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ESR-1685

Reissued 01/2017

This report is subject to renewal 01/2018.

DIVISION: 31 00 00—EARTHWORK

SECTION: 31 66 00—SPECIAL FOUNDATIONS

REPORT HOLDER:

GEOPIER FOUNDATION COMPANY

130 HARBOUR PLACE DRIVE, SUITE 280
DAVIDSON, NORTH CAROLINA 28036

EVALUATION SUBJECT:

RAMMED AGGREGATE PIER INTERMEDIATE FOUNDATION/SOIL REINFORCEMENT SYSTEM

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DIVISION: 31 00 00—EARTHWORK
Section: 31 66 00—Special Foundations

REPORT HOLDER:

GEOPIER FOUNDATION COMPANY
130 HARBOUR PLACE DRIVE, SUITE 280
DAVIDSON, NORTH CAROLINA 28036
(800) 371-7470
www.geopier.com
info@geopier.com

EVALUATION SUBJECT:

RAMMED AGGREGATE PIER INTERMEDIATE FOUNDATION/SOIL REINFORCEMENT SYSTEM

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2012, 2009, 2006 and 2003 *International Building Code®* (IBC)
- 2013 *Abu Dhabi International Building Code* (ADIBC)†

†The ADIBC is based on the 2009 IBC. 2009 IBC code sections referenced in this report are the same sections in the ADIBC.

Property evaluated:

Structural

2.0 USES

The Rammed Aggregate Pier® Intermediate Foundation/Soil Reinforcement System (RAP System) is a supplemental foundation system to the shallow foundations specified in Section 1809 of the 2012 and 2009 IBC (Section 1805 of the 2006 and 2003 IBC), as applicable. The Rammed Aggregate Pier Intermediate Foundation/Soil Reinforcement System is used to support shallow footings, reinforced concrete mat foundations, and reinforced concrete floor slabs on-grade.

3.0 DESCRIPTION

The Rammed Aggregate Pier elements are constructed from generally available graded stone aggregate through use of processes proprietary to Geopier Foundation Company, Inc. Aggregates shall comply with ASTM D1241-00. The geotechnical investigation described in Section 4.1 of this report may specify additional requirements. Aggregate is densified by ramming, forming rammed aggregate piers with a stabilized base.

4.0 DESIGN AND INSTALLATION

4.1 Design:

The Rammed Aggregate Pier Intermediate Foundation/Soil Reinforcement System, including aggregate type and size and pier diameter and depth, must be designed for its intended use, in accordance with Chapter 18 of the IBC, and account for the site-specific geotechnical investigation, described in this Section 4.1. The design must be prepared by a registered design professional, retained by the local, licensed RAP system installer, using the Geopier Foundation and Soil Reinforcement Manual dated September 1998. Additionally, each system design must be approved by the Chief Engineer of the Geopier Foundation Company, Inc., of Mooresville, North Carolina.

A geotechnical investigation must be conducted and reported in accordance with Section 1803 of the 2012 and 2009 IBC (Section 1802 of the 2006 and 2003 IBC), as applicable. At a minimum, the geotechnical investigation must address the following: soil strength, ground-water table, the effect of moisture variation on soil bearing capacity, compressibility, liquefaction and expansiveness. For structures assigned to Seismic Design Category C, D, E or F, Site Class E or F sites, the geotechnical investigation must include an evaluation of potential geologic and seismic hazards, such as liquefaction, soil instability, differential settlement and surface displacement, and provide recommended mitigation measures. Drainage, and the effects of surcharges from new site grading fill, shall be considered, when applicable.

Loading imposed on the RAP system and the corresponding induced force and deformation, must be determined using accepted structural and geotechnical engineering procedures appropriate for the soil and geometric conditions specific for the RAP system, and must address the effect of geologic and seismic hazards described in Section 4.1, and consider soil-RAP pier supported shallow foundation-structure interaction, when applicable.

