

PROPOSAL 4-3 (2009)

SCOPE: Sec. 14.2 Concrete Sec. 14.2.3 Additional Detailing Requirements for Concrete Piles

PROPOSAL FOR CHANGE:

1 **Revise Sec. 14.2.3 and Sec. 14.2.3.1 of Part 1 of the 2009 Provisions as follows:**

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3 **14.2.3 Additional Detailing Requirements for Concrete Piles.** In addition to the foundation
4 requirements set forth in Section 12.1.5 and 12.13 and in Section ~~21.12~~ ~~21.10~~ of ACI 318,
5 design, detailing and construction of concrete piles shall conform to the provisions this section.
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7 **14.2.3.1 Concrete Pile Requirements for Seismic Design Category C.** Concrete piles in
8 structures assigned to Seismic Design Category C shall comply with the requirements of this
9 section.
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11 **14.2.3.1.1 Anchorage of Piles.** All concrete piles and concrete filled pipe piles shall be
12 connected to the pile cap by embedding the pile reinforcement in the pile cap for a distance equal
13 to the development length as specified in ACI 318 as modified by Section 14.2.2 of this standard
14 or by the use of field-placed dowels anchored in the concrete pile. For deformed bars, the
15 development length is the full development length for compression or tension, in the case of
16 uplift, without reduction in length for excess area.
17

18 Hoops, spirals, and ties shall be terminated with seismic hooks as defined in Section ~~2.2~~ ~~21.1~~ of
19 ACI 318.
20

21 Where a minimum length for reinforcement or the extent of closely spaced confinement
22 reinforcement is specified at the top of the pile, provisions shall be made so that those specified
23 lengths or extents are maintained after pile cut-off.
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25 **Revise Sections 14.2.3.2.1 through 14.2.3.2.5 of Part 1 of the 2009 Provisions as**
26 ***follows:***
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28 **14.2.3.2.1 Site Class E or F Soil.** Where concrete piles are used in Site Class E or F, they
29 shall ~~have transverse reinforcement be designed and detailed~~ in accordance with Sections
30 ~~21.6.4.2 through 21.6.4.4~~ ~~21.4.4.1, 21.4.4.2, and 21.4.4.3~~ of ACI 318 within seven pile diameters
31 of the pile cap and the interfaces between strata that are hard or stiff and strata that are
32 liquefiable or are composed of soft to medium stiff clay.
33

34 **14.2.3.2.2 Nonapplicable ACI 318 Sections for Grade Beam and Piles.** Section ~~21.12.3.3~~
35 ~~21.10.3.3~~ of ACI 318 need not apply where grade beams have the required strength to resist the
36 forces from the load combinations with overstrength factor of Section 12.4.3.2 or 12.14.3.2.2.

1 Section ~~21.12.4.4(a)~~ ~~21.10.4.4(a)~~ of ACI 318 need not apply to concrete piles. Section
2 ~~21.12.4.4(b)~~ ~~21.10.4.4(b)~~ of ACI 318 need not apply to precast, prestressed concrete piles.
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4 **14.2.3.2.3 Reinforcement for Uncased Concrete Piles (SDC D through F).** Reinforcement
5 shall be provided where required by analysis. For uncased cast-in-place drilled or augered
6 concrete piles, a minimum of four longitudinal bars with a minimum longitudinal reinforcement
7 ratio of 0.005 and transverse reinforcement in accordance with Sections 21.6.4.2 through
8 21.6.4.4 ~~Section 21.4.4.1, 21.4.4.2, and 21.4.4.3~~ of ACI 318 shall be provided throughout the
9 minimum reinforced length of the pile as defined below starting at the top of the pile. The
10 longitudinal reinforcement shall extend beyond the minimum reinforced length of the pile by the
11 tension development length.
12

13 The minimum reinforced length of the pile shall be taken as the greater of

- 14 1. One-half of the pile length.
- 15 2. A distance of 10 ft (3m).
- 16 3. Three times the pile diameter
- 17 4. The flexural length of the pile which shall be taken as the length of from the bottom of the
18 pile cap to a point where the concrete section cracking moment multiplied by a resistance
19 factor 0.4 exceeds the required factored moment at that point.
20

