SECTION 02360 / 31 66 13.13 & 14

ENGINEERED AGGREGATE PIERS
(SOIL REINFORCEMENT AND FOUNDATION SYSTEM)

PART 1 GENERAL

1.01 WORK INCLUDED

A. Provide all equipment, material, labor and supervision to design and install Engineered Aggregate Piers for the soil reinforcement. Design shall rely on subsurface information presented in the project geotechnical report, and structural loading provided by the project Structural Engineer.

B. Provide design submittal, including appropriate drawings and calculations, sealed by a Professional Engineer licensed in the state in which the project is located.

C. Design engineer for the project shall be directly employed by the aggregate pier installer, and shall be readily available throughout project Design Development and pier installation to address Requests For Information (RFI's).

D. Installer's Design Engineer and Quality Control representative shall each have a minimum of 5 years of documented experience with engineered aggregate piers constructed with high energy, vertical ramming of the type specified herein.

1.02 RELATED WORK BY OTHERS

A. Prior to any pier installation, the Engineered Aggregate Pier installer shall be provided with written confirmation that settlement caused by any fill placed on the site prior to pier installation has stopped. Such confirmation shall come from or be approved by the project Geotechnical Engineer.

B. Layout of footings, mats, grade beams and staking of all aggregate pier locations prior to aggregate pier installation shall be the responsibility of the General Contractor. If layout and pier staking is not conducted by a licensed surveyor, then General Contractor shall assume full responsibility. Information provided shall include existing ground surface elevations (± 3") within 50 feet of each aggregate pier element. General Contractor shall assume full responsibility for any and all costs associated with piers that may be found later to have been mislocated or constructed to the wrong elevation control.

C. All above and below ground utilities shall be located, clearly marked, and relocated as necessary prior to installation of aggregate pier elements.

D. Pier aggregate, if supplied or placed by the Owner's representatives or Contractors, shall be placed within 50 feet of the pier construction area and in sufficient locations as to facilitate unhindered, continuous pier construction, determined in coordination with the aggregate pier installer.

E. Removal of drill spoils from the site, and fugitive dust control are not included.

F. Foundation excavations to expose the tops of aggregate piers shall be made in a workmanlike manner, and shall be protected until concrete placement, with procedures and equipment best suited to (1) preventing softening of the matrix soil between and around aggregate piers prior to pouring structural concrete, and (2) achieving suitable contact between the dense, undisturbed aggregate piers and the concrete footing.

Procedures that can be employed for the purpose of achieving these goals include but are not limited to (1) excavate using a smooth bucket, (2) prevent excavation below scheduled bottom-of-footing elevation, (3) place footing concrete or suitable concrete seal ("mud mat") immediately after footing excavation is made and approved.

Footing excavations shall be inspected by the project Special Inspector or Owner's Quality Assurance (QA) representative (typically the Geotechnical Engineer of Record). The following criteria shall apply, and a written inspection report sealed by the appropriate inspecting representative shall be furnished the aggregate pier installer confirming that:

a) water (which may have softened unconfined matrix soil between and around aggregate piers, and may have detrimental effects on the supporting capability of the pier-reinforced subgrade) has not been allowed to pond in any footing excavation at any time;

   dewatering pumps should be installed to lower any head of water down to 2 or 3 feet below the bottom of footing level to help the installation of our piers and subsequent trades (mainly earthwork) who have to excavate or install footings.

b) all aggregate pier elements designed for each footing have been exposed in the footing excavation;

c) immediately prior to footing construction, the tops of all aggregate piers exposed in each footing excavation have been inspected by the Geotechnical Engineer and recompacted, as necessary, with mechanical (*not vibratory*) compaction equipment; and that the tops of any 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 AASHTO compaction procedure (ASTM D1557);

d) any structural fill placed between the tops of aggregate pier elements and the bottoms of foundations consists of the same quality and gradation material, or better, as used in constructing the piers; and that the fill has been compacted to a dry density equivalent to at least 95% of the maximum dry density obtainable by the modified AASHTO compaction procedure (ASTM D1557); and

e) no excavations or drilled shafts have been made after installation of aggregate pier elements within a horizontal distance of 10' from the edge of any pier, without the written approval of the aggregate pier installer.

G. Failure to provide the above items, which are beyond the responsibility of the aggregate pier installer, may void any written or implied warranty on the performance of the aggregate pier system.