4.2 Installation:

Rammed Aggregate Pier systems must be installed using either a replacement (trade name Geopier® system) or displacement (trade name Impact® system). Each replacement Geopier element must be constructed by first excavating a hole in the soil. Most holes are from 10 to 20 feet (3 048 to 6 096 mm) deep, with diameters ranging from 24 to 36 inches (610 to 914 mm). The size and depth of the holes must be determined by the Geopier system designer on the basis of the geotechnical site conditions and structural requirements of the project. Once a hole is excavated, a bottom bulb is created by placing graded stone aggregate into the bottom of the hole and ramming the aggregate using equipment with a specially designed rammer head having 45-degree angled sides. Once the

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bottom bulb is in place, successive lifts of graded stone aggregate, with an average lift thickness of 12 to 24 inches (305 to 610 mm), are placed in the hole and rammed. Figure 1 of this report illustrates the Geopier construction process.

Each displacement Impact element must be constructed by first driving a specially designed 14- to 16- inch-diameter (356 to 406 mm) tamper foot and 10- to 12- inch-outer diameter (250 to 305 mm) hollow mandrel into the soil using a large static force augmented by high-frequency vertical impact energy. The piers can typically extend between 25 and 45 feet (7.6 to 13.7 m) below grade, but may extend deeper depending on project requirements and equipment size. A sacrificial steel plate placed at the bottom of the tamper or other flow restrictors in the mandrel prevent soil from entering the mandrel during driving.

After driving to the design depth, aggregate is placed inside the mandrel and the mandrel is raised approximately 3 feet (914 mm) and then redriven down to 2 feet (610 mm), forming an approximate 1-foot-thick (305 mm) compacted lift. Compaction is achieved through the static crowd force and dynamic impact energy from the hammer. Subsequent lifts are performed using the same approach of raising and lowering the mandrel. Upon completion of the pier to the top-of-pier elevation, the crowd force is used to pre-stress the top of the pier. Figure 2 of this report illustrates the Impact construction process.

The combined effect of the pattern of RAP elements (either by Geopier or Impact system installation) and the prestrained soil matrix between and around RAP elements results in a reinforced block of RAP/matrix soil beneath the footing to the depth of the RAP element construction.

Spread footings must be placed over the top of the RAP elements in accordance with Chapter 18 of the IBC. Depending on the soil conditions and loads to be supported from the structure, RAP elements are typically constructed to cover 10 percent to 35 percent of the footprint of the supported spread footing. The RAP designer must provide the allowable design bearing pressure for spread footings, mats or slabs placed over the RAP reinforced soil.

Geopier elements are constructed to a level 6 to 12 inches (152 to 305 mm) above the scheduled bottom of the shallow foundations, and the remaining portion of the open holes is temporarily filled to the ground surface with loosely placed drilling spoils. Impact piers are constructed in a similar manner except that the hole is often backfilled with aggregate as the mandrel is withdrawn. For placement of the concrete footings over the Geopier or Impact elements, the soil is excavated to the specified level of the bottom of the footing. The tops of the exposed RAP elements, as well as the bottom of the footing excavation, are tamped with a mechanical compactor prior to placement of the concrete footings.

4.3 Special Inspection:

Special inspection must be provided in accordance with Section 1705 for 2012 IBC (Section 1704 for 2009, 2006 and 2003 IBC), as applicable. The special inspector's responsibilities include, but are not limited to, review of the RAP designer's use of soil parameters as presented in the project soils report; and, during construction, verification of aggregate properties, type and number of lifts of aggregate, pier size and depths and top elevations of constructed RAP elements, and applied rammer energy. Additionally, results of qualitative tests on production RAP elements, outlined in the Geopier Foundation and Soil Reinforcement Manual, dated September 1998 and the RAP specification, such as modulus load testing, uplift pull-out testing, bottom or crowd stabilization tests and dynamic cone penetration tests, must be reviewed to verify compliance with the design specifications. Testing must be conducted by an approved testing laboratory and the results must be approved by the code official.

