

resulting from the seismic load effects including overstrength factor in accordance with Section 12.4.3 or 12.14.3.2 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 12.4.3 or 12.14.3.2 of ASCE 7; or shall be capable of developing the full axial, bending and shear nominal strength of the element.

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 12.4.3 or 12.14.3.2 of ASCE 7.

1810.3.12 Grade beams. For structures assigned to *Seismic Design Category D, E or F*, grade beams shall comply with the provisions in Section 21.12.3 of ACI 318 for grade beams, except where they are designed to resist the seismic load effects including overstrength factor in accordance with Section 12.4.3 or 12.14.3.2 of ASCE 7.

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

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

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

1810.4.1 Structural integrity. Deep foundation elements shall be installed in such a manner and sequence as to prevent distortion or damage that may 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 at least 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 Casing. Where cast-in-place deep foundation elements are formed through unstable soils and concrete is placed in an open-drilled hole, a casing shall be inserted in the hole prior to placing the concrete. Where the casing is withdrawn during concreting, the level of concrete shall be maintained above the bottom of the casing at a sufficient height to offset any hydrostatic or lateral soil pressure. Driven casings shall be mandrel driven their full length in contact with the surrounding soil.

1810.4.1.3 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 the concrete surface in any completed element rises or drops, the element shall be replaced. Driven uncased deep foundation elements shall not be installed in soils that could cause heave.

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

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 struc-

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21.12.2.3 — Columns or boundary elements of special structural walls that have an edge within one-half the footing depth from an edge of the footing shall have transverse reinforcement in accordance with 21.6.4.2 through 21.6.4.4 provided below the top of the footing. This reinforcement shall extend into the footing, mat, or pile cap and be developed for f_y in tension.

21.12.2.4 — Where earthquake effects create uplift forces in boundary elements of special structural walls or columns, flexural reinforcement shall be provided in the top of the footing, mat, or pile cap to resist actions resulting from the design load combinations, and shall not be less than required by 10.5.

21.12.2.5 — See 22.10 for use of structural plain concrete in footings and basement walls.

21.12.3 — Grade beams and slabs-on-ground

21.12.3.1 — Grade beams designed to act as horizontal ties between pile caps or footings shall have continuous longitudinal reinforcement that shall be developed within or beyond the supported column or anchored within the pile cap or footing at all discontinuities.

21.12.3.2 — Grade beams designed to act as horizontal ties between pile caps or footings shall be proportioned such that the smallest cross-sectional dimension shall be equal to or greater than the clear spacing between connected columns divided by 20, but need not be greater than 18 in. Closed ties shall be provided at a spacing not to exceed the lesser of one-half the smallest orthogonal cross-sectional dimension and 12 in.

21.12.3.3 — Grade beams and beams that are part of a mat foundation subjected to flexure from columns that are part of the seismic-force-resisting system shall conform to 21.5.

21.12.3.4 — Slabs-on-ground that resist seismic forces from walls or columns that are part of the seismic-force-resisting system shall be designed as structural diaphragms in accordance with 21.11. The contract documents shall clearly state that the slab-on-ground is a structural diaphragm and part of the seismic-force-resisting system.

21.12.4 — Piles, piers, and caissons

21.12.4.1 — Provisions of 21.12.4 shall apply to concrete piles, piers, and caissons supporting structures designed for earthquake resistance.

COMMENTARY

R21.12.2.3 — Columns or boundary members supported close to the edge of the foundation, as often occurs near property lines, should be detailed to prevent an edge failure of the footing, pile cap, or mat.

R21.12.2.4 — The purpose of 21.12.2.4 is to emphasize that top reinforcement should be provided as well as other required reinforcement.

R21.12.2.5 — Committee 318 recommends that foundation or basement walls be reinforced in buildings assigned to SDC D, E, or F.

R21.12.3 — Grade beams and slabs-on-ground

For seismic conditions, slabs-on-ground (soil-supported slabs) are often part of the lateral-force-resisting system and should be designed in accordance with this Code as well as other appropriate standards or guidelines. See 1.1.7.

R21.12.3.2 — Grade beams between pile caps or footings can be separate beams beneath the slab-on-ground or can be a thickened portion of the slab-on-ground. The cross-sectional limitation and minimum tie requirements provide reasonable proportions.

R21.12.3.3 — Grade beams resisting seismic flexural stresses from column moments should have reinforcement details similar to the beams of the frame above the foundation.

R21.12.3.4 — Slabs-on-ground often act as a diaphragm to hold the building together at the ground level and minimize the effects of out-of-phase ground motion that may occur over the footprint of the building. In these cases, the slab-on-ground should be adequately reinforced and detailed. The contract documents should clearly state that these slabs-on-ground are structural members so as to prohibit sawcutting of the slab.

R21.12.4 — Piles, piers, and caissons

Adequate performance of piles and caissons for seismic loadings requires that these provisions be met in addition to other applicable standards or guidelines. See R1.1.6.