

SPECIAL PROVISION**SPECIFICATION 996- SPECIALLY COMPACTED AGGREGATE PIERS – DISPLACEMENT METHOD****996-1 DESCRIPTION**

996-1.01 Scope – This work shall consist in designing, furnishing, and installing materials, and constructing a ground improvement system including submittal of shop drawings at the locations noted on the drawings and as specified herein. The Displacement Specially Compacted Aggregate Piers (DSCAP) elements shall be constructed by pushing a displacement mandrel to the design depth and using the rammer head to ram thin lifts of aggregate into the cavity created by the mandrel. The DSCAP elements shall be in a columnar-type configuration and shall be used to reinforce soils for the support of transportation structures. Ground improvement system installations shall be installed by qualified Specially Compacted Aggregate Piers installers.

996-1.02 Related Work

- a. Specification 202 – Removal of Structures and Obstructions
- b. Specification 203 – Excavation and Embankment
- c. Geotechnical Report and Recommendations

996-1.03 Reference Standards

- a. The Contractor shall be responsible for installation of DSCAP ground improvement system that meets the global stability, bearing capacity, and settlement requirements stated on the contract plans or contract documents. The Contractor shall be responsible for the submittal of shop drawings and computations. Industry recognized standards or design methods specific to the Contractor's equipment and construction methods shall be used.
- b. Modulus 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 D-422 – Gradation of Soils
 - 3. ASTM STP 399 – Dynamic Penetrometer Testing

**996-2 MATERIALS**

- a. Aggregate used for DSCAP construction shall be clean angular stone, or shall be other open-graded aggregate with a maximum nominal particle size of 1.5-inches and minimum nominal

particle size of 0.75-inches selected by the Contractor and successfully used in a modulus test.

- b. To facilitate construction in soft or loose soils, the maximum particle size aggregate of 2 inches or larger may be used provided the flow of the aggregate is verified at the site with flow tests, the performance is verified with the modulus test and the Contractor's specialty designer approves the type and gradation of the aggregate.
- c. The Contractor will provide adequate and suitable marshalling areas on the project site for the storage of aggregate and equipment.

996-3 CONSTRUCTION REQUIREMENTS

996-3.01 General – The DSCAP stiffness modulus shall be verified by the results of a modulus test, described in the specification. DSCAPs shall be installed in accordance with generally-accepted engineering practice and the methods described in these Specifications. The performance shall meet the following criteria:

- a. Minimum Bearing Pressure for DSCAP Reinforced Soils: As indicated on the plans.
 - b. Estimated Total Long-Term Settlement for the structure: $\leq 1/2$ -inch; unless otherwise required on the contract plans.
 - c. Estimated Long-Term Differential Settlement of Adjacent Footings: $\leq 1/4$ -inch; unless otherwise required on the contract plans.
 - d. The details submitted by the Contractor shall consider the bearing capacity and settlement of all footings supported by DSCAPs, 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 75 years.
 - e. The DSCAP system shall avoid plastic bulging deformations at the top-of-pier. The system shall also avoid 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 performance assumptions.
- f. **996-3.02** Approved Installers
- a. Installers of DSCAP systems shall have a minimum of 5 years of experience with the installation of DSCAPs and shall have completed at least 10 projects. The Contractor shall submit evidence of his experience and previous projects completed with the same number or more DSCAP as compared to this project for approval.
 - b. The Designer of the DSCAP system shall have at least 10 years of experience in the design of ground improvement technologies and provide evidence of at least 20 ground improvement projects completed in Puerto Rico.
 - c. The Contractor's installer shall adhere to all methods and standards described in this Specification.