5.0 CONDITIONS OF USE

The RAP Intermediate Foundation/Soil Reinforcement System for Geopier® and Impact® system installation methods described in this report complies with, or is a suitable alternative to what is specified in, those codes listed in Section 1.0 of this report, subject to the following conditions:

5.1 The installation of the system shall comply with this evaluation report, the Geopier Foundation and Soil Reinforcement Manual dated September 1998, and the RAP QC and construction specifications dated December 2006 and October 2008.

5.2 The system must be installed by a Geopier Foundation Company licensed installer. The evidence of such approval by the Geopier Foundation Company must be submitted to the code official upon request.

5.3 Copies of the Geopier Foundation and Soil Reinforcement Manual, dated September 1998, RAP QC and construction specifications, dated December 2006 and October 2008, and the RAP specification, dated April 1, 2011, must be provided to the code official upon request.

5.4 Special inspection shall be provided in accordance with Section 4.3 of this report.

5.5 Engineering design of the Rammed Aggregate Pier Intermediate Foundation/Soil Reinforcement System in accordance with the Section 4.1 of this report, prepared by a Geopier Foundation Company authorized registered design professional and approved by the Geopier Engineer, must be submitted to the code official for approval at the time of permit application- In the event of conflict between the Geopier Foundation and Soil Reinforcement Manual and this report, this report governs.

6.0 EVIDENCE SUBMITTED

Descriptive information and the Geopier Foundation and Soil Reinforcement Manual, dated September 1998, and construction specifications, dated December 2006 and October 2008.

7.0 IDENTIFICATION

The engineering design of the Rammed Aggregate Pier Intermediate Foundation/Soil Reinforcement System for Geopier® or Impact® installation method must include reference to the Geopier Foundation Company, Inc., name and address, and the ICC-ES evaluation report number (ESR-1685).

