SECTION 02472
GEOPIER RAMMED AGGREGATE PIER SOIL REINFORCEMENT

PART 1 – GENERAL REQUIREMENTS

1.1 DESCRIPTION

A. Work shall consist of designing, furnishing and installing short aggregate pier elements to the lines and grades designated on the project foundation plan and as specified herein. The short aggregate pier elements shall be constructed by compacting aggregate in an excavated hole using special high-energy impact densification equipment. The short aggregate pier elements shall be in a columnar-type configuration and shall be used to reinforce soils for the support of spread footings.

1.2 WORK INCLUDED

A. Provision of all equipment, material, labor, and supervision to design and install short aggregate pier elements. Design shall rely on subsurface information presented in the project geotechnical report. Layout of short aggregate pier elements, removal of spoils from the site (which result from short aggregate pier construction), removal of spoils off the working pad, footing excavation, and subgrade preparation following short aggregate pier installation is not included.

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

C. This Project is a registered US Green Building Council “LEED” project.
   1. Select materials to maximize use of recycled steel.
   2. Select locally or regionally fabricated products wherever possible.

1.3 APPROVED INSTALLERS

A. Installers of Aggregate Pier Foundation Systems shall have a minimum of 5 years of experience with the installation of short aggregate piers and shall have completed at least 50 projects.

B. Installers shall be licensed by Geopier Foundation Company, Inc. and shall have demonstrated experience in the construction of similar size and types of projects. The aggregate pier Installer shall be approved by the Geotechnical Engineer and must be approved two weeks prior to bid opening. The Installer shall adhere to all methods and standards described in this Specification.

C. Installers currently approved for these works are:

GeoConstructors, Inc.
Leesburg, VA
C/o: GeoConstructors, Inc.
6548 Vintage Ridge Lane
Fuquay-Varina, NC 27526
(919) 557-9069
Fax: (919) 557-9709
1.4 RELATED WORK SPECIFIED ELSEWHERE

A. Division 2 Sections

B. Section 02468 – Drilled Foundation Caissons

C. Section 03300 – Cast-In-Place Concrete

1.5 REFERENCE STANDARDS

A. Design


B. Modulus and Uplift Testing

1. ASTM D-1143 – Pile Load Test Procedures

2. ASTM D-1194 – Spread Footing Load Test

3. ASTM-D-3689 – Uplift Load Test

C. Materials and Inspection

1. ASTM D-1241 – Aggregate Quality

2. ASTM STP 399 – Dynamic Penetrometer Testing

3. ASTM D-422 – Gradation Soils

1.6 CONFLICTS IN SPECIFICATIONS/REFERENCES

Where specifications and reference documents conflict, the Architect/Engineer shall make the final determination of the applicable document.

1.7 CERTIFICATIONS AND SUBMITTALS
A. The installer shall submit detailed design calculations and construction drawings prepared by the Aggregate Pier Designer (the Designer) to the Owner or Owner’s Engineer for approval prior to the start of construction. All plans shall be sealed by a Professional Engineer in the State in which the project is constructed.

B. The Aggregate Pier Designer shall have Errors and Omissions design insurance for the work. The insurance policy should provide a minimum coverage of $2 million per occurrence.

C. Modulus and uplift test data - The Installer shall furnish the General Contractor a description of the installation equipment, installation records, complete test data, analysis of the test data and recommended design parameter values based on the modulus test results. The report shall be prepared under supervision of a registered professional engineer.

D. Daily Aggregate Pier Progress Reports – The Testing Agency shall furnish a complete and accurate record of aggregate pier installation to the General Contractor. The record shall indicate the pier location, length, average lift thickness and final elevations of the base and top of piers. The record shall also indicate the type and size of the densification equipment used. The Installer shall immediately report any unusual conditions encountered during installation to the General Contractor, to the Designer and to the Testing Agency.

1.8 METHOD OF MEASUREMENT

A. Measurement of the aggregate pier elements is on a per-pier basis.

B. Payment shall cover design and installation of the aggregate pier foundation system. Excavation of unsuitable materials, drilling obstructions, delays, and remobilization as documented and approved by the Owner or Geotechnical Engineer shall be paid for under separate pay items.

C. Quantities of piers, as shown on plans, may be increased or decreased at the direction of the Owner or Owner's Engineer, based on construction procedures and actual site conditions.

