SPECIFICATION FOR RAMMED AGGREGATE PIER® AND RIGID INCLUSION FOUNDATION SYSTEMS

PART 1: GENERAL REQUIREMENTS

1.01 Description

Work shall consist of designing, furnishing and installing Rammed Aggregate Pier foundations and/or Rigid Inclusions Piers to the lines and grades designated on the project drawings and as specified herein. The piers shall be constructed by either augering a shaft or driving a hollow mandrel to the design depth and vertically ramming lifts of aggregate or an aggregate/cement mixture using the specially designed tamper head and high-energy impact densification equipment to create the compacted aggregate pier or rigid inclusion pier. The pier elements shall be in a columnar-type configuration and shall be used to produce an intermediate foundation system.

1.02 Work Included

A. Provision of all equipment, material, labor, and supervision to design and install pier elements. Design shall rely on subsurface information presented in the project geotechnical report. Layout of pier elements, spoil removal (as required), footing excavations, and subgrade preparation following aggregate pier installation is not included.

B. The Rammed Aggregate Pier or Rigid Inclusion Pier design and installation shall adhere to all methods and standards described in this Specification.

C. Drawings and General Provisions of the Contract, including General and Supplemental Conditions, and Division 1 Specifications, apply to the work in this specification.

1.03 Approved Installers

A. The Pier Installer (the Installer) shall be approved by the Owner's Engineer prior to bid opening. Without exception, no alternate installer will be accepted unless approved by the Owner's Engineer at least two (2) weeks prior to bid opening and shall have the following minimum qualifications:

a. A minimum of 5 years of experience with the installation of Rammed Aggregate Pier (RAP) and Rigid Inclusion (RI) Pier systems.

b. Successfully completed at least 50 projects with RAP's or RI's.

c. General Liability Coverage of at least $10 million.

d. Professional Liability Insurance of at least $3 million.

e. Bonding Capability commensurate with the project size.

C. Installers licensed by the Geopier Foundation Company, Inc. (www.geopier.com) will be accepted as approved installer.

D. Without exception, no alternate installer will be accepted unless approved by Owner's Engineer and Geopier Foundation Company, Inc.

E. Installers currently approved for these works are:

a. GeoConstructors, Inc., 413 Browning Court, Purcellville, VA 20132
   703-771-9844

2/16/2015
1.04 Reference Standards

A. Design

1. "Control of Settlement and Uplift of Structures Using Short Aggregate Piers," by Evert C. Lawton (Assoc. Prof., Dept. of Civil Eng., Univ. of Utah), Nathaniel S. Fox (President, Geopier Foundation Co., Inc.), and Richard L. Handy (Distinguished Prof. Emeritus, Iowa State Univ., Dept. of Civil Eng.), reprinted from IN-SITU DEEP SOIL IMPROVEMENT, Proceedings of sessions sponsored by the Geotechnical Engineering Division/ASCE in conjunction with the ASCE National Convention held October 9-13, 1994, Atlanta, Georgia.


B. Modulus Testing

1. ASTM D1143 - Pile Load Test Procedures
2. ASTM D1194 - Spread Footing Load Test
3. ASTM D7383-08 – Axial Compressive Force Pulse (Rapid) testing of Deep Foundations (Statnamic Testing)

C. Materials and Inspection

1. ASTM D1241 - Aggregate Quality
2. ASTM D422 - Gradation of Soils
3. ASTM C31 Standard Practice for Making and Curing Cement Test Specimens in the field

D. Where specifications and reference documents conflict, the Pier Designer shall make the final determination of the applicable document.

1.05 Base Line Geotechnical, Civil and Structural Engineering Information

The design of RAPS's and/or RI's shall be based on the soils data provided in the project geotechnical report.

The structural engineer shall provide actual dead and live loads for each footing location and bearing pressure diagrams for retaining wall and shear wall footings to be able to calculate estimated total and differential settlement values. A loading diagram shall be provided for any footings subject to a moment. Any net uplift loads shall be highlighted so uplift anchors can be provided.

Civil Site design drawings shall highlight all existing and future utilities and new fill that will be placed on site. A construction sequence shall be provided that highlights when abandoned
utilities will be excavated and when new utilities and fill will be placed. (i.e. before or after ground improvement installation)

1.06 Certifications and Submittals

A. Design Calculations - The Installer shall submit design calculations and construction drawings prepared by the Pier Designer (the Designer) for review and approval by the Owner or Owner’s Engineer. All plans shall be sealed by a Professional Engineer in the State in which the project is constructed.

