

SPECIFICATION FOR AGGREGATE PIER GROUND IMPROVEMENT

PART 1: GENERAL REQUIREMENTS

1.01 Description

Work shall consist of designing, furnishing and installing aggregate pier ground improvement to the lines and grades designated on the project foundation plan and as specified herein. Aggregate pier ground improvement as referenced in this specification shall be constructed by either vibro-stone columns or Rammed Aggregate Pier[®] systems. The aggregate piers shall be in a columnar-type configuration and shall be used for support of foundation and slab loads.

1.02 Work Included

- A. Provision of all equipment, material, labor, and supervision to design and install aggregate piers. Design shall rely on subsurface information presented in the project geotechnical report. Layout of aggregate piers, spoil removal (as required), and load testing shall be considered incidental. Footing excavation and subgrade preparation following aggregate pier installation is not included.
- B. The aggregate 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 Aggregate 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.
- B. Installers of aggregate pier foundation systems shall have a minimum of 2 years of experience with the installation of aggregate pier systems and shall have completed at least 10 projects.

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.*
 - 2. "Settlement of Structures Supported on Marginal or Inadequate Soils Stiffened with Short Aggregate Piers," by Evert C. Lawton and Nathaniel S. Fox. *Geotechnical Special Publication No. 40: Vertical and Horizontal Deformations of Foundations and Embankments*, ASCE, 2, 962-974.
 - 3. "The design of vibro replacement." H.J. Priebe. *Ground Engineering*, London. Dec 1995.

- B. Load Testing
 - 1. ASTM D 1143 - Pile Load Test Procedures
 - 2. ASTM D 1194 - Spread Footing Load Test
- C. Materials and Inspection
 - 1. ASTM D 1241 - Aggregate Quality
 - 2. ASTM D 422 - Gradation of Soils
- D. Where specifications and reference documents conflict, the Aggregate Pier Designer shall make the final determination of the applicable document.

1.05 Certifications and Submittals

- A. Design Calculations - The Installer shall submit detailed design calculations and construction drawings prepared by the Aggregate 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. Professional Liability Insurance - 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. Building Code Acceptance – The Aggregate Pier Installer shall demonstrate that the Aggregate Pier system has been evaluated by the International Code Council.
- D. Load Test Reports – At least three load test(s) shall be performed on Aggregate Pier elements at three distinct locations across the building footprint as identified by the Aggregate Pier Designer to verify the design assumptions. The Installer shall furnish the General Contractor a description of the installation equipment, installation records, complete test data, analysis of the test data and verification of the design parameter values based on the load test results. The report shall be prepared and stamped by a Professional Engineer licensed in the State of Maine.
- E. Daily Aggregate Pier Progress Reports – The Installer shall furnish a complete and accurate record of Aggregate Pier installation to the Construction Manager. The record 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 record shall also indicate the type and size of the installation equipment used, and the type of aggregate used. The Installer shall immediately report any unusual conditions encountered during installation to the Construction Manager, to the Designer and to the Testing Agency.

PART 2: MATERIALS

2.01 Aggregate

- A. Aggregate used by the Aggregate Pier Installer for pier construction shall be pre-approved by the Designer and shall demonstrate suitable performance during load 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 source shall be used to increase aggregate moisture content where required. The Site Contractor shall provide such water to the Installer.
- C. Grout used by the Installer shall be pre-approved by the Designer and shall be used to overcome weak and voided soil strata as presented in the project geotechnical report.

PART 3: DESIGN REQUIREMENTS

3.01 Aggregate Pier Design

- A. The design of the Aggregate Pier system shall be based on the service load bearing pressure and the allowable total and differential settlement criteria of all footings indicated by the design team for support by the Aggregate Pier system. The Aggregate Pier system 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 50 years.
- B. The design shall meet the following criteria.

Maximum Allowable Bearing Pressure for Footings Supported by Aggregate Pier Reinforced Soils	3,000 psf
Estimated Total Long-Term Settlement for Footings:	≤ 1-inch
Estimated Long-Term Differential Settlement between Adjacent Footings:	≤ ½-inch
Modulus of Subgrade Reaction of On-Grade Floor Slabs	150 pci
Maximum Allowable Bearing Pressure for On-Grade Floor Slabs supported by Aggregate Pier Reinforced Soils	150psf

3.02 Design Submittal

The Installer shall submit detailed design calculations, construction drawings, and shop drawings, (the Design Submittal), for approval at least 2 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 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 where the piers are to be built. Submittals will be submitted electronically 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 Aggregate Piers. Unless otherwise approved by the Designer, the installation method used for Aggregate Pier construction shall be that as used in the construction of the successful load test.