21 In addition, for piles located in Site Classes E or F, longitudinal reinforcement and transverse
22 confinement reinforcement, as described above, shall extend the full length of the pile.
23

24 Where transverse reinforcement is required, transverse reinforcing ties shall be a minimum of
25 No. 3 bars for up to 20-in.-diameter (300 mm) piles and No.4 bars for piles of larger diameter.
26

27 In Site Classes A through D, longitudinal reinforcement and transverse confinement
28 reinforcement, as defined above, shall extend a minimum of seven times the pile diameter above
29 and below the interfaces of soft to medium stiff clay or liquefiable strata except that transverse
30 reinforcing ties not located within the minimum reinforced length shall be permitted to use a
31 transverse spiral reinforcement ratio of not less than one-half of that required in Section
32 21.6.4.4(a) ~~21.4.4.1(a)~~ of ACI 318. Spacing of transverse reinforcement not located within the
33 minimum reinforced length is permitted to be increased, but shall not exceed the least of the
34 following:

- 35 1. 12 longitudinal bar diameters.
- 36 2. One-half the pile diameter.
- 37 3. 12 in. (305 mm).

38
39 **14.2.3.2.4 Reinforcement for Metal-Cased Concrete Piles (SDC D through F).**
40 Reinforcement requirements are the same as for uncased concrete piles.
41

42 **EXCEPTION:** Spiral-welded metal-casing of a thickness not less than No. 14 gauge
43 can be considered as providing concrete confinement equivalent to the closed ties or
44 equivalent spirals required in an uncased concrete pile, provided that the metal casing
45 is adequately protected against possible deleterious action due to soil constituents,
46 changing water levels, or other factors indicated by boring records of site conditions.

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2 **14.2.3.2.5 Reinforcement for Precast Concrete Piles (SDC D through F).** Transverse
3 confinement reinforcement consisting of closed ties or equivalent spirals shall be provided in
4 accordance with Sections 21.6.4.2 through 21.6.4.4 ~~21.4.4.1, 21.4.4.2, and 21.4.4.3~~ of ACI 318
5 for the full length of the pile.

6
7 **EXCEPTION:** In other than Site Classes E or F, the specified transverse confinement
8 reinforcement shall be provided within three pile diameters below the bottom of the pile cap,
9 but it shall be permitted to use a transverse reinforcing ratio of not less than one-half of that
10 required in Section 21.6.4.4(a) ~~21.4.4.1(a)~~ of ACI 318 throughout the remainder of the pile
11 length.

12 13 **COMMENTARY**

14 15 **C14.2.3 Additional Detailing Requirements for Concrete Piles**

16 Chapter 20 of the PCI Bridge Design Manual provides detailed information on the structural
17 design of piles and on pile to cap connections for precast prestressed concrete piles. ACI 318
18 does not contain provisions governing the design and installation of portions of concrete piles,
19 drilled piers, and caissons embedded in ground except for SDC D, E and F structures.

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21 PCI Bridge Design Manual, 2004, “Precast Prestressed Concrete Piles”, Chapter 20, PCI
22 Publication BM-20-04, Precast/Prestressed Concrete Institute, Chicago, IL.

23 24 **C14.2.3.1 Concrete Pile Requirements for Seismic Design Category C**

25 26 **C14.2.3.1.2 Reinforcement for Uncased Concrete Piles (SDC C):**

27 The transverse reinforcing requirements in the potential plastic hinge zone of uncased concrete
28 piles in Seismic Design Category C is a selective composite of two ACI 318 requirements. In
29 the potential plastic hinge region of an intermediate moment-resisting concrete frame column,
30 the transverse reinforcement spacing is restricted to the least of: (1) 8 times the diameter of the
31 smallest longitudinal bar, (2) 24 times the diameter of the tie bar, (3) one-half the smallest cross-
32 sectional dimension of the column, and (4) 12 in. Outside of the potential plastic hinge region of
33 a special moment-resisting frame column, the transverse reinforcement spacing is restricted to
34 the smaller of: 6 times the diameter of the longitudinal column bars and 6 in.

