapes shall be completely filled with concrete or cement grout.

~~1805.4.5~~ **1809.12 Timber footings.** Timber footings ~~are~~ shall be permitted for buildings of Type V construction and as otherwise approved by the building official. Such footings shall be treated in accordance with AWPA U1 (Commodity Specification A, Use Category 4B). Treated timbers are not required where placed entirely below permanent water level, or where used as capping for wood piles that project above the water level over submerged or marsh lands. The compressive stresses perpendicular to grain in untreated timber footings supported upon treated piles shall not exceed 70 percent of the allowable stresses for the species and grade of timber as specified in the AF&PA NDS.

~~1805.4.2.2~~ 1809.13 **Footing seismic ties.** Where a structure is assigned to Seismic Design Category D, E or F in accordance with Section 1613, individual spread footings founded on soil defined in Section 1613.5.2 as Site Class E or F shall be interconnected by ties. Unless it is demonstrated that equivalent restraint is provided by reinforced concrete beams within slabs on grade or reinforced concrete slabs on grade, ties shall be capable of carrying, in tension or compression, a force equal to the lesser of the product of the larger footing design gravity load times the seismic coefficient S_{DS} divided by 10 ~~unless it is demonstrated that equivalent restraint is provided by reinforced concrete beams within slabs on grade or reinforced concrete slabs on grade~~, and 25 percent of the smaller footing design gravity load.

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.

~~1808.2.2~~ **1810.1.1 ~~General~~ Geotechnical investigation.** ~~Pier and pile~~ Deep foundations shall be designed and installed on the basis of a ~~foundation~~ geotechnical investigation as ~~defined~~ set forth in Section ~~1802~~ 1803 ~~unless sufficient data upon which to base the design and installation is available~~.

~~The investigation and report provisions of Section 1802 shall be expanded to include, but not be limited to, the following:~~

~~1. Recommended pier or pile types and installed capacities.~~
~~2. Recommended center-to-center spacing of piers or piles.~~
~~3. Driving criteria.~~
~~4. Installation procedures.~~
~~5. Field inspection and reporting procedures (to include procedures for verification of the installed bearing capacity where required).~~
~~6. Pier or pile load test requirements.~~
~~7. Durability of pier or pile materials.~~
~~8. Designation of bearing stratum or strata.~~
~~9. Reductions for group action, where necessary.~~

~~1808.2.18~~ **1810.1.2 Use of existing ~~piers or piles~~ deep foundation elements.** ~~Piers or piles~~ 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 ~~piers or piles~~ elements are sound and meet the requirements of this code. Such ~~piers or piles~~ elements shall be load tested or redriven to verify their capacities. The design load applied to such ~~piers or piles~~ 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.

~~1808.2.3~~ **1810.1.4 Special types of ~~piles~~ deep foundations.** The use of types of ~~piles~~ 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 ~~piles~~ 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.

~~1808.2.9.1~~ **1810.2.1 ~~General~~ Lateral support.** Any soil other than fluid soil shall be deemed to afford sufficient lateral support ~~the pier or pile~~ to prevent buckling of deep foundation elements and to permit the design of the ~~pier or pile~~ elements in accordance with accepted engineering practice and the applicable provisions of this code.

~~1808.2.9.2 Unbraced piles.~~ ~~Piles standing~~ Where deep foundation elements stand unbraced in air, water, or ~~in~~ fluid soils, it shall be ~~designed as columns in accordance with the provisions of this code. Such piles driven into firm ground can be~~

~~considered~~ permitted to consider them ~~fixed and~~ laterally supported at a point 5 feet (1524 mm) ~~below the ground surface and in soft material at~~ into stiff soil or 10 feet (3048 mm) ~~below the ground surface~~ into soft soil unless otherwise ~~prescribed~~ approved by the building official ~~after~~ on the basis of a ~~foundation~~ geotechnical investigation by ~~an approved agency~~ a registered design professional.

~~1808.2.5~~ **1810.2.2 Stability.** ~~Piers or piles~~ Deep foundation elements shall be braced to provide lateral stability in all directions. Three or more ~~piles~~ elements connected by a rigid cap shall be considered braced, provided that the ~~piles~~ elements are located in radial directions from the centroid of the group not less than 60 degrees (1 rad) apart. A ~~two-pile~~ two-element group in a rigid cap shall be considered to be braced along the axis connecting the two ~~piles~~ elements. Methods used to brace ~~piers or piles~~ deep foundation elements shall be subject to the approval of the building official.

~~Piles~~ Deep foundation elements supporting walls shall be ~~driven~~ placed alternately in lines spaced at least 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 ~~wall piles~~ foundation elements are adequately braced to provide for lateral stability. ~~A single row of piles 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 the centers of the piles are located within the width of the foundation wall.~~

Exceptions:

1. Isolated cast-in-place deep foundation elements without lateral bracing shall be permitted where the least horizontal dimension is no 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 the centers of the elements are located within the width of the supported wall.

~~1808.2.12~~ **1810.2.3 Settlement ~~analysis~~.** The settlement of ~~piers, individual piles or groups of piles~~ 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 ~~stresses to exceed allowable values~~ element to be loaded beyond its capacity.

~~1808.2.23.1.2~~ **1810.2.4 ~~Design details~~ Lateral loads.** ~~Pier or pile~~ 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 ~~recommended~~ determined by a registered design professional. Where the ratio of the depth of embedment of the ~~pile-to-pile diameter or width~~ element to its least horizontal dimension is less than or equal to six, ~~the pile may be assumed to be~~ it shall be permitted to assume the element is rigid.

~~Pile group effects from soil on lateral pile nominal strength shall be included where pile center-to-center spacing in the direction of lateral force is less than eight pile diameters. Pile group effects on vertical nominal strength shall be included where pile center-to-center spacing is less than three pile diameters. The pile uplift soil nominal strength shall be taken as the pile uplift strength as limited by the frictional force developed between the soil and the pile.~~

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

~~1808.2.23.2.1~~ **1810.2.4.1 ~~Design details for piers, piles and grade beams~~ Seismic Design Categories D through F.** ~~Piers or piles~~ 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 1613.5.2, 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-~~pile~~ foundation-structure interaction coupled with ~~pier or pile~~ foundation element deformations ~~induced by lateral pier or pile resistance to structure seismic forces~~ associated with earthquake loads imparted to the foundation by the structure.

Exception: ~~Piers or piles~~ 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 ~~1809.2.3.2.2~~ 1810.3.8.3.3.
2. Cast-in-place ~~concrete piles~~ deep foundation elements with a minimum longitudinal reinforcement ratio of 0.005 extending the full length of the ~~pile~~ element and detailed in accordance with Sections ~~21.4.4.1~~ 21.6.4.2, ~~21.4.4.2~~ 21.6.4.3 and ~~21.4.4.3~~ 21.6.4.4 of ACI 318 as required by ~~this~~ Section 1810.3.9.4.2.2.

~~Where constructed of nonprestressed concrete such piers or piles shall be designed and detailed in accordance with Sections 21.4.4.1, 21.4.4.2 and 21.4.4.3 of ACI 318 within seven pile diameters of the pile cap and within seven pile diameters of the interfaces of strata that are hard or stiff and strata that are liquefiable or are composed of soft to medium stiff clay.~~

~~Grade beams shall comply with the provisions in Section 21.10.3 of ACI 318 for grade beams, except where they have the capacity to resist the forces from the load combinations in Section 1605.4.~~

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.

1810.3 Design and Detailing. Deep foundations shall be designed and detailed in accordance with Sections 1810.3.1 through 1810.3.12.

1810.3.1 Design conditions. Design of deep foundations shall include the design conditions specified in Sections 1810.3.1.1 through 1810.3.1.5, 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 no greater than those resulting from accidental eccentricities, structural design of the element using the load combinations of Section 1605.3 and the allowable stresses specified in this chapter shall be permitted. Otherwise, the structural design of concrete deep foundation elements shall use the load combinations of Section 1605.2 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.

~~**1808.2.8.8**~~ **1810.3.1.3** ~~**Overloads on piers or piles**~~ **Mislocation.** The ~~maximum compressive load on any pier or pile due to mislocation shall not exceed~~ foundation or superstructure shall be designed to resist the effects of the mislocation of any deep foundation element by no less than 3 inches. To resist the effects of mislocation, compressive overload of deep foundation elements to 110 percent of the allowable design load shall be permitted.

~~**1809.2.1.1**~~ **1810.3.1.4** ~~**Design and manufacture**~~ **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.

~~**1810.5.1**~~ **1810.3.1.5** ~~**Materials**~~ **Casings.** ~~Pile shells or~~ Temporary and permanent casings shall be of steel and shall be sufficiently strong to resist collapse and sufficiently water tight to exclude any foreign materials during the placing of concrete. ~~Steel shells shall have a sealed tip with a diameter of not less than 8 inches (203 mm).~~ 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 foundations elements shall satisfy the requirements of Sections 1810.3.2.1 through 1810.3.2.8, as applicable.

~~**1810.2.1**~~ **1810.3.2.1** ~~**Materials**~~ **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 ~~for concrete~~ shall be 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 in accordance with Section 1613, 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 (10.5). Where this chapter requires detailing of concrete deep foundation elements in accordance with Section 21.6.4.4 of ACI 318, compliance with Equation (10-5) of ACI 318 shall not be required.

1810.3.2.2 Prestressing steel. Prestressing steel shall conform to ASTM A 416.

~~1809.3.1~~ **1810.3.2.3 ~~Materials~~ Structural steel.** Structural steel piles, steel pipe and fully welded steel piles fabricated from plates shall conform to ASTM A 36, ASTM A 252, ASTM A 283, ASTM A 572, ASTM A 588, ASTM A 690, ASTM A 913 or ASTM A 992.

~~1809.1~~ **1810.3.2.4 Timber ~~piles~~.** Timber ~~piles~~ deep foundation elements shall be designed as piles or poles in accordance with the AF&PA NDS.

~~1809.1.1 Materials~~**.** Round timber ~~piles~~ elements shall conform to ASTM D 25. Sawn timber ~~piles~~ elements shall conform to DOC PS-20.