- A. Aggregate Piers Installed using Displacement Rammed Aggregate Pier systems –
1. Displacement Rammed Aggregate Pier systems shall be constructed by advancing a steel mandrel with at least 15 tons of 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 cavity, 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. High-energy impact densification tamper shall be employed to vertically densify the Rammed Aggregate Pier elements during installation of each approximate 1-foot thick constructed lift. The tamper diameter shall be at least 50% of the Aggregate Pier design diameter.
3. Downward crowd pressure shall be applied to the mandrel during installation.
4. The Installer shall provide a full-time quality control technician on-site during the installation process.

B. Aggregate Piers Installed using Vibroflot Stone Columns

1. If vibroflot stone column construction is used to construct the Aggregate Piers, the Installer shall use an electric down-hole vibroflot (probe) capable of providing at least 200 HP of rated energy and a centrifugal force of 30 tons. The vibroflot diameter must be at least 60% of the Aggregate Pier design diameter. An appropriate metering device should be provided at such a location that inspection of amperage build-up may be verified during the operation of the equipment. Metering device may be an ammeter directly indicating the performance of the vibroflot tip of the eccentric. Complete equipment specifications should be submitted to the Engineer prior to commencement of the fieldwork.
2. The probe and follower tubes shall be of sufficient length to reach the elevations shown on the installer's approved construction drawings. The probe, used in combination with the available pressure to the tip jet, shall be capable of penetration to the required tip elevation. Pre-augering shall be used to aid penetration.
3. The probe shall penetrate into the foundation soil layer to the minimum depths required in the installer's construction plans. After penetration to the required depth, the probe shall not be withdrawn more than 2 feet at any time unless the stone stops flowing to the bottom of the probe.
4. Redriving the probe into the treated depth shall be attempted at approximately 12 to 18-inch intervals to observe resistance to penetration and amperage build-up. During redriving, the probe tip shall penetrate to within 1 foot of the previous redriving depth.
5. Amperage build-up and backfill quantities will be contingent upon the type of probe used and procedures. Prior to commencement of work, the contractor shall discuss the equipment capabilities with the Engineer to determine if trial probes will be necessary.
6. The Installer shall provide a full-time quality control technician on-site during the installation process.

4.02 Plan Location and Elevation of Aggregate Piers

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 Aggregate Piers

Aggregate Pier elements installed beyond the maximum allowable tolerances or that penetrate the bearing stratum 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.

PART 5: QUALITY CONTROL

5.01 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 Aggregate Pier Designer, the Construction Manager, and to the Owner’s Engineer. The quality control procedures shall include the preparation of Aggregate Pier Progress Reports completed during each day of installation containing the following information:

1. Footing and Aggregate Pier location.
2. Pre-auger diameter and soil conditions encountered during drilling (if required).
3. Aggregate Pier length.
4. Planned and actual Aggregate Pier elevations at the top and bottom of the Aggregate Pier.
5. Average lift thickness of each Aggregate Pier.
6. Volume of aggregate used in each Aggregate Pier.
7. Documentation of any unusual conditions encountered.
8. Type and size of densification equipment used.

5.02 Aggregate Pier Load Test

Aggregate Pier Load Test(s) shall be performed at locations agreed upon by the Aggregate Pier Designer and the Owner’s Engineer to verify or modify Aggregate Pier designs. Load Test Procedures shall utilize appropriate portions of ASTM D 1143 and ASTM D 1194, as outlined in the Aggregate Pier design submittal. Aggregate Piers shall be tested to 150 percent of the maximum design stress as shown in the aggregate pier design submittal. 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 30% 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. As a minimum, the following loading increments, decrements and duration shall be used.

<u>Increment</u>	<u>Approximate Load (percent design)</u>	<u>Minimum Duration (min)</u>	<u>Maximum Duration (min)</u>
Seat	< 9	0	N/A
1	17	15	60
2	33	15	60
3	50	15	60
4	67	15	60
5	83	15	60
6	100	15	60
7	117	60	120
8	133	15	60
9	150	15	60
10	100	N/A	N/A
11	66	N/A	N/A
12	33	N/A	N/A
13	0	N/A	N/A

- C. With the exception of the load increment representing approximately 117% of the design maximum top of Aggregate Pier stress, all load increments shall be held for a minimum of 15

minutes. Loads are then maintained until the rate of deflection reduces to 0.01 inch per hour or for the maximum of 1 hour, whichever is occurs first.

- D. The load increment that represents approximately 117% of the design maximum stress on the Aggregate Pier shall be held for a minimum of 60 minutes. Loads are then maintained until the rate of deflection reduces to 0.01 inch per hour or for the maximum of 2 hours, whichever is occurs first.
- 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.

