CHAPTER 18
SOILS AND FOUNDATIONS

User notes:

About this chapter: *Chapter 18 provides criteria for geotechnical and structural considerations in the selection, design and installation of foundation systems to support the loads imposed by the structure above. This chapter includes requirements for soils investigation and site preparation for receiving a foundation, including the load-bearing values for soils and protection for the foundation from frost and water intrusion. Section 1808 addresses the basic requirements for all foundation types while subsequent sections address foundation requirements that are specific to shallow foundations and deep foundations.*

Code development reminder: *Code change proposals to this chapter will be considered by the IBC–Structural Code Development Committee during the 2022 (Group B) Code Development Cycle.*

Legend.

- Traditional Massachusetts changes supported by the GAC in red text *(those differing from ninth in* red text with gray shading*)*;
- Changes made by ICC from 2015 – 2018 in light blue highlighting;
- Changes made by ICC from 2018 – 2021 in yellow highlighting;

SECTION 1801
GENERAL

1801.1 Scope.
The provisions of this chapter shall apply to building and foundation systems.

1801.2 Foundation Types Not Covered by the Code. Types of foundations not specifically covered by the provisions of 780 CMR 18.00, and ground modification treatments to improve soils with inadequate load bearing capacity or settlement characteristics, may be permitted subject to approval by the building official. A report shall be submitted to the building official that identifies the foundation as a type not covered by existing code provisions, and contains sufficient data and analyses to substantiate the adequacy of the proposed foundation. The report shall be prepared by a registered design professional knowledgeable in the design of the proposed type of foundation or ground modification. The building official may require that an independent peer review be performed to evaluate the adequacy of the proposed design.

SECTION 1802
DESIGN BASIS

1802.1 General.
Allowable bearing pressures, allowable stresses and design formulas provided in this chapter shall be used with the *allowable stress design* load combinations specified in ASCE 7, Section

2.4 or the alternative allowable stress design load combinations of Section 1605.2. The quality and desig2 of materials used structurally in excavations and foundations shall comply with the requirements specified in Chapters 16, 19, 21, 22 and 23. Excavations and fills shall comply with Chapter 33.

SECTION 1803
GEOTECHNICAL INVESTIGATIONS

1803.1 General.
Geotechnical investigations shall be conducted in accordance with Section 1803.2 and reported in accordance with Section 1803.6. Where required ~~by the *building official* or where geotechnical~~ such investigations ~~involve in-situ testing, laboratory testing or engineering calculations, such investigations~~ shall be conducted by a *registered design professional*.

1803.2 Investigations required.
Geotechnical investigations shall be conducted in accordance with Sections 1803.3 through 1803.5.

> **Exception:** The *building official* shall be permitted to waive the requirement for a geotechnical investigation ~~where satisfactory data from adjacent areas is available that demonstrates an investigation is not necessary for any of the conditions in Sections 1803.5.1 through 1803.5.6 and Sections 1803.5.10 and 1803.5.11.:~~
>
> 1. Where satisfactory data from adjacent areas is available that demonstrates an investigation is not necessary to meet the requirements of 780 CMR 18.00;
> 2. For unoccupied structures that do not pose a significant risk to public safety in the event of failure; or
> 3. For structures used for agricultural purposes.

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.

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

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

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

1803.5.1 Classification.
Soil materials shall be classified in accordance with ASTM D2487.

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 a geotechnical investigation be conducted.

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

Soils meeting all four of the following provisions shall be considered to be 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 D4318.

2. More than 10 percent of the soil particles pass a No.200 sieve (75 µm), determined in accordance with ASTM D422.

3. More than 10 percent of the soil particles are less than 5 micrometers in size, determined in accordance with ASTM D422.

4. Expansion index greater than 20, determined in accordance with ASTM D4829.

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 1805.~~

1803.5.5 Deep foundations.
Where *deep foundations* will be used, a geotechnical investigation shall be conducted and shall include all of the following, unless sufficient data on 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.

1803.5.6 Rock strata.
Where subsurface explorations at the project site indicate variations in the structure of rock on which foundations are to be constructed, a sufficient number of borings shall be drilled to sufficient depths to assess the competency of the rock and its load-bearing capacity.

1803.5.7 Excavation near foundations.
Where excavation will reduce support from any foundation, a *registered design professional* shall prepare an assessment of the structure as determined from examination of the structure, available design documents, available subsurface data, and, if necessary, excavation of test pits. The *registered design professional* shall determine the requirements for support and protection of any existing foundation and prepare site-specific plans, details and sequence of work for submission. Such support shall be provided by underpinning, bracing, excavation retention systems, or by other means acceptable to the *building official*.

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.

1803.5.11 Seismic Design Categories B, C through F.
For structures assigned to *Seismic Design Category* B, C, D, E or F, a geotechnical investigation shall be conducted, and shall include an evaluation of all of the following potential geologic and seismic hazards:

1. Slope instability.

2. Liquefaction.

3. Total and differential settlement.

4. Surface displacement due to faulting or seismically induced lateral spreading or lateral flow.

1803.5.12 Seismic Design Categories B, C, D through F.
For structures assigned to *Seismic Design Category* B, C, D, E or F, the geotechnical investigation required by Section 1803.5.11 shall include all of the following as applicable:

1. The determination of dynamic seismic lateral earth pressures on foundation walls and retaining walls supporting more than 6 feet (1.83 m) of backfill height due to *design earthquake ground motions*.

2. The potential for liquefaction and soil strength loss evaluated for site peak ground acceleration, earthquake magnitude and source characteristics consistent with the maximum considered earthquake ground motions. Peak ground acceleration shall be determined based on one of the following:

   2.1. A site-specific study in accordance with Chapter 21 of ASCE 7.

   2.2. In accordance with Section 11.8.3 of ASCE 7.

3. An assessment of potential consequences of liquefaction and soil strength loss including, but not limited to, the following:

    3.1. Estimation of total and differential settlement.

    3.2. Lateral soil movement.

    3.3. Lateral soil *loads* on foundations.

    3.4. Reduction in foundation soil-bearing capacity and lateral soil reaction.

    3.5. Soil downdrag and reduction in axial and lateral soil reaction for pile foundations.

    3.6. Increases in soil lateral pressures on retaining walls.

    3.7. Flotation of buried structures.

4. Discussion of mitigation measures such as, but not limited to, the following:

    4.1. Selection of appropriate foundation type and depths.

    4.2. Selection of appropriate structural systems to accommodate anticipated displacements and forces.

    4.3. Ground stabilization.

    4.4. Any combination of these measures and how they shall be considered in the design of the structure.

1803.6 Reporting.
Where geotechnical investigations are required, a written report of the investigations shall be submitted to the *building official* by the permit applicant 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 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. *Deep foundation* information in accordance with Section 1803.5.5.

8. Special design and construction provisions for foundations of structures founded on expansive soils, as necessary.

9. Compacted fill material properties and testing in accordance with Section 1803.5.8.

10. *Controlled low-strength material* properties and testing in accordance with Section 1803.5.9.

11. Magnitude and distribution of lateral soil and ground water pressures, including seismic loads, on foundation and retaining walls.

SECTION 1804
EXCAVATION, GRADING AND FILL

1804.1 Excavation near foundations.
Excavation for any purpose shall not reduce vertical or lateral support for any foundation or adjacent foundation without first *underpinning* or protecting the foundation against detrimental lateral or vertical movement, or both, in accordance with Section 1803.5.7.

1804.2 Underpinning.
Where *underpinning* is chosen to provide the protection or support of adjacent structures, the *underpinning* system shall be designed and installed in accordance with provisions of this chapter and Chapter 33.

1804.2.1 Underpinning sequencing.
Underpinning shall be installed in a sequential manner that protects the neighboring structure and the working construction site. The sequence of installation shall be identified in the *approved construction documents*.

1804.3 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: *CLSM* need not be compacted.

1804.4 Site grading.
The ground immediately adjacent to the foundation shall be sloped away from the building at a slope of not less than 1 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* alternative method of diverting water away from the foundation. Swales used for this purpose shall be sloped not less than 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 not less than 2 percent away from the building.

Exceptions:

1. Where climatic or soil conditions warrant, the slope of the ground away from the building foundation shall be permitted to be reduced to not less than 1 unit vertical in 48 units horizontal (2-percent slope).

2. Impervious surfaces shall be permitted to be sloped less than 2 percent where the surface is a door landing or *ramp* that is required to comply with Section 1010.1.4, 1012.3 or 1012.6.1.

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

1804.5 Grading and fill in flood hazard areas.
In *flood hazard areas* established in Section 1612.3, grading, fill, or both, 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 *flood* 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 *coastal high hazard areas*, unless such fill is conducted 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 *flood hazard area* encroachment, when combined with all other existing and anticipated *flood hazard area* encroachment, will not increase the *design flood elevation* more than 1 foot (305 mm) at any point.

1804.6 Compacted fill material.
Where *shallow foundations* will bear on compacted fill material, the compacted fill shall comply with the provisions of an *approved* geotechnical report, as set forth in Section 1803.

Exception: Compacted fill material 12 inches (305 mm) in depth or less need not comply with an *approved* report, provided that the in-place dry density is not less than 90 percent of the maximum dry density at optimum moisture content determined in accordance with ASTM D1557. The compaction shall be verified by *special inspection* in accordance with Section 1705.6.

1804.7 Controlled low-strength material (CLSM).
Where *shallow foundations* will bear on *controlled low-strength material* (*CLSM*), the *CLSM* shall comply with the provisions of an *approved* geotechnical report, as set forth in Section 1803.

SECTION 1805
DAMPPROOFING AND WATERPROOFING

1805.1 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 1202.4.

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 1805.2 and a foundation drain shall be installed in accordance with Section 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 1803.5.4, 1805.3 and 1805.4.1 shall not apply in this case.

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 1803.5.4, 1805.2, 1805.3 and 1805.4 shall not apply in this case.

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 one side or more.

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

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 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.

1805.2 Dampproofing.
Where hydrostatic pressure will not occur as determined by Section 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 AWC PWF.

1805.2.1 Floors.
Dampproofing materials for floors shall be installed between the floor and the base course

required by Section 1805.4.1, 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.

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, $^1/_8$ inch (3.2 mm) coat of *surface-bonding mortar* complying with ASTM C887, any of the materials permitted for waterproofing by Section 1805.3.2 or other *approved* methods or materials.

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 below ground level with not less than $^3/_8$ 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.

1805.3 Waterproofing.
Where the ground-water investigation required by Section 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 1805.1.3, walls and floors shall be waterproofed in accordance with this section.

1805.3.1 Floors.
Floors required to be waterproofed shall be of concrete and 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.

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 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.

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 1805.2.2.1.

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.

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 1805.1.3 shall be deemed adequate for lowering the ground-water table.

1805.4.1 Floor base course.
Floors of basements, except as provided for in Section 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.

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 not less than 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 1805.4.1, and shall be covered with not less than 6 inches (152 mm) of the same material.

EXCEPTION: The foundation drain may be omitted if determined not to be necessary by a registered design professional.

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.

1805.5 Impacts on Groundwater Levels. Below-grade structures, their appurtenances and foundation drains shall be designed and constructed so as not to cause changes to the temporary or permanent groundwater level if such changes could adversely impact nearby structures or facilities including deterioration of timber piles, settlement, flooding or other impacts.

SECTION 1806
PRESUMPTIVE LOAD-BEARING VALUES OF SOILS

1806.1 Load combinations.
The presumptive load-bearing values provided in Table 1806.2 shall be used with the *allowable stress design* load combinations specified in ASCE 7, Section 2.4 or the alternative allowable stress design load combinations of Section 1605.2. 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 allowable stress design load combinations of Section 1605.2 that include wind or earthquake *loads*.

1806.2 Presumptive load-bearing values.
The load-bearing values used in design for supporting soils near the surface shall not exceed the values specified in Table 1806.2 or Table 1806.2a unless data to substantiate the use of higher 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 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 or temporary structures.

TABLE 1806.2
PRESUMPTIVE LOAD-BEARING VALUES

CLASS OF MATERIALS	VERTICAL FOUNDATION PRESSURE (psf)	LATERAL BEARING PRESSURE (psf/ft below natural grade)	LATERAL SLIDING RESISTANCE	
			Coefficient of friction[a]	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 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	100	—	130

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

a. Coefficient to be multiplied by the dead load.

b. Cohesion value to be multiplied by the contact area, as limited by Section 1806.3.2.