B. Modulus Test Reports – A modulus test(s) is performed on a non-production Rammed Aggregate Pier element and/or Rigid Inclusion Pier as required by the Pier Designer to verify the design assumptions. The Installer shall furnish to the General Contractor installation records, test data, analysis of the test data and verification of the design parameter values based on the modulus test results. The report shall be prepared under direction of a Registered Professional Engineer.

C. Daily Pier Progress Reports – The Installer shall furnish complete and accurate records of pier installation to the General Contractor. The records shall indicate the pier location, length, volume of aggregate used or number of lifts, densification forces during installation, and final elevations or depths of the base and top of piers. The records shall also indicate the type and size of the installation equipment used, and the type of aggregate used and testing and material sampling that was performed. The Installer shall immediately report any unusual conditions encountered during installation to the General Contractor, to the Designer and to the Testing Agency.

PART 2: MATERIALS

2.01 Aggregate

A. Aggregate used by the Rammed Aggregate Pier Installer for pier construction shall be pre-approved by the Designer and shall demonstrate suitable performance during modulus testing. Typical aggregate consists of Type 1 Grade B in accordance with ASTM D-1241-68, No. 57 stone, recycled concrete, or other graded aggregate approved by the Designer.

B. Potable water or other suitable water source shall be used to increase aggregate moisture content where required.

C. Cement used in Rigid Inclusion Piers shall meet the requirements for Type I or Type II Portland cement per ASTM C150.

PART 3: DESIGN REQUIREMENTS

3.01 Rammed Aggregate Pier Design

A. The design of the Rammed Aggregate Pier elements shall be based on the service load contact pressure and the allowable total and differential settlement criteria as indicated by the design team for support by the Rammed Aggregate Pier elements. The Rammed Aggregate Pier elements shall be designed in accordance with generally-accepted engineering practice and the methods described in Section 1 of these Specifications. The design life of the structure shall be XXX years.

B. The design shall meet the following criteria.
Maximum Allowable Bearing Pressure for Footings supported by Rammed Aggregate Pier Reinforced Soils TBD psf

Estimated Total Long-Term Settlement ≤ TBD-inch

Estimated Long-Term Differential Settlement ≤ TBD-inch

C. The Rammed Aggregate Pier elements shall be designed and installed to completely penetrate existing fills where encountered.

D. The Rammed Aggregate Pier elements shall be designed using a Rammed Aggregate Pier stiffness modulus to be verified by the results of the modulus test described in Section 5.02 of these specifications.

3.02 Rigid Inclusion Pier Design

A. Rigid Inclusion Pier Design Capacity – the capacity of individual rigid inclusions shall be the lesser of the geotechnical and structural capacity as defined below:

a. Geotechnical Requirements – The geotechnical capacity shall be calculated using Meyerhof bearing capacity method. Shaft capacity shall not be considered in fill materials. Shaft resistance may be considered when the pier extends a minimum 5 feet into a competent soils stratum. For piers where the shaft extends a minimum of five feet into the bearing stratum or extends through multiple soils strata below an unsuitable layer, a unit friction value should be computed for each layer and the total shaft resistance should be taken as the summation of the individual layers.

b. Structural Requirements – The structural capacity of the pier used for design shall not exceed 0.3 x f’c, where f’c equals the 28-day compressive strength of the cement/aggregate mixture as sampled on site and confirmed by QC compressive strength testing per ASTM C39.

B. Load Transfer Platform Design - where rigid inclusions are utilized design calculations and design details shall be provided to determine the thickness and lateral extent needed for an aggregate load transfer layer to transfer the load from the concrete footing, slab or wall or embankment fill, to the rigid inclusion element.

C. The design of Rigid Inclusion Piers shall meet the following criteria.

Maximum Allowable Bearing Pressure for Footings supported by Rigid Inclusion Piers TBD psf

Estimated Total Long-Term Settlement for Footings: ≤ TBD-inch

Estimated Long-Term Differential Settlement of Adjacent Footings: ≤ TBD-inch

D. The Rigid Inclusion Pier elements shall be designed and installed to completely penetrate existing fills where encountered.

E. The Rigid Inclusion Pier elements shall be designed using a pier stiffness and capacity to be verified by the results of the modulus test described in Section 5.02 of these specifications.

3.02 Design Submittal

A. Adjacent Footings and New Fill Placement– Settlement calculations for individual footings shall take into account loading from adjacent footings and any new fill placed on the site to
meet grades or for site retaining walls. Calculations showing that these conditions have been accounted for in the design shall be provided in the submittal.