1.9 BASIS OF PAYMENT

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

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

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit Price</th>
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<tbody>
<tr>
<td>Additional Installed Piers (w/o remobilization)</td>
<td>$____ Each</td>
</tr>
<tr>
<td>Add for Casing Holes</td>
<td>$____ Each</td>
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<tr>
<td>Additional Mobilizations</td>
<td>$____ Each</td>
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<tr>
<td>Additional Modulus or Uplift Load Tests</td>
<td>$____ Each</td>
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<tr>
<td>Removal of Obstructions</td>
<td>$____/Hour</td>
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PART 2 – PRODUCTS

2.1 MATERIALS

A. Aggregate used for piers constructed above the water table shall be Type I Grade B in accordance with ASTM D-1241-68, or shall be other graded aggregate selected by the Installer.
and successfully used in the modulus test. It shall be compacted to a densification and strength, which provides resistance to the dynamic penetration test (ASTM STP 399) of a minimum average of 15 blows per 1.75-inch vertical movement.

B. For aggregate used for piers constructed below the water table, the gradation shall be the same as Type I Gradation B, except that particles passing the No. 40 sieve shall be eliminated. Alternatively, No.57 stone or other open-graded stone selected by the Aggregate Pier Installer may be used. Dynamic penetration resistance testing is inappropriate for this material.

C. Potable water or other suitable source shall be used to increase aggregate moisture content where required. The General Contractor shall provide such water to the Installer.

D. The General Contractor will provide adequate and suitable marshalling areas on the project site for the use of the Installer for the storage of aggregate and equipment.

PART 3 – DESIGN REQUIREMENTS

3.1 AGGREGATE PIER DESIGN

A. The Aggregate Pier elements shall be designed for an Aggregate Pier stiffness modulus value that will be verified by the results of the Aggregate Pier modulus test, described in this specification.

B. Aggregate piers shall be designed in accordance with generally accepted engineering practice and the methods described in Section 1 of these Specifications. The design shall meet the following criteria.

- Maximum Allowable Bearing Pressure for Aggregate Pier Reinforced Soils: 6,000 psf
- Estimated Total Long-Term Settlement for Footings: ≤ 1-inch
- Estimated Long-Term Differential Settlement of Adjacent Footings: ≤ ½-inch

C. The design submitted by the Installer shall consider the bearing pressure and settlement of all footings supported by short aggregate piers, and shall be in accordance with acceptable engineering practice and these specifications. Total and differential settlement shall be considered. The design life of the structure shall be 50 years.

D. The Aggregate Pier system shall be designed to preclude plastic bulging deformations at the top-of-pier design stress and to preclude significant tip stresses as determined from the shape of the telltale test curve from telltales installed in modulus test piers. The results of the modulus test shall be used to verify the design assumptions.

3.2 DESIGN SUBMITTAL

The Installer shall submit sets of detailed design calculations, construction drawings, and shop drawings, (the Design Submittal), per section 01330, for approval at least 4 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. 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.

PART 4 – CONSTRUCTION

Art Museum of Western Virginia
GMP-R1/Permit Application
Roanoke, VA

Geopier Rammed Aggregate Pier Soil Reinforcement
02472-4
Randall Stout Architects, Inc.
November 18, 2005 - RSA Project # 0104
4.1 EXCAVATION

A. All Aggregate Pier elements shall be pre-augered using mechanical drilling or excavation equipment. Installation of piers without pre-augering shall not be allowed because this technique results in significant disturbance and remolding of the matrix soils surrounding the piers.

B. If cave-ins occur during excavation such that the sidewalls of the hole are deemed to be unstable, steel casing or drilling slurry shall be used to stabilize the excavation.

4.2 DENSIFICATION

A. Special high-energy impact densification apparatus shall be employed to densify the Aggregate Pier elements during installation. The apparatus shall apply direct downward impact energy to each lift of aggregate.

B. Minimum tamper energy CIMA rating of 1200 foot-pounds of force per blow applied by the energy source.

C. The bottom of the excavation shall be densified prior to the placement of the aggregate. If wet, soft or sensitive soils are present, open-graded aggregate, such as ASTM No.57 stone or other, shall be placed at the bottom of the excavation and compacted to stabilize the element bottom and may serve as the initial lift.

D. Densification shall be performed using a beveled tamper. The beveled tamper foot is required to adequately increase the lateral earth pressure in the matrix soil during installation.

E. Downward pressure shall be applied to the tamper shaft during tamping.

F. Each lift of aggregate shall be tamped for a minimum of 10 seconds.

4.3 PLAN LOCATION AND ELEVATION OF AGGREGATE PIER ELEMENTS

A. The center of each pier shall be within 6 inches of the plan locations indicated. The General Contractor shall provide ground elevations in sufficient detail to estimate drilling depth elevations to within 2 inches. The final measurement of the top of piers shall be the lowest point on the aggregate in the last compacted lift. Piers installed outside of the above tolerances and deemed not acceptable shall be rebuilt at no additional expense to the Owner.