1.03 QUALITY CONTROL / QUALITY ASSURANCE

A. Upon request, the installer of the aggregate pier system shall provide evidence of satisfactory experience with the design and installation of Aggregate Pier Soil Reinforcement systems using high energy vertical ramming with no vibration, including examples of at least 3 previous projects for which the installer has supported comparable structural loads, controlled settlement to the project tolerances, and utilized real-time quality control monitoring of rammer deflections. The design and installation shall be conducted and overseen by a registered professional engineer employed by the installer.

B. The installer of the aggregate pier system shall use exclusively high energy, low frequency vertical ramming to construct the piers. No vibratory energy shall be used in constructing the piers. The installer shall provide credible research data to confirm

that the rammer design to be used for constructing the aggregate piers develops nearly full passive lateral pressure in the soil surrounding the aggregate pier for a distance of at least 4 feet horizontally beyond the edge of the pier.

C. The installer of the engineered aggregate pier system shall provide a full time Quality Control (QC) representative on-site during pier construction to maintain QC records during pier installation. This work shall be conducted under the supervision of a registered professional engineer employed by the pier designer. A testing agency or Geotechnical Engineer shall be retained by the Architect/Owner for Quality Assurance (QA) services.

D. Quality Control observations shall include:

a) rammer force determination;

b) rammer stroke deflection measurements;

c) confirmation that piers are constructed at staked locations and within established tolerances;

d) confirmation that aggregate lifts 3 feet or more above the bottom of the pier have been constructed to the design criteria established by the aggregate pier design engineer.

e) all other observations required for completing the Daily Aggregate Pier Progress Report (DAPPR), as noted below.

E. A Daily Aggregate Pier Progress Report (DAPPR) shall be completed by the installer during each day of installation, and shall consist of the following:

f) Date of installation and summary of installation equipment and installation procedures.

g) Pier location, length, and diameter.

h) Final elevations of the pier top and bottom.

i) Documentation of any unusual subsurface conditions encountered.

j) Soil and groundwater observations, if any.

k) The results of any field Quality Control testing or deflection monitoring done.

F. The aggregate pier installer shall confirm pier modulus based on the dynamic rammer modulus achieved during ramming of aggregate lifts. The modulus shall be evaluated by measuring the dynamic force delivered by each rammer stroke, and applying that to the measured deflection of the rammer foot per stroke. Ramming of each aggregate lift shall be continued until the "design" pier modulus has been achieved.

G. Prior to installing production piers, the aggregate pier installer shall measure on-site the energy output per stroke for the rammer being used. "Rated" energy provided by the rammer manufacturer shall not be used. During lift ramming, deflection of the rammer foot accompanying each stroke shall be monitored with instrumentation capable of recording rammer deflection to a precision of at least 0.001 inch per rammer stroke. Rammer-blow deflection monitoring shall be performed randomly in at least 5% of the piers installed for the project to confirm that terminal rammer-blow deflections on pier lifts meet the established acceptance criterion and that the "design" pier modulus has been achieved.

H. A calibrated dynamic penetration test (ASTM STP 399) may be performed on representative aggregate pier elements as a supplement to rammer modulus values obtained during lift ramming. A minimum of 15 blows per 1.75 inch vertical movement shall be the minimum average penetration resistance of compacted, graded aggregate

base course stone. On lifts of open graded aggregate, lower values may be approved by the system designer as appropriate.

I. The testing agency/Geotechnical Engineer providing QA services, shall monitor installation procedures relative to these specifications, and shall confirm that subsurface conditions across the installation area as revealed by the pier drilling are in general agreement with the project geotechnical explorations.

J. The designer of the aggregate pier system shall carry Errors and Omissions / Professional Liability Insurance with coverage of at least $2 Million.

1.04 REFERENCES

A. The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

1.	ASTM D1143	Pile Load Test Procedures
2.	ASTM D1194	Spread Footing Load Test
3.	ASTM D1557	Aggregate Densification
4.	ASTM D1241	Aggregate Quality
5.	ASTM STP 399	Dynamic Penetrometer Testing
6.	ASTM D3689	Uplift Load Test

1.05 SUBMITTALS

A. Make submittals in accordance with requirements of Division 1 and as specified in this section.

B. A Daily Aggregate Pier Progress Report (DAPPR) shall be furnished by the installer to the General Contractor. The final DAPPR shall include select graphs of the rammer deflection data and modulus determinations for constructed piers.