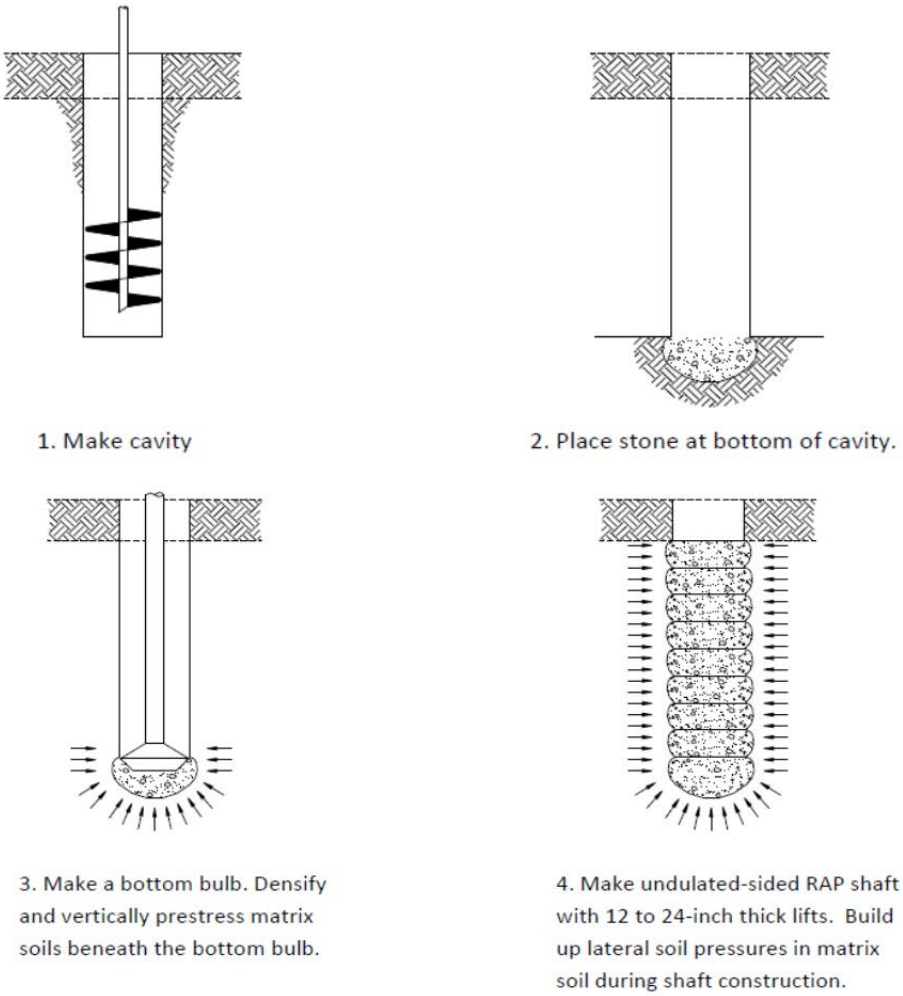
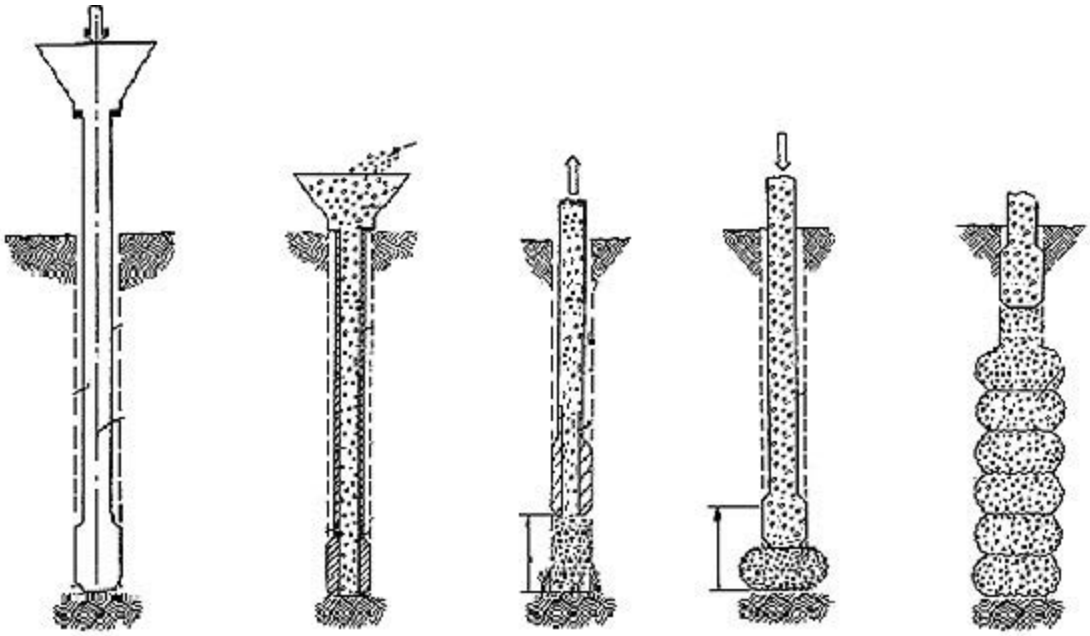


FIGURE 1—RAP CONSTRUCTION PROCESS USING THE GEOPIER SYSTEM



1. Drive Impact mandrel to bottom of pier depth
2. Fill hopper and mandrel with aggregate
3. Raise mandrel a preset distance (3 or 4 ft typ) while discharging aggregate
4. Redrive mandrel a preset distance (2 or 3 ft typ) to create 1-ft (typ) compacted lift
5. Repeat Steps 3 and 4 until pier construction is complete

FIGURE 2—RAP CONSTRUCTION PROCESS USING THE IMPACT SYSTEM