~~1809.1.2~~ **1810.3.2.4.1 Preservative treatment.** Timber ~~piles~~ 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 ~~piles~~ 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 ~~piles~~ elements and AWPA U1 (Commodity Specification A, Use Category 4B) for sawn timber ~~piles~~ elements. Preservative-treated timber ~~piles~~ elements shall be subject to a quality control program administered by an approved agency. ~~Pile~~ Element cutoffs shall be treated in accordance with AWPA M4.

~~1808.2.17~~ **1810.3.2.5 Protection of ~~pile~~ materials.** Where boring records or site conditions indicate possible deleterious action on ~~pier or pile~~ the materials used in deep foundation elements because of soil constituents, changing water levels or other factors, the ~~pier or pile materials~~ elements shall be adequately protected by materials, methods or processes approved by the building official. Protective materials shall be applied to the ~~piles~~ elements so as not to be rendered ineffective by ~~driving~~ 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 [a]
1. Concrete or grout in compression [b]	
Cast-in-place with a permanent casing in accordance with Section 1810.3.2.7	$0.4 f'_c$
Cast-in-place in a pipe, tube, other permanent casing, or rock	$0.33 f'_c$
Cast-in-place without a permanent casing	$0.3 f'_c$
Precast nonprestressed	$0.33 f'_c$
Precast prestressed	$0.33 f'_c - 0.27 f_{pc}$
2. Nonprestressed reinforcement in compression	$0.4 f_y \le 30{,}000$ psi
3. Structural steel in compression	
Cores within concrete-filled pipes or tubes	$0.5 F_y \le 32{,}000$ psi
Pipes, tubes, or H-piles, where justified in accordance with Section 1810.3.2.8	$0.5 F_y \le 32{,}000$ psi
Pipes or tubes for micropiles	$0.4 F_y \le 32{,}000$ psi
Other pipes, tubes, or H-piles	$0.35 F_y \le 16{,}000$ psi
5. Nonprestressed reinforcement in tension	
Within micropiles	$0.6 f_y$
Other conditions	$0.5 f_y \le 24{,}000$ psi
6. Structural steel in tension	
Pipes, tubes, or H-piles, where justified in accordance with Section 1810.3.2.8	$0.5 F_y \le 32{,}000$ psi
Other pipes, tubes, or H-piles	$0.35 F_y \le 16{,}000$ psi
7. Timber	In accordance with the AF&PA NDS

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 structural steel.

b. The stresses specified apply to the gross cross-sectional area within the concrete surface. Where a temporary or permanent casing is used, the inside face of the casing shall be considered the concrete surface.

~~**1810.5.2**~~ **1810.3.2.7** ~~**Allowable stresses**~~ **Increased allowable compressive stress for cased cast-in-place elements.** The allowable ~~design~~ compressive stress in the concrete ~~shall not exceed 33 percent of the 28-day specified compressive strength (f'_c). The allowable concrete compressive stress shall be 0.40 (f'_c) for that portion of the pile meeting the conditions specified in Sections 1810.5.2.1 through 1810.5.2.4.~~ 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. ~~**1810.5.2.1 Shell thickness.**~~ The thickness of the ~~steel shell~~ casing shall not be less than manufacturer's standard gage No. 14 ~~gage~~ (0.068 inch) (1.75 mm) ~~minimum~~.
4. ~~**1810.5.2.2 Shell type.**~~ The ~~shell~~ 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. ~~**1810.5.2.3 Strength.**~~ The ratio of steel yield strength (F_y) to ~~28-day~~ specified compressive strength (f'_c) shall not be less than six.
6. ~~**1810.5.2.4 Diameter.**~~ The nominal ~~pile~~ diameter of the element shall not be greater than 16 inches (406 mm).

~~**1808.2.10**~~ **1810.3.2.8** ~~**Use**~~ **Justification of higher allowable ~~pier or pile~~ stresses.** Use of allowable stresses greater than those specified ~~for piers or for each pile type in Sections 1809 and 1810 are~~ 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:

1. A ~~soils~~ geotechnical investigation in accordance with Section ~~1802~~ 1803~~.~~; and
2. ~~Pier or pile~~ Load tests in accordance with Section ~~1808.2.8.3~~ 1810.3.3.1.2, regardless of the load supported by the ~~pier or pile~~ element.

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

~~**1808.2.8.1**~~ **1810.3.3 Determination of allowable loads.** The allowable axial and lateral loads on ~~piers or piles~~ 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 Section 1810.3.3.1.1 through 1810.3.3.1.8.

~~**1808.2.8.2**~~ **1810.3.3.1.1 Driving criteria.** The allowable compressive load on any ~~pile~~ 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 ~~pile~~ driveability ~~of~~ 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 ~~1808.2.8.3~~ 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 ~~piles~~ 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.

~~**1808.2.8.3**~~ **1810.3.3.1.2 Load tests.** Where design compressive loads ~~per pier or pile~~ are greater than those ~~permitted by Section 1808.2.10 or~~ determined using the allowable stresses specified in Section 1810.3.2.6, where the design load for any ~~pier or pile~~ 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 ~~piers or piles~~ elements shall be tested in accordance with ASTM D 1143 or ASTM D 4945. At least one ~~pier or pile~~ element shall be ~~test loaded~~ load tested in each area of uniform subsoil conditions. Where required by the building official, additional ~~piers or piles~~ 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 ~~pier or pile~~ element as assessed by one of the published methods listed in Section ~~1808.2.8.3.1~~ 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 ~~1808.2.12~~

1810.2.3. In subsequent installation of the balance of deep foundation ~~piles~~ elements, all ~~piles~~ elements shall be deemed to have a supporting capacity equal to that of the control ~~pile~~ element where such ~~piles~~ elements are of the same type, size and relative length as the test ~~pile~~ element; are installed using the same or comparable methods and equipment as the test ~~pile~~ element; are installed in similar subsoil conditions as the test ~~pile~~ element; and, for driven ~~piles~~ elements, where the rate of penetration (e.g., net displacement per blow) of such ~~piles~~ elements is equal to or less than that of the test ~~pile~~ element driven with the same hammer through a comparable driving distance.

~~**1808.2.8.3.1**~~ **1810.3.3.1.3 Load test evaluation methods.** It shall be permitted to evaluate ~~pile~~ load tests ~~with~~ of deep foundation elements using any of the following methods:

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

~~**1808.2.8.4**~~ **1810.3.3.1.4 Allowable frictional resistance.** The assumed frictional resistance developed by any ~~pier or~~ uncased cast-in-place ~~pile~~ deep foundation element shall not exceed one-sixth of the bearing value of the soil material at minimum depth as set forth in Table ~~1804.2~~ 1806.2, up to a maximum of 500 psf (24 kPa), unless a greater value is allowed by the building official ~~after~~ on the basis of a ~~soil~~ geotechnical investigation as specified in Section ~~1802~~ 1803 is submitted or a greater value is substantiated by a load test in accordance with Section ~~1808.2.8.3~~ 1810.3.3.1.2. Frictional resistance and bearing resistance shall not be assumed to act simultaneously unless ~~recommended~~ determined by a ~~soil~~ geotechnical investigation ~~as specified~~ in accordance with Section ~~1802~~ 1803.

~~**1808.2.8.5**~~ **1810.3.3.1.5 Uplift capacity of a single deep foundation element.** Where required by the design, the uplift capacity of a single ~~pier or pile~~ 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 D 3689. The maximum allowable uplift load shall not exceed the ultimate load capacity as determined in Section ~~1808.2.8.3~~ 1810.3.3.1.2, using the results of load tests conducted in accordance with ASTM D 3689, 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 2 where capacity is determined by analysis and 1.5 where capacity is determined by load tests.

1810.3.3.1.6 Uplift capacity of grouped deep foundation elements. For ~~pile groups~~ grouped deep foundation elements subjected to uplift, the allowable working uplift load for the group shall be calculated by an approved method of analysis. If the deep foundation elements in the group are placed at a center-to-center spacing of at least 2.5 times the least horizontal dimension of the largest single element, the allowable working uplift load for the group is permitted to be calculated as the lesser of:

1. The proposed individual ~~pile~~ uplift working load times the number of ~~piles~~ elements in the group.
2. Two-thirds of the effective weight of the ~~pile~~ group and the soil contained within a block defined by the perimeter of the group and the length of the ~~pile~~ element.

~~**1808.2.8.6**~~ **1810.3.3.1.7 Load-bearing capacity.** ~~Piers, individual piles and groups of piles~~ Deep foundation elements shall develop ultimate load capacities of at least twice the design working loads in the designated load-bearing layers. Analysis shall show that no soil layer underlying the designated load-bearing layers causes the load-bearing capacity safety factor to be less than two.

~~**1808.2.8.7**~~ **1810.3.3.1.8 Bent ~~piers or piles~~ deep foundation elements.** The load-bearing capacity of ~~piers or piles~~ 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 ~~pier or pile~~ element.

~~**1808.2.9.3**~~ **1810.3.3.2 Allowable lateral load.** Where required by the design, the lateral load capacity of a ~~pier, a~~ single ~~pile~~ deep foundation element or a ~~pile~~ group thereof shall be determined by an approved method of analysis or by lateral load tests to at least twice the proposed design working load. The resulting allowable load shall not be more than one-half of the ~~that test~~ 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.

~~1808.2.11~~ **1810.3.4** ~~**Piles in S**~~**Subsiding** ~~**areas**~~ **soils.** Where ~~piles~~ deep foundation elements are installed through subsiding fills or other subsiding strata and derive support from underlying firmer materials, consideration shall be given to the downward frictional forces that may be imposed on the ~~piles~~ elements by the subsiding upper strata.

Where the influence of subsiding fills is considered as imposing loads on the ~~pile~~ element, the allowable stresses specified in this chapter ~~are~~ 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.

~~1809.2.1.2~~ **1810.3.5.1** ~~**Minimum dimension**~~ **Precast.** The minimum lateral dimension of precast concrete deep foundation elements shall be 8 inches (203 mm). Corners of square ~~piles~~ 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 deep foundation elements with a permanent casing shall have a nominal outside diameter of not less than 8 inches (203 mm).