TABLE 1806.2a PRESUMPTIVE ALLOWABLE VERTICAL BEARING PRESSURES

Material Class	Description	Notes	Consistency in Place	Net Bearing Pressure (tons/ft²)[1,2,3]
1a	Massive bedrock: Granite, diorite, gabbro, basalt, gneiss	4	Hard, sound rock, minor jointing	100
1b	Quartzite, well-cemented conglomerate	4	Hard, sound rock moderate jointing	60
2	Foliated bedrock: slate, schist	4	Medium hard rock, minor jointing	40
3	Sedimentary bedrock: cementation shale, siltstone, sandstone, limestone, dolomite, conglomerate	4	Soft rock, moderate jointing	20
4	Weakly-cemented sedimentary bedrock: compaction shale or other similar rock in sound condition	4	Very soft rock	10
5	Weathered bedrock: any of the above except shale.	5	Very soft rock, weathered and/or major jointing and fracturing	8
6	Slightly-cemented sand and/or gravel, glacial till (basal or lodgement), hardpan	6	Very dense	10
7	Gravel, widely-graded sand and gravel; and granular ablation till	6	Very dense Dense Medium dense Loose Very loose	8 6 4 2 NOTE9
8		6, 7	Dense Medium dense	4 3

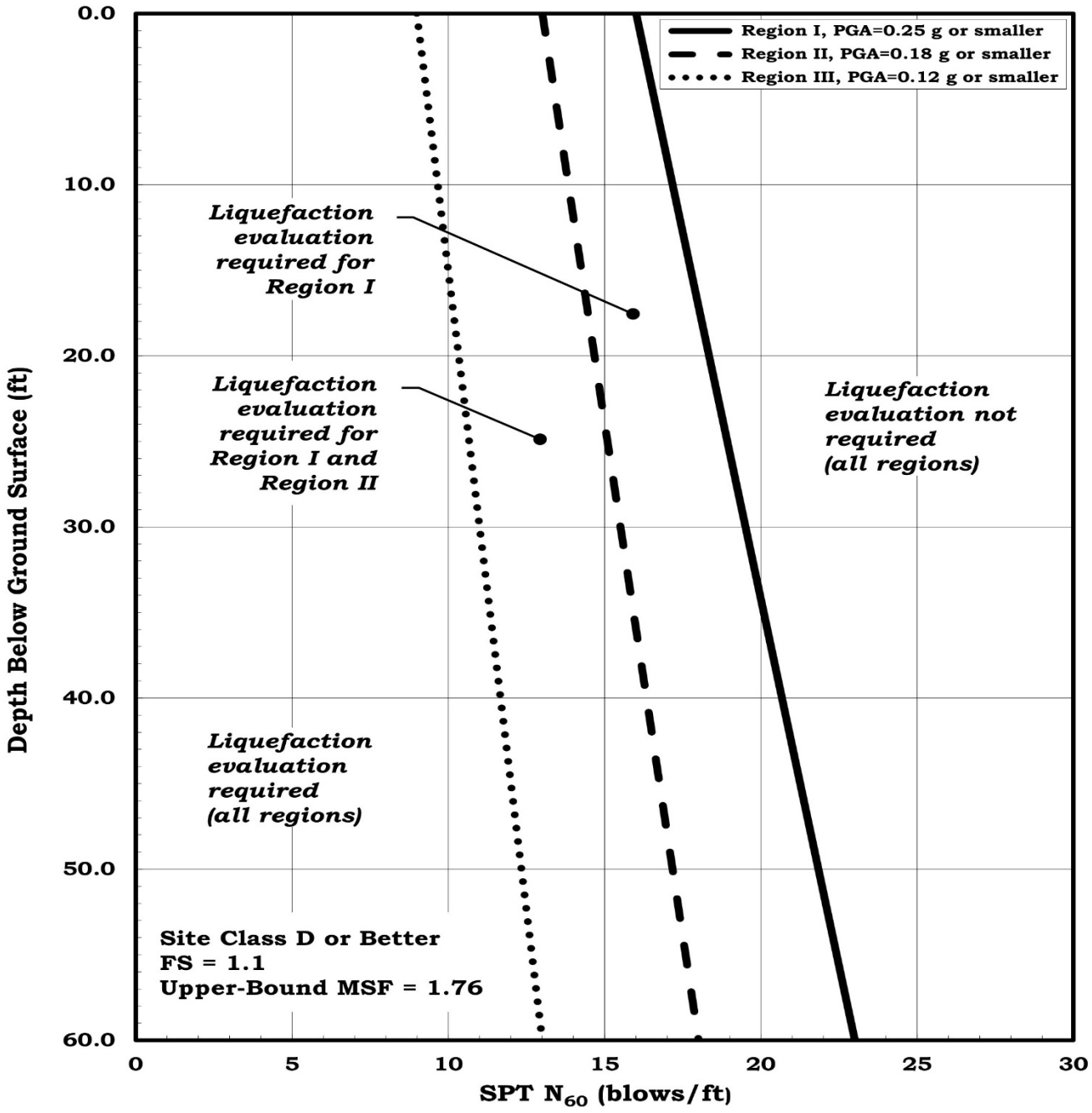
Material Class	Description	Notes	Consistency in Place	Net Bearing Pressure (tons/ft^2)[1,2,3]
	Sands and non-plastic silty sands with little or no gravel (except for Class 9 materials)		Loose Very loose	1 NOTE 9
9	Fine sand, silty fine sand, and non-plastic inorganic silt	6, 7	Dense Medium dense Loose Very loose	3 2 1 NOTE 9
10	Inorganic sandy or silty clay, clayey sand, clayey silt, clay, or varved clay; low to high plasticity	8	Hard Stiff Medium Soft	4 2 1 NOTE 9
11	Organic soils: peat, organic silt, organic clay	8,9		NOTE 9

NOTES:

1. Net bearing pressure shall consist of the bearing pressure applied at the bottom of the foundation, including the weight of the foundation and any soil immediately overlying the foundation, minus the pressure calculated for a height of soil extending from the bottom of the foundation to the lowest ground surface level immediately adjacent to the foundation.
2. Where the load-bearing layer directly below the foundation is underlain by a weaker layer, the bearing pressure on the weaker layer shall be checked by assuming that the load is spread uniformly at an angle of 30^o with the vertical, or by using another suitable method to determine the bearing pressure on the weaker layer.
3. The bearing strata shall be adequately protected against disturbance. If the bearing materials are disturbed from any cause, for example, by flow of water, freezing or construction activities, the extent of the disturbance shall be evaluated by a registered design professional to determine appropriate remedial measures or reduced allowable bearing pressures.
4. The allowable bearing pressures may be increased by an amount equal to ten percent for each foot of depth below the surface of sound rock; however, the increase shall not exceed two times the value given in the table.
5. Weathered shale and/or weathered compaction shale shall be included in Material Class 10. Other highly weathered rocks and/or residual soils shall be treated as soil under the appropriate description in Material Classes 6 to 10. Where the transition between residual soil and bedrock is gradual, a registered design professional shall make a judgment as to the appropriate bearing pressure.

6. Allowable bearing pressures may be increased by an amount equal to five percent for each foot of depth of the bearing area below the minimum required in section 1806.0; however, the bearing pressure shall not exceed two times the value given in the table. For foundation bearing areas having a least lateral dimension smaller than three feet, the allowable bearing pressure shall be 1/3 of the tabulated value times the least dimension in feet.
7. Evaluate susceptibility to liquefaction in accordance with section 1806.4.
8. Evaluate long-term settlement due to consolidation for these materials.
9. A registered design professional shall be engaged to provide recommendations for these special cases.

Figure 1806.4
Liquefaction Susceptibility



1806.3 Lateral 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~~ foundations are required to resist lateral loads, the allowable values of sliding friction, adhesion and passive pressure for design shall be determined by a registered design professional.

~~**1806.3.1 Combined resistance.**~~
~~The total resistance to lateral *loads* shall be permitted to be determined by combining the values derived from the lateral bearing pressure and the lateral sliding resistance specified in Table 1806.2.~~

~~**1806.3.2 Lateral sliding resistance limit.**~~
~~For clay, sandy clay, silty clay, clayey silt, silt and sandy silt, the lateral sliding resistance shall not exceed one-half the *dead load*.~~

~~**1806.3.3 Increase for depth.**~~
~~The lateral bearing pressures specified in Table 1806.2 shall be permitted to be increased by the tabular value for each additional foot (305 mm) of depth to a value that is not greater than 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 $^{1}/_{2}$-inch (12.7 mm) motion at the ground surface due to short-term lateral *loads* shall be permitted to be designed using lateral bearing pressures equal to two times the tabular values.~~

1806.3.1 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 1/2-inch (12.7 mm) motion at the ground surface due to short-term lateral loads shall be permitted to be designed using lateral bearing pressures equal to two times the tabular values of Table 1806.2.

1806.4 Liquefaction. The potential for liquefaction induced by the design earthquake in saturated clean to silty sands and non-plastic silts (Soil Classes 8 and 9 in Table 1806.2a) shall be evaluated as indicated in sections 1806.4.1 through 1806.4.4.

1806.4.1 Standard Penetration Test. For cases with a generally flat ground surface, the susceptibility to liquefaction may be evaluated using Figure 1806.4 on the basis of Standard Penetration Test ("SPT") blow counts, N (blows per foot) values that have been corrected for hammer efficiency to be SPT N_{60} (blows per foot) values. N_{60}-values are intended to be used with Figure 1806.4 and SPT N-values measured in the field should only be corrected for hammer energy. Hammer type shall be as described in ASTM Standard Method D6066. If the type of hammer is not known, Figure 1806.4 may be used assuming the SPT N-values were determined using a 140-lb donut drop weight and SPT N-values shall be corrected with a hammer efficiency correction factor (C_E) of 0.75.

Figure 1806.4 is intended to be a screening tool for Site Classes A through D, determined in accordance with section 1613.5.2. The figure is based on Maximum Considered Geometric Mean Earthquake (MCE_G) Peak Ground Accelerations (PGAs) at outcropping Site Class B rock of 0.25 g, 0.18 g, and 0.12 g and site amplification factors (F_{PGA}) of 1.35, 1.44, and 1.56, respectively for Site Class D, and a factor of safety of 1.1. Refer to Table 1604.11 or USGS earthquake hazard data for PGA specific to where the site is located. This figure is based on observed behavior of clean sand, and is conservative for other (more silty) materials. Soils that do not screen out using Figure 1806.4 shall be evaluated for liquefaction per section 1803.5.12.

If the SPT N_{60}-values plot above or to the right of the applicable line in Figure 1806.4, the soil shall be considered not susceptible to liquefaction. Liquefaction for soils below a depth of 60 feet (18 m) from final grade need not be considered for level ground. For pressure-injected footings, the ten-foot (3-m) thickness of soil immediately below the bottom of the driven shaft shall be considered not susceptible to liquefaction.

1806.4.2 Compacted Fills. Compacted granular fills shall be considered not susceptible to liquefaction provided that they are systematically compacted to at least 93% of the maximum dry density determined in accordance with ASTM Standard Method D1557.

1806.4.3 Evaluation by a Registered Design Professional. Soils that do not meet the criteria in section 1806.4.1 or 1806.4.2 shall be considered potentially susceptible to liquefaction. For these cases, studies shall be performed by a registered design professional in accordance with section 1803.5.12.

1806.4.4 Lateral Sliding. For sites underlain by the saturated soils identified in section 1806.4, and where the ground surface at the site or adjacent to the site is sloping such that lateral sliding (slope instability) may occur, studies by a registered design professional shall be made to establish the safety against sliding and lateral deformations as a result of the design earthquake.

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.

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

1807.1.4 Permanent wood foundation systems.
Permanent wood foundation systems shall be designed and installed in accordance with AWC PWF. Lumber and plywood shall be preservative treated in accordance with AWPA

U1 (Commodity Specification A, Special Requirement 4.2) and shall be identified in accordance with Section 2303.1.9.1.

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

> **Exception:** Concrete and masonry foundation walls shall be permitted to be designed and constructed in accordance with Section 1807.1.6.

1807.1.6 Prescriptive design of concrete and masonry foundation walls.
Concrete and masonry foundation walls shall be permitted to be designed and constructed in accordance with this section, provided that are laterally supported at the top and bottom, not subject to net hydrostatic pressures or surcharge loadings, and the backfill adjacent to the walls is not subjected to heavy compaction loads ~~shall be permitted to be designed and constructed in accordance with this section~~.

1807.1.6.1 Foundation wall thickness.
The thickness of prescriptively designed foundation walls shall be not less than the thickness of the wall supported, except that foundation walls of not less than 8-inch (203 mm) nominal width shall be permitted to support brick-veneered frame walls and 10-inch-wide (254 mm) *cavity walls* provided that the requirements of Section 1807.1.6.2 or 1807.1.6.3 are met.

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 1807.1.6.2 are based on the use of reinforcement with a minimum yield strength of 60,000 pounds per square inch (psi) (414 MPa). Vertical reinforcement with a minimum yield strength of 40,000 psi (276 MPa) or 50,000 psi (345 MPa) shall be permitted, provided that 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, where 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 $\pm 3/8$ inch (9.5 mm) where d is less than or equal to 8 inches (203 mm) or $\pm 1/2$ inch (12.7 mm) where d is greater than 8 inches (203 mm).

4. In lieu of the reinforcement shown in Table 1807.1.6.2, smaller reinforcing bar sizes with closer spacings that provide an equivalent cross-sectional area of reinforcement per unit length shall be permitted.

5. Concrete cover for reinforcement measured from the inside face of the wall shall be not less than $^{3}/_{4}$ inch (19.1 mm). Concrete cover for reinforcement measured from the outside face of the wall shall be not less than $1^{1}/_{2}$ 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).

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.

TABLE 1807.1.6.2
CONCRETE FOUNDATION WALLS[b, c]

MAXIMUM WALL HEIGHT (feet)	MAXIMUM UNBALANCED BACKFILL HEIGHT[e] (feet)	MINIMUM VERTICAL REINFORCEMENT-BAR SIZE 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, see Section 1610.
b. Provisions for this table are based on design and construction requirements specified in Section 1807.1.6.2.
c. PC = 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 1807.1.2.

1807.1.6.2.1 Seismic requirements.

Based on the *seismic design category* assigned to the structure in accordance with Section 1613, concrete foundation walls designed using Table 1807.1.6.2 shall be subject to the following limitations:

1. *Seismic Design Categories* A and B. Not less than one No. 5 bar shall be provided around window, door and similar sized openings. The bar shall be anchored to develop f_y in tension at the corners of openings.

2. *Seismic Design Categories* C, D, E and F. Tables shall not be used except as allowed for plain concrete members in Section 1905.1.7.