35 36 **C14.2.3.1.3 Reinforcement for Metal-Cased Concrete Piles (SDC C)**

37 **C14.2.3.1.4 Reinforcement for Concrete-Filled Pipe Piles (SDC C)**

38 39 **C14.2.3.1.5 Reinforcement for Precast Nonprestressed Concrete Piles (SDC C)**

40 Transverse reinforcement requirements in and outside of the plastic hinge zone of precast
41 nonprestressed piles are clarified. The transverse reinforcement requirement in the potential
42 plastic hinge zone is a composite of two ACI 318 requirements (see Section C14.2.3.1.2).
43 Outside of the potential plastic hinge region the eight longitudinal-bar-diameter spacing is
44 doubled. The maximum 8-in. tie spacing comes from current building code provisions for
45 precast concrete piles.

1 **C14.2.7.1.6 Reinforcement for Precast Prestressed Piles (SDC C)**

2 The transverse and longitudinal reinforcing requirements given in ACI 318, Chapter 21, were
3 never intended for slender precast prestressed concrete elements and will result in unbuildable
4 piles. These requirements are based on the *Recommended Practice for Design, Manufacture and*
5 *Installation of Prestressed Concrete Piling*, PCI Committee on Prestressed Concrete Piling,
6 1993.

7
8 Equation 14.2-1, originally from ACI 318, has always been intended to be a lower-bound spiral
9 reinforcement ratio for larger diameter columns. It is independent of the member section
10 properties and can therefore be applied to large or small diameter piles. For cast-in-place
11 concrete piles and precast prestressed concrete piles, the resulting spiral reinforcing ratios from
12 this formula are considered to be sufficient to provide moderate ductility capacities. (Fanous et
13 al., 2007).

14
15 Full confinement per Eq. 14.2-1 is required for the upper 20 ft.of the pile length where
16 curvatures are large. The amount is relaxed by 50 percent outside of that length in view of lower
17 curvatures and in consideration of confinement provided by the soil.

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19 Fanous, A., Sritharan, S., Suleiman, M., and Arulmoli, A., “ Minimum Spiral Reinforcement
20 Requirements and lateral Displacement Limits for Prestressed Concrete Piles in High Seismic
21 Regions” ISU-ERI Ames Report, Department of Civil, Construction and Environmental
22 Engineering, Iowa State University, September, 2007. 157p.

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24 **C14.2.3.2 Concrete Pile requirements for Seismic Design Categories D through F.**

25 **C14.2.3.2.1 Site Class E or F Soil**

26 **C14.2.3.2.2 Nonapplicable ACI 318 Sections for Grade Beams and Piles**

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28 **C14.2.3.2.3 Reinforcement for Uncased Concrete Piles (SDC D through F).**

29 The reinforcement requirements for uncased concrete piles are taken from the 2006 IBC code
30 requirements, and should be adequate to provide ductility in the potential plastic hinge zones
31 (Fanous et al., 2007).

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33 **C14.2.3.2.4 Reinforcement for Metal-Cased Concrete Piles (SDC D through F)**

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35 **C14.2.3.2.5 Reinforcement for Precast Concrete Piles (SDC D through F).**

36 The transverse reinforcement requirements for precast nonprestressed concrete piles are taken
37 from the 2006 IBC code requirements and are should be adequate to provide ductility in the
38 potential plastic hinge zones (Fanous et al., 2007).

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40 **C14.2.3.2.6 Reinforcement for Precast-Prestressed Piles (SDC D through F).**

41 The reduced amounts of transverse reinforcement specified in this provisions compared to those
42 required for column members in ACI 318 are justified by the results of the study by Fanous et
43 al., 2007. The last paragraph of the provision provides minimum transverse reinforcement
44 requirements outside of the zone of prescribed ductile detailing.

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46 **REASON FOR PROPOSAL:**

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To amend the ACI 318 Section Numbers in ASCE/SEI 7-05 Section 14.2.3 so that they are consistent with ACI 318-08 rather than ACI 318-05.

No additional significant revisions of this ASCE/SEI Sec. 14.2.3 are proposed at this time because of several on-going studies in the area of this proposal. The recently completed PCI sponsored study by Fanous et al. (see text of proposal), and work by Mays et al. in South Carolina and by the Structural Engineers Association of Washington, and others, needs to be reviewed before such revisions are proposed. An ACI 318 Task Group is working on the development of appropriate revisions for the next ACI 318 Code.