~~1810.3.2~~ **1810.3.5.2.2** ~~**Dimensions**~~ **Uncased.** Cast-in-place deep foundation elements without a permanent casing shall have a diameter of not less than 12 inches (305 mm). The ~~pile~~ element length shall not exceed 30 times the average diameter. ~~The minimum diameter shall be 12 inches (305 mm).~~

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

1810.3.5.2.3 Micropiles. Micropiles shall have an outside 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.

~~1809.3.3~~ **1810.3.5.3.1** ~~**Dimensions of**~~ **H-piles.** Sections of H-piles 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 not be less than 80 percent of the depth of the section.
2. The nominal depth in the direction of the web shall not be less than 8 inches (203 mm).
3. Flanges and web shall have a minimum nominal thickness of 3/8 inch (9.5 mm).

~~1809.3.4~~ **1810.3.5.3.2** ~~**Dimensions of**~~ **Steel pipes** ~~**piles**~~ **and tubes.** Steel ~~pipe piles driven open ended~~ pipes and tubes used as deep foundation elements shall have a nominal outside diameter of not less than 8 inches (203 mm). ~~The pipe~~ Where steel pipes or tubes are driven open-ended, they shall have a minimum of 0.34 square inch (219 mm^2) 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 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 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. ~~**1810.6.3 Minimum dimensions.** Piles shall have a nominal outside diameter of not less than 8 inches (203 mm) and a minimum wall thickness in accordance with Section 1809.3.4.~~ For mandrel-driven pipes or tubes ~~piles~~, the minimum wall thickness shall be 1/10 inch (2.5 mm).

~~**1808.2.7**~~ **1810.3.6 Splices.** Splices shall be constructed so as to provide and maintain true alignment and position of the component parts of the ~~pier or pile~~ deep foundation element during installation and subsequent thereto and shall be ~~of adequate strength~~ designed to ~~transmit the vertical and lateral loads~~ resist the axial and shear forces and moments occurring at the location of the splice during driving and ~~under service loading~~ 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 ~~least capacity of the pier or pile in~~ 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.

~~In addition,~~ Splices occurring in the upper 10 feet (3048 mm) of the embedded portion of ~~the pier or pile~~ an element shall be ~~capable of resisting~~ designed to resist at allowable ~~working~~ stresses the moment and shear that would result from an assumed eccentricity of the ~~pier or pile~~ axial load of 3 inches (76 mm), or the ~~pier or pile~~ element shall be braced in accordance with Section ~~1808.2.5~~ 1810.2.2 to other ~~piers or piles~~ 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 full strength of the deep foundation element; and
2. The axial and shear forces and moments from the load combinations with overstrength factor in Section 12.4.3.2 of ASCE 7.

1810.3.7 Top of pile 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.

~~**1809.2.1**~~ **1810.3.8 ~~General~~ Precast concrete piles.** ~~The materials, reinforcement and installation of~~ Precast concrete piles shall ~~conform to~~ be designed and detailed in accordance with Sections ~~1809.2.1.1 through 1809.2.1.4~~ 1810.3.8.1 through 1810.3.8.3.

~~**1809.2.1.3**~~ **1810.3.8.1 Reinforcement.** Longitudinal steel shall be arranged in a symmetrical pattern and be laterally tied with steel ties or wire spiral spaced center to center as follows:

1. At not more than 1 inch (25 mm) for the first five ties or spirals at each end; then
2. At not more than 4 inches (102 mm) ~~apart, center to center,~~ for ~~a distance of~~ the remainder of the first 2 feet (610 mm) from ~~the ends of the pile~~ each end; and then
3. At not more than 6 inches (152 mm) elsewhere ~~except that at the ends of each pile, the first five ties or spirals shall be spaced 1 inch (25 mm) center to center~~.

The size ~~gage~~ of ties and spirals shall be as follows:

1. For piles having a ~~diameter~~ least horizontal dimension of 16 inches (406 mm) or less, wire shall not be smaller than 0.22 inch (5.6 mm) (No. 5 gage).
2. For piles having a ~~diameter~~ least horizontal dimension of more than 16 inches (406 mm) and less than 20 inches (508 mm), wire shall not be smaller than 0.238 inch (6 mm) (No. 4 gage).
3. For piles having a ~~diameter~~ least horizontal dimension of 20 inches (508 mm) and larger, wire shall not be smaller than 0.25 inch (6.4 mm) round or 0.259 inch (6.6 mm) (No. 3 gage).

~~**1809.2.2**~~ **1810.3.8.2 Precast nonprestressed piles.** Precast nonprestressed concrete piles shall ~~conform to~~ comply with the requirements of Sections ~~1809.2.2.1~~ 1810.3.8.2.1 through ~~1809.2.2.5~~ 1810.3.8.2.3.

~~**1809.2.2.2**~~ **1810.3.8.2.1 Minimum reinforcement.** ~~The minimum amount of~~ Longitudinal reinforcement shall ~~be 0.8 percent of the concrete section and shall consist of at least four bars~~ consist of at least four bars with a minimum longitudinal reinforcement ratio of 0.008.

~~**1809.2.2.2.1**~~ **1810.3.8.2.2 Seismic reinforcement in Seismic Design ~~Category~~ Categories C through F.** ~~Where a~~ For structures ~~is~~ assigned to Seismic Design Category C, D, E, or F in accordance with Section 1613, ~~the following shall apply~~ precast nonprestressed piles shall be reinforced as specified in this section. The minimum longitudinal reinforcement ~~with a minimum steel~~ ratio ~~of~~ shall be 0.01 ~~shall be provided~~ throughout the length ~~of precast concrete piles~~. ~~Within three pile diameters of the bottom of the pile cap, the longitudinal reinforcement shall be confined with~~ Transverse reinforcement shall consist of closed ties or spirals ~~of~~ with a minimum 3/8 inch (9.5 mm) diameter. ~~Ties or spirals shall be provided at a maximum spacing of~~ Spacing of transverse reinforcement shall not exceed the smaller of eight times the diameter of the smallest longitudinal bar ~~not to exceed~~ or, 6 inches (152 mm) within a distance of three times the least pile dimension from the bottom of the pile cap. Spacing of transverse reinforcement shall not exceed 6 inches (152 mm) throughout the remainder of the pile~~, the closed ties or spirals shall have a maximum spacing of 16 times the smallest longitudinal bar diameter, not to exceed 8 inches (203 mm)~~.

~~**1809.2.2.2.2**~~ **1810.3.8.2.3 Additional seismic reinforcement in Seismic Design ~~Category~~ Categories D through~~, E or~~ F.** ~~Where a~~ For structures ~~is~~ assigned to Seismic Design Category D, E or F in accordance with Section 1613, ~~the requirements for Seismic Design Category C in Section 1809.2.2.2.1 shall apply except as modified by this section. Transverse confinement reinforcement consisting of closed ties or equivalent spirals shall be provided in accordance with Sections 21.4.4.1, 21.4.4.2 and 21.4.4.3 of ACI 318 within three pile diameters of the bottom of the pile cap. For other than Site Class E or F, or liquefiable sites and where spirals are used as the transverse reinforcement, it shall be permitted to use a volumetric ratio of spiral reinforcement of not less than one-half that required by Section 21.4.4.1(a) of ACI 318~~ transverse reinforcement shall be in accordance with Section 1810.3.9.4.2.

~~**1809.2.3**~~ **1810.3.8.3 Precast prestressed piles.** Precast prestressed concrete piles shall ~~conform to~~ comply with the requirements of Sections ~~1809.2.3.1~~ 1810.3.8.3.1 through ~~1809.2.3.5~~ 1810.3.8.3.3.

~~**1809.2.3.2**~~ **1810.3.8.3.1 ~~Design~~ Effective prestress.** ~~Precast prestressed piles shall be designed to resist stresses induced by handling and driving as well as by loads.~~ The effective prestress in the pile shall not be less than 400 psi (2.76 MPa) for piles up to 30 feet (9144 mm) in length, 550 psi (3.79 MPa) for piles up to 50 feet (15 240 mm) in length and 700 psi (4.83 MPa) for piles greater than 50 feet (15 240 mm) in length.

Effective prestress shall be based on an assumed loss of 30,000 psi (207 MPa) in the prestressing steel. The tensile stress in the prestressing steel shall not exceed the values specified in ACI 318.

~~**1809.2.3.2.1**~~ **1810.3.8.3.2 ~~Design~~ Seismic reinforcement in Seismic Design Category C.** ~~Where a~~ For structures ~~is~~ assigned to Seismic Design Category C in accordance with Section 1613, ~~the following shall apply~~ precast prestressed piles shall have transverse reinforcement in accordance with this section. The ~~minimum~~ volumetric ratio of spiral reinforcement shall not be less than ~~0.007 or~~ the amount required by the following formula for the upper 20 feet (6096 mm) of the pile.

$$\rho_s = 0.12 f'_c / f_{yh} \qquad \textbf{(Equation 18-4)}$$

where:

f'_c = Specified compressive strength of concrete, psi (MPa)
f_{yh} = Yield strength of spiral reinforcement ≤ 85,000 psi (586 MPa).
ρ_s = Spiral reinforcement index (vol. spiral/vol. core).

At least one-half the volumetric ratio required by Equation 18-4 shall be provided below the upper 20 feet (6096 mm) of the pile.

~~The pile cap connection by means of dowels as indicated in Section 1808.2.23.1 is permitted. Pile cap connection by means of developing pile reinforcing strand is permitted provided that the pile reinforcing strand results in a ductile connection.~~

~~**1809.2.3.2.2**~~ **1810.3.8.3.3 ~~Design~~ Seismic reinforcement in Seismic Design ~~Category~~ Categories D through~~, E or~~ F.** ~~Where a~~ For structures ~~is~~ assigned to Seismic Design Category D, E or F in accordance with Section 1613, ~~the requirements for Seismic Design Category C in Section 1809.2.3.2.1 shall be met, in addition to~~ precast prestressed piles shall have transverse reinforcement in accordance with the following:

1. Requirements in ACI 318, Chapter 21, need not apply, unless specifically referenced.
2. Where the total pile length in the soil is 35 feet (10 668 mm) or less, the lateral transverse reinforcement in the ductile region shall occur through the length of the pile. Where the pile length exceeds 35 feet (10 668 mm), the

ductile pile region shall be taken as the greater of 35 feet (10 668 mm) or the distance from the underside of the pile cap to the point of zero curvature plus three times the least pile dimension.