B. **Utility Conflicts** – Conflicts with new and existing utilities shall be taken into account in the design and specific recommendations for no dig zones or design modifications to prevent excavations from undermining ground improvement in place and to prevent damage to existing utilities during placement of ground improvement elements.

C. **Design Submittal** - The Installer shall submit detailed design calculations, construction drawings, and shop drawings, (the Design Submittal), for approval at least \( X \) week(s) prior to the beginning of construction. A detailed explanation of the design parameters for settlement calculations shall be included in the Design Submittal. Additionally, the quality control test program for Aggregate Pier and/or Rigid Inclusion Pier system, meeting these design requirements, shall be submitted. All computer-generated calculations and drawings shall be prepared and sealed by a Professional Engineer, licensed in the State or Province where the piers are to be built. Submittals will be submitted electronically only unless otherwise required by specific submittal instructions.

**PART 4: EXECUTION**

4.01 **Approved Installation Procedures**

The following sections provide general criteria for the construction of the Rammed Aggregate Pier elements and Rigid Inclusion Pier elements. Unless otherwise approved by the Designer, the installation method used for pier construction shall be that as used in the construction of the successful modulus test.

A. **Augered Rammed Aggregate Pier or Rigid Inclusion Pier elements** –

1. Augered Rammed Aggregate Pier system shall be pre-augered using mechanical drilling or excavation equipment.

2. If cave-ins exceeding 10 percent of the lift volume occur during excavation such that the sidewalls of the hole are deemed to be unstable, steel casing shall be used to stabilize the shaft or a displacement Rammed Aggregate Pier system may be used.

3. Aggregate shall be placed in the augered shaft in lift thicknesses as determined by the Rammed Aggregate Pier Designer.

4. A specially-designed beveled tamper and high-energy impact densification apparatus shall be employed to densify lifts of aggregate during installation. The apparatus shall apply direct downward impact energy to each lift of aggregate. Compaction equipment that induces horizontal vibratory energy (such as Vibroflot equipment) is not permitted.

5. For Rigid Inclusion Pier elements using Cement Treated Aggregate (CTA) the same procedures (1 through 4 apply). The CTA materials that are mixed or delivered on site shall mixed dry and shall all be used within 8 hours of mixing.
B. Displacement Rammed Aggregate Pier and Rigid Inclusion Piers –

1. Displacement Rammed Aggregate Pier systems shall be constructed by advancing a specially designed mandrel with a minimum 15 ton static force augmented by dynamic vertical ramming energy to the full design depth. The hollow-shaft mandrel, filled with aggregate, is incrementally raised, permitting the aggregate to be released into the shaft, and then lowered by vertically advancing and/or ramming to densify the aggregate and force it laterally into the adjacent soil. The cycle of raising and lowering the mandrel is repeated to the top of pier elevation. The cycle distance shall be determined by the Rammed Aggregate Pier designer.

2. Special high-energy impact densification apparatus shall be employed to vertically densify the Rammed Aggregate Pier elements during installation of each constructed lift of aggregate.

3. Densification shall be performed using a mandrel/tamper. The mandrel/tamper foot is required to adequately increase the lateral earth pressure in the matrix soil during installation. Compaction equipment that induces horizontal vibratory energy (such as Vibroflot equipment) is not permitted.

4. Downward crowd pressure shall be applied to the mandrel during installation.

5. For Rammed Aggregate pier elements using #57 stone and neat cement or sand cement grout mixtures a minimum of 3 cylinders shall be taken daily in accordance with ASTM C31 to perform compressive strength testing of the stone/cement mixture to show it is in accordance with the project strength requirements.

6. For GeoConcrete Columns (GCC) using structural concrete, 3 cylinders of the concrete shall be taken daily per ASTM C31 to confirm the 28-day concrete strength of the concrete.

7. GCC elements shall be installed using the displacement pier method as described above however the compacted pier shall be restricted to the lower 5 feet of the pier and concrete shall be extruded under pressure to assure a uniform diameter of pier is built above the lower bulb.

8. Note compressive strength testing of Rigid Inclusion Piers may be limited to initial testing of the design mix to confirm that the design strength is met, if the structural design requirements are not controlling the Rigid Inclusion design as approved by the Rigid Inclusion design engineer.

4.02 Plan Location and Elevation of Pier Elements

The as-built center of each pier shall be within 6 inches of the locations indicated on the plans. Piers installed outside of the above tolerances and deemed not acceptable shall be rebuilt at no additional expense to the Owner.