C. When load tests are performed, the installer shall furnish within 5 working days of the completion of the test, a report including a description of the installation, test data, and any changes in design parameters based on the load test results. The report shall be prepared by or under the direct supervision of a registered professional engineer experienced in performance and analysis of the aggregate pier system.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Any materials ordered or delivered to the project site before approval will be at the aggregate pier installer's risk.

B. Deliver materials to project site in quantities and at times to assure conformity of activities with the installation schedule for the aggregate pier system.

PART 2 PRODUCTS

2.01 MATERIALS

A. Aggregate for the piers shall typically consist of materials that are in general conformance with gradation requirements for State DOT highway base course and/or drainage materials, or as approved by the aggregate pier designer. Wet weather or soil conditions may require that the aggregate contain less than 5 percent fines (silt and clay particles passing the No. 200 sieve). The aggregate pier system designer and

installer shall make the determination of acceptable materials to be used in pier construction.

B. A suitable washed, open graded aggregate may be used in wet conditions or as initial lifts where soft soils are present at the bottom of the aggregate pier.

C. Potable water or other suitable source shall be used to increase aggregate moisture content as needed for workability. Water shall be made available on-site to the installer of the aggregate pier system for his use in moisture conditioning aggregate for compaction, as needed. The need for moisture conditioning aggregate shall be made by the aggregate pier system installer based on workability and/or dust control; however, moisture content of aggregate is not a requirement for pier acceptance.

PART 3 EXECUTION

3.01 INSPECTION

A. Examine areas and conditions under which aggregate pier elements are to be installed.

B. Notify General Contractor of conditions detrimental to proper and timely completion of Work.

C. Do not proceed with Work until unsatisfactory conditions have been corrected in an acceptable manner.

3.02 PREPARATION

A. The General Contractor shall locate and protect underground and above ground utilities, and other structures from damage during installation of the engineered aggregate pier system.

B. Install aggregate pier elements after Earthwork in the installation area has been completed as follows:

a) Site subgrade established by General Contractor shall be within 6 inches of finish subgrade, or as approved by installer of the aggregate pier system.

b) Any fills needed to establish finish subgrade have been installed, and settlement resulting from fill loads is complete (unless specifically approved in writing by the aggregate pier designer prior to installation).

c) GC shall provide and maintain a firm, relatively level, drained all-weather working pad. GC will prevent perching water upon or within the working pad material and shall provide proper dewatering to lower the head below the bottom-of-footing elevation.

3.03 INSTALLATION

A. The locations, size, and spacing of aggregate pier elements are described on the appropriate drawings or details. Any modifications in size and spacing of the aggregate pier element layout shall be approved by the system designer.

B. Should any obstruction, including but not limited to boulders, timber, concrete, asphalt, large roots etc., be encountered which prevents placing the elements to the required depth, or causes the aggregate pier to drift from the required location, the obstruction shall be removed by the General Contractor. The excavation shall be backfilled by General Contractor with suitable materials and sufficiently compacted, in order to continue with installation of the aggregate pier element. Piers may be

terminated short of design depth on rock, gravel or other suitable materials. Additional aggregate pier elements shall be installed when required by the presence of obstacles.

C. Special high-energy impact apparatus shall be used to construct the aggregate pier elements. Specially designed rammers per paragraph 1.03 of this specification shall be used. Approval of constructed pier lifts shall be based on observed rammer modulus achieved over the last several blows of ramming.

D. The bottom of the pier excavation shall be rammed prior to the placement of aggregate. If wet, soft or sensitive soils are present, open graded aggregate shall be placed and rammed to stabilize the pier bottom and may serve as the initial pier lift.

E. The center of each constructed aggregate pier element shall be within 6 inches of the design location, as located and staked in accordance with Article 1.02.B. Foundation elements installed outside of the above tolerance and deemed not to be acceptable, shall be either rebuilt or other remedial measures taken as approved by the aggregate pier system designer.

F. Casing for elevator jack shafts located within 10 feet horizontally of any aggregate element shall be installed by others prior to aggregate pier installation, and shall be grouted in-place for the full length of the casing.

G. Acceptable constructed lift thickness shall be established by the aggregate pier designer and confirmed by the aggregate pier installer for each lift installed.