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 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 TMS 602, Article 3.4.B.11, of the specified location.

4. Grout shall comply with Section 2103.3.

5. Concrete *masonry units* shall comply with ASTM C90.

6. Clay *masonry units* shall comply with ASTM C652 for hollow brick, except compliance with ASTM C62 or ASTM C216 shall be permitted where solid *masonry units* are installed in accordance with Table 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 2103.2.1.

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. Not less than 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 2104.1. 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 not less than 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.

TABLE 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) Design lateral soil loada (psf per foot of depth)		
		30[f]	45[f]	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.

b. Provisions for this table are based on design and construction requirements specified in Section 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 1807.1.6.3(2) is required.

e. For height of unbalanced backfill, see Section 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 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)	MINIMUM VERTICAL REINFORCEMENT-BAR SIZE AND SPACING (inches)		
		Design lateral soil load[a] (psf per foot of depth)		
		30[e]	45[e]	60
7-4	4-0 (or less)	#4 at 48	#4 at 48	#4 at 48
	5-0	#4 at 48	#4 at 48	#4 at 48
	6-0	#4 at 48	#5 at 48	#5 at 48
	7-4	#5 at 48	#6 at 48	#7 at 48
8-0	4-0 (or less)	#4 at 48	#4 at 48	#4 at 48
	5-0	#4 at 48	#4 at 48	#4 at 48
	6-0	#4 at 48	#5 at 48	#5 at 48
	7-0	#5 at 48	#6 at 48	#7 at 48
	8-0	#5 at 48	#6 at 48	#7 at 48
8-8	4-0 (or less)	#4 at 48	#4 at 48	#4 at 48
	5-0	#4 at 48	#4 at 48	#5 at 48
	6-0	#4 at 48	#5 at 48	#6 at 48
	7-0	#5 at 48	#6 at 48	#7 at 48
	8-8[e]	#6 at 48	#7 at 48	#8 at 48
9-4	4-0 (or less)	#4 at 48	#4 at 48	#4 at 48
	5-0	#4 at 48	#4 at 48	#5 at 48
	6-0	#4 at 48	#5 at 48	#6 at 48
	7-0	#5 at 48	#6 at 48	#7 at 48
	8-0	#6 at 48	#7 at 48	#8 at 48
	9-4[e]	#7 at 48	#8 at 48	#9 at 48
10-0	4-0 (or less)	#4 at 48	#4 at 48	#4 at 48
	5-0	#4 at 48	#4 at 48	#5 at 48
	6-0	#4 at 48	#5 at 48	#6 at 48
	7-0	#5 at 48	#6 at 48	#7 at 48
	8-0	#6 at 48	#7 at 48	#8 at 48
	9-0[e]	#7 at 48	#8 at 48	#9 at 48
	10-0[e]	#7 at 48	#9 at 48	#9 at 48

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.
b. Provisions for this table are based on design and construction requirements specified in Section 1807.1.6.3.
c. For alternative reinforcement, see Section 1807.1.6.3.1.
d. For height of unbalanced backfill, see Section 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 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)	MINIMUM VERTICAL REINFORCEMENT-BAR SIZE AND SPACING (inches)		
		Design lateral soil load[a] (psf per foot of depth)		
		30[e]	45[e]	60
7-4	4-0 (or less)	#4 at 56	#4 at 56	#4 at 56
	5-0	#4 at 56	#4 at 56	#4 at 56
	6-0	#4 at 56	#4 at 56	#5 at 56
	7-4	#4 at 56	#5 at 56	#6 at 56
8-0	4-0 (or less)	#4 at 56	#4 at 56	#4 at 56
	5-0	#4 at 56	#4 at 56	#4 at 56
	6-0	#4 at 56	#4 at 56	#5 at 56
	7-0	#4 at 56	#5 at 56	#6 at 56
	8-0	#5 at 56	#6 at 56	#7 at 56
8-8	4-0 (or less)	#4 at 56	#4 at 56	#4 at 56
	5-0	#4 at 56	#4 at 56	#4 at 56
	6-0	#4 at 56	#4 at 56	#5 at 56
	7-0	#4 at 56	#5 at 56	#6 at 56
	8-8[e]	#5 at 56	#7 at 56	#8 at 56
9-4	4-0 (or less)	#4 at 56	#4 at 56	#4 at 56
	5-0	#4 at 56	#4 at 56	#4 at 56
	6-0	#4 at 56	#5 at 56	#5 at 56
	7-0	#4 at 56	#5 at 56	#6 at 56
	8-0	#5 at 56	#6 at 56	#7 at 56
	9-4[e]	#6 at 56	#7 at 56	#7 at 56
10-0	4-0 (or less)	#4 at 56	#4 at 56	#4 at 56
	5-0	#4 at 56	#4 at 56	#4 at 56
	6-0	#4 at 56	#5 at 56	#5 at 56
	7-0	#5 at 56	#6 at 56	#7 at 56
	8-0	#5 at 56	#7 at 56	#8 at 56
	9-0[e]	#6 at 56	#7 at 56	#9 at 56
	10-0[e]	#7 at 56	#8 at 56	#9 at 56

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot per foot = 1.157 kPa/m.

a. For design lateral soil loads, see Section 1610.
b. Provisions for this table are based on design and construction requirements specified in Section 1807.1.6.3.
c. For alternative reinforcement, see Section 1807.1.6.3.1.
d. For height of unbalanced backfill, see Section 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 1807.1.6.3(4)
12-INCH MASONRY FOUNDATION WALLS WITH REINFORCEMENT WHERE d ≥ 8.75 INCHESa, b, c

MAXIMUM WALL HEIGHT (feet-inches)	MAXIMUM UNBALANCED BACKFILL HEIGHT[d] (feet-inches)	MINIMUM VERTICAL REINFORCEMENT-BAR SIZE AND SPACING (inches)		
		Design lateral soil load[a] (psf per foot of depth)		
		30[e]	45[e]	60
7-4	4 (or less)	#4 at 72	#4 at 72	#4 at 72
	5-0	#4 at 72	#4 at 72	#4 at 72
	6-0	#4 at 72	#4 at 72	#5 at 72
	7-4	#4 at 72	#5 at 72	#6 at 72
8-0	4 (or less)	#4 at 72	#4 at 72	#4 at 72
	5-0	#4 at 72	#4 at 72	#4 at 72
	6-0	#4 at 72	#4 at 72	#5 at 72
	7-0	#4 at 72	#5 at 72	#6 at 72
	8-0	#5 at 72	#6 at 72	#8 at 72
8-8	4 (or less)	#4 at 72	#4 at 72	#4 at 72
	5-0	#4 at 72	#4 at 72	#4 at 72
	6-0	#4 at 72	#4 at 72	#5 at 72
	7-0	#4 at 72	#5 at 72	#6 at 72
	8-8[e]	#5 at 72	#7 at 72	#8 at 72
9-4	4 (or less)	#4 at 72	#4 at 72	#4 at 72
	5-0	#4 at 72	#4 at 72	#4 at 72
	6-0	#4 at 72	#5 at 72	#5 at 72
	7-0	#4 at 72	#5 at 72	#6 at 72
	8-0	#5 at 72	#6 at 72	#7 at 72
	9-4[e]	#6 at 72	#7 at 72	#8 at 72
10-0	4 (or less)	#4 at 72	#4 at 72	#4 at 72
	5-0	#4 at 72	#4 at 72	#4 at 72
	6-0	#4 at 72	#5 at 72	#5 at 72
	7-0	#4 at 72	#6 at 72	#6 at 72
	8-0	#5 at 72	#6 at 72	#7 at 72
	9-0[e]	#6 at 72	#7 at 72	#8 at 72
	10-0[e]	#7 at 72	#8 at 72	#9 at 72

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.
b. Provisions for this table are based on design and construction requirements specified in Section 1807.1.6.3.
c. For alternative reinforcement, see Section 1807.1.6.3.1.
d. For height of unbalanced backfill, see Section 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.

1807.1.6.3.1 Alternative foundation wall reinforcement.
In lieu of the reinforcement provisions for masonry foundation walls in Table 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 shall be permitted to be used, provided that the spacing of

reinforcement does not exceed 72 inches (1829 mm) and reinforcing bar sizes do not exceed No. 11.

1807.1.6.3.2 Seismic requirements.
Based on the *seismic design category* assigned to the structure in accordance with Section 1613, masonry foundation walls designed using Tables 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 1807.1.6.3(1) through 1807.1.6.3(4) is subject to the seismic requirements of Section 7.4.3 of TMS 402.

3. *Seismic Design Category* D. A design using Tables 1807.1.6.3(2) through 1807.1.6.3(4) is subject to the seismic requirements of Section 7.4.4 of TMS 402.

4. *Seismic Design Categories* E and F. A design using Tables 1807.1.6.3(2) through 1807.1.6.3(4) is subject to the seismic requirements of Section 7.4.5 of TMS 402.

~~**1807.2 Retaining walls.**~~
~~Retaining walls shall be designed in accordance with Sections 1807.2.1 through 1807.2.4.~~

~~**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. For structures assigned to *Seismic Design Category* D, E, or F, the design of retaining walls supporting more than 6 feet (1829 mm) of backfill height shall incorporate the additional seismic lateral earth pressure in accordance with the geotechnical investigation where required in Section 1803.2.~~

~~**1807.2.3 Safety factor.**~~
~~Retaining walls shall be designed to resist the lateral action of soil to produce sliding and overturning with a minimum safety factor of 1.5 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.~~

1807.2 Retaining Walls. Retaining walls shall be designed in accordance with sections 1807.2.1 through 1807.2.6. The requirements of this section shall apply to any type of retaining structure

or system that has any portion of its exposed face inclined steeper than one horizontal to one vertical, including conventional retaining walls, crib and bin wall systems, reinforced or mechanically stabilized earth systems, anchored walls, soil nail walls, multi-tiered systems, boulder walls or other types of retaining structures. The requirements of this section do not apply to slope facings, armor or riprap placed for the sole purpose of protection against surface erosion.

1807.2.1 Design. Retaining walls shall be designed to resist the static and seismic pressures of the retained materials, water pressures, and dead and live load surcharges to which such walls are subjected, and to ensure stability against excessive movements, overturning, sliding, excessive foundation pressure, and water uplift. Retaining walls that support an unbalanced height of retained material greater than six feet (1.83 m), ~~and~~ or any retaining system or slope that could impact public safety or the stability of an adjacent structure shall be designed by a registered design professional.

1807.2.2 Design Lateral Soil Loads. Retaining walls shall be designed for the lateral soil loads set forth in section 1610, including seismic lateral pressure, or the lateral loads determined by a registered design professional based on a geotechnical investigation performed in accordance with section 1803.

1807.2.3 Safety Factor. Retaining walls shall be designed to resist ~~the lateral action of soil to produce~~ sliding and overturning with a minimum factor of safety of 1.5 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 factor of safety for retaining wall sliding and overturning shall be 1.1.

1807.2.4 Overall Stability. The overall global stability of a retaining wall, considering potential failure surfaces extending through the materials located below, in front of and behind the wall shall be evaluated.

1807.2.5 Discrete Elements. For retaining walls constructed of discrete elements, such as unmortared masonry, rock, boulders, or stacked modular units, the elements shall be bonded or fastened together to prevent dislodgement under static and seismic loading conditions where dislodgement of the elements could pose a risk to public safety.

1807.2.6 Wall Drainage. Retaining walls shall be designed to support a hydrostatic head of water pressure equal to the full height of the wall, unless a drainage system is provided to reduce or eliminate hydrostatic pressure on the wall. Drainage systems shall be designed with sufficient permeability and discharge capacity, and shall be provided with appropriate filters and other design features to prevent blockage due to siltation, clogging, or freezing.

1807.2.4 Segmental retaining walls.

Dry-cast concrete units used in the construction of segmental retaining walls shall comply with ASTM C1372.

1807.3 Embedded posts and poles.
Designs to resist both axial and lateral *loads* employing posts or poles as columns embedded in earth or in concrete footings in earth shall be in accordance with Sections 1807.3.1 through 1807.3.3.

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).

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

1807.3.2.1 Nonconstrained.
The following formula shall be used in determining the depth of embedment required to resist lateral *loads* where lateral constraint is not provided at the ground surface, such as by a rigid floor or rigid ground surface pavement, and where lateral constraint is not provided above the ground surface, such as by a structural *diaphragm*.

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

where:

A = $2.34P/(S_1 b)$.
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 1806.2 based on a depth of onethird the depth of embedment in pounds per square foot (psf) (kPa).

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.

$$d = \sqrt{\frac{4.25Ph}{S_3 b}} \qquad \textbf{(Equation 18-2)}$$

or alternatively

$$d = \sqrt{\frac{4.25M_g}{S_3 b}} \qquad \textbf{(Equation 18-3)}$$

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 1806.2 based on a depth equal to the depth of embedment in pounds per square foot (kPa).

1807.3.2.3 Vertical load.
The resistance to vertical *loads* shall be determined using the vertical foundation pressure set forth in Table 1806.2.

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 a specified compressive strength of not less than 2,000 psi (13.8 MPa). The hole shall be not 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 1808
FOUNDATIONS

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

1808.2 Design for capacity and settlement.
Foundations shall be ~~so~~ designed to provide adequate load ~~that the allowable bearing~~ capacity

while limiting settlement, heave and lateral movement to tolerable levels ~~of the soil is not exceeded, and that differential settlement is minimized~~. Foundations in areas with expansive soils shall be designed in accordance with the provisions of Section 1808.6.