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. The tests are performed by applying downward vertical energy to the tamper, mandrel or probe following lift construction and monitoring the amount of additional deflection from the applied energy. Additional testing as required by the Aggregate Pier Designer (typically 10% of the production Aggregate Piers) shall be performed on selected production Aggregate Pier elements to compare results with the modulus test pier.

PART 6: QUALITY ASSURANCE

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

The Aggregate Pier Installer shall provide full-time Quality Control monitoring of Aggregate Pier construction activities. The Owner or Construction Manager 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 load 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 Aggregate Piers to verify that the production installation practices are similar to those used during the installation of the load test elements.
- C. The Testing Agency shall report any discrepancies to the Installer and Construction Manager 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 CONSTRUCTION MANAGER

7.01 Site Preparation and Protection

- A. The Construction Manager shall locate all underground and above ground utilities. The Installer shall take measures to protect all utilities and other structures from damage during installation of the Aggregate Piers.
- B. Site grades for aggregate pier installation shall be within 4 foot of the top of footing elevation or bottom of slab elevation to minimize aggregate pier installation depths. Ground elevations and bottom of footing elevations shall be provided to the Rammed Aggregate Pier Installer in sufficient detail to estimate installation depth elevations to within 3 inches.

- C. The Site 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 Site Contractor to provide wet weather protection of the subgrade and to provide access for efficient operation of the Aggregate Pier installation.
- D. Prior to, during and following Aggregate Pier installation, the Site Contractor shall provide positive drainage to protect the site from wet weather and surface ponding of water.
- E. If spoils are generated by aggregate pier installation, remove spoils from the work area in a timely manner to prevent interruption of aggregate pier installation.

7.02 Aggregate Pier Layout

The location of aggregate pier-supported foundations for this project, including layout of individual aggregate pier elements, shall be marked in the field using survey stakes or similar means at locations shown on the drawings. The Construction Manager will provide control lines, layout of footings and a benchmark. The Installer is responsible for laying out the Aggregate Pier locations within the footings and slab area.

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

The Owner is responsible to retain an Independent Testing Agency (Quality Assurance). Testing Agency roles are as described in Part 6 of this specification. The Aggregate Pier Installer will provide Quality Control services as described in Part 5 of this specification.

7.04 Excavations for Obstructions

- A. Should any obstruction be encountered during Aggregate Pier installation, the Site 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 Construction Manager shall coordinate all excavations made subsequent to Aggregate Pier installations so that excavations do not encroach on the piers as shown in the Aggregate Pier construction drawings. Protection of completed Aggregate Piers is the responsibility of the Construction Manager. In the event that utility excavations are required in close proximity to the installed Aggregate Piers, the Construction Manager shall contact the Aggregate Pier Designer immediately to develop construction solutions to minimize impacts on the installed Aggregate Pier elements.

7.06 Footing Bottoms

- A. Excavation and surface compaction of all footings and slab areas shall be the responsibility of the Site Contractor.
- B. Foundation excavations to expose the tops of Aggregate Piers shall be made using a smooth-edged bucket 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 Aggregate Piers before pouring structural concrete, and (3) achieve direct and firm contact between the dense, undisturbed Aggregate Piers and the concrete footing.

- C. All excavations for footing bottoms supported by Aggregate Pier foundations shall be prepared in the following manner by the Site Contractor. Recommended procedures for achieving these goals are to:
 - 1. Limit over-excavation below the bottom of the footing to 6-inches (including disturbance from the excavation equipment).
 - 2. Install 6-inches of ¾-inch minus crushed stone (No. 57 Stone) and compact using a ½-ton vibratory plate compactor.
 - 3. Protect prepared footing bearing surfaces from surface water accumulation, freezing or other disturbances until footing concrete is placed.
- D. The following criteria shall apply, and a written inspection report sealed by the Construction Manager shall be furnished to the Installer to confirm:
 - 1. That water has not been allowed to pond in the footing excavation at any time.
 - 2. That all Aggregate Piers designed for each footing have been exposed in the footing excavation.
 - 3. That immediately before footing construction, the tops of Aggregate 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 Aggregate Pier construction drawings, without the written approval of the Installer or Designer.

PART 8: PAYMENT

8.01 Method of Measurement

- A. Measurement of the aggregate piers is on a lump sum basis.
- B. Payment shall cover design, supply and installation of the aggregate pier foundation system.

8.02 Basis of Payment

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

<u>Pay Item:</u>	<u>Pay Unit:</u>
Preparation of plans and specifications and installation of aggregate pier elements	\$___ Lump Sum

- B. Unit prices shall be provided to account for:

Additional Installed Piers (w/o remobilization)	\$___ Lineal Foot
Additional Mobilizations	\$___ Each
Additional Load Test	\$___ Each
Additional BST or CST	\$___ Each