H. Required ramming time per lift, or acceptable terminal rammer deflection per blow, shall be established by the aggregate pier designer, and (if a test pier is constructed) shall be consistent with the time or deflection criteria used for the test pier construction.

3.04 AGGREGATE PIER MODULUS TESTING

A. <u>Real-Time Modulus Testing of Multiple Piers and Multiple Lifts:</u>

1. See Section 1.03 regarding real-time modulus testing to be conducted during the ramming of pier lifts.

B. <u>Post-Construction, Single Pier Modulus Testing:</u>

1. At the aggregate pier designer's discretion, Post-Construction, Single Pier Modulus Testing may be omitted if Real-Time Modulus Testing (as described in Section 1.03) is performed. However, when specifically required, a single pier modulus test may be conducted on a specific aggregate pier element after it is constructed and has cured for at least 3 days so that excess pore water pressures developed in the surrounding soils during ramming have dissipated. The pier to be tested shall be constructed in the same manner and with the same ramming equipment as used on the project production piers, and rammer deflection monitoring shall be employed on each lift of the test pier.

2. Aggregate pier elements used for single pier modulus testing which are located within tolerance and provide a safe design capacity may, upon approval of the aggregate pier designer, be used in the finished work.

3. Compressive load test procedures shall be conducted in general accordance with ASTM D1143 and D1194, as appropriate. A test pier shall be loaded to 150 percent of the estimated element design pressure. Alternatively, at the discretion of the

aggregate pier designer, the modulus test may be terminated when a modulus equal to 150 percent of the modulus used in the design is achieved.

4. The post-construction, single pier modulus test shall be conducted as follows:

   a) ASTM D1143 general test procedures shall be used as a guide to establishing load increments, load increment duration, load decrements, and total applied load.

   b) In order to evaluate bulging of the aggregate pier element itself under loading, the test pier shall be constructed in such a manner that deflections at both the bottom and top of the pier can be measured at each increment of loading.

   c) With the exception of the load increment representing approximately 112% of the design maximum aggregate pier element 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 which represents approximately 112% of the design maximum aggregate pier element stress shall be held for a minimum of 15 minutes, a maximum of 4 hours, and until the rate of deflection reduces to 0.01 inch 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) The test data shall be presented as a graph showing deflection of the pier top and bottom under each load increment.

   g) At the design load, deflection measured at the top of the pier shall not exceed the design settlement for the aggregate pier-reinforced soil zone, and the ratio of bottom plate deflection to top plate deflection shall not exceed 0.25 unless specifically approved by the aggregate pier designer.

3.05 AGGREGATE PIER UPLIFT TESTING

A. When field uplift tests are performed on aggregate pier elements, ASTM D-3689-07 shall serve as a basis. Uplift deflections shall be measured for both the reaction plate installed at the bottom of the aggregate pier element shaft and for a steel plate installed at the top of the element. Dial gages accurate to at least 0.001" shall be used and shall be supported on independent reference supported beams. Unloading shall be in at least four equal decrements, if possible.

B. The following procedure shall be followed in performance of field tests to confirm uplift design parameters for aggregate pier elements designed to resist seismic uplift, as required.

1. The pier shall be constructed in such a manner that deflections at each load increment can be measured for the top of the pier as well as the bottom of the pier.
2. Apply a seating load to the top plate not to exceed 5 kips.
3. Zero dial gages following application of seating load.
4. Rapidly apply loads in approximately equal increments of at least 5 kips each, with a maximum of 8 increments between the seating load and 200 percent of the element design load. Record deflections at each load increment.
5. The final increment of loading shall be equal to at least 200 percent of the design load.
6. Unload to approximately 5 kips in 4 approximately equal increments, and record rebound for each increment.

7. Repeat the load-unload cycle at least 3 times.

C. For tests conducted to evaluate performance under sustained uplift conditions (such as hydrostatic), the loading procedure shall be generally as described in B, above, except that only one load-unload cycle is required. Additionally, each load shall be maintained for a minimum of 10 minutes and until the rate of deflection equals 0.01 inch per hour, or less.

D. The deflections recorded during the test shall be averaged, and a load vs. deflection curve plotted for the top plate and the bottom plate. The ultimate uplift capacity for the aggregate pier element shall be defined as the load at which the rate of deflection measured at the top of the element is approximately equal to the rate of deflection at the bottom of the element. Loading beyond 200 percent of the design load is not required.