4.4 REJECTED AGGREGATE PIER ELEMENTS

A. Aggregate pier elements improperly located or installed beyond the maximum allowable tolerances shall be abandoned and replaced with new piers, unless the Structural Engineer approves 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 the rejection is due to an obstruction or mislocation.

PART 5 – QUALITY CONTROL

5.1 QUALITY CONTROL REPRESENTATIVE
A. The Installer shall have a full-time Quality Control (QC) representative to verify and report all QC installation procedures. The Installer shall immediately report any unusual conditions encountered during installation to the Designer, the Geotechnical Engineer, Structural Engineer, the General Contractor, and to the Testing Agency.

5.2 MODULUS TEST

When required, a modulus test shall be performed to verify the parameter values selected for design. Aggregate Piers shall be tested to 150 percent of the maximum design stress as shown in the aggregate pier design submittal. Modulus Test Procedures shall utilize appropriate portions of ASTM D 1143, ASTM D 1194 and ASTM D 3689, as outlined below. The modulus tests shall be of the type and installed in a manner specified herein.

A. A telltale shall be installed at the bottom of the test pier so that bottom-of-pier deflections may be determined. Acceptable performance is indicated when the bottom of the pier deflection is no more than 20% of the top of pier deflection at the design stress level.

B. ASTM D-1143 general test procedures shall be used as a guide to establishing load increments, load increment duration, and load decrements.

C. With the exception of the load increment representing approximately 115% of the design maximum top of Aggregate Pier stress, all load increments shall be held for a minimum of 15 minutes, a maximum of 1 hour, and until the rate of deflection reduces to 0.01 inch per hour, or less.

D. The load increment that represents approximately 115% of the design maximum stress on the Aggregate Pier shall be held for a minimum of 15 minutes, a maximum of 4 hours and until the rate of deflection reduces to 0.01 inches per hour or less.

E. A seating load equal to 5 percent of the total load shall be applied to the loaded steel plate prior to application of load increments and prior to measurement of deflections to compensate for surficial disturbance.

F. Aggregate Pier modulus testing shall be performed in accordance with the requirements outlined in the Design Submittal.

G. The location of the aggregate pier modulus test should be coordinated with the project Geotechnical Engineer of record.

5.3 UPLIFT LOAD TEST (WHEN REQUIRED)

A. Uplift load test procedures shall be conducted in general accordance with ASTM D-3689, as appropriate and except as modified herein. Uplift aggregate-pier testing shall be performed in accordance with the requirements outlined in the Design Submittal.

B. The location of the uplift load test should be coordinated with the project Geotechnical Engineer of record.

C. Uplift load test information shall be used to verify that the aggregate-pier system design is consistent with the behavior exhibited during the uplift load test.
5.4 BOTTOM STABILIZATION VERIFICATION TEST

A. After completion of the bottom pier bulb, or at anytime during the process of constructing the pier, the energy source may be turned off, and bottom stabilization verification test may be performed. These tests shall be performed when a new soil formation is encountered, or at the beginning of a project to provide quantitative information on pier stabilization.

B. Bottom Stabilization Tests are performed by placing a reference bar over the cavity, marking the tamper shaft, applying energy to the tamper for an additional 15 seconds, and observing the downward deflection of the tamper shaft by observing the deflection of the mark on the tamper shaft.

C. Acceptable performance is indicated if the vertical movement of the shaft is less than 150% of the vertical movement measured for the modulus test pier.

D. If the measured vertical movement exceeds 150% of the value achieved during the modulus test, added energy is applied to re-densify the bulb. The procedure for measure is then repeated. If there is still movement greater than 150% of that achieved during the modulus test and greater than ½ inch, a lift of loose aggregate may be placed on top of the compacted aggregate, and the verification test may be performed on this next lift after it is densified. If there is excessive movement on this lift, another lift may be placed and tested. Movement must be limited to below 150% of the values achieved for the modulus test before completion of 2/3 of the pier depth.

PART 6 – QUALITY ASSURANCE

6.1 INDEPENDENT ENGINEERING TESTING AGENCY

A. The Owner or General Contractor is responsible for retaining an independent engineering testing firm to provide Quality Assurance services. The Testing Agency should be the Geotechnical Engineer of Record, if possible.

6.2 RESPONSIBILITIES OF INDEPENDENT ENGINEERING TESTING AGENCY

A. The Testing Agency shall monitor the modulus and uplift test(s) when modulus or uplift test(s) are to be performed. The Installer shall provide and install all dial indicators and other measuring devices.

B. The Testing Agency shall monitor the installation of aggregate 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 may perform Dynamic Cone Penetrometer tests.