3. In the ductile region, the center-to-center spacing of the spirals or hoop reinforcement shall not exceed one-fifth of the least pile dimension, six times the diameter of the longitudinal strand, or 8 inches (203 mm), whichever is ~~smaller~~ smallest.
4. Circular spiral reinforcement shall be spliced by lapping one full turn and bending the end of ~~the~~ each spiral to a 90-degree hook or by use of a mechanical or welded splice complying with Sec. 12.14.3 of ACI 318.
5. Where the transverse reinforcement consists of circular spirals, the volumetric ratio of spiral transverse reinforcement in the ductile region shall comply with the following:

$$\rho_s = 0.25(f'_c/f_{yh})(A_g/A_{ch} - 1.0)[0.5 + 1.4P/(f'_c A_g)] \quad \textbf{(Equation 18-5)}$$

but not less than:

$$\rho_s = 0.12(f'_c/f_{yh})[0.5 + 1.4P/(f'_c A_g)] \geq 0.12 f'_c/f_{yh} \quad \textbf{(Equation 18-6)}$$

and need not exceed:

$$\rho_s = 0.021 \quad \textbf{(Equation 18-7)}$$

where:

A_g = Pile cross-sectional area, square inches (mm^2).
A_{ch} = Core area defined by spiral outside diameter, square inches (mm^2).
f'_c = Specified compressive strength of concrete, psi (MPa)
f_{yh} = Yield strength of spiral reinforcement ≤ 85,000 psi (586 MPa).
P = Axial load on pile, pounds (kN), as determined from Equations 16-5 and ~~16-6~~ 16-7.
ρ_s = Volumetric ratio (vol. spiral/ vol. core).

This required amount of spiral reinforcement is permitted to be obtained by providing an inner and outer spiral.

6. ~~When~~ Where transverse reinforcement consists of rectangular hoops and cross ties, the total cross-sectional area of lateral transverse reinforcement in the ductile region with spacing, s, and perpendicular ~~to~~ dimension, h_c, shall conform to:

$$A_{sh} = 0.3s\,h_c\,(f'_c/f_{yh})(A_g/A_{ch} - 1.0)[0.5 + 1.4P/(f'_c A_g)] \quad \textbf{(Equation 18-8)}$$

but not less than:

$$A_{sh} = 0.12s\,h_c\,(f'_c/f_{yh})[0.5 + 1.4P/(f'_c A_g)] \quad \textbf{(Equation 18-9)}$$

where:

f_{yh} = ≤ 70,000 psi (483 MPa).
h_c = Cross-sectional dimension of pile core measured center to center of hoop reinforcement, inch (mm).
s = Spacing of transverse reinforcement measured along length of pile, inch (mm).
A_{sh} = Cross-sectional area of tranverse reinforcement, square inches (mm^2)
f'_c = Specified compressive strength of concrete, psi (MPa)

The hoops and cross ties shall be equivalent to deformed bars not less than No. 3 in size. Rectangular hoop ends shall terminate at a corner with seismic hooks.

Outside of the length of the pile requiring transverse confinement reinforcing, the spiral or hoop reinforcing with a volumetric ratio not less than one-half of that required for transverse confinement reinforcing shall be provided.

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 (ϕM_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 18-10)**

where:
f'_c = Specified compressive strength of concrete or grout, psi (MPa)
S_m = Elastic section modulus, neglecting reinforcement and casing, in^3 (mm^3)

1810.3.9.2 Required reinforcement. Where subject to uplift or where the required moment strength determined using the load combinations of Section 1605.2 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.

~~**1810.1.2**~~ **1810.3.9.3 Placement of reinforcement.** ~~Except for steel dowels embedded 5 feet (1524 mm) or less in the pile and as provided in Section 1810.3.4,~~ Reinforcement where required shall be assembled and tied together and shall be placed in the ~~pile~~ deep foundation element as a unit before the reinforced portion of the ~~pile~~ element is filled with concrete ~~except in augered uncased cast-in-place piles. Tied reinforcement in augered uncased cast-in-place piles shall be placed after piles are concreted, while the concrete is still in a semifluid state~~.

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.
2. ~~**1810.3.4 Reinforcement.**~~ For ~~piles~~ deep foundation elements installed with a hollow-stem auger ~~where full-length~~, tied reinforcement shall be placed after elements are concreted, while the concrete is still in a semifluid state. Longitudinal ~~steel~~ reinforcement ~~is placed~~ without lateral ties~~,~~ ~~the reinforcement~~ shall be placed either through the hollow stem of the auger prior to ~~filling the pile with concrete~~ concreting or after concreting, while the concrete is still in a semifluid state. ~~All pile reinforcement shall have a concrete cover of not less than 2.5 inches (64 mm).~~
   ~~**Exception:** Where physical constraints do not allow the placement of the longitudinal reinforcement prior to filling the pile with concrete or where partial-length longitudinal reinforcement is placed without lateral ties, the reinforcement is allowed to be placed after the piles are completely concreted but while 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 the construction method can be demonstrated to the satisfaction of the building official.

~~**1812.4**~~ **1810.3.9.4** ~~**Reinforcement**~~ **Seismic reinforcement.** ~~Except for steel dowels embedded 5 feet (1524 mm) or less in the pier, reinforcement where required shall be assembled and tied together and shall be placed in the pier hole as a unit before the reinforced portion of the pier is filled with concrete~~ 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.

~~**Exception:** Reinforcement is permitted to be wet set and the 2-1/2 inch (64 mm) concrete cover requirement be reduced to 2 inches (51 mm) for Group R-3 and U occupancies not exceeding two stories of light-frame construction, provided the construction method can be demonstrated to the satisfaction of the building official.~~

~~Reinforcement shall conform to the requirements of Sections 1810.1.2.1 and 1810.1.2.2.~~

Exceptions:
1. Isolated ~~piers~~ deep foundation elements supporting posts of Group R-3 and U occupancies not exceeding two stories of light-frame construction ~~are~~ shall be permitted to be reinforced as required by rational analysis but with not less than ~~a minimum of~~ one No. 4 bar, without ties or spirals, ~~when~~ where detailed so the ~~pier~~ element is not subject to lateral loads and the soil ~~is determined to be of adequate stiffness~~ provides adequate lateral support in accordance with Section 1810.2.1.
2. Isolated ~~piers~~ 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 ~~are~~ shall be permitted to be reinforced as required by rational analysis but with not less than one No. 4 bar, without ties or spirals, ~~when~~ where the lateral load, E, to the top of the ~~pier~~ element does not exceed 200 pounds (890 N) and the soil ~~is determined to be of adequate stiffness~~ provides adequate lateral support in accordance with Section 1810.2.1.

3. ~~Piers~~ Deep foundation elements supporting the concrete foundation wall of Group R-3 and U occupancies not exceeding two stories of light-frame construction ~~are~~ shall be permitted to be reinforced as required by rational analysis but with not less than two No. 4 bars, without ties or spirals, ~~when it can be shown the concrete pier will not rupture when designed for the maximum seismic load, E_m,~~ 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 12.4.3.2 of ASCE 7 and the soil ~~is determined to be of adequate stiffness~~ provides adequate lateral support in accordance with Section 1810.2.1.
4. Closed ties or spirals where required by Section ~~1810.1.2.2~~ 1810.3.9.4.2 ~~are~~ shall be permitted to be limited to the top 3 feet (914 mm) of ~~the piers~~ 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.

~~1810.1.2.1~~ 1810.3.9.4.1 Seismic reinforcement in Seismic Design Category C. For ~~Where a~~ structures ~~is~~ assigned to Seismic Design Category C in accordance with Section 1613, ~~the following shall apply~~ cast-in-place deep foundation elements shall be reinforced as specified in this section. Reinforcement shall be provided where required by analysis.

A minimum of four longitudinal bars, with a minimum longitudinal reinforcement ratio of 0.0025, shall be provided ~~for uncased cast-in-place concrete drilled or augered piles, piers or caissons in the top~~ throughout the minimum reinforced length of the element as defined below 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 ~~pile~~ element length;
2. A ~~minimum length~~ distance of 10 feet (3048 mm);
3. Three times the least element dimension; and
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 Section 1605.2. ~~below the ground or that required by analysis, whichever length is greatest. The minimum reinforcement ratio, but no less than that ratio required by rational analysis, shall be continued throughout the flexural length of the pile. There shall be a minimum of four longitudinal bars with~~

Transverse reinforcement shall consist of closed ties ~~(~~or ~~equivalent~~ spirals~~) of~~ with a minimum 3/8 inch (9.5 mm) diameter ~~provided at 16 longitudinal bar diameter maximum spacing. Transverse confinement reinforcement with a maximum~~. Spacing of transverse reinforcement shall not exceed the smaller of 6 inches (152 mm) or 8-longitudinal-bar diameters~~, whichever is less, shall be provided~~ within a distance ~~equal to~~ of three times the least ~~pile~~ element dimension ~~of~~ 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 manufacturer's standard gage 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.

~~1810.1.2.2~~ 1810.3.9.4.2 Seismic reinforcement in Seismic Design ~~Category~~ Categories D~~, E or~~ through F. For ~~Where a~~ structures ~~is~~ assigned to Seismic Design Category D, E or F in accordance with Section 1613, ~~the requirements for Seismic Design Category C given above shall be met, in addition to the following~~ cast-in-place deep foundation elements shall be reinforced as specified in this section. Reinforcement shall be provided where required by analysis.