4.03 Rejected Pier Elements

Pier elements installed beyond the maximum allowable tolerances shall be abandoned and replaced with new piers, unless the Designer approves the condition or provides other remedial measures. All material and labor required to replace rejected piers shall be provided at no additional cost to the Owner, unless the cause of rejection is due to an obstruction or mislocation.
PART 5: QUALITY CONTROL

5.01 Quality Control Technician

The Installer shall have a full-time, on-site Quality Control Technician to verify and report all installation procedures. The Installer shall immediately report any unusual conditions encountered during installation to the Pier Designer, the General Contractor, and to the Testing Agency.

5.02 Rammed Aggregate Pier Modulus and Rigid Inclusion Load Testing

As required, Rammed Aggregate Pier Modulus Test(s) and Rigid Inclusion Load Test(s) will be performed at locations agreed upon by the Pier Designer and the Testing Agency to verify or modify Rammed Aggregate Pier or Rigid Inclusion designs. Test Procedures shall utilize appropriate portions of ASTM D 1143, ASTM D 1194, or ASTM D7383-08 as outlined in the design submittal.

5.03 Bottom Stabilization Testing (BSTs) / Crowd Stabilization Testing (CSTs)

Bottom stabilization testing (BSTs) or Crowd stabilization testing (CSTs) shall be performed by the Control Technician during the installation of the modulus test pier. Additional testing as required by the Pier Designer shall be performed on selected production Pier elements to compare results with the modulus or load test pier.

PART 6: QUALITY ASSURANCE

6.01 Independent Engineering Testing Agency (Owner's Quality Assurance)

The Pier Installer shall provide full-time Quality Control monitoring of Pier construction activities. The Owner or General Contractor is responsible for retaining an independent engineering testing firm to provide Quality Assurance services.

6.02 Responsibilities of Independent Engineering Testing Agency

A. The Testing Agency shall monitor the modulus test pier installation and testing. The Installer shall provide and install all dial indicators and other measuring devices.

B. The Testing Agency shall monitor the installation of Pier elements to verify that the production installation practices are similar to those used during the installation of the modulus test elements.

C. The Testing Agency shall report any discrepancies to the Installer and General Contractor immediately.

D. The Testing Agency shall observe the excavation, compaction and placement of the foundations as described in Section 7.05. Dynamic Cone Penetration testing may be performed to evaluate the footing bottom condition as determined by the Testing Agency.

PART 7: RESPONSIBILITIES OF THE GENERAL CONTRACTOR

7.01 Site Preparation and Protection

A. The General Contractor shall locate and protect underground and aboveground utilities and other structures from damage during installation of the Pier elements.
B. Site grades for Pier installation shall be within 1 foot of the top of footing elevation or finished grade elevation to minimize Pier installation depths. Ground elevations and bottom of footing elevations shall be provided to the Pier Installer in sufficient detail to estimate installation depth elevations to within 3 inches.

C. The General Contractor will provide site access to the Installer, after earthwork in the area has been completed. A working surface shall be established and maintained by the General Contractor to provide wet weather protection of the subgrade and to provide access for efficient operation of the Pier installation.

D. Prior to, during and following Pier installation, the General Contractor shall provide positive drainage to protect the site from wet weather and surface ponding of water.

E. If spoils are generated by Pier installation, spoil removal from the Pier work area in a timely manner to prevent interruption of Pier installation is required.

F. For Rigid Inclusions a minimum of 9 inches of aggregate or granular soil shall separate the rigid inclusion from the bottom of footing, slab or embankment fill. The thickness and type of granular soil shall be as specified in the rigid inclusion design and shall be the responsibility of the general contractor for placement.

7.02 Pier Layout

The location of Pier-supported foundations for this project, including layout of individual Pier elements, shall be marked in the field using survey stakes or similar means at locations shown on the drawings.

7.03 Contractor's / Owner's Independent Testing Agency (Owner's Quality Assurance)

General Contractor is responsible for acquiring an Independent Testing Agency (Quality Assurance) as required. Testing Agency roles are as described in Part 6 of this specification. The Pier Installer will provide Quality Control services as described in Part 5 of this specification.

7.04 Excavations of Obstructions

A. Should any obstruction be encountered during Pier installation, the General Contractor shall be responsible for promptly removing such obstruction or the pier shall be relocated or abandoned. Obstructions include, but are not limited to, boulders, timbers, concrete, bricks, utility lines, etc., which shall prevent placing the piers to the required depth, or shall cause the pier to drift from the required location.