996-3.03 Work Included

- a. A Contractor's specialty designer shall comply with a design following criteria as per AASHTO Section 10: Foundations, and Section 11: Walls, Abutments and Piers.
- b. The Contractor's specialty designer shall submit detailed design calculations and construction drawing to the Engineer and to the Geotechnical Engineer for acceptance at least three (3) weeks prior to the start of construction. All plans shall be sealed by a Professional Engineer registered in Puerto Rico, and working with the Contractor.
- c. Modulus and uplift test data – The Contractor shall provide the Engineer 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 the Professional Engineer registered in Puerto Rico.
- d. Layout of DSCAP elements, footing excavation, and subgrade preparation following DSCAP installation.
- e. Provision of all equipment, material, labor, and supervision to design and install DSCAP elements. Design shall rely on subsurface information presented in the project geotechnical report.
- f. Drawings and General Provisions of the Contract, including General and Supplemental Conditions, and Specifications, applied to the work in this specification.
- g. Daily Progress Reports – The Contractor shall furnish a complete and accurate record of aggregate pier installation to the Engineer. 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 Contractor shall immediately report any unusual conditions encountered during installation to the Engineer, and to the Geotechnical Engineer.

996-3.04 Demonstration Piers and Flow Tests

- a. The installer shall install a minimum of two initial "demonstration piers" to provide project-specific construction procedures prior to installing production piers and to verify appropriate flow of selected aggregate out of the mandrel.
- b. The production DSCAPs shall be installed using methods that are consistent with the demonstration pier procedures.
- c. The installation of the demonstration piers shall be observed and the details recorded by an installer control technician provided by the Contractor.

996-3.05 Installation Procedures

- a. The mandrel and tamping foot shall be pushed to the design depth through a combination of static crowd force and impact energy.

- b. The mandrel and hopper shall be filled with aggregate.
- c. The impact hammer shall begin operation and remain in operation during the raising of the mandrel. The impact hammer may remain in operation during the lowering of the mandrel depending on the specific installation procedures established at the site.
- d. The mandrel shall be raised 3 feet (or as determined by the Contractor specialty designer) at a constant rate as determined from the flow rate tests.
- e. Water or compressed air shall be used if necessary, to enhance free flow of aggregate through the mandrel as determined during the performance of a flow test. Water or air flow may be discontinued when the mandrel reaches the 3-foot raise height.
- f. The mandrel shall then be lowered, applying crowd pressure, such that an approximate 1-foot compacted lift is created. The crowd pressure shall be recorded to provide a measure of the vertical densification force. Additional impact ramming may be used depending on site-specific installation procedures.
- g. Subsequent lifts shall be constructed following the same procedure described above until the pier is constructed to the top of pier elevation.
- h. Alternative lift heights and lowering depth, may be used as appropriate for the project site.
- i. At the completion of the pier installation, the hammer shall be turned off and the mandrel pushed downward applying crowd pressure on the top of the pier to provide preloading.
- j. At completion of the DSCAP installation, the remaining stone in the mandrel may be emptied outside the pier location to allow for a measure of the remaining volume of aggregate. Procedures for determining the amount of material remaining in the hopper shall be developed by the Contractor's specialty installer to provide the most efficient method for determining this quantity. The following approach may be used to evaluate the volume of aggregate remaining in the hopper:
 - 1. After completion of the preloading of the pier, the remaining volume of stone in the hopper shall be discharged to form a conical pile of aggregate.
 - 2. The quality control representative shall measure the height of the cone as well as the approximate diameter of bottom of the cone. The volume of unused aggregate may be determined by using the following relationship:

$$V_{\text{aggregate-unused}} = \frac{\pi h (d_{\text{base}}^2)}{12}$$

where:

d_{bottom} = diameter of unused aggregate pile.

h = height of unused aggregate pile (cone)

996-3.06 Densification

- a. Special high-energy impact densification apparatus shall be employed to densify the DSCAP elements during installation. The apparatus shall apply direct vertical impact energy to each constructed lift of aggregate.

- b. Densification shall be performed using a specially-designed chained tamper foot. The tamper foot is required to adequately increase the lateral earth pressure in the matrix soil during installation.
- c. Downward crowd pressure shall be constantly applied to the tamper shaft during tamping.

996-3.07 Plan Location and Elevation of Impact DSCAP Elements

The center of each pier shall be within six 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 PRHTA.

996-3.08 Rejected DSCAP elements

DSCAP elements improperly located or installed beyond the maximum allowable tolerances shall be abandoned or reinstalled with new piers, unless the Designer approves other remedial measures or approves the location depending on the application. All material and labor required to replace rejected piers shall be provided at no additional cost to the PRHTA, unless the cause of the rejection is due to an obstruction or misallocation.