A minimum of four longitudinal bars, with a minimum longitudinal reinforcement ratio of 0.005 shall be provided ~~for uncased cast-in-place drilled or augered concrete piles, piers or caissons in the top~~ throughout the minimum reinforced length of the element as defined below 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 ~~pile~~ element length;
2. A ~~minimum length~~ distance of 10 feet (3048 mm);
3. Three times the least element dimension; and

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 Section 1605.2.

~~below ground or throughout the flexural length of the pile, whichever length is greatest. The flexural length shall be taken as the length of the pile to a point where the concrete section cracking moment strength multiplied by 0.4 exceeds the required moment strength at that point. There shall be a minimum of four longitudinal bars with transverse confinement reinforcement provided in the pile in accordance with Sections 21.4.4.1, 21.4.4.2 and 21.4.4.3 of ACI 318 within three times the least pile dimension of the bottom of the pile cap. A transverse spiral reinforcement ratio of not less than one-half of that required in Section 21.4.4.1(a) of ACI 318 for other than Class E, F or liquefiable sites is permitted. Tie spacing throughout the remainder of the concrete section shall not exceed 12 longitudinal bar diameters, one half the least dimension of the section, nor 12 inches (305 mm). Ties shall be a minimum of No. 3 bars for piles with a least dimension up to 20 inches (508 mm), and No. 4 bars for larger piles.~~

Transverse reinforcement shall consist of closed ties or spirals no 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; and
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. ~~**1810.5.4.1 Seismic reinforcement.** Where a structure is assigned to Seismic Design Category C, D, E or F in accordance with Section 1613, the reinforcement requirements for drilled or augered uncased piles in Section 1810.3.5 shall be met.~~

   ~~**Exception:**~~ A spiral-welded metal casing of a thickness not less than manufacturer's standard gage No. 14 gage (0.068 inch) is permitted to provide concrete confinement in lieu of the closed ties or ~~equivalent~~ spirals ~~required in an uncased concrete pile~~. 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 21.6.4.2, 21.6.4.3 and 21.6.4.4 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 Section 21.6.4.4(a) 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 21.6.4.2, 21.6.4.3 and 21.6.4.4 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.

~~**1812.6**~~ **1810.3.9.5 Belled ~~bottoms~~ drilled shafts.** Where ~~pier foundations~~ drilled shafts are belled at the bottom, the edge thickness of the bell shall not be 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.

~~**1810.7.1**~~ **1810.3.9.6 ~~Construction~~ Socketed drilled shafts.** ~~Caisson piles shall consist of a shaft section of concrete-filled pipe extending to bedrock with an uncased socket drilled into the bedrock and filled with concrete.~~ 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. ~~The caisson pile~~ Socketed drilled shafts shall have reinforcement or a ~~full-length~~ structural steel core ~~or a stub core installed in the rock socket and extending into the pipe portion a distance equal to the socket depth~~ for the length as indicated by an approved method of analysis.

~~**1810.7.3 Design.**~~ The depth of the rock socket shall be sufficient to develop the full load-bearing capacity of the ~~caisson pile~~ element with a minimum safety factor of two, but the depth shall not be 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. ~~The minimum outside diameter of the caisson pile shall be 18 inches (457 mm), and the diameter of the rock socket shall be approximately equal to the inside diameter of the pile.~~

~~**1810.7.4 Structural core.**~~ Where a structural steel core is used, the gross cross-sectional area of the ~~structural steel~~ core shall not exceed 25 percent of the gross area of the ~~caisson~~ drilled shaft. ~~The minimum clearance between the structural core and the pipe shall be 2 inches (51 mm). Where cores are to be spliced, the ends shall be milled or ground to provide full contact and shall be full-depth welded.~~

~~**1810.8**~~ **1810.3.10 [Suppl] Micropiles.** Micropiles shall ~~comply with the requirements of~~ be designed and detailed in accordance with Sections ~~1810.8.1~~ 1810.3.10.1 through ~~1810.8.5~~ 1810.3.10.4.

~~**1810.8.1**~~ **1810.3.10.1 [Suppl] Construction.** ~~Micropiles shall consist of a grouted section reinforced with steel pipe or steel reinforcement~~ Micropiles shall develop their load-carrying capacity ~~through~~ by means of a bond zone in soil, bedrock or a combination of soil and bedrock. ~~The steel pipe or steel reinforcement shall extend the full length of the micropile~~ 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 extending the bars into the pipe or tube section by at least their tension development length in accordance with ACI 318.

~~**1810.8.2**~~ **1810.3.10.2 [Suppl] Materials.** ~~Grout shall have a specified compressive strength (f'_c) of not less than 4,000 psi (27.58 Mpa). The grout mix shall be designed and proportioned so as to produce a pumpable mixture.~~ Reinforcement shall consist of deformed reinforcing bars in accordance with ASTM A 615 Grade 60 or 75 or ASTM A 722 Grade 150. The steel pipe or tube shall have a minimum wall thickness of 3/16 inch (4.8 mm). Splices shall comply with Section ~~1808.2.7~~ 1810.3.6. The steel pipe or tube shall have a minimum yield strength ~~exceeding~~ 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.

~~**1810.8.4**~~ **1810.3.10.3 [Suppl] Reinforcement.** For micropiles or portions thereof ~~piles~~ 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 at least 40 percent of the design compression load. Micropiles or portions thereof ~~piles~~ 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.

~~**1810.8.4.1**~~ **1810.3.10.4 [Suppl] Seismic reinforcement.** ~~Where a~~ For structures ~~is~~ assigned to Seismic Design Category C, a permanent steel casing shall be provided from the top of the micropile down ~~a minimum of 120 percent of the flexural length~~ to the point of zero curvature. ~~Where a~~ For structures ~~is~~ assigned to Seismic Design D, E or F, the micropile shall be considered as an alternative system in accordance with Section 104.11. The alternative ~~pile~~ system design, supporting documentation and test data shall be submitted to the building official for review and approval.

~~**1808.2.4**~~ **1810.3.11 Pile caps.** Pile caps shall be of reinforced concrete, and shall include all elements to which ~~piles~~ 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. The tops of ~~piles~~ vertical deep foundation elements shall be embedded not less than 3 inches (76 mm) into pile caps and the caps shall extend at least 4 inches (102 mm) beyond the edges of ~~piles~~ the elements. The tops of ~~piles~~ elements shall be cut or chipped back to sound material before capping.

~~**1808.2.23.1.1**~~ **1810.3.11.1 ~~Connection to pile cap~~ Seismic Design Categories C through F.** ~~Concrete piles and concrete-filled steel pipe piles~~ For structures assigned to Seismic Design Category C, D, E, or F in accordance with Section 1613, concrete deep foundation elements shall be connected to the pile cap by embedding the ~~pile~~ element reinforcement or field-placed dowels anchored in the ~~concrete pile~~ element into the pile cap for a distance equal to ~~the~~ their development length in accordance with ACI 318. It shall be permitted to connect precast prestressed piles to the pile cap by developing the element prestressing strands into the pile cap provided the connection is ductile. For deformed bars, the development length is the full development length for compression, or tension~~,~~ in the case of uplift, without reduction ~~in length~~ for excess ~~area~~ reinforcement in accordance with Section 12.2.5 of ACI 318. Alternative measures for laterally confining concrete and maintaining toughness and ductile-like behavior at the top of the ~~pile will~~ element shall be permitted provided the design is such that any hinging occurs in the confined region.

~~Ends of hoops, spirals and ties shall be terminated with seismic hooks, as defined in Section 21.1 of ACI 318 turned into the confined concrete core.~~ The minimum transverse steel ratio for confinement shall not be less than one-half of that required for columns.

For resistance to uplift forces, anchorage of steel ~~pipe (round HSS sections), concrete-filled steel pipe or~~ 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 tension development length of the reinforcement.

~~**Exception:** Anchorage of concrete-filled steel pipe piles is permitted to be accomplished using deformed bars developed into the concrete portion of the pile.~~

~~Splices of pile segments shall develop the full strength of the pile, but the splice need not develop the nominal strength of the pile in tension, shear and bending when it has been designed to resist axial and shear forces and moments from the load combinations of Section 1605.4.~~

~~**1808.2.23.2.2**~~ **1810.3.11.2** ~~**Connection to pile cap**~~ **Seismic Design Categories D through F.** For ~~piles required to resist~~ structures assigned to Seismic Design Category D, E, or F in accordance with Section 1613, deep foundation element resistance to uplift forces or ~~provide~~ rotational restraint~~, design of anchorage of piles into the pile cap shall be provided~~ 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 a minimum of 25 percent of the strength of the ~~pile~~ element in tension. Anchorage into the pile cap shall be capable of developing the following:

1. In the case of uplift, the ~~lesser~~ least of the following: nominal tensile strength of the longitudinal reinforcement in a concrete ~~pile~~ element~~,~~; ~~or~~ the nominal tensile strength of a steel ~~pile~~ element~~,~~; ~~or~~ the ~~pile uplift soil nominal strength factored~~ frictional force developed between the element and the soil multiplied by 1.3; ~~or~~ and the axial tension force resulting from the load combinations ~~of Section 1605.4~~ with overstrength factor in Section 12.4.3.2 of ASCE 7.
2. In the case of rotational restraint, the lesser of the following: the axial ~~and~~ force, shear forces, and bending moments resulting from the load combinations ~~of Section 1605.4~~ with overstrength factor in Section 12.4.3.2 of ASCE 7; ~~or~~ and development of the full axial, bending and shear nominal strength of the ~~pile~~ element.

~~**1808.2.23.2.3 Flexural strength.**~~ Where the vertical lateral-force-resisting elements are columns, the ~~grade beam or~~ pile cap flexural strengths shall exceed the column flexural strength. The connection between batter piles and ~~grade beams or~~ 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 capable of resisting forces and moments from the load combinations ~~of Section 1605.4~~ with overstrength factor in Section 12.4.3.2 of ASCE 7.

1810.3.12 Grade beams. For structures assigned to Seismic Design Category D, E, or F in accordance with Section 1613, grade beams shall comply with the provisions in Section 21.12.3 of ACI 318 for grade beams, except where they have the capacity to resist the forces from the load combinations with overstrength factor in Section 12.4.3.2 of ASCE 7.