B. Dense natural rock or weathered rock layers shall not be deemed obstructions, and piers may be terminated short of design lengths on such materials.

7.05 Utility Excavations

The General Contractor shall coordinate all excavations made subsequent to Pier installations so that excavations do not encroach on the piers as shown in the Pier construction drawings. Protection of completed Pier elements is the responsibility of the General Contractor. In the event that utility excavations are required in close proximity to the installed Pier elements, the General Contractor shall contact the Pier Designer immediately to develop construction solutions to minimize impacts on the installed Pier elements.
7.06 Footing Bottoms

A. Excavation and surface compaction of all footings shall be the responsibility of the General Contractor.

B. Foundation excavations to expose the tops of Pier elements shall be made in a workman-like manner, and shall be protected until concrete placement, with procedures and equipment best suited to (1) avoid exposure to water, (2) prevent softening of the matrix soil between and around the Rammed Aggregate Pier elements before pouring structural concrete, and (3) achieve direct and firm contact between the dense, undisturbed Rammed Aggregate Pier elements and the concrete footing.

C. All excavations for footing bottoms supported by Rammed Aggregate Pier foundations shall be prepared in the following manner by the General Contractor. Recommended procedures for achieving these goals are to:

1. Limit over-excavation below the bottom of the footing to 3-inches (including disturbance from the teeth of the excavation equipment).

2. Compaction of surface soil and top of Rammed Aggregate Pier elements shall be prepared using a motorized impact compactor ("Wacker Packer," “Jumping Jack," or similar). Sled-type tamping devices shall only be used in granular soils and when approved by the designer. Loose or soft surficial soil over the entire footing bottom shall be recompacted or removed, respectively. The surface of the aggregate pier shall be recompacted prior to completing footing bottom preparation.

3. Place footing concrete immediately after footing excavation is made and approved, preferably the same day as the excavation. Footing concrete must be placed on the same day if the footing is bearing on moisture-sensitive soils. If same day placement of footing concrete is not possible, open excavations shall be protected from surface water accumulation. A lean concrete mud-mat may be used to accomplish this. Other methods must be pre-approved by the Designer.

D. The following criteria shall apply, and a written inspection report sealed by the project Testing Agency shall be furnished to the Installer to confirm:

1. That water (which may soften the unconfined matrix soil between and around the Rammed Aggregate Pier elements, and may have detrimental effects on the supporting capability of the Rammed Aggregate Pier reinforced subgrade) has not been allowed to pond in the footing excavation at any time.

2. That all Rammed Aggregate Pier and rigid inclusion elements designed for each footing have been exposed in the footing excavation.

3. That immediately before footing construction, the tops of Rammed Aggregate Pier elements and the ungrouted tops of Rigid Inclusion Piers exposed in each footing excavation have been inspected and recompacted as necessary with mechanical compaction equipment.

4. That no excavations or drilled shafts (elevator, etc) have been made after installation of Aggregate Pier elements within the excavation limits described in the Rammed Aggregate Pier construction drawings, without the written approval of the Installer or Designer.

E. Failure to provide the above inspection and certification by the Testing Agency, which is beyond the responsibility of the Pier Installer, may void any written or implied warranty on the performance of the Rammed Aggregate Pier and Rigid Inclusion Pier system.
PART 8: PAYMENT

8.01 Method of Measurement

A. Measurement of the Rammed Aggregate Piers and Rigid Inclusion Piers is on a lump sum basis.

B. Payment shall cover design, supply and installation of the aggregate pier foundation system and rigid inclusion system. Excavation of unsuitable materials, delays, re-engineering, and remobilization as documented and approved by the Owner or Owner’s Engineer, shall be paid for under separate pay items.

8.02 Basis of Payment

A. The accepted quantities of piers will be paid per approval, in-place aggregate-pier and rigid inclusions. Payment will be made under:

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<thead>
<tr>
<th>Pay Item:</th>
<th>Pay Unit:</th>
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<tr>
<td>Preparation of plans and specifications and installation of rammed aggregate pier elements and rigid inclusion elements</td>
<td>$___ Lump Sum</td>
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B. Unit prices shall be provided to account for:

- Additional Installed Piers (w/o remobilization) $___/Linear Foot up to 25 feet
- Additional Installed Piers (w/o mobilization) $___/Linear Foot over 25 feet
- Add for Casing Holes $___/Linear Foot
- Additional Mobilizations $___ Each
- Additional Modulus or Load Tests $___ Each