ASCE 7-05 reference section(s)	2006 IBC (2007 CBC) reference section(s)	Other standard reference section(s)
12.13, 14.2.3, 14.3.2	1808, 1809, 1810, 1811, 1908.1.10	ACI 318-05, 21.10

Design Overview

An overview of the design of piles, pile caps, and grade beams under ASCE 7-05 and the 2006 IBC (2007 CBC) is provided in Article 7.01.001, Foundation Design Overview. That article explains that the 2006 IBC is based upon provisions initiated by the 2000 NEHRP/2000 IBC provisions. ASCE 7-05 also incorporates substantial changes from Chapter 7 of the *2003 NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*. The 1999 Blue Book provisions (SEAOC 1999) do not cover detailing provisions in as much depth as ASCE 7-05 does. However, the 1999 Blue Book provisions are still relevant to the design of piles, pile caps, and grade beams, particularly where a capacity design approach is taken.

A performance-based design approach for pile foundations has not yet been addressed by any of the above codes, standards, or guidelines. However, researchers at the University of California, San Diego did propose performance-based design criteria for specific pile types (Silva, Seible, Priestley, 1997). This work can be used as a basis for the performance-based design of other piles and for pile connections where progressive cyclic testing has been done to establish various damage levels versus deformation.

The design force level for the vertical system that resists lateral forces and for the foundation (except the superstructure-to-footing connection) are the same. This has been and still is a recognized area requiring research and code changes (Harden, Hutchinson, and Moore 2006), and it is therefore uncertain as to where the majority of the inelastic deformation occurs. To address this uncertainty and to prevent excessive concentration of inelastic deformation in the foundation system, a BSSC Issue Study (BSSC 2007) has recommended that the foundation design force be higher than the code level design force where there is a high system ductility (high R value). This does not preclude nonlinear behavior in the foundation system, it simply endeavors to limit the ductility demand level imposed on the foundation system. This article recommends, in addition to the philosophical approach of limiting the ductility demand on the foundation system, that a capacity design approach be applied to preclude the formation of any non-ductile mechanisms. The following outlines an approach for the design of the pile cap and reinforced concrete piles. The approach can be extended to other forms of deep foundations and to shallow foundations.

Pile Cap Design

The above references have a limited number of seismic design and detailing provisions for pile caps. If the pile cap should yield or fail in shear before developing the strength of the piles, then the displacement capacity of a yielding foundation system may be compromised. Such a pile cap mechanism can occur due to joint shear stresses from column or wall pier bending moments or from under-reinforcement for bending moments necessary to transfer the overturning forces to the piles. Joint shear failure in footings has occurred prematurely under large-scale testing of column to footing connections (Xiao, Priestley, and Seible, 1996). This type of mechanism lacks the ductility capacity to achieve the performance intended by the code. The exception to this is where flexural yielding of a grade beam or pile cap occurs first. The component in this scenario should be treated as a flexural element and either meet the detailing requirements of ACI 318-05 Section 21.3 or be demonstrated to afford sufficient ductility.

Below are suggested strength and ductile detailing provisions for the pile cap as a flexural member and an evaluation approach to prevent pile cap joint shear failure before flexural yielding of the pile cap.