996-3.09 Modulus Test

A modulus test may be performed to verify the parameter values selected for design. The modulus tests shall be of the type and installed in a manner specified herein.

- a. The top of the pier shall be prepared by compacting the surface using impact compaction energy.
- b. ASTM D-1143 general test procedures shall be used as a guide to establishing load increments, load increment duration, and load decrements.
- c. Except for the load increment representing approximately 115% of the design maximum top of DSCAP 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 DSCAP 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. DSCAP modulus testing shall be performed in accordance with the requirements outlined in the Design Submittal.
- g. The location of the DSCAP modulus test should be coordinated with the project Geotechnical Engineer of record.

- h. The DSCAP test pier shall be installed in a manner that will be consistently used throughout the project. The details of the installation procedure shall be recorded by the Quality Control representative as described above.

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QUALITY CONTROL

The Contractor shall be responsible for the design of a Quality Control (QC) program to assure the quality of the construction. The program shall verify that the installed ground improvement system satisfies the performance requirements noted on the contract plans. As a minimum, the verification program shall include the following:

- a. Monitoring of the performance of the ground improvement system during and after construction of the proposed structure, or embankment to be supported; if applicable. This program may include installation of settlement plates, monitoring points, inclinometers, piezometers, or other instrumentation.
- b. Proposed means and methods for verification that the installed DSCAPs meet the strength and/or stiffness criteria by the design. This may include, but shall not be limited to modulus tests on individual elements and/or groups, soil borings, and other methods as approved by the DSCAP designer.
- c. QC program to verify that the ground improvements system is installed in accordance with the contract specifications and the requirements in this special provision. The quality control program shall include testing and observations by qualified personnel employed by the ground improvement Contractor or an independent testing laboratory.
- d. The Contractor shall have a full-time Quality Control (QC) representative to verify and report all QC installation procedures. The Contractor shall immediately report any unusual conditions encountered during installation to the design Engineer. The quality procedures shall include the preparation of DSCAPs progress reports completed during each day of installation and containing the following information:
 - 1. Footing and DSCAP location.
 - 2. Volume of aggregate introduced into the hopper (number of buckets)
 - 3. Mandrel installation depth.
 - 4. Mandrel stroke used to construct each lift
 - 5. Total pier installation time
 - 6. Hydraulic pressures during installation. (from installation or data record)
 - 7. Volume of unused aggregate (minimum 20% of production piers).
 - 8. Planned and actual DSCAP elevations at the top and bottom of the element (based on installation depth).
 - 9. Documentation of any unusual conditions encountered.

10. Aggregate description.
11. Crowd Stabilization Tests (CSTs)
12. Hammer Revolution Per Minutes (RPMs)
13. Equipment model and type

996-5 QUALITY ASSURANCE

996-5.01 Responsibilities of the PRHTA

Quality assurance will be the responsibility of the PRHTA's Soils Engineering Office and the Engineer. The Engineer will:

- a. Review and accept the Contactor's Submittal and shop drawings.
- b. Monitor the installation of the DSCAP elements to verify that all work is performed in accordance with the accepted Submittal.
- c. Observe footing excavations and densification of footing subgrade, inspect and approve subgrade condition, inspect and confirm top of DSCAP element compaction, and provide written reports.
- d. The PRHTA's Geotechnical Engineer shall be on site to observe installations, compaction, and modulus testing, as required by the Engineer.
- e. Report any discrepancies of the installation of DSCAPs immediately.

996-5.02 Responsibilities of the Contractor

- a. Preparation:
 1. The Contractor shall locate and protect, or relocate/demolish underground and aboveground utilities and other buried structures from damage during installation of the DSCAP elements.
 2. Site subgrade shall be established by the Contractor within six (6) inches of final subgrade, as approved by the Contractor's specialty designer.
- b. Utility Excavations
 1. The Contractor shall coordinate all excavations made after DSCAP installations so that at least five (5) feet of horizontal distance remains between the edge of any installed DSCAP and the excavation. If utility excavations are required at horizontal distances of less than five (5) feet from installed DSCAP, the Contractor shall develop construction solutions to minimize impacts on the installed DSCAPs.
 2. Recommended procedures may include:
 - a) Using lean concrete to construct the tops of the DSCAP subject to future excavations.
 - b) Replacing excavated soil with compacted crushed stone in the portions of