1808.3 Design loads.
Foundations shall be designed for the most unfavorable effects due to the combinations of *loads* specified in Section 2.3 or 2.4 of ASCE 7 or the alternative allowable stress design load combinations of Section 1605.2. The *dead load* is permitted to include the weight of foundations and overlying fill. Reduced *live loads*, as specified in Sections 1607.12 and 1607.14, shall be permitted to be used in the design of foundations.

1808.3.1 Seismic overturning.
Where foundations are proportioned using the load combinations of Section 2.3 or 2.4 of ASCE 7 and the computation of seismic overturning effects is by equivalent lateral force analysis or modal analysis, the proportioning shall be in accordance with Section 12.13.4 of ASCE 7.

1808.3.2 Surcharge.
Fill or other surcharge *loads* shall not be placed adjacent to any building or structure unless such building or structure is capable of withstanding the additional *loads* caused by the fill or the surcharge. Existing footings or foundations that will be affected by any excavation shall be underpinned or otherwise protected against settlement and shall be protected against detrimental lateral or vertical movement or both.

Exception: Minor grading for landscaping purposes shall be permitted where done with walk-behind equipment, where the grade is not increased more than 1 foot (305 mm) from original design grade or where *approved* by the *building official*.

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

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

1808.6 Design for expansive soils.
Foundations for buildings and structures founded on expansive soils shall be designed in accordance with Section 1808.6.1 or 1808.6.2.

Exceptions: Foundation design need not comply with Section 1808.6.1 or 1808.6.2 where one of the following conditions is satisfied:

1. The soil is removed in accordance with Section 1808.6.3.

2. The *building official* approves stabilization of the soil in accordance with Section 1808.6.4.

1808.6.1 Foundations.
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.

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 DC 10.5*.* 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 DC 10.5. 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.

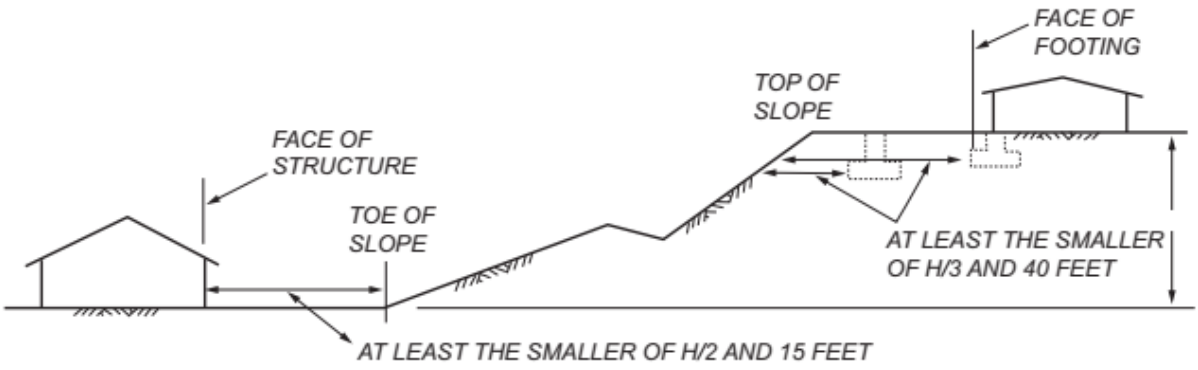
1808.6.3 Removal of expansive soil.
Where expansive soil is removed in lieu of designing foundations in accordance with Section 1808.6.1 or 1808.6.2, the soil shall be removed to a depth sufficient to ensure a constant moisture content in the remaining soil. Fill material shall not contain expansive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

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

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

1808.7 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 comply with Sections 1808.7.1 through 1808.7.5.

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 in Section 1808.7.5 and Figure 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.



Insert H @ Vertical Dimension Line

For SI: 1 foot = 304.8 mm.

FIGURE 1808.7.1
FOUNDATION CLEARANCES FROM SLOPES

1808.7.2 Foundation setback from descending slope surface.
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 foundation without detrimental settlement. Except as provided for in Section 1808.7.5 and Figure 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.

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.

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 not less than

12 inches (305 mm) plus 2 percent. Alternate elevations are permitted subject to the approval of the *building official*, provided that 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.

1808.7.5 Alternate setback and clearance.
Alternate setbacks and clearances are permitted, subject to the approval of the *building official*. The *building official* shall be permitted to require a geotechnical investigation as set forth in Section 1803.5.10.

1808.8 Concrete foundations.
The design, materials and construction of concrete foundations shall comply with Sections 1808.8.1 through 1808.8.6 and the provisions of Chapter 19.

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

1808.8.1 Concrete or grout strength and mix proportioning.
Concrete or grout in foundations shall have a specified compressive strength (f'_c) not less than the largest applicable value indicated in Table 1808.8.1.

Where concrete or grout is to be pumped, the mix design including slump shall be adjusted to produce a pumpable 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
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
2b. Foundations for other structures assigned to Seismic Design Category D, E or F	3,000 psi
3. Precast nonprestressed driven piles	4,000 psi
4. Socketed drilled shafts	4,000 psi
5. Micropiles	4,000 psi
6. Precast prestressed driven piles	5,000 psi

For SI: 1 pound per square inch = 0.00689 MPa.

1808.8.2 Concrete cover.
The concrete cover provided for prestressed and nonprestressed reinforcement in foundations shall be not less than the largest applicable value specified in Table 1808.8.2. Longitudinal bars spaced less than $1\frac{1}{2}$ inches (38 mm) clear distance apart shall be considered to be bundled bars for which the concrete cover provided shall be not less than

that required by Section 20.6.1.3.4 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 to be the concrete surface.

TABLE 1808.8.2
MINIMUM CONCRETE COVER

FOUNDATION ELEMENT OR CONDITION	MINIMUM COVER
1. Shallow foundations	In accordance with Section 20.6 of ACI 318
2. Precast nonprestressed deep foundation elements Exposed to seawater Not manufactured under plant conditions Manufactured under plant control conditions	 3 inches 2 inches In accordance with Section 20.6.1.3.3 of ACI 318
3. Precast prestressed deep foundation elements Exposed to seawater Other	 2.5 inches In accordance with Section 20.6.1.3.3 of ACI 318
4. Cast-in-place deep foundation elements not enclosed by a steel pipe, tube or permanent casing	2.5 inches
5. Cast-in-place deep foundation elements enclosed by a steel pipe, tube or permanent casing	1 inch
6. Structural steel core within a steel pipe, tube or permanent casing	2 inches
7. Cast-in-place drilled shafts enclosed by a stable rock socket	1.5 inches

For SI:1 inch = 25.4 mm.

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-size foundation. Concrete 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.

1808.8.4 Protection of concrete.
Concrete foundations shall be protected from freezing during depositing and for a period of not less than 5 days thereafter. Water shall not be allowed to flow through the deposited concrete.

1808.8.5 Forming of concrete.
Concrete foundations are permitted to be cast against the earth where, in the opinion of the *building official*, soil conditions do not require formwork. Where formwork is required, it shall be in accordance with Section 26.11 of ACI 318.

1808.8.6 Seismic requirements.
See Section 1905 for additional requirements for 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 Section 18.13 of ACI 318 shall apply where not in conflict with the provisions of Sections 1808 through 1810.

Exceptions:

1. Detached one- and two-family dwellings of *light-frame construction* and two stories or less above *grade plane* are not required to comply with the provisions of Section 18.13 of ACI 318.

2. Section 18.13.4.3(a) of ACI 318 shall not apply.

1808.9 Vertical masonry foundation elements.
Vertical masonry foundation elements that are not *foundation piers* as defined in Section 202 shall be designed as piers, walls or columns, as applicable, in accordance with TMS 402.

SECTION 1809
SHALLOW FOUNDATIONS

1809.1 General.
Shallow foundations shall be designed and constructed in accordance with Sections 1809.2 through 1809.13.

1809.2 Supporting soils.
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 1804.5. *CLSM* shall be placed in accordance with Section 1804.6.

1809.3 Stepped footings.
The top surface of footings shall be level. The bottom surface of footings shall be permitted to have a slope not exceeding 1 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 1 unit vertical in 10 units horizontal (10-percent slope).

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 requirements of Section 1809.5 shall be satisfied. The minimum width of footings shall be 12 inches (305 mm).

1809.5 Frost protection.
Except where otherwise protected from frost, foundations 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.

3. Erecting on solid rock.

Exception: Free-standing buildings meeting all of the following conditions shall not be required to be protected:

1. Assigned to *Risk Category* I.

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*.

3. Eave height of 10 feet (3048 mm) or less.

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

1809.5.1 Frost protection at required exits.
Frost protection shall be provided at exterior landings for all required exits with outward-swinging doors. Frost protection shall only be required to the extent necessary to ensure the unobstructed opening of the required *exit* doors.

1809.6 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 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 1809.4.
b. The ground under the floor shall be permitted to be excavated to the elevation of the top of the footing.
c. Interior stud-bearing walls 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 1905 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 1807.1.6.
f. Footings 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 shall be permitted to be 6 inches thick.

1809.8 Plain concrete footings.
The edge thickness of plain concrete footings supporting walls of other than *light-frame construction* shall be not 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.

1809.9 Masonry-unit footings.
The design, materials and construction of masonry-unit footings shall comply with Sections 1809.9.1 and 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* shall be permitted to be designed in accordance with Table 1809.7.

1809.9.1 Dimensions.
Masonry-unit footings shall be laid in Type M or S *mortar* complying with Section 2103.2.1 and the depth shall be not less than twice the projection beyond the wall, pier or column. The width shall be not less than 8 inches (203 mm) wider than the wall supported thereon.

1809.9.2 Offsets.
The maximum offset of each course in brick foundation walls stepped up from the footings shall be $1^1/_2$ inches (38 mm) where laid in single courses, and 3 inches (76 mm) where laid in double courses.

1809.10 Pier and curtain wall foundations.
Except in *Seismic Design Categories* D, E and F, pier and curtain wall foundations shall be permitted to be used to support *light-frame construction* not more than two *stories above grade plane*, provided that 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 be not less than 4 inches (102 mm) nominal or $3^5/_8$ 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 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 (102 mm) 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 (305 mm) for hollow masonry.

1809.11 Steel grillage footings.
Grillage footings of *structural steel elements* shall be separated with *approved* steel spacers and be entirely encased in concrete with not less than 6 inches (152 mm) on the bottom and not less than 4 inches (102 mm) at all other points. The spaces between the shapes shall be completely filled with concrete or cement grout.

1809.12 Timber footings.
Timber footings 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 on treated piles shall not exceed 70 percent of the allowable stresses for the species and grade of timber as specified in the ANSI/AWC NDS.

1809.13 Footing seismic ties.
Where a structure is assigned to *Seismic Design Category* D, E or F, individual spread footings founded on soil defined in Chapter 20 of ASCE 7 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 and 25 percent of the smaller footing design gravity load.

1809.14 Ground Improvement. *Ground Improvement*, for purposes of this Section, shall be defined as a system that uses elements of aggregate, concrete, grout, or other mixture of cementitious materials and/or aggregates, or other materials that are significantly stiffer than the ground being improved, installed into the ground upon which building foundation units such as footings, slabs or mats are supported, to improve the engineering properties of the bearing strata. The *Ground*

Improvement system includes the elements and all strata and materials within the zone of influence beneath the foundation units.

This Section provides requirements for the design, testing and construction of *Ground Improvement* systems.

1809.14.1 Design. *Ground Improvement* for foundation unit support shall be designed by a *registered design professional,* referred to in this Section as the *Ground Improvement Designer*.

1809.14.1.1 Design Determinations. *Ground Improvement* design shall include the determination of the following, at a minimum:

1. Applied loads on the *Ground Improvement* system including the following:
   a. Compression, tensile and lateral loads, static and dynamic.
   b. Downdrag.
2. Load distribution and strain compatibility between *Ground Improvement* elements and the surrounding soil being improved, considering all loading conditions.
3. Lateral confinement and the potential for element bulging or necking.
4. Seismic response including kinematic movements, and potential for liquefaction and its impact on bearing, settlements and confinement.
5. Allowable geotechnical capacity (vertical, and lateral if applicable) of individual *Ground Improvement* elements and groups of elements.
6. Allowable structural capacity (axial, flexure, and shear) of individual *Ground Improvement* elements consistent with the allowable stresses for the materials listed in Table 1810.3.2.6.
7. Structural compatibility between *Ground Improvement* elements and the supported foundation units including:
   a. Confirmation of the thickness and characteristics of any granular Load Transfer Pad to separate the foundation units from the elements and the improved ground, as applicable.
   b. Evaluation of potential impacts of concentrated reaction loads imposed by the elements on supported foundation units including floor slabs.
   c. Minimum number and configuration of elements to establish vertical, lateral and rotational stability of isolated and strip footings.
8. Short-term and long-term settlements of foundations and other structural units bearing above *Ground Improvement* systems.
9. Potential impacts of *Ground Improvement* element installations on previously-installed elements and on existing facilities in the proximity of element installations.

1809.14.1.2 Rigid Inclusions. *Rigid Inclusions,* for purposes of this Section, shall be defined as *Ground Improvement* elements comprised of or containing concrete, cement grout or materials of similar stiffness.