~~**1808.2.23.1**~~ **1810.3.13** **[Suppl]** ~~**Seismic Design Category C**~~ **Seismic ties.** ~~Where a~~ For structures ~~is~~ assigned to Seismic Design Category C, D, E, or F in accordance with Section 1613, ~~the following shall apply.~~ individual ~~pile caps, piers or piles~~ deep foundations shall be interconnected by ties. Unless it can be demonstrated that equivalent restraint is provided by reinforced concrete beams within slabs on grade or reinforced concrete slabs on grade or confinement by competent rock, hard cohesive soils or very dense granular soils, ties shall be capable of carrying, in tension ~~and~~ or compression, a force equal to the lesser of the product of the larger pile cap or column design gravity load times the seismic coefficient, S_{DS}, divided by 10 ~~unless it can be demonstrated that equivalent restraint is provided by reinforced concrete beams within slabs on grade or reinforced concrete slabs on grade or confinement by competent rock, hard cohesive soils or very dense granular soils~~, and 25 percent of the smaller pile cap or column design gravity load.

Exception: In Group R-3 and U occupancies of light-frame construction, ~~pier foundations~~ deep foundation elements supporting foundation walls, isolated interior posts detailed so the ~~pier~~ element is not subject to lateral loads, or exterior decks and patios are not subject to interconnection ~~if it can be shown~~ 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.

~~1808.2.6~~ **1810.4.1 Structural integrity.** ~~Piers or piles~~ Deep foundation elements shall be installed in such a manner and sequence as to prevent distortion or damage that may adversely affect the structural integrity of ~~piles~~ 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.

~~1809.2.2.4~~ **1810.4.1.1 ~~Installation~~ Compressive strength of precast concrete piles.** A precast concrete pile shall not be driven before the concrete has attained a compressive strength of at least 75 percent of the ~~28-day~~ specified compressive strength (f'_c), but not less than the strength sufficient to withstand handling and driving forces.

1810.4.1.2 Casing. Where cast-in-place deep foundation elements are formed through unstable soils and concrete is placed in an open-drilled hole, a casing shall be inserted in the hole 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.

~~1810.4.3~~ **1810.4.1.3 ~~Installation~~ Driving near uncased concrete.** ~~Piles~~ Deep foundation elements shall not be driven within six ~~pile~~ element diameters center to center in granular soils or within one-half the ~~pile~~ element length in cohesive soils of ~~a pile~~ an uncased element filled with concrete less than 48 hours old unless approved by the building official. If the concrete surface in any completed ~~pile~~ element rises or drops, the ~~pile~~ element shall be replaced. ~~Piles~~ Driven uncased deep foundation elements shall not be installed in soils that could cause ~~pile~~ heave.

~~1810.5.3~~ **1810.4.1.4 ~~Installation~~ Driving near cased concrete.** ~~Steel shells shall be mandrel driven their full length in contact with the surrounding soil.~~

~~The steel shells shall be driven in such order and with such spacing as to ensure against distortion of or injury to piles already in place. A pile~~ Deep foundation elements shall not be driven within four and one-half average ~~pile~~ diameters of a ~~pile~~ cased element filled with concrete less than 24 hours old unless approved by the building official. Concrete shall not be placed in ~~steel shells~~ casings within heave range of driving.

~~1809.1.3~~ **1810.4.1.5 Defective timber piles.** Any substantial sudden increase in rate of penetration of a timber pile shall be investigated for possible damage. If the sudden increase in rate of penetration cannot be correlated to soil strata, the pile shall be removed for inspection or rejected.

~~1808.2.20~~ **1810.4.2 Identification.** ~~Pier or pile~~ 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 official.

~~1808.2.21~~ **1810.4.3 ~~Pier or pile~~ Location plan.** A plan showing the location and designation of ~~piers or piles~~ deep foundation elements by an identification system shall be filed with the building official prior to installation of such ~~piers or piles~~ elements. Detailed records for ~~piers or individual piles~~ elements shall bear an identification corresponding to that shown on the plan.

~~1808.2.13~~ **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 ~~piers or piles~~ deep foundation elements subject to load tests and in such a manner that will not impair the carrying capacity of the ~~piers or piles~~ elements already in place or damage adjacent structures. ~~Pile~~ Element tips shall be driven below the preexcavated depth until the required resistance or penetration is obtained.

~~1808.2.15~~ **1810.4.5 ~~Use of~~ Vibratory ~~drivers~~ driving**. Vibratory drivers shall only be used to install ~~piles~~ deep foundation elements where the ~~pile~~ element load capacity is verified by load tests in accordance with Section ~~1808.2.8.3~~ 1810.3.3.1.2. The installation of production ~~piles~~ elements shall be controlled according to power consumption, rate of penetration or other approved means that ensure ~~pile~~ element capacities equal or exceed those of the test ~~piles~~ elements.

~~1808.2.19~~ **1810.4.6 Heaved ~~piles~~ elements.** ~~Piles~~ Deep foundation elements that have heaved during the driving of adjacent ~~piles~~ elements shall be redriven as necessary to develop the required capacity and penetration, or the capacity of the ~~pile~~ element shall be verified by load tests in accordance with Section ~~1808.2.8.3~~ 1810.3.3.1.2.

~~**1810.2.3**~~ **1810.4.7** ~~**Installation**~~ **Enlarged base cast-in-place elements.** Enlarged bases for cast-in-place deep foundation elements formed ~~either~~ by compacting concrete or by driving a precast base shall be formed in or driven into granular soils. ~~Piles~~ Such elements shall be constructed in the same manner as successful prototype test ~~piles~~ elements driven for the project. ~~Pile~~ 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 ~~pile~~ shaft shall be filled sufficiently to reestablish lateral support by the soil. Where ~~pile~~ heave occurs, the ~~pile~~ element shall be replaced unless it is demonstrated that the ~~pile~~ element is undamaged and capable of carrying twice its design load.

~~**1810.3.3**~~ **1810.4.8** ~~**Installation**~~ **Hollow-stem augered, cast-in-place elements.** ~~Where pile shafts are formed through unstable soils and concrete is placed in an open-drilled hole, a steel liner shall be inserted in the hole prior to placing the concrete. Where the steel liner is withdrawn during concreting, the level of concrete shall be maintained above the bottom of the liner at a sufficient height to offset any hydrostatic or lateral soil pressure.~~

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 ~~shall be~~ is withdrawn ~~in continuous increments~~ at a steady rate or in increments not to exceed 1 ft (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 ~~pile~~ element is equal to or greater than the theoretical volume of the hole created by the auger. Where the installation process of any ~~pile~~ element is interrupted or a loss of concreting or grouting pressure occurs, the ~~pile~~ 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 ~~piles~~ elements shall not be installed within six ~~pile~~ diameters center to center of ~~a pile~~ 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 ~~pile~~ element drops due to installation of an adjacent ~~pile~~ element, the ~~pile~~ element shall be replaced.

~~**1810.7.6**~~ **1810.4.9** ~~**Installation**~~ **Socketed drilled shafts.** The rock socket and ~~pile~~ 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. ~~Concrete shall not be placed through water except where a tremie or other approved method is used.~~

~~**1810.8.5**~~ **1810.4.10** ~~**Installation**~~ **Micropiles.** ~~The pile~~ Micropile deep foundation elements shall be permitted to be formed in ~~a~~ holes advanced by rotary or percussive drilling methods, with or without casing. The ~~pile~~ elements shall be grouted with a fluid cement grout. The grout shall be pumped through a tremie pipe extending to the bottom of the ~~pile~~ element until grout of suitable quality returns at the top of the ~~pile~~ 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 ~~pile~~ 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 ~~check~~ verify that the flow of grout inside the casing is not obstructed.
2. For a micropile or portion thereof ~~a pile~~ 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 ~~piles~~ 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 assure grout coverage outside the casing.

~~**1808.2.22**~~ **1810.4.11 Special inspection.** Special inspections in accordance with Sections 1704.8 and 1704.9 shall be provided for ~~piles and piers~~ driven and cast-in-place deep foundation elements, respectively.

3. Revise code sections following Chapter 18 as follows:

3304.1.4 Fill supporting foundations. Fill to be used to support the foundations of any building or structure shall comply with Section ~~1803.5~~ 1804.5. Special inspections of compacted fill shall be in accordance with Section 1704.7.

J101.1 Scope. The provisions of this chapter apply to grading, excavation and earthwork construction, including fills and embankments. Where conflicts occur between the technical requirements of this chapter and the ~~soils~~ geotechnical report, the ~~soils~~ geotechnical report shall govern.

J104.3 Soils report. A ~~soils~~ geotechnical report prepared by a registered design ~~professionals~~ professional shall be provided ~~which~~. The report shall ~~identify~~ contain at least the following:

1. The nature and distribution of existing soils;
2. Conclusions and recommendations for grading procedures;
3. Soil design criteria for any structures or embankments required to accomplish the proposed grading; and
4. Where necessary, slope stability studies, and recommendations and conclusions regarding site geology.

Exception: A ~~soils~~ geotechnical report is not required where the building official determines that the nature of the work applied for is such that a report is not necessary.

J106.1 Maximum slope. The slope of cut surfaces shall be no steeper than is safe for the intended use, and shall be no steeper than 2 horizontal to 1 vertical (50 percent) unless the ~~applicant~~ owner or authorized agent furnishes a ~~soils~~ geotechnical report justifying a steeper slope.

Exceptions:

1. A cut surface may be at a slope of 1.5 horizontal to 1 vertical (67 percent) provided that all the following are met:
   - 1.1. It is not intended to support structures or surcharges.
   - 1.2. It is adequately protected against erosion.
   - 1.3. It is no more than 8 feet (2438 mm) in height.
   - 1.4. It is approved by the building official.
   - 1.5. Ground-water is not encountered.
2. A cut surface in bedrock shall be permitted to be at a slope of 1 horizontal to 1 vertical (100 percent).

