**AGGREGATE COLUMNS: AGGREGATE PIERS**

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**Basic Function**

Aggregate Piers are a ground improvement method that uses compacted aggregate to create stiff pier elements. Aggregate Piers help increase bearing capacity, shear strength, rate of consolidation, and liquefaction resistance; and reduces settlement.

**Advantages:**
- Rapid installation
- Cost effective compared to other foundations options
- Creates additional drainage
- Allows for high level of compaction.
- Efficient QC/QA procedures

**General Description:**

Aggregate piers are a ground improvement system that places aggregate in predrilled holes to form stiff, high density aggregate piers. As the aggregate is rammed to form the piers, the aggregate is forced laterally into the sidewalls of the hole, partially densifying the surrounding soil.

**Geologic Applicability:**
- Soft organic clays, loose silt and sand, uncompacted fill, stiff to very stiff clays, and medium dense to dense sands.
- Elevated water tables and cohesionless soils complicate the installation.
- Can extend 7 to 30 feet (2 to 9 m) below grade.
- Construction may be difficult in soft clays and loose sands, necessitating casing of the borehole

**Construction Methods:**

24- to 36-inch (600 to 900 mm) diameter holes are drilled into the foundation soils. The holes normally reach depths of 7 to 30 feet (2 to 9 m) below grade. Casings are needed for cohesionless soils where the water table is above the depth of the pier. This lifts of well-graded aggregate are rammed into the holes. The first lift is open graded aggregate forms a bulb at the bottom of the pier. The subsequent compacted lifts are typically 12 inches deep. A high-energy beveled tamper mounted on excavator equipment is used to compact the aggregate. Design parameters include pier length, spacing, pier stiffness, and stress concentration.
ratio. Pier spacing is from 5 to 8 feet (1.5 to 2.5 m) center to center of the piers. Load capacities range from 50 to 100 kips (222 to 445 kN).

**Additional Information:**

Quality control operations consist of monitoring drill depth, number and thickness of aggregate lifts, compaction time per lift (normally 15 seconds), bottom stabilization tests, and dynamic cone penetration index tests. Quality assurance can consist of a full-scale load test to verify the design pier stiffness.

**SHRP2 Applications:**

- Embankment and roadway construction over unstable soils
- Roadway and embankment widening

**Example Successful Applications:**

- Remediation of a Failed Slope – North Carolina
- Large Box Culvert Supported by Aggregate Piers – Iowa

**Complementary Technologies:**

Rammed aggregate piers are often used to support embankments, MSE walls, and reinforced slopes with other technologies.

**Alternate Technologies:**

Site preloading, excavation and replacement, piles, stone columns, deep-mixing-method columns, jet grout columns and drilled piers.

**Potential Disadvantages:**

- Limited treatment depth.
- Lack of bending resistance.
- Difficult to install in clean sands when the groundwater table is above the bottom of the pier.
- Not applicable of wide heavy load applications.
- Usually only effective to a depth of 7 to 30 ft (2 to 9 m) below foundation.

**Key References for this Fact Sheet:**


**Aggregate Columns: Stone Columns**

**Basic Function**
Stone Columns are a ground improvement method that uses compacted aggregate to create stiff pier elements. Stone Columns help increase bearing capacity, shear strength, rate of consolidation, and liquefaction resistance; and reduces settlement.

**Advantages:**
- Rapid installation
- Cost effective compared to other foundations options
- Creates an additional drainage path and accelerates consolidation
- Allows for high level of compaction.
- Efficient QC/QA procedures

**General Description:**
Stone Columns are columns formed with densified gravel or crushed rock in a pattern to create a composite foundation of the columns and the surrounding soil. The stiff columns carry a larger load than the surrounding soil to increase strength and capacity and reduce settlement.

**Geologic Applicability:**
- Improves clays, silts, and loose silty sands.
- Recommended in soft clays with an undrained shear strength greater than 400 psf but has been used in clays with a strength as low as 150 psf.
- Bulging columns is a concern in soft clays.
- Particle sizes and shape of the column infill material depends on the construction technique used, but generally ranged from ½ in to 3 in.
- Peat deposits can make the site unsuitable for stone columns.

**Construction Methods:**
Can be installed by water jetting, referred to as vibro-replacement or a wet, top feed method. Another method used is air jetting with dry, top and/or bottom feed method. In both methods, cylindrical vibrating probes are jetted into the ground to form holes, which are backfilled with gravel or crushed rock. Pre-augering can be used to reduce the ground displacement and vibration during construction. Depth of stone columns is normally between 20 and 30 feet.

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Bottom Feed Vibro Displacement
(Figure from Elias et al. (2006))

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feet with a limit of 90 feet. The rock is densified by the vibratory probes as they are withdrawn from the ground. Stone columns are placed in a triangular or rectangular pattern. The spacing and depth of the columns are determined by design standards.

**Additional Information:**

The vibro-replacement method has less displacement and vibration disturbance than the vibro-displacement method; however it creates a slurry in the process, creating more impact on the environment. Stone columns carry more load than the surrounding soils due to their greater stiffness. The stone columns and soil should be treated as a composite foundation. Stone columns cost about $15 to $20 per foot. Post improvement settlement ranges from 30% to 50%.

**SHRP2 Applications:**

- Embankment and roadway construction over unstable soils
- Roadway and embankment widening

**Example Successful Applications:**

- Office Building – Missouri
- Slope Stabilization – New York

**Complementary Technologies:**

Stone columns have been used in conjunction with dynamic compaction to stabilize liquefiable soils at depths greater than those which could be treated by dynamic compaction alone.

**Alternate Technologies:**

Site preloading, excavation and replacement, aggregate piers, piles, deep-mixing-method columns, jet grout columns and drilled piers.

**Potential Disadvantages:**

- With the wet technique of installation, the jetting water must be disposed.
- Uncertain whether all stone reaches the bottom of the hole using the dry-construction method.
- Soft soils may not provide adequate lateral support for the columns.

**Key References for this Fact Sheet:**