Ground Improvement using *Rigid Inclusions* shall conform to the following additional requirements:

1. The allowable geotechnical load capacity of *Rigid Inclusions* shall not exceed fifty (50) percent of the *demonstrated maximum load capacity* as determined by load testing in accordance with Section 1809.14.2.
2. The allowable geotechnical load capacity of a foundation unit shall not exceed forty (40) percent of the ultimate load capacity of the modified bearing strata beneath the unit, considering the combined contribution of the ultimate bearing capacity of the subsurface strata and the *demonstrated maximum load capacity* of the *Ground Improvement* elements.
3. The allowable geotechnical load capacity of a foundation unit shall be equal to or greater than the foundation unit's bearing area multiplied by the design foundation bearing pressure indicated on the foundation design drawing(s) or otherwise specified by the *registered design professional* responsible for the foundation unit structural design.
4. A *Load Transfer Pad* consisting of a minimum of 6 in. of ¾ in. crushed stone, or other material and thickness with equivalent load-deformation characteristics and shear resistance, shall be provided between tops of *Rigid Inclusions* and the underside of foundation units. If thicker than 8 inches, the resistance of the *Load Transfer Pad* to punching by the elements shall be demonstrated by analysis or testing.
5. Determination of allowable load capacity of *Rigid Inclusions* by load testing such that anticipated foundation settlements are tolerable and protective of the integrity of the supported structure.

1809.14.1.3 Design Documentation. Documentation of *Ground Improvement design* shall be prepared by the *Ground Improvement Designer* and provided to the Building Official and the building owner, which includes the following at a minimum:

1. Detailed description of the proposed *Ground Improvement* elements and other system components.
2. Key assumptions used in system design.
3. Element allowable design load and minimum diameter.
4. Subsurface conditions within zone of influence below foundation units including bearing strata, design element penetration into bearing strata, and proportion of capacity anticipated to be achieved in friction and end-bearing.
5. Potential impacts of the presence of soft, organic or compressible soils.
6. Process, equipment, materials and criteria for element installations.
7. Measures to achieve and to confirm element shaft integrity, and accommodate the presence of soft or organic soils.
8. Requirements for load testing.
9. Description of the results, including calculations, of design determinations required in Sections 1809.14.1.1 and 1809.14.1.2.
10. *Ground Improvement* design drawing(s) including layout and dimensions of supported foundation units; foundation unit design structural loads and allowable bearing pressures; element locations, diameters and allowable design loads; and minimum element spacing.

1809.14.2 Rigid Inclusion Load Testing. Load testing of *Rigid Inclusions* shall be performed at on-site location(s) representative of the subsurface conditions at production element locations, to determine the allowable design load in vertical compression and adequate element performance for the *Ground Improvement* system. Testing shall be performed in accordance with the following requirements:

1. Load in Bearing Stratum. The load reaching the top of the bearing stratum under the maximum test load shall not be less than the following:
    a. For end-bearing elements: 100% of the allowable design load.
    b. For friction elements: 150% of the allowable design load.
    c. For elements designed for a combination of end-bearing and friction, the required test load reaching the bearing stratum shall be based on the predominant support mode.
2. Instrumentation. The test element shall be instrumented using redundant systems of strain gauges, tell-tales, or other methods to enable measurement or computation of the load in the element where it enters the bearing stratum. For foundation elements containing grout or concrete, instrumentation shall be installed to permit direct measurement of the elastic modulus of the element during the test.

3. Loading Procedure. The loading procedure shall be as follows:
    a. Apply 25% of the proposed allowable design load every 0.5 hour. Longer time increments may be used, but each time increment should be the same. In no case shall a load be changed if the rate of settlement is not decreasing with time.
    b. At 200% of the proposed allowable design load, maintain the load for a minimum of one hour and until the settlement meets the criteria in Section 1809.14.2.4.
    c. Remove 50% of the design load every 15 minutes until zero load is reached. Longer time increments may be used, but each should be the same.
    d. Measure rebound at zero load for a minimum of one hour.
    e. For each load increment or decrement, take readings at the top of the element and on the instrumentation at one, two, four, eight and 15 minutes and at 15-minute intervals thereafter.
    f. A load greater than 200% of the proposed allowable design load may be applied at the top of the test element, using the above loading procedure, to ensure that the requirement for minimum load reaching the bearing stratum is fulfilled. Other optional methods may be approved by the Building Official upon submittal in advance of satisfactory justification prepared by a *registered design professional*.

4. Load Test Evaluation. Provided that the requirement for minimum load reaching the bearing stratum is satisfied, the element allowable design load shall be determined by the *Ground Improvement Designer*. The allowable design load shall not exceed 50 percent of the *demonstrated maximum load capacity*, defined as the load at which the settlement at the top of the element does not exceed 0.01 in. during one hour, and

which provides the minimum factor of safety and settlement control required by the Building Code.

5. Documentation. The results of the load testing, including the testing methodology, system setup, *demonstrated maximum load capacity*, allowable design load and acceptance criteria shall be documented in a report prepared by the *Ground Improvement Designer*.

1809.14.3 Construction.

1. Elements and other aspects of the *Ground Improvement* system shall be constructed and installed in accordance with the *Ground Improvement* design.
2. Special inspections with documentation shall be performed in accordance with the procedures of Chapter 17, continuously during all construction activities related to *Ground Improvement* including but not limited to materials, load testing, element installation, element cut-offs, subgrade preparation, Load Transfer Pads and any fill placed between elements and footing bottoms.
3. As-built drawing(s) and other information as required to document the *Ground Improvement* system installations and related activities shall be prepared and made available to the Building Official and the building owner, sealed by the *Ground Improvement Designer*. The information shall include, at a minimum, the load test report, the final foundation unit layout, element locations and cut-off elevations, and any deviations between the *Ground Improvement* design and the as-built conditions.

SECTION 1810
DEEP FOUNDATIONS

1810.1 General.
Deep foundations shall be analyzed, designed, detailed and installed in accordance with Sections 1810.1 through 1810.4.

1810.1.1 Geotechnical investigation.
Deep foundations shall be designed and installed on the basis of a geotechnical investigation as set forth in Section 1803.

1810.1.2 Use of existing deep foundation elements.
Deep foundation elements left in place that have previously supported a partially or fully ~~where a structure has been~~ demolished structure may ~~shall not~~ be used for the support of new construction if ~~unless~~ satisfactory evidence is submitted by a registered design professional to the *building official*, which indicates that the foundation elements have not been adversely impacted by the demolition, are structurally sound, have adequate load-bearing capacity to support the new design loads, and meet all of the requirements of 780 CMR, including seismic requirements. ~~are sound and meet the requirements of this code. Such elements shall be load tested or redriven to verify their capacities. The design *load* applied to such elements shall be the lowest allowable *load* as determined by tests or redriving data.~~ The load-bearing capacities of the deep foundation elements shall be determined by one of the following methods:

1. Analyses to determine the actual sustained load that the foundations supported satisfactorily in the previous structure.
2. Analyses based on documented foundation geometry and presumptive bearing value of the supporting soil, where applicable to the foundation type.
3. Load testing or re-driving performed on representative foundation elements. Records of previous pile-driving and load testing may be utilized where such records are deemed adequate by the registered design professional.

1810.1.3 Deep foundation elements classified as columns.
Deep foundation elements standing unbraced in air, water or fluid soils shall be classified as columns and designed as such in accordance with the provisions of this code from their top down to the point where adequate lateral support is provided in accordance with Section 1810.2.1.

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

1810.1.4 Special types of deep foundations.
The use of types of *deep foundation* elements not specifically mentioned herein is permitted, subject to the approval of the *building official*, upon the submission of acceptable test data, calculations and other information relating to the structural properties and load capacity of such elements. The allowable stresses for materials shall not in any case exceed the limitations specified herein.

1810.2 Analysis.
The analysis of *deep foundations* for design shall be in accordance with Sections 1810.2.1 through 1810.2.5.

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

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

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

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

lateral forces, or the foundation elements are adequately braced to provide for lateral stability.

Exceptions:

1. Isolated cast-in-place *deep foundation* elements without lateral bracing shall be permitted where the least horizontal dimension is not less than 2 feet (610 mm), adequate lateral support in accordance with Section 1810.2.1 is provided for the entire height and the height does not exceed 12 times the least horizontal dimension.

2. A single row of *deep foundation* elements without lateral bracing is permitted for one- and two-family dwellings and lightweight construction not exceeding two *stories above grade plane* or 35 feet (10 668 mm) in *building height*, provided that the centers of the elements are located within the width of the supported wall.

1810.2.3 Settlement.
The settlement of a single *deep foundation* element or group thereof shall be estimated based on *approved* methods of analysis. The predicted settlement shall cause neither harmful distortion of, nor instability in, the structure, nor cause any element to be loaded beyond its capacity.

1810.2.4 Lateral loads.
The moments, shears and lateral deflections used for design of *deep foundation* elements shall be established considering the nonlinear interaction of the shaft and soil, as determined by a *registered design professional*. Where the ratio of the depth of embedment of the element to its least horizontal dimension is less than or equal to six, it shall be permitted to assume the element is rigid.

1810.2.4.1 Seismic Design Categories D through F.
For structures assigned to *Seismic Design Category* D, E or F, *deep foundation* elements on *Site Class* E or F sites, as determined in Section 1613.2.2, shall be designed and constructed to withstand maximum imposed curvatures from earthquake ground motions and structure response. Curvatures shall include free-field soil strains modified for soil-foundation-structure interaction coupled with foundation element deformations associated with earthquake *loads* imparted to the foundation by the structure.

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

1. Precast prestressed concrete piles detailed in accordance with Section 1810.3.8.

2. Cast-in-place *deep foundation* elements with a minimum longitudinal reinforcement ratio of 0.005 extending the full length of the element and detailed in accordance with Sections 18.7.5.2, 18.7.5.3 and 18.7.5.4 of ACI 318 as required by Section 1810.3.9.4.2.2.

1810.2.5 Group effects.
The analysis shall include group effects on lateral behavior where the center-to-center spacing of *deep foundation* elements in the direction of lateral force is less than eight times the least horizontal dimension of an element. The analysis shall include group effects on axial behavior where the center-to-center spacing of *deep foundation* elements is less than three times the least horizontal dimension of an element. Group effects shall be evaluated using a generally accepted method of analysis; the analysis for uplift of grouped elements with center-to-center spacing less than three times the least horizontal dimension of an element shall be evaluated in accordance with Section 1810.3.3.1.6.

1810.3 Design and detailing.
Deep foundations shall be designed and detailed in accordance with Sections 1810.3.1 through 1810.3.13.

1810.3.1 Design conditions.
Design of *deep foundations* shall include the design conditions specified in Sections 1810.3.1.1 through 1810.3.1.6, as applicable.

1810.3.1.1 Design methods for concrete elements.
Where concrete *deep foundations* are laterally supported in accordance with Section 1810.2.1 for the entire height and applied forces cause bending moments not greater than those resulting from accidental eccentricities, structural design of the element using the allowable stress design load combinations specified in ASCE 7, Section 2.4 or the alternative allowable stress design load combinations of Section 1605.2 and the allowable stresses specified in this chapter shall be permitted. Otherwise, the structural design of concrete *deep foundation* elements shall use the strength load combinations specified in ASCE 7, Section 2.3 and *approved* strength design methods.

1810.3.1.2 Composite elements.
Where a single *deep foundation* element comprises two or more sections of different materials or different types spliced together, each section of the composite assembly shall satisfy the applicable requirements of this code, and the maximum allowable *load* in each section shall be limited by the structural capacity of that section.

1810.3.1.3 Mislocation.
The foundation or superstructure shall be designed to resist the effects of the mislocation of any *deep foundation* element by not less than 3 inches (76 mm). To resist the effects of mislocation, compressive overload of *deep foundation* elements to 110 percent of the allowable design load shall be permitted.

1810.3.1.4 Driven piles.
Driven piles shall be designed and manufactured in accordance with accepted engineering practice to resist all stresses induced by handling, driving and service loads.

1810.3.1.5 Helical piles.
Helical piles shall be designed and manufactured in accordance with accepted engineering practice to resist all stresses induced by installation into the ground and service loads.

1810.3.1.6 Casings.
Temporary and permanent casings shall be of steel and shall be sufficiently strong to resist collapse and sufficiently watertight to exclude any foreign materials during the placing of concrete. Where a permanent casing is considered reinforcing steel, the steel shall be protected under the conditions specified in Section 1810.3.2.5. Horizontal joints in the casing shall be spliced in accordance with Section 1810.3.6.

1810.3.2 Materials.
The materials used in *deep foundation* elements shall satisfy the requirements of Sections 1810.3.2.1 through 1810.3.2.8, as applicable.

1810.3.2.1 Concrete.
Where concrete is cast in a steel pipe or where an enlarged base is formed by compacting concrete, the maximum size for coarse aggregate shall be $^{3}/_{4}$ inch (19.1 mm). Concrete to be compacted shall have a zero slump.

1810.3.2.1.1 Seismic hooks.
For structures assigned to *Seismic Design Category* C, D, E or F, the ends of hoops, spirals and ties used in concrete deep foundation elements shall be terminated with seismic hooks, as defined in ACI 318, and shall be turned into the confined concrete core.

1810.3.2.1.2 ACI 318 Equation (25.7.3.3).
Where this chapter requires detailing of concrete deep foundation elements in accordance with Section 18.7.5.4 of ACI 318, compliance with Equation (25.7.3.3) of ACI 318 shall not be required.

1810.3.2.2 Prestressing steel.
Prestressing steel shall conform to ASTM A416.

1810.3.2.3 Steel.
Structural steel H-piles and structural steel sheet piling shall conform to the material requirements in ASTM A6. Steel pipe piles shall conform to the material requirements in ASTM A252. Fully welded steel piles shall be fabricated from plates that conform to the material requirements in ASTM A36, ASTM A283, ASTM A572, ASTM A588 or ASTM A690.

1810.3.2.4 Timber.
Timber deep foundation elements shall be designed as piles or poles in accordance with ANSI/AWC NDS. Round timber elements shall conform to ASTM D25. Sawn timber elements shall conform to DOC PS-20.

