ACI 336.3R-14

Report on Design and Construction of Drilled Piers

Reported by ACI Committee 336

American Concrete Institute
Always advancing

American Concrete Institute
Always advancing

First Printing
August 2014
ISBN: 978-0-87031-914-3

Report on Design and Construction of Drilled Piers

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
Phone: +1.248.848.3700
Fax: +1.248.848.3701

www.concrete.org

ACI 336.3R-14

Report on Design and Construction of Drilled Piers

Reported by ACI Committee 336

William H. Oliver Jr., Chair

Bernard H. Hertlein, Secretary

Clyde N. Baker Jr.
William D. Brant
Diane M. Campione
Joseph P. Colaco
Conrad W. Felice
Rudolph P. Frizzi
Shraddhakar Harsh
Matthew Johnson
John W. Johnston
Johnny H. Kwok
Hugh S. Lacy
Adam C. Ramme
Satish K. Sachdev
Rodrigo Salgado
Harold R. Sandberg
Edward J. Ulrich

Consulting members
Ronald W. Harris
John F. Seidensticker

This report covers design and construction of 30 in. (760 mm) diameter or larger foundation piers constructed by excavation of a hole in a subgrade that is later filled with concrete. The 30 in. (760 mm) diameter boundary is an arbitrary size; smaller-diameter drilled piers can be designed and installed in accordance with ACI 543R. Although determination of overall pier size and concrete section design are two basic drilled pier design procedures, emphasis is focused on the determination of overall pier size, which is affected by the interaction between subgrade and pier. Because pier capacity is significantly affected by construction means and methods, the licensed design professional should understand these limitations. Construction methods described include excavation, casing, reinforcing steel installation, and concrete placement. Acceptance criteria and recommended procedures for construction, engineering, and evaluation are presented.

Keywords: bearing capacity; caisson; casing; excavation; foundation; geotechnical engineering; lateral pressure; lining; slurry; tremie.

CONTENTS

ACI 336.3R-14 supersedes ACI 336.3R-93 and was adopted and published August 2014.

CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

This report addresses design and construction of drilled pier foundations constructed by digging, drilling, or otherwise excavating a hole in the subgrade that is subsequently filled with plain or reinforced concrete. Although structural design and construction of drilled pier foundations are the primary objectives of this report, relevant aspects of geotechnical engineering are also discussed, as variations in subgrade properties have a critical influence on design, construction, and subsequent performance. Successful drilled pier design, construction, and performance requires reliable data on the applied loads and supporting subgrade. Because construction limitations often govern design, combined cooperation among the geotechnical engineer, structural engineer, and drilled pier contractor are essential.

1.2—Scope

This report is generally limited to piers of 30 in. (760 mm) or larger diameter, made by open or slurry stabilized construction methods. A 30 in. (760 mm) diameter boundary is an arbitrary size. Although smaller-diameter drilled piers have been designed and installed in accordance with this report, it is difficult to detect sidewall collapse. Refer to ACI 543R for concrete piles having diameters smaller than 30 in. (760 mm), piles installed by the use of hollow stem augers, or other pile types. Also beyond the scope of this report are rectangular columns on spread footings in deep excavations and foundations constructed without excavations by methods such as mortar intrusion or mixed-in-place.

Piers installed by tapping or ramming concrete or aggregate into an excavated shaft are beyond the scope of this report. Engineers and contractors have used the terms "caissons," "foundation piers," "bored piles," "drilled shafts," and "drilled piers" interchangeably. The term "drilled pier" is used in this report. A drilled pier with an enlarged base can be called a belled caisson, belled pier, or drilled and underreamed footing. Drilled pier foundations excavated and concreted with water or slurry in the hole have been called slurry shafts, piers installed by wet-hole methods, or piers installed by slurry displacement methods.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

A_b = pier base area, in.^{2} (mm^2)
A_p = pier shaft surface area, in.^{2} (mm^2)
D = dead load, lb (N)
D_g = dead loads from the supported structure and weight of the pier (gross weight of the pier), lb (N)
d = diameter of pier, in. (mm)
E = earthquake load, lb (N)
E_c = modulus of elasticity, psi (MPa)
F = vertical load, lb (N)
FS = allowable strength design safety factor
FS_1 = allowable strength design safety factor for bearing resistance
FS_2 = allowable strength design safety factor for side resistance
f_p = average side resistance, ton/ft^2 (kPa)
f_z = unit load transfer from shaft to ground at depth z, ton/ft^2 (kPa)
H_g = horizontal shear at ground surface, lb (N)
I = moment of inertia, in.^{4} (mm^4)
k_s = modulus of horizontal soil beam reaction, psi (MPa)
L = live load, lb (N)
M_g = moment at ground surface, usually applied to pier by superstructure, in.-lb (N-mm)
N = number of blows in a standard penetration test
P_{an} = anchorage resistance, lb (N)
P_q = ultimate end bearing acting at the base, lb (N)
P_{up} = uplift force, lb (N)
p = subgrade resistance per unit length along the pier, lb/in. (N/mm)
p-y = lateral load deflection curve at an element of pier, lb/in., in. (N/mm, mm)
Q = ultimate axial capacity, tons (kN)
q_b = unit end-bearing pressure, ton/ft^2 (kPa)
S_n = force from side friction, lb (N)
S_p = positive side resistance, lb (N)
S_{p1} = positive side resistance, acting upward on the pier; normally caused by downward movement of the pier relative to surrounding soil, lb (N)
T = relative stiffness factor
W = wind load, lb (N)
w_b = movement of the pier at depth z, in. (mm)
w_z = unit deflection corresponding to f_z, in. (mm)
y = lateral deflection of pier, in. (mm)

2.2—Definitions

ACI provides a comprehensive list of definitions through an online resource, "ACI Concrete Terminology," http://concrete.org/Tools/ConcreteTerminology.aspx. Definitions provided here complement that source.

bearing-type pier—a pier that receives its principal vertical capacity from a subgrade layer at the bottom of the pier.

bell—an enlargement at the pier bottom to spread the load over a larger area, or to engage additional subgrade mass for uplift loading conditions; also called **under-ream**.

cap—an upper pier termination, usually placed separately, to correct deviations from desired location, facilitate anchor bolt or dowel setting within acceptable tolerances, or combine two or more piers into a unit supporting a column.

casing—a protective temporary or permanent steel tube, usually cylindrical in shape, lowered into the excavated hole