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

PART 7 – RESPONSIBILITIES OF GENERAL CONTRACTOR

7.1 PREPARATION

A. The General Contractor shall locate and protect underground and aboveground utilities and other structures from damage during installation of the Aggregate Pier elements.
B. The General Contractor will provide the site to the Installer, after earthwork in the area has been completed.

C. Site subgrade shall be established by the General Contractor within 6 inches of final design subgrade.

D. A working surface will 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 Aggregate Pier installation.

7.2 LAYOUT OF THE AGGREGATE PIER ELEMENTS

A. The General Contractor shall provide layout (construction staking) of the Aggregate Piers. The General Contractor shall provide ground elevations in sufficient detail to estimate drilling depth elevations to within 2 inches.

7.3 AGGREGATE PIER EXCAVATION

A. Should any obstruction be encountered during drilling or excavation for aggregate piers, the General Contractor shall be responsible for 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., that prevent installing the aggregate piers to the required depth, or cause the aggregate pier to drift from the required locations. Dense natural rock or weathered rock shall not be deemed obstructions, and piers may be terminated short of design lengths on such materials. If the General Contractor cannot or does not remove such obstructions within one hour from the time the Installer reports the obstruction to the General Contractor, the Installer may remove such obstructions with his own means. Should this occur, the Installer shall receive an extra to the contract to account for their additional expenses, including delay time involved to crew and equipment.

7.4 UTILITY EXCAVATIONS

The General Contractor shall coordinate all excavations made subsequent to Aggregate Pier installations so that at least five feet of horizontal distance remains between the edge of any installed Aggregate Pier and the excavation. Protection of completed Aggregate Pier elements is the responsibility of the General Contractor. In the event that utility excavations are required at horizontal distances of less than five feet from installed Aggregate Piers, the General Contractor shall contact the Aggregate Pier Designer to develop construction solutions to minimize impacts on the installed Aggregate Piers. Recommended procedures may include:

A. Using cement-treated base to construct portions of the Aggregate Piers subject to future excavations.

B. Replacing excavated soil with compacted crushed stone in the portions of excavations where Aggregate Piers have been disturbed. The placement and compaction of the crushed stone shall meet the following requirements.
   1. The crushed stone shall meet the gradation specified by the Geotechnical Engineer.
   2. The crushed stone shall be placed in a controlled manner using motorized impact compaction equipment.
   3. The aggregate should be compacted to 95% of the maximum dry density as determined by the modified Proctor method (ASTM D-1557).
   4. The Testing Agency shall be on site to observe placement, compaction, and provide density testing. The test results shall be submitted to the Geotechnical Engineer, Structural Engineer and the General Contractor. The General Contractor shall provide
notification to the Testing Agency and the Geotechnical Engineer when excavation, placement, and compaction will occur and arrange for construction observation and testing.

7.5 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 Aggregate Pier elements shall be made in a workmanlike manner, and shall be protected until concrete placement, with procedures and equipment best suited to (1) prevent softening of the matrix soil between and around the Aggregate Pier elements before pouring structural concrete, and (2) achieving direct and firm contact between the dense, undisturbed Aggregate Pier elements and the concrete footing.

C. 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 Aggregate Pier elements shall be prepared using a motorized impact compactor (“Wacker Packer,” “Jumping Jack,” or similar). Sled-type tamping devices shall not be used. Compaction shall be performed over the entire footing bottom to compact any loose surface soil and loose surface pier aggregate.
   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 expansive or sensitive soils.
   4. If same day placement of footing concrete is not possible, place a minimum 3-inch thick lean concrete seal (“mud mat”) immediately after the footing is excavated and approved.

D. The following criteria shall apply, and a written inspection report sealed by the project Geotechnical Engineer shall be furnished to the Installer to confirm:
   1. That water (which may soften the unconfined matrix soil between and around the Aggregate Pier elements, and may have detrimental effects on the supporting capability of the Aggregate Pier reinforced subgrade) has not been allowed to pond in the footing excavation at any time.
   2. That all Aggregate Pier elements designed for each footing have been exposed in the footing excavation.
   3. That immediately before footing construction, the tops of all the Aggregate Pier elements exposed in each footing excavation have been inspected and recompacted as necessary with mechanical compaction equipment, and that the tops of any Aggregate Pier elements which may have been disturbed by footing excavation and related activity have been recompacted to a dry density equivalent to at least 95% of the maximum dry density obtainable by the modified Proctor method (ASTM D-1557).
   4. That no excavations or drilled shafts have been made after installation of Aggregate Pier elements within horizontal distance of five feet from the edge of any pier, without the written approval of the Installer.

E. Failure to provide the above inspection and certification by the project Geotechnical Engineer, which is beyond the responsibility of the Aggregate Pier Installer, may void any written or implied warranty on the performance of the Aggregate Pier system.

END OF SECTION 02472