J107.1 General. Unless otherwise recommended in the ~~soils~~ geotechnical report, fills shall ~~conform to~~ comply with the provisions of this section.

J107.6 Maximum slope. The slope of fill surfaces shall be no steeper than is safe for the intended use. Fill slopes steeper than 2 horizontal to 1 vertical (50 percent) shall be justified by ~~soils reports~~ a geotechnical report or engineering data.

4. Delete without substitution:

~~**1802.3 Soil classification.** Where required, soils shall be classified in accordance with Section 1802.3.1 or 1802.3.2.~~

~~**1805.4 Footings.** Footings shall be designed and constructed in accordance with Sections 1805.4.1 through 1805.4.6.~~

~~**1805.5.1.2 Thickness based on soil loads, unbalanced backfill height and wall height.** The thickness of foundation walls shall comply with the requirements of Table 1805.5(5) for concrete walls, Table 1805.5(1) for plain masonry walls or Table 1805.5(2), 1805.5(3) or 1805.5(4) for masonry walls with reinforcement. When using the tables, masonry shall be laid in running bond and the mortar shall be Type M or S.~~

~~Unbalanced backfill height is the difference in height between the exterior finish ground level and the lower of the top of the concrete footing that supports the foundation wall or the interior finish ground level. Where an interior concrete slab on grade is provided and is in contact with the interior surface of the foundation wall, the unbalanced backfill height is permitted to be measured from the exterior finish ground level to the top of the interior concrete slab.~~

~~**1805.5.2 Foundation wall materials.** Concrete foundation walls constructed in accordance with Table 1805.5(5) shall comply with Section 1805.5.2.1. Masonry foundation walls constructed in accordance with Table 1805.5(1), 1805.5(2), 1805.5(3) or 1805.5(4) shall comply with Section 1805.5.2.2.~~

~~**1805.5.4 Hollow masonry walls.** At least 4 inches (102 mm) of solid masonry shall be provided at girder supports at the top of hollow masonry unit foundation walls.~~

1805.5.5 Seismic requirements. Tables 1805.5(1) through 1805.5(5) shall be subject to the following limitations in Sections 1805.5.5.1 and 1805.5.5.2 based on the seismic design category assigned to the structure as defined in Section 1613.

1805.5.6 Foundation wall drainage. Foundation walls shall be designed to support the weight of the full hydrostatic pressure of undrained backfill unless a drainage system is installed in accordance with Sections 1807.4.2 and 1807.4.3.

1805.6 Foundation plate or sill bolting. Wood foundation plates or sills shall be bolted or strapped to the foundation or foundation wall as provided in Chapter 23.

SECTION 1806
RETAINING WALLS

1808.2 Piers and piles—general requirements.

1808.2.1 Design. Piles are permitted to be designed in accordance with provisions for piers in Section 1808 and Sections 1812.3 through 1812.10 where either of the following conditions exists, subject to the approval of the building official:

1. Group R-3 and U occupancies not exceeding two stories of light-frame construction, or
2. Where the surrounding foundation materials furnish adequate lateral support for the pile.

1808.2.8 Allowable pier or pile loads.

1808.2.9 Lateral support.

1808.2.14 Installation sequence. Piles shall be installed in such sequence as to avoid compacting the surrounding soil to the extent that other piles cannot be installed properly, and to prevent ground movements that are capable of damaging adjacent structures.

1808.2.16 Pile driveability. Pile cross sections shall be of sufficient size and strength to withstand driving stresses without damage to the pile, and to provide sufficient stiffness to transmit the required driving forces.

1808.2.23 Seismic design of piers or piles.

1808.2.23.2 Seismic Design Category D, E or F. Where a structure is assigned to Seismic Design Category D, E or F in accordance with Section 1613, the requirements for Seismic Design Category C given in Section 1808.2.23.1 shall be met, in addition to the following. Provisions of ACI 318, Section 21.10.4, shall apply when not in conflict with the provisions of Sections 1808 through 1812. Concrete shall have a specified compressive strength of not less than 3,000 psi (20.68 MPa) at 28 days.

Exceptions:

1. Group R or U occupancies of light-framed construction and two stories or less above grade plane are permitted to use concrete with a specified compressive strength of not less than 2,500 psi (17.2 MPa) at 28 days.
2. Detached one- and two-family dwellings of light-framed construction and two stories or less in height are not required to comply with the provisions of ACI 318, Section 21.10.4.
3. Section 21.10.4.4(a) of ACI 318 need not apply to concrete piles.

SECTION 1809
DRIVEN PILE FOUNDATIONS

1809.1.4 Allowable stresses. The allowable stresses shall be in accordance with the AF&PA NDS.

1809.2 Precast concrete piles.

1809.2.1.4 Installation. Piles shall be handled and driven so as not to cause injury or overstressing, which affects durability or strength.

1809.2.2.1 Materials. Concrete shall have a 28-day specified compressive strength (f'_c) of not less than 3,000 psi (20.68 MPa).

1809.2.2.3 Allowable stresses. The allowable compressive stress in the concrete shall not exceed 33 percent of the 28-day specified compressive strength (f'_c) applied to the gross cross-sectional area of the pile. The allowable compressive stress in the reinforcing steel shall not exceed 40 percent of the yield strength of the steel (f_y) or a maximum of 30,000 psi (207 MPa). The allowable tensile stress in the reinforcing steel shall not exceed 50 percent of the yield strength of the steel (f_y) or a maximum of 24,000 psi (165 MPa).

1809.2.2.5 Concrete cover. Reinforcement for piles that are not manufactured under plant conditions shall have a concrete cover of not less than 2 inches (51 mm).

Reinforcement for piles manufactured under plant control conditions shall have a concrete cover of not less than 1.25 inches (32 mm) for No. 5 bars and smaller, and not less than 1.5 inches (38 mm) for No. 6 through No. 11 bars except that longitudinal bars spaced less than 1.5 inches (38 mm) clear distance apart shall be considered bundled bars for which the minimum concrete cover shall be equal to that for the equivalent diameter of the bundled bars.

Reinforcement for piles exposed to seawater shall have a concrete cover of not less than 3 inches (76 mm).

1809.2.3.1 Materials. Prestressing steel shall conform to ASTM A 416. Concrete shall have a 28-day specified compressive strength (f'_c) of not less than 5,000 psi (34.48 MPa).

1809.2.3.3 Allowable stresses. The allowable design compressive stress, f_c, in concrete shall be determined as follows:

$$f_c = 0.33 f'_c - 0.27 f_{pc} \quad \textbf{(Equation 18-10)}$$

where:

f'_c = The 28-day specified compressive strength of the concrete.
f_{pc} = The effective prestress stress on the gross section.

1809.2.3.4 Installation. A prestressed pile shall not be driven before the concrete has attained a compressive strength of at least 75 percent of the 28-day specified compressive strength ($f'c$), but not less than the strength sufficient to withstand handling and driving forces.

1809.2.3.5 Concrete cover. Prestressing steel and pile reinforcement shall have a concrete cover of not less than 1-1/4 inches (32 mm) for square piles of 12 inches (305 mm) or smaller size and 1-1/2 inches (38 mm) for larger piles, except that for piles exposed to seawater, the minimum protective concrete cover shall not be less than 2-1/2 inches (64 mm).

1809.3 Structural steel piles. Structural steel piles shall conform to the requirements of Sections 1809.3.1 through 1809.3.4.

1809.3.2 Allowable stresses. The allowable axial stresses shall not exceed 35 percent of the minimum specified yield strength (F_y).

Exception: Where justified in accordance with Section 1808.2.10, the allowable axial stress is permitted to be increased above $0.35F_y$, but shall not exceed $0.5F_y$.

SECTION 1810
CAST-IN-PLACE CONCRETE PILE FOUNDATIONS

1810.1 General. The materials, reinforcement and installation of cast-in-place concrete piles shall conform to Sections 1810.1.1 through 1810.1.3.

1810.1.3 Concrete placement. Concrete shall be placed in such a manner as to ensure the exclusion of any foreign matter and to secure a full-sized shaft. Concrete shall not be placed through water except where a tremie or other approved method is used. When depositing concrete from the top of the pile, the concrete shall not be chuted directly into the pile but shall be poured in a rapid and continuous operation through a funnel hopper centered at the top of the pile.

1810.2 Enlarged base piles. Enlarged base piles shall conform to the requirements of Sections 1810.2.1 through 1810.2.5.

1810.2.2 Allowable stresses. The maximum allowable design compressive stress for concrete not placed in a permanent steel casing shall be 25 percent of the 28-day specified compressive strength (f'_c). Where the concrete is place in a permanent steel casing, the maximum allowable concrete stress shall be 33 percent of the 28-day specified compressive strength (f'_c).

1810.2.4 Load-bearing capacity. Pile load-bearing capacity shall be verified by load tests in accordance with Section 1808.2.8.3.

1810.2.5 Concrete cover. The minimum concrete cover shall be 2-1/2 inches (64 mm) for uncased shafts and 1 inch (25 mm) for cased shafts.

1810.3 Drilled or augered uncased piles. Drilled or augered uncased piles shall conform to Sections 1810.3.1 through 1810.3.5.

1810.3.1 Allowable stresses. The allowable design stress in the concrete of drilled or augered uncased piles shall not exceed 33 percent of the 28-day specified compressive strength (f'_c). The allowable compressive stress of reinforcement shall not exceed 40 percent of the yield strength of the steel or 25,500 psi (175.8 MPa).

1810.3.5 Reinforcement in Seismic Design Category C, D, E or F. Where a structure is assigned to Seismic Design Category C, D, E or F in accordance with Section 1613, the corresponding requirements of Sections 1810.1.2.1 and 1810.1.2.2 shall be met.

1810.4 Driven uncased piles. Driven uncased piles shall conform to Sections 1810.4.1 through 1810.4.4.

1810.4.1 Allowable stresses. The allowable design stress in the concrete shall not exceed 25 percent of the 28-day specified compressive strength (f'_c) applied to a cross-sectional area not greater than the inside area of the drive casing or mandrel.