excavations where the DSCAP 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 PRHTA Specifications.
 - 2) The crushed stone shall be placed in a controlled manner using motorized impact compaction equipment.
 3. The aggregate shall be compacted to 95% of the maximum dry density as determined by the modified Proctor method (ASTM D-1557).
 4. The Contractor shall provide notification to the Engineer when excavation, placement, and compaction will occur and arrange for construction observing and testing. The PRHTA's Geotechnical Engineer shall be on site to observe placement, compaction, and density testing.
- c. Bottom of Footing Preparation
1. Excavation and surface compaction of all footings shall be the responsibility of the Contractor.
 2. Foundation excavations to expose the tops of DSCAP 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 DSCAP elements before pouring structural concrete, and (2) achieving direct and firm contact between the dense, undisturbed DSCAP elements and concrete footing.
 3. Recommended procedures for achieving these goals are to:
 - a) Limit over- excavation below the bottom of the footing to 3-inches (including disturbance from the teeth of the excavation equipment).
 - b) Compaction of surface soil and top of DSCAP 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 bottom of footing area to compact any loose surface soil and loose surface pier aggregate.
 - c) Place footing concrete immediately after 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.
 - d) If the same day placement of footing concrete is not possible, place a minimum of 3-inch lean concrete seal ("mud mat") immediately after the footing is excavated and approved.
 4. The following criteria shall apply, and a written inspection report sealed by the PRHTA's Geotechnical Engineer shall be furnished to the Contractor to confirm:
 - a) That there is no ponded water (which may soften the unconfined matrix soil between and around the DSCAP elements, and may have detrimental effects on the supporting capability of the DSCAP reinforced subgrade) in the footing excavation at the moment of the inspection.

- b) That all DSCAP elements designed for each footing have been exposed in the footing excavation.
- c) That immediately before footing construction, the tops of all the DSCAP elements exposed in each excavation have been inspected and recompactd as necessary with mechanical compaction equipment, and that the tops of any DSCAP elements which may have been disturbed by footing excavation and related activity have been re-compacted to a dry density equivalent to at least 95% of the maximum dry density obtainable by the modified Proctor method (ASTM D-1557).
- d) That no excavations or drilled shafts have been made after installation of DSCAP elements within horizontal distance of five (5) feet from the edge of any pier, without the written approval on the Contractor specialty designer.

996-6 CONFLICTS IN SPECIFICATIONS OR REFERENCES

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

996-7 CERTIFICATIONS AND SUBMITTALS

1. The Contractor shall submit detailed design calculations and construction drawings prepared for the DSCAP construction to the Engineer for approval at least 4 week(s) prior to the start of construction. All plans shall be sealed by a Professional Engineer in Puerto Rico. The Designer shall approve the procedures prior to construction of the DSCAPs.
2. Modulus test data - The Contractor shall furnish the Engineer 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.
3. Daily DSCAP Progress Reports – The Contractor shall furnish a complete and accurate record of DSCAP installation to the PRHTA. The record shall indicate the pier location, length, volume of aggregate used, crowd pressure 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 Contractor shall immediately report any unusual conditions encountered during installation to the Engineer.

996-8 METHOD OF MEASUREMENT

Measurement of the DSCAP solution is on linear meter basis. The work shall include design, equipment, mobilization, installation of the DSCAP elements, modulus tests, quality control, reports, calculations, predrilling when required, and any other incidental established in this specification which is not defined to be paid under another specification.

996-9 BASIS OF PAYMENT

The accepted quantities of DSCAP measured will be paid as linear meter. Such price and payment shall be full compensation for furnishing and placing all materials and for all design, labor, mobilization, equipment, tools, modulus test, and incidentals necessary to complete the work as required by the plans, specifications and/or indicated by the Engineer.

Payment will be made under:

<u>Pay Item:</u>	<u>Pay Unit:</u>
Specially Compacted Aggregate Piers Displacement Method (DSCAP)	Linear Meter