1810.3.2.4.1 Preservative treatment.
Timber deep foundation elements used to support permanent structures shall be treated in accordance with this section unless it is established that the tops of the untreated timber elements will be below the lowest ground-water level assumed to exist during the life of the structure. Preservative and minimum final retention shall be in accordance with AWPA U1 (Commodity Specification E, Use Category 4C) for round timber elements and AWPA U1 (Commodity Specification A, Use Category 4B) for sawn timber elements. Preservative-treated timber elements shall

be subject to a quality control program administered by an *approved agency*. Element cutoffs shall be treated in accordance with AWPA M4.

1810.3.2.5 Protection of materials.
Where boring records or site conditions indicate possible deleterious action on the materials used in deep foundation elements because of soil constituents, changing water levels or other factors, the elements shall be adequately protected by materials, methods or processes *approved* by the *building official*. Protective materials shall be applied to the elements so as not to be rendered ineffective by installation. The effectiveness of such protective measures for the particular purpose shall have been thoroughly established by satisfactory service records or other evidence.

1810.3.2.6 Allowable stresses.
The allowable stresses for materials used in deep foundation elements shall not exceed those specified in Table 1810.3.2.6.

EXCEPTIONS:
1. Maximum allowable stress for concrete or grout in compression for elements that are cast in place without a permanent casing shall be 0.33 f'c.
2. Maximum allowable stresses for timber foundation elements shall be 80% of the values determined in accordance with the AWC NDS.

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 or Section 1810.3.5.3.4	$0.4 f'_c$
Cast-in-place in other permanent casing or rock	$0.33 f'_c$
Cast-in-place without a permanent casing	$0.3 f'_c$
Precast nonprestressed	$0.33 f'_c$
Precast prestressed	$0.33 f'_c - 0.27 f_{pc}$
2. Nonprestressed reinforcement in compression	$0.4 f_y \leq 30{,}000$ psi
3. Steel in compression	
Cores within concrete-filled pipes or tubes	$0.5 F_y \leq 32{,}000$ psi
Pipes, tubes or H-piles, where justified in accordance with Section 1810.3.2.8	$0.5 F_y \leq 32{,}000$ psi
Pipes or tubes for micropiles	$0.4 F_y \leq 32{,}000$
Other pipes, tubes or H-piles	$0.35 F_y \leq 24{,}000$ psi
Helical piles	$0.6 F_y \leq 0.5 F_u$
4. Nonprestressed reinforcement in tension	

Within micropiles	$0.6 f_y$
Other conditions For load combinations that do not include wind or seismic loads For load combinations that include wind or seismic loads	$0.5 f_y \leq 30{,}000$ psi $0.5 f_y \leq 40{,}000$ psi
5. Steel in tension Pipes, tubes or H-piles, where justified in accordance with Section 1810.3.2.8	$0.5 F_y \leq 32{,}000$ psi
Other pipes, tubes or H-piles	$0.35 F_y \leq 24{,}000$ psi
Helical piles	$0.6 F_y \leq 0.5 F_u$
6. Timber	In accordance with the ANSI/AWC 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 steel; F_u is the specified minimum tensile stress of structural steel.

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

1810.3.2.7 Increased allowable compressive stress for cased mandrell-driven cast-in-place elements.
The allowable compressive stress in the concrete shall be permitted to be increased as specified in Table 1810.3.2.6 for those portions of permanently cased cast-in-place elements that satisfy all of the following conditions:

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

1810.3.2.8 Justification of higher allowable stresses.
Use of allowable stresses greater than those specified in Section 1810.3.2.6 shall be permitted where supporting data justifying such higher stresses is filed with the *building official*. Such substantiating data shall include the following:

1. A geotechnical investigation in accordance with Section 1803.

2. Load tests in accordance with Section 1810.3.3.1.2, regardless of the load supported by the element.

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

1810.3.3 Determination of allowable loads.
The allowable axial and lateral loads on deep foundation elements shall be determined by an *approved* formula, load tests or method of analysis.

1810.3.3.1 Allowable axial load.
The allowable axial load on a deep foundation element shall be determined in accordance with Sections 1810.3.3.1.1 through 1810.3.3.1.~~9~~ 11. Where the allowable load capacity is not determined by using one of the formulas or analysis methods provided in sections 1810.3.3.1.1 through 1810.3.3.1.11, or the presumptive load- bearing values in section 1806, the allowable load capacity shall be verified by load tests. Dynamic load testing of instrumented driven piles performed in accordance with ASTM D4945 may be used in lieu of static load testing, where the testing program consists of a minimum of three instrumented piles tested to a minimum factor of safety of 2.5 using an analysis procedure that matches the force and velocity traces measured at the top of the pile. Load testing may be waived by the building official based upon submittal of substantiating data prepared by a registered design professional which include load test data or performance records for the proposed deep foundation elements under similar soil and loading conditions.

EXCEPTION: The allowable frictional resistance of cast-in-place elements greater than or equal to 12 inches in diameter obtaining capacity in Material Classes 1 through 6 in Table 1806.2a may be determined by a registered design professional based on analyses incorporating results of testing in similar bearing materials.

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

~~**1810.3.3.1.1 Driving criteria.**~~
~~The allowable compressive load on any driven deep foundation element where determined by the application of an *approved* driving formula shall not exceed 40 tons (356 kN). For allowable loads above 40 tons (356 kN), the wave equation method of analysis shall be used to estimate driveability for both driving stresses and net displacement per blow at the ultimate load. Allowable loads shall be verified by load tests in accordance with Section 1810.3.3.1.2. The formula or wave equation load shall be determined for gravity-drop or power-actuated hammers and the hammer energy used shall be the maximum consistent with the size, strength and weight of the driven elements. The use of a follower is permitted only with the approval of the *building official*. The introduction of fresh hammer cushion or pile cushion material just prior to final penetration is not permitted.~~

~~**1810.3.3.1.2 Load tests.**~~

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

~~**1810.3.3.1.3 Load test evaluation methods.**~~

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

~~1. Davisson Offset Limit.~~

~~2. Brinch-Hansen 90-percent Criterion.~~

~~3. Butler-Hoy Criterion.~~

~~4. Other methods *approved* by the *building official*.~~

1810.3.3.1.1 Driving Criteria. For driven piles with a design load capacity not exceeding 50tons (445 kN), the allowable load capacity may be determined based on final driving criteria (net displacement per hammer blow) obtained from an appropriate pile driving formula using a factor of safety not less than 3.5, or from wave equation analysis using a factor of safety not less than 2.75. The use of followers shall be allowed only as directed by a registered design professional.

The introduction of fresh hammer cushion material just prior to final penetration is not permitted.

1810.3.3.1.2 Load Tests. Where static load testing is required to determine the allowable load bearing capacity of deep foundation elements in vertical compression, the load tests shall be performed in accordance with ASTM D1143 and the following requirements:

1. **Load in Bearing Stratum**. The load reaching the top of the bearing stratum under themaximum test load shall not be less than the following:
   a. For end-bearing elements: 100% of the allowable design load.
   b. For friction elements: 150% of the allowable design load.
   c. For foundation elements designed for a combination of end-bearing and friction, the required test load reaching the bearing stratum shall be based on the predominant support mode.

2. **Instrumentation**. The test element shall be instrumented using strain gauges, tell-tales, or similar methods to enable measurement or computation of the load in the element where it enters the bearing stratum. For foundation elements containing concrete, instrumentation shall be installed to permit direct measurement of the elastic modulus of the element during the test.
   Instrumentation of the test element is not required for the following cases:
   a. The test element is installed within a casing that extends to within ten feet above the bearing stratum.
   b. Load testing is performed on an existing foundation element, and appropriate consideration is given to potential frictional resistance developed above the bearing stratum during the load test.
   c. The foundation element length does not exceed 30 feet and no appreciable load will be supported above the bearing stratum.

3. **Loading Procedure**. The loading procedure shall be as follows:
   a. Apply 25% of the proposed allowable design load every 0.5 hour. Longer time increments may be used, but each time increment should be the same. In no case shall a load be changed if the rate of settlement is not decreasing with time.
   b. At 200% of the proposed allowable design load maintain the load for a minimum of one hour and until the settlement (measured at the lowest point on the element at which measurements are made) over a one-hour period is not greater than 0.01 in.
   c. Remove 50% of the design load every 15 minutes until zero load is reached. Longer time increments may be used, but each should be the same.
   d. Measure rebound at zero load for a minimum of one hour.
   e. For each load increment or decrement, take readings at the top of the element and on the instrumentation at one, two, four, eight and 15 minutes and at 15-minute intervals thereafter.
   f. A load greater than 200% of the proposed allowable design load may be applied at the top of the test element, using the above loading procedure, to ensure that the requirement for minimum load reaching the bearing stratum is fulfilled. Other optional methods listed in ASTM D1143 may be approved by the building official upon submittal in advance of satisfactory justification prepared by a registered design professional.

1810.3.3.1.3 Load Test Evaluation Methods. Provided that the requirement for minimum load reaching the bearing stratum is satisfied, the allowable design load is permitted to be the greater of the following:

1. Allowable design load based on settlement during loading: 50% of the applied test load which causes a gross settlement at the top equal to the sum of:
   a) the theoretical elastic compression of the element in inches assuming all the load at the top is transmitted to the tip, plus
   b) 0.15 inch (3.8 mm), plus
   c) 1% of the tip diameter or width in inches.
2. Allowable design load based on the net settlement after rebound: 50% of the applied test load which results in a net settlement at the top of 0.5 inch (13 mm) after rebound at zero load.

   If the allowable design load is not governed by one of the above criteria, the allowable design load shall be equal to 50% of the maximum test load.

   If the requirement for minimum test load reaching the bearing stratum is not satisfied, the allowable design load shall not exceed: a) the load reaching the bearing stratum for end- bearing elements and b) two-thirds of the load reaching the bearing stratum for friction elements.

   The allowable design load capacity determined from load tests can be applied to other foundation elements of the same type and size that are installed in similar subsurface conditions using the same installation methods and equipment. Where the design is based on a minimum embedment length, minimum penetration resistance, or friction over a minimum surface area, the applicable design value for the production elements shall equal or exceed the value used for the test element.

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

1810.3.3.1.5 Uplift capacity of a single *deep foundation* element.
Where required by the design, the uplift capacity of a single deep foundation element shall be determined by an *approved* method of analysis based on a minimum factor of safety of three or by load tests conducted in accordance with ASTM D3689. The maximum allowable uplift *load* shall not exceed the ultimate load capacity as determined in Section 1810.3.3.1.2, using the results of load tests conducted in accordance with ASTM D3689, divided by a factor of safety of two.

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

1810.3.3.1.6 Allowable uplift load of grouped *deep foundation elements*.
For grouped *deep foundation* elements subjected to uplift, the allowable uplift load for the group shall be calculated by a generally accepted method of analysis. Where the *deep foundation* elements in the group are placed at a center-to-center spacing less than three times the least horizontal dimension of the largest single element, the allowable uplift *load* for the group is permitted to be calculated as the lesser of:

1. The proposed individual allowable uplift *load* times the number of elements in the group.

2. Two-thirds of the effective weight of the group and the soil contained within a block defined by the perimeter of the group and the length of the element, plus two-thirds of the ultimate shear resistance along the soil block.

1810.3.3.1.7 Load-bearing capacity.
Deep foundation elements shall develop ultimate load capacities of not less than twice the design working *loads* in the designated load-bearing layers. Analysis shall show that soil layers underlying the designated load-bearing layers do not cause the load-bearing capacity safety factor to be less than two.

1810.3.3.1.8 Bent deep foundation elements.
The load-bearing capacity of *deep foundation* elements discovered to have a sharp or sweeping bend shall be determined by an *approved* method of analysis or by load testing a representative element.

1810.3.3.1.9 Helical piles.
The allowable axial design *load*, P_a, of *helical piles* shall be determined as follows:

$$P_a = 0.5 P_u \qquad \textbf{(Equation 18-4)}$$

where P_u is the least value of:

1. Base capacity plus shaft resistance of the *helical pile*. The base capacity is equal to the sum of the areas of the helical bearing plates times the ultimate bearing capacity of the soil or rock comprising the bearing stratum. The shaft resistance is equal to the area of the shaft above the uppermost helical bearing plate times the ultimate skin resistance.

2. Ultimate capacity determined from well-documented correlations with installation torque.

3. Ultimate capacity determined from load tests where required by Section 1810.3.3.1.2.

4. Ultimate axial capacity of pile shaft.

5. Ultimate axial capacity of pile shaft couplings.

6. Sum of the ultimate axial capacity of helical bearing plates affixed to pile.

1810.3.3.1.10 Enlarged Base Piles. For enlarged base piles with compacted concrete bases and design capacities up to 120 tons, that are formed on or in bearing materials of Classes 1 to9 inclusive in Table 1806.2a, the allowable load may be computed by the following formula.

The Class 9 material (fine sand) shall have a maximum of 15% by weight finer than the No. 200 mesh sieve and the fines shall be non-plastic.

$$R = [(B \times E)/C] V^{2/3} \qquad \textbf{(Equation 18-12)}$$

Where:

R = allowable load in pounds.
B = average number of blows required to inject one cubic foot of concrete, during injection of the last batch.
E = energy per blow in foot-pounds.
C = constant.
V = total volume of base concrete in cubic feet.

The values of R, E, and C shall conform to Table 1810.3.3.1 unless other values are determined by load test, in which case the latter values shall control. The value of V shall include an allowance of one standard batch volume of concrete, if concrete is used in the tube during the driving process, plus the additional volume of concrete injected during formation of the base.