1810.4.2 Dimensions. The pile length shall not exceed 30 times the average diameter. The minimum diameter shall be 12 inches (305 mm).

> **Exception:** The length of the pile is permitted to exceed 30 times the diameter, provided that the design and installation of the pile foundation is under the direct supervision of a registered design professional knowledgeable in the field of soil mechanics and pile foundations. The registered design professional shall certify to the building official that the piles were installed in compliance with the approved design.

1810.4.4 Concrete cover. Pile reinforcement shall have a concrete cover of not less than 2.5 inches (64 mm), measured from the inside face of the drive casing or mandrel.

1810.5 Steel-cased piles. Steel-cased piles shall comply with the requirements of Sections 1810.5.1 through 1810.5.4.

1810.5.4 Reinforcement. Reinforcement shall not be placed within 1 inch (25 mm) of the steel shell. Reinforcing shall be required for unsupported pile lengths or where the pile is designed to resist uplift or unbalanced lateral loads.

1810.6 Concrete-filled steel pipe and tube piles. Concrete-filled steel pipe and tube piles shall conform to the requirements of Sections 1810.6.1 through 1810.6.5.

1810.6.1 Materials. Steel pipe and tube sections used for piles shall conform to ASTM A 252 or ASTM A 283. Concrete shall conform to Section 1810.1.1. The maximum coarse aggregate size shall be 3/4 inch (19.1 mm).

1810.6.2 Allowable stresses. The allowable design compressive stress in the concrete shall not exceed 33 percent of the 28-day specified compressive strength (f'_c). The allowable design compressive stress in the steel shall not exceed 35 percent of the minimum specified yield strength of the steel (F_y), provided F_y shall not be assumed greater than 36,000 psi (248 MPa) for computational purposes.

> **Exception:** Where justified in accordance with Section 1808.2.10, the allowable stresses are permitted to be increased to 0.50 F_y.

1810.6.4 Reinforcement. Reinforcement steel shall conform to Section 1810.1.2. Reinforcement shall not be placed within 1 inch (25 mm) of the steel casing.

1810.6.4.1 Seismic reinforcement. Where a structure is assigned to Seismic Design Category C, D, E or F in accordance with Section 1613, the following shall apply. Minimum reinforcement no less than 0.01 times the cross-sectional area of the pile concrete shall be provided in the top of the pile with a length equal to two times the required cap embedment anchorage into the pile cap, but not less than the tension development length of the reinforcement. The wall thickness of the steel pipe shall not be less than 3/16 inch (5 mm).

1810.6.5 Placing concrete. The placement of concrete shall conform to Section 1810.1.3, but is permitted to be chuted directly into smooth sided pipes and tubes without a centering funnel hopper.

1810.7 Caisson piles. Caisson piles shall conform to the requirements of Sections 1810.7.1 through 1810.7.6.

1810.7.2 Materials. Pipe and steel cores shall conform to the material requirements in Section 1809.3. Pipes shall have a minimum wall thickness of 3/8 inch (9.5 mm) and shall be fitted with a suitable steel driving shoe welded to the bottom of the pipe. Concrete shall have a 28-day specified compressive strength (f'_c) of not less than 4,000 psi (27.58 MPa). The concrete mix shall be designed and proportioned so as to produce a cohesive workable mix with a slump of 4 inches to 6 inches (102 mm to 152 mm).

1810.7.5 Allowable stresses. The allowable design compressive stresses shall not exceed the following: concrete, 0.33 f'_c; steel pipe, 0.35 F_y and structural steel core, 0.50 F_y.

1810.8.3 Allowable stresses. The allowable compressive stress in the grout shall not exceed 0.33 f'_c. The allowable compressive stress in the steel pipe and steel reinforcement shall not exceed the lesser of 0.4 F_y, and 32,000 psi (220 Mpa). The allowable tensile stress in the steel reinforcement shall not exceed 0.60 F_y. The allowable tensile stress in the cement grout shall be zero.

SECTION 1811
COMPOSITE PILES

1811.1 General. Composite piles shall conform to the requirements of Sections 1811.2 through 1811.5.

1811.2 Design. Composite piles consisting of two or more approved pile types shall be designed to meet the conditions of installation.

1811.3 Limitation of load. The maximum allowable load shall be limited by the capacity of the weakest section incorporated in the pile.

1811.4 Splices. Splices between concrete and steel or wood sections shall be designed to prevent separation both before and after the concrete portion has set, and to ensure the alignment and transmission of the total pile load. Splices shall be designed to resist uplift caused by upheaval during driving of adjacent piles, and shall develop the full compressive strength and not less than 50 percent of the tension and bending strength of the weaker section.

1811.5 Seismic reinforcement. Where a structure is assigned to Seismic Design Category C, D, E or F in accordance with Section 1613, the following shall apply. Where concrete and steel are used as part of the pile assembly, the concrete reinforcement shall comply with that given in Sections 1810.1.2.1 and 1810.1.2.2 or the steel section shall comply with Section 1810.6.4.1.

SECTION 1812
PIER FOUNDATIONS

1812.1 General. Isolated and multiple piers used as foundations shall conform to the requirements of Sections 1812.2 through 1812.10, as well as the applicable provisions of Section 1808.2.

1812.2 Lateral dimensions and height. The minimum dimension of isolated piers used as foundations shall be 2 feet (610 mm), and the height shall not exceed 12 times the least horizontal dimension.

1812.3 Materials. Concrete shall have a 28-day specified compressive strength (f'_c) of not less than 2,500 psi (17.24 MPa). Where concrete is placed through a funnel hopper at the top of the pier, the concrete mix shall be designed and proportioned

~~so as to produce a cohesive workable mix having a slump of not less than 4 inches (102 mm) and not more than 6 inches (152 mm). Where concrete is to be pumped, the mix design including slump shall be adjusted to produce a pumpable concrete.~~

~~**1812.5 Concrete placement.** Concrete shall be placed in such a manner as to ensure the exclusion of any foreign matter and to secure a full-sized shaft. Concrete shall not be placed through water except where a tremie or other approved method is used. When depositing concrete from the top of the pier, the concrete shall not be chuted directly into the pier but shall be poured in a rapid and continuous operation through a funnel hopper centered at the top of the pier.~~

~~**1812.8 Concrete.** Where adequate lateral support is not provided, and the unsupported height to least lateral dimension does not exceed three, piers of plain concrete shall be designed and constructed as pilasters in accordance with ACI 318. Where the unsupported height to least lateral dimension exceeds three, piers shall be constructed of reinforced concrete, and shall conform to the requirements for columns in ACI 318.~~

~~**Exception:** Where adequate lateral support is furnished by the surrounding materials as defined in Section 1808.2.9, piers are permitted to be constructed of plain or reinforced concrete. The requirements of ACI 318 for bearing on concrete shall apply.~~

~~**1812.9 Steel shell.** Where concrete piers are entirely encased with a circular steel shell, and the area of the shell steel is considered reinforcing steel, the steel shall be protected under the conditions specified in Section 1808.2.17. Horizontal joints in the shell shall be spliced to comply with Section 1808.2.7.~~

~~**1812.10 Dewatering.** Where piers are carried to depths below water level, the piers shall be constructed by a method that will provide accurate preparation and inspection of the bottom, and the depositing or construction of sound concrete or other masonry in the dry.~~

~~**1908.1.12 ACI 318, Section 21.12.5.** Modify ACI 318, Section 21.12.5, by adding new Section 21.12.5.6 to read as follows:~~

~~***21.12.5.6**. Columns supporting reactions from discontinuous stiff members, such as walls, shall be designed for the special load combinations in Section 1605.4 of the International Building Code, and shall be provided with transverse reinforcement at the spacing, s_o, as defined in Section 21.12.5.2 over their full height beneath the level at which the discontinuity occurs. This transverse reinforcement shall be extended above and below the column as required in Section 21.4.4.5.*~~

5. Excerpts from the code change proposals illustrating actual proposed changes to the current text:

~~**1802.2.4**~~ **1803.5.5** ~~**Pile and pier**~~ **Deep foundations.** ~~Pile and pier foundations shall be designed and installed on the basis of a foundation investigation and report as specified in Sections 1802.4 through 1802.6 and Section 1808.2.1.~~ Where deep foundations will be used, a geotechnical investigation shall be conducted and shall include all of the following, unless sufficient data upon which to base the design and installation is otherwise available:

1. Recommended ~~pier or pile~~ deep foundation types and installed capacities.
2. Recommended center-to-center spacing of ~~piers or piles~~ deep foundation elements.
3. Driving criteria.
4. Installation procedures.
5. Field inspection and reporting procedures (to include procedures for verification of the installed bearing capacity where required).
6. ~~Pier or pile~~ Load test requirements.
7. ~~Durability of pier or pile materials~~ Suitability of deep foundation materials for the intended environment.
8. Designation of bearing stratum or strata.
9. Reductions for group action, where necessary.

1803.5.8 Compacted fill material. Where shallow foundations will bear on compacted fill material more than 12 inches (305 mm) in depth, a geotechnical investigation shall be conducted and shall include all of the following:

1. Specifications for the preparation of the site prior to placement of compacted fill material.
2. Specifications for material to be used as compacted fill.

3. Test methods to be used to determine the maximum dry density and optimum moisture content of the material to be used as compacted fill.
4. Maximum allowable thickness of each lift of compacted fill material.
5. Field test method for determining the in-place dry density of the compacted fill.
6. Minimum acceptable in-place dry density expressed as a percentage of the maximum dry density determined in accordance with Item 3.
7. Number and frequency of field tests required to determine compliance with Item 6.

1803.5.9 Controlled low-strength material (CLSM). Where shallow foundations will bear on controlled low-strength material (CLSM), a geotechnical investigation shall be conducted and shall include all of the following:

1. Specifications for the preparation of the site prior to placement of the CLSM.
2. Specifications for the CLSM.
3. Laboratory or field test method(s) to be used to determine the compressive strength or bearing capacity of the CLSM.
4. Test methods for determining the acceptance of the CLSM in the field.
5. Number and frequency of field tests required to determine compliance with Item 4.