During injection of the last batch of concrete in the base, the height of concrete within the drive tube shall not be more than 1/3 of the drive-tube inside diameter.

TABLE 1810.3.3.1

R (tons)	Energy, E (foot-pounds)	C	Standard Batch Volume (ft^3)
over 100	140,000	18	5
51 to 100	100,000	18	5
25 to 50	60,000	30	2

1810.3.3.1.11 Alternate Load Test Procedure for Micropiles. For micropiles designed as friction piles, the friction capacity in compression may be verified by load testing in tension in accordance with ASTM D3689 and the following requirements:

1. The test pile shall be cased or left un-grouted down to the top of the bearing stratum in a manner which will ensure that no friction resistance is developed above the bearing stratum.
2. The maximum design load shall be taken as 50% of the applied test load which results in a movement under load of 0.5 inch (13 mm) at the pile tip. The movement at the pile tip shall be:

a. measured directly by a tell-tale; or
b. computed by deducting the theoretical elastic elongation of the pile from thedisplacement measured at the top of the pile.

1810.3.3.2 Allowable lateral load.
Where required by the design, the lateral load capacity of a single *deep foundation* element or a group thereof shall be determined by an *approved* method of analysis or by lateral load tests to not less than twice the proposed design working *load*. The resulting allowable *load* shall not be more than one-half of the *load* that produces a gross lateral movement of 1 inch (25 mm) at the lower of the top of foundation element and the ground surface, unless it can be shown that the predicted lateral movement shall cause neither harmful distortion of, nor instability in, the structure, nor cause any element to be loaded beyond its capacity.

1810.3.4 Subsiding soils or strata.
Where *deep foundation* elements are installed through subsiding soils or other subsiding strata and derive support from underlying firmer materials, consideration shall be given to the downward frictional forces potentially imposed on the elements by the subsiding upper strata.

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

1810.3.5 Dimensions of deep foundation elements.
The dimensions of *deep foundation* elements shall be in accordance with Sections 1810.3.5.1 through 1810.3.5.3, as applicable.

1810.3.5.1 Precast.
The minimum lateral dimension of precast concrete deep foundation elements shall be 8 inches (203 mm). Corners of square elements shall be chamfered.

1810.3.5.2 Cast-in-place or grouted-in-place.
Cast-in-place and grouted-in-place *deep foundation* elements shall satisfy the requirements of this section.

1810.3.5.2.1 Cased.
Cast-in-place or grouted-in-place *deep foundation* elements with a permanent casing shall have a nominal outside diameter of not less than 8 inches (203 mm).

1810.3.5.2.2 Uncased.
Cast-in-place or grouted-in-place *deep foundation* elements without a permanent casing shall have a specified diameter of not less than 12 inches (305 mm). The element length shall not exceed 30 times the specified diameter.

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

building official stating that the elements were installed in compliance with the *approved construction documents*.

1810.3.5.2.3 Micropiles.
Micropiles shall have a nominal diameter of 12 inches (305 mm) or less. The minimum diameter set forth elsewhere in Section 1810.3.5 shall not apply to micropiles.

1810.3.5.3 Steel.
Steel *deep foundation* elements shall satisfy the requirements of this section.

1810.3.5.3.1 Structural steel H-piles.
Sections of structural steel H-piles shall comply with the requirements for HP shapes in ASTM A6, or the following:

1. The flange projections shall not exceed 14 times the minimum thickness of metal in either the flange or the web and the flange widths shall be not less than 80 percent of the depth of the section.

2. The nominal depth in the direction of the web shall be not less than 8 inches (203 mm).

3. Flanges and web shall have a minimum nominal thickness of $^{3}/_{8}$ inch (9.5 mm).

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

1810.3.5.3.2 Fully welded steel piles fabricated from plates.
Sections of fully welded steel piles fabricated from plates shall comply with the following:

1. The flange projections shall not exceed 14 times the minimum thickness of metal in either the flange or the web and the flange widths shall be not less than 80 percent of the depth of the section.

2. The nominal depth in the direction of the web shall be not less than 8 inches (203 mm).

3. Flanges and web shall have a minimum nominal thickness of $^{3}/_{8}$ inch (9.5 mm).

1810.3.5.3.3 Structural steel sheet piling.
Individual sections of structural steel sheet piling shall conform to the profile indicated by the manufacturer, and shall conform to the general requirements specified by ASTM A6.

1810.3.5.3.4 Steel pipes and tubes.
Steel pipes and tubes used as *deep foundation* elements shall have a nominal outside diameter of not less than 8 inches (203 mm). Where steel pipes or tubes are driven open ended, they shall have not less than 0.34 square inch (219 mm^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. For mandrel-driven pipes or tubes, the minimum wall thickness shall be $^1/_{10}$ inch (2.5 mm).

1810.3.5.3.5 Helical piles.
Dimensions of the central shaft and the number, size and thickness of helical bearing plates shall be sufficient to support the design loads.

1810.3.6 Splices.
Splices shall be constructed so as to provide and maintain true alignment and position of the component parts of the *deep foundation* element during installation and subsequent thereto and shall be designed to resist the axial and shear forces and moments occurring at the location of the splice during driving and for design load combinations. Where *deep foundation* elements of the same type are being spliced, splices shall develop not less than 50 percent of the bending strength of the weaker section. Where *deep foundation* elements of different materials or different types are being spliced, splices shall develop the full compressive strength and not less than 50 percent of the tension and bending strength of the weaker section. Where structural steel cores are to be spliced, the ends shall be milled or ground to provide full contact and shall be full-depth welded.

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

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

1810.3.6.1 Seismic Design Categories C through F.
For structures assigned to *Seismic Design Category* C, D, E or F splices of *deep foundation* elements shall develop the lesser of the following:

1. The nominal strength of the *deep foundation* element.

2. The axial and shear forces and moments from the seismic *load effects* including overstrength factor in accordance with Section 2.3.6 or 2.4.5 of ASCE 7.

1810.3.7 Top of element detailing at cutoffs.
Where a minimum length for reinforcement or the extent of closely spaced confinement reinforcement is specified at the top of a *deep foundation* element, provisions shall be made so that those specified lengths or extents are maintained after cutoff.

1810.3.8 Precast concrete piles.
Precast concrete piles shall be designed and detailed in accordance with ACI 318.

Exceptions:

1. For precast prestressed piles in *Seismic Design Category* C, the minimum volumetric ratio of spirals or circular hoops required by Section 18.13.5.10.4 of ACI 318 shall not apply in cases where the design includes full consideration of load combinations specified in ASCE 7, Section 2.3.6 or Section 2.4.5 and the applicable overstrength factor, Ω0. In such cases, minimum transverse reinforcement index shall be as specified in Section 13.4.5.6 of ACI 318.

2. For precast prestressed piles in *Seismic Design Categories* D through F, the minimum volumetric ratio of spirals or circular hoops required by Section 18.13.5.10.5(c) of ACI 318 shall not apply in cases where the design includes full consideration of load combinations specified in ASCE 7, Section 2.3.6 or Section 2.4.5 and the applicable overstrength factor, Ω_0. In such cases, minimum transverse reinforcement shall be as specified in Section 13.4.5.6 of ACI 318.

1810.3.9 Cast-in-place deep foundations.
Cast-in-place *deep foundation* elements shall be designed and detailed in accordance with Sections 1810.3.9.1 through 1810.3.9.6.

1810.3.9.1 Design cracking moment.
The design cracking moment (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 18-5)**

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

where:

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

S_m = Elastic section modulus, neglecting reinforcement and casing, cubic inches (mm^3).

1810.3.9.2 Required reinforcement.
Where subject to uplift or where the required moment strength determined using the load combinations of ASCE 7, Section 2.3 exceeds the design cracking moment determined in accordance with Section 1810.3.9.1 , cast-in-place *deep foundations* not enclosed by a structural steel pipe or tube shall be reinforced.

1810.3.9.3 Placement of reinforcement.
Reinforcement where required shall be assembled and tied together and shall be placed in the *deep foundation* element as a unit before the reinforced portion of the element is filled with concrete.

Exceptions:

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

2. For *deep foundation* elements installed with a hollow-stem auger, tied reinforcement shall be placed after elements are concreted, while the concrete is still in a semifluid state. Longitudinal reinforcement without lateral ties shall be placed either through the hollow stem of the auger prior to concreting or after concreting, while the concrete is still in a semifluid state.

3. For Group R-3 and U occupancies not exceeding two stories of *light-frame construction*, reinforcement is permitted to be placed after concreting, while the concrete is still in a semifluid state, and the concrete cover requirement is permitted to be reduced to 2 inches (51 mm), provided that the construction method can be demonstrated to the satisfaction of the *building official*.

1810.3.9.4 Seismic reinforcement.
Where a structure is assigned to *Seismic Design Category* C, reinforcement shall be provided in accordance with Section 1810.3.9.4.1. Where a structure is assigned to *Seismic Design Category* D, E or F, reinforcement shall be provided in accordance with Section 1810.3.9.4.2.

Exceptions:

1. Isolated *deep foundation* elements supporting posts of Group R-3 and U occupancies not exceeding two stories of *light-frame construction* shall be permitted to be reinforced as required by rational analysis but with not less than one No. 4 bar, without ties or spirals, where detailed so the element is not subject to lateral loads and the soil provides adequate lateral support in accordance with Section 1810.2.1 .

2. Isolated *deep foundation* elements supporting posts and bracing from decks and patios appurtenant to Group R-3 and U occupancies not exceeding two stories of *light-frame construction* shall be permitted to be reinforced as required by rational analysis but with not less than one No. 4 bar, without ties or spirals, where the lateral *load*, E, to the top of the element does not exceed 200 pounds (890 N) and the soil provides adequate lateral support in accordance with Section 1810.2.1.

3. *Deep foundation* elements supporting the concrete foundation wall of Group R-3 and U occupancies not exceeding two stories of light-frame construction shall be permitted to be reinforced as required by rational analysis but with not less than two No. 4 bars, without ties or spirals, where the design cracking moment determined in accordance with Section 1810.3.9.1 exceeds the required moment strength determined using the load combinations with overstrength factor in Section 2.3.6 or 2.4.5 of ASCE 7 and the soil provides adequate lateral support in accordance with Section 1810.2.1.

4. Closed ties or spirals where required by Section 1810.3.9.4.2 shall be permitted to be limited to the top 3 feet (914 mm) of *deep foundation* elements 10 feet (3048 mm) or less in depth supporting Group R-3 and U occupancies of *Seismic Design Category* D, not exceeding two stories of *light-frame construction*.

1810.3.9.4.1 Seismic reinforcement in Seismic Design Category C.
For structures assigned to *Seismic Design Category* C, cast-in-place *deep foundation* elements shall be reinforced as specified in this section. Reinforcement shall be provided where required by analysis.

Not fewer than four longitudinal bars, with a minimum longitudinal reinforcement ratio of 0.0025, shall be provided throughout the minimum reinforced length of the element as defined in this section starting at the top of the element. Where the actual cross-section area is greater than the minimum area required by design, the minimum reinforcement ratio can be applied to the minimum design area. The minimum reinforced length of the element shall be taken as the greatest of the following:

1. One-third of the element length.

2. A distance of 10 feet (3048 mm).

3. Three times the least element dimension.

4. The distance from the top of the element to the point where the design cracking moment determined in accordance with Section 1810.3.9.1 exceeds the required moment strength determined using the load combinations of ASCE 7, Section 2.3.

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

Exceptions:

1. The requirements of this section shall not apply to concrete cast in structural steel pipes or tubes.

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

1810.3.9.4.2 Seismic reinforcement in Seismic Design Categories D through F.

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

Not fewer than four longitudinal bars, with a minimum longitudinal reinforcement ratio of 0.005, shall be provided throughout the minimum reinforced length of the element as defined in this section starting at the top of the element. Where the actual cross-section area is greater than the minimum area required by design, the minimum reinforcement ratio can be applied to the minimum design area. The minimum reinforced length of the element shall be taken as the greatest of the following:

1. One-half of the element length.

2. A distance of 10 feet (3048 mm).

3. Three times the least element dimension.

4. The distance from the top of the element to the point where the design cracking moment determined in accordance with Section 1810.3.9.1 exceeds the required moment strength determined using the load combinations of ASCE 7, Section 2.3.

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

1. 12 longitudinal bar diameters.

2. One-half the least dimension of the element.

3. 12 inches (305 mm).

Exceptions:

1. The requirements of this section shall not apply to concrete cast in structural steel pipes or tubes.

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

1810.3.9.4.2.1 Site Classes A through D.
For *Site Class* A, B, C or D sites, transverse confinement reinforcement shall be provided in the element in accordance with Sections 18.7.5.2, 18.7.5.3 and 18.7.5.4 of ACI 318 within three times the least element dimension of the bottom of the pile cap. A transverse spiral reinforcement ratio of not less than one-half of that required in Table 18.10.6.4(g) of ACI 318 shall be permitted.

1810.3.9.4.2.2 Site Classes E and F.
For *Site Class* E or F sites, transverse confinement reinforcement shall be provided in the element in accordance with Sections 18.7.5.2, 18.7.5.3 and 18.7.5.4 of ACI 318 within seven times the least element dimension of the pile cap and within seven times the least element dimension of the interfaces of strata that are hard or stiff and strata that are liquefiable or are composed of soft- to medium-stiff clay.

1810.3.9.5 Belled drilled shafts.
Where *drilled shafts* are belled at the bottom, the edge thickness of the bell shall be not less than four inches (102 mm) ~~that required for the edge of footings~~. Where the sides of the bell slope at an angle less than 60 degrees (1 rad) from the horizontal, the effects of vertical shear shall be considered.

1810.3.9.6 Socketed drilled shafts.
Socketed *drilled shafts* shall have a permanent pipe or tube casing that extends down to bedrock and an uncased socket drilled into the bedrock, both filled with concrete. Alternatively, slurry may be used under appropriate conditions per Section 1810.4.1.2.

Socketed *drilled shafts* shall have reinforcement or a structural steel core for the length as indicated by an *approved* method of analysis.

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

Where a structural steel core is used, the gross cross-sectional area of the core shall not exceed 25 percent of the gross area of the drilled *shaft*. ~~and suitable~~ confinement shall be provided that extends from the underside of structure to the top of rock. Confinement shall include permanent steel casing conforming to 1810.3.5.3.4 or a reinforcing cage conforming with ACI 318 for composite members.

1810.3.10 Micropiles.
Micropiles shall be designed and detailed in accordance with Sections 1810.3.10.1 through 1810.3.10.4.

1810.3.10.1 Construction.
Micropiles shall develop their load-carrying capacity by means of a bond zone in soil, bedrock or a combination of soil and bedrock. Micropiles shall be grouted and have either a steel pipe or tube or steel reinforcement at every section along the length. It shall be permitted to transition from deformed reinforcing bars to steel pipe or tube reinforcement by extending the bars into the pipe or tube section by not less than their development length in tension in accordance with ACI 318.

1810.3.10.2 Materials.
Reinforcement shall consist of deformed reinforcing bars in accordance with ASTM A615 Grade 60 or 75 or ASTM A722 Grade 150.

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

1810.3.10.3 Reinforcement.
For micropiles or portions thereof grouted inside a temporary or permanent casing or inside a hole drilled into bedrock or a hole drilled with grout, the steel pipe or tube or steel reinforcement shall be designed to carry not less than 40 percent of the design compression load. Micropiles or portions thereof grouted in an open hole in soil without temporary or permanent casing and without suitable means of verifying the hole diameter during grouting shall be designed to carry the entire compression *load* in the reinforcing steel. Where a steel pipe or tube is used for reinforcement, the portion of the grout enclosed within the pipe is permitted to be included in the determination of the allowable stress in the grout.

1810.3.10.4 Seismic reinforcement.
For structures assigned to *Seismic Design Category* C, a permanent steel casing shall

be provided from the top of the *micropile* down to the point of zero curvature. For structures assigned to *Seismic Design Category* D, E or F, the *micropile* shall be considered as an alternative system in accordance with Section 104.11. The alternative system design, supporting documentation and test data shall be submitted to the *building official* for review and approval.

1810.3.11 Pile caps.
Pile caps shall conform with ACI 318 and this section. Pile caps shall be of reinforced concrete, and shall include all elements to which vertical *deep foundation* elements are connected, including grade beams and mats. The soil immediately below the pile cap shall not be considered as carrying any vertical *load*, with the exception of a *combined pile raft*. The tops of vertical *deep foundation* elements shall be embedded not less than 3 inches (76 mm) into pile caps and the caps shall extend not less than 4 inches (102 mm) beyond the edges of the elements. The tops of elements shall be cut or chipped back to sound material before capping.

1810.3.11.1 Seismic Design Categories C through F.
For structures assigned to *Seismic Design Category* C, D, E or F, concrete *deep foundation* elements shall be connected to the pile cap in accordance with ACI 318.

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

1810.3.11.2 Seismic Design Categories D through F.
For structures assigned to *Seismic Design Category* D, E or F, deep foundation element resistance to uplift forces or rotational restraint shall be provided by anchorage into the pile cap, designed considering the combined effect of axial forces due to uplift and bending moments due to fixity to the pile cap. Anchorage shall develop not less than 25 percent of the strength of the element in tension. Anchorage into the pile cap shall comply with the following:

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

   1.1. The nominal tensile strength of the longitudinal reinforcement in a concrete element.

   1.2. The nominal tensile strength of a steel element.

   1.3. The frictional force developed between the element and the soil multiplied by 1.3.

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

2. In the case of rotational restraint, the anchorage shall be designed to resist the axial and shear forces, and moments resulting from the seismic *load effects* including overstrength factor in accordance with Section 2.3.6 or 2.4.5 of ASCE 7 or the anchorage shall be capable of developing the full axial, bending and shear nominal strength of the element.

3. The connection between the pile cap and the steel H-piles or unfilled steel pipe piles in structures assigned to *Seismic Design Category* D, E or F shall be designed for a tensile force of not less than 10 percent of the pile compression capacity.

Exceptions:

1. Connection tensile capacity need not exceed the strength required to resist seismic load effects including overstrength of ASCE 7 Section 12.4.3 or 12.14.3.2.

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

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

1810.3.12 Grade beams.
Grade beams shall comply with the provisions of ACI 318.

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

1810.3.13 Seismic ties.
Seismic ties shall comply with the provisions of ACI 318.

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

1810.3.14 Spacing. The minimum center-to-center spacing of piles shall be not less than twice the average diameter of a round pile, nor less than 1.75 times the diagonal dimension of a rectangular pile. When driven to or penetrating into rock, the spacing shall be not less than 24 inches (610 mm). When receiving principal support from end-bearing on materials other than rock or through frictional resistance, pile spacing shall be not less than 30 inches (762 mm). For enlarged base piles, the center-to-center spacing with uncased shafts shall be not less than 2.5 times the outside diameter of the drive tube and

not less than 42 inches (1,067 mm). The center- to-center spacing of enlarged base piles with cased shafts shall be not less than three times the shaft diameter. For auger-cast piles, the minimum center-to-center spacing between adjacent piles shall not be less than 30 inches (760 mm) or two times the pile diameter, whichever is greater. The minimum center-to-center spacing between adjacent piers designed for friction support shall be not less than two times the shaft diameter.

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

1810.4.1 Structural integrity.
Deep foundation elements shall be installed in such a manner and sequence as to prevent distortion or damage that would adversely affect the structural integrity of adjacent structures or of foundation elements being installed or already in place and as to avoid compacting the surrounding soil to the extent that other foundation elements cannot be installed properly.

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

1810.4.1.2 Shafts in unstable soils.
Where cast-inplace *deep foundation* elements are formed through unstable soils, the open hole shall be stabilized by a casing, slurry, or other approved method prior to placing the concrete. Where the casing is withdrawn during concreting, the level of concrete shall be maintained above the bottom of the casing at a sufficient height to offset any hydrostatic or lateral soil pressure. Driven casings shall be mandrel driven their full length in contact with the surrounding soil.

1810.4.1.3 Driving near uncased concrete.
Deep foundation elements shall not be driven within six element diameters center to center in granular soils or within one-half the element length in cohesive soils of an uncased element filled with concrete less than 48 hours old unless *approved* by the *building official*. If driving near uncased concrete elements causes the concrete surface in any completed element to rise or drop significantly or bleed additional water, the completed element shall be replaced.

1810.4.1.4 Driving near cased concrete.
Deep foundation elements shall not be driven within four and one-half average diameters of a cased element filled with concrete less than 24 hours old unless *approved* by the *building official*. Concrete shall not be placed in casings within heave range of driving.

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

1810.4.2 Identification.
Deep foundation materials shall be identified for conformity to the specified grade with this identity maintained continuously from the point of manufacture to the point of installation or shall be tested by an *approved agency* to determine conformity to the specified grade. The *approved agency* shall furnish an affidavit of compliance to the *building official*.

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

1810.4.4 Preexcavation.
The use of jetting, augering or other methods of preexcavation shall be subject to the approval of the *building official*. Where permitted, preexcavation shall be carried out in the same manner as used for deep foundation elements subject to load tests and in such a manner that will not impair the carrying capacity of the elements already in place or damage adjacent structures. Element tips shall be advanced below the preexcavated depth until the required resistance or penetration is obtained.

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

Exceptions:

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

1810.4.6 Heaved elements.
Deep foundation elements in the vicinity of piles being driven shall be monitored to observe heave of the elements. Accurate reference points shall be established on each element immediately after its installation; for cast-in-place piles with unfilled casings or shells, the reference point shall be at the bottom of the pile. If, following the installation of piles in the vicinity, heaving of ½ inch (13 mm) or more occurs, the heaved element shall be re-driven to develop the required capacity and penetration, or the capacity of the element shall be verified by load testing in accordance with section 1810.3.3.1.2 or by analyses performed by a registered design professional. ~~that have heaved during the driving of adjacent elements shall be redriven as necessary to develop the required capacity and penetration, or the capacity of the element shall be verified by load tests in accordance with Section 1810.3.3.1.2.~~

1810.4.7 Enlarged base cast-in-place elements.
Enlarged bases for cast-in-place *deep foundation* elements formed by compacting concrete or by driving a precast base shall be formed in or driven into granular soils. Such elements

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

1810.4.8 Hollow-stem augered, cast-in-place elements.
Where concrete or grout is placed by pumping through a hollow-stem auger, the auger element shall be formed by advancing a closed-end continuous-flight hollow-stem auger of uniform diameter into a satisfactory bearing material followed by removal of the tip closure and pumping cement grout or concrete through the hollow-stem while the hollow-stem auger is extracted. The installation shall conform to the following requirements: ~~shall be permitted to rotate in a clockwise direction during withdrawal. As the auger is withdrawn at a steady rate or in increments not to exceed 1 foot (305 mm), concreting or grouting pumping pressures shall be measured and maintained high enough at all times to offset hydrostatic and lateral earth pressures. Concrete or grout volumes shall be measured to ensure that the volume of concrete or grout placed in each element is equal to or greater than the theoretical volume of the hole created by the auger. Where the installation process of any element is interrupted or a loss of concreting or grouting pressure occurs, the element shall be redrilled to 5 feet (1524 mm) below the elevation of the tip of the auger when the installation was interrupted or concrete or grout pressure was lost and reformed. Augered cast-in-place elements shall not be installed within six diameters center to center of an element filled with concrete or grout less than 12 hours old, unless *approved* by the *building official*. If the concrete or grout level in any completed element drops due to installation of an adjacent element, the element shall be replaced.~~

1. During advancement, the hollow-stem auger shall be rotated at a higher rate than required for advancement, so that the material through which the auger is being advanced is removed by the auger flights and is not displaced laterally by the auger. During withdrawal, if the hollow stem auger is rotated, it shall be rotated in a positive (advancing) direction.
2. The grout or concrete shall be pumped under continuous pressure and in one continuous operation. Grout or concrete pump pressures shall be measured and maintained at all times sufficiently high to offset hydrostatic and lateral earth pressures. The rate of withdrawal of the auger shall be carefully controlled to exclude all foreign matter and ensure that the augered hole is completely filled with grout or concrete as the auger is withdrawn. The actual volume of grout or concrete pumped into each hole shall be equal to, or greater than, the theoretical volume of the augered hole.
3. If the grouting or concreting process of any element is interrupted, or a loss of concreting or grouting pressure occurs, the element shall be re-drilled to five feet (1,524 mm) below the elevation of the tip of the auger when the installation was interrupted or concreting or grouting pressure was lost, or to the bottom of the element if less than five feet, and the installation shall resume from this point.
4. Elements shall not be installed within six diameters (center-to-center) of an element filled with grout or concrete less than 24-hours old except where approved by the registered design professional.

5. The continuous flight auger rig utilized to install augered uncased elements shall be equipped with data logging equipment that automatically monitors and produces a real-time printout of depth, grout or concrete pressure, grout or concrete flow, and rate of auger withdrawal. The automatic monitoring equipment shall immediately indicate to the equipment operator, and record on the printed record, any instance during the withdrawal of the hollow-stem auger where the rate of auger withdrawal times the theoretical element cross-sectional area exceeds the rate of grout or concrete placement. Printed instrumentation readout for each element shall be provided to the registered design professional's representative upon completion of each element.

1810.4.9 Socketed drilled shafts.
The rock socket and pipe or tube casing of socketed *drilled shafts* shall be thoroughly cleaned of foreign materials before filling with concrete. ~~Steel cores shall be bedded in cement grout at the base of the rock socket.~~

1810.4.10 Micropiles.
Micropile deep foundation elements shall be permitted to be formed in holes advanced by rotary or percussive drilling methods, with or without casing. The elements shall be grouted with a fluid cement grout. The grout shall be pumped through a tremie pipe extending to the bottom of the element until grout of suitable quality returns at the top of the element. The following requirements apply to specific installation methods:

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

2. For a *micropile* or portion thereof grouted in an open drill hole in soil without temporary casing, the minimum design diameter of the drill hole shall be verified by a suitable device during grouting.

3. For micropiles designed for end bearing, a suitable means shall be employed to verify that the bearing surface is properly cleaned prior to grouting.

4. Subsequent micropiles shall not be drilled near elements that have been grouted until the grout has had sufficient time to harden.

5. Micropiles shall be grouted as soon as possible after drilling is completed.

6. For micropiles designed with a full-length casing, the casing shall be pulled back to the top of the bond zone and reinserted or some other suitable means employed to ensure grout coverage outside the casing.

1810.4.11 Helical piles.
Helical piles shall be installed to specified embedment depth and torsional resistance criteria as determined by a *registered design professional*. The torque applied during

installation shall not exceed the manufacturer's rated maximum installation torque resistance of the *helical pile*.

1810.4.12 Special inspection.
Special inspections in accordance with Sections 1705.7 and 1705.8 shall be provided for driven and cast-in-place *deep foundation* elements, respectively. *Special inspections* in accordance with Section 1705.9 shall be provided for *helical piles*.