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## Supplemental Technical Specification for

# High Strain Dynamic Load Testing of Drilled Shafts

SCDOT Designation: SC-M-712-2 (07/19)

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### 1.0 GENERAL

**1.1** This work shall consist of performing high-strain dynamic testing using a drop weight loading system on a test drilled shaft for the purpose of determining and/or verifying the nominal bearing resistance that may be used in the design of production drilled shafts. In addition, the structural integrity of the test drilled shaft, the load-deflection and soil-load transfer relationships shall also be determined. Production drilled shaft lengths may be adjusted after results of the test drilled shaft have been analyzed. No materials shall be ordered until drilled shaft lengths are approved by the Department. The test shaft depth, diameter, and location shall be as specified in the plans. The testing specified in the project documents shall be conducted in general accordance with ASTM D4945 – *Standard Test Method for High-Strain Dynamic Testing of Deep Foundations* and this Supplemental Technical Specification.

**1.2** The drop weight load testing equipment shall have sufficient capacity to fully mobilize the test shafts' nominal bearing resistance shown in the plans.

**1.3** The location of the test drilled shaft (non-production) shall be as indicated in the plans. The test drilled shaft shall maintain a minimum distance of 25 feet from any foundation element of any future bent. The Contractor shall submit the proposed location to the Department for approval.

**1.4** Load testing of the test drilled shaft shall not begin until the concrete has attained a compressive strength ( $f'_c$ ) as indicated in the plans and had a curing time of no less than 7 days. High early strength concrete may be used to obtain the required strength at an earlier time to prevent testing delays, upon the approval of the Department.

**1.5** The Contractor will be required to furnish and include all costs in the bid item for all materials, personnel, and equipment as described in the plans, this Supplemental Technical Specification, the Special Provisions and as required by the contract to adequately perform High Strain Dynamic Load Testing of Drilled Shafts. The Contractor shall engage the services of an approved High Strain Dynamic Load Test supplier for instrumenting, performing, and reporting of the high strain dynamic load test. The Contractor may contact the Engineer for names of High Strain Dynamic Load Test suppliers.

**1.6** Supply the name and qualifications of the selected High Strain Dynamic Load Test supplier a minimum of 45 days prior to conducting the High Strain Load Test. Electronically submit all shop drawings, erection plans, details, calculations, and procedures to the Department at least 21 days prior to beginning the High Strain Dynamic Load Testing. Include with the submittal details with respect to the movement measuring system and the method for measuring the applied load. Approval of these submittals by the Department shall not relieve the Contractor from making subsequent changes that may become necessary to carry out the test.

**1.7** The Contractor, in cooperation with the High Strain Dynamic Load Test supplier, shall supply and supervise the mobilization, assembly, and operation of the High Strain Dynamic Load Test equipment. The High Strain Dynamic Load Test supplier shall provide and install the required

instrumentation for the test drilled shaft, acquire the test data during testing, and reduce the data into a report. This report shall be presented to the Contractor and the Department for evaluation. Interpretation of the test data with regard to foundation recommendations will be performed by the Geotechnical Engineer-of-Record (GEOR) with acceptance by the Department.

## **2.0 MATERIALS & EQUIPMENT**

**2.1** The Contractor shall supply all materials, personnel and equipment as described below and as required by the contract to adequately perform the High Strain Dynamic Load Test. Such materials and equipment are:

1. The High Strain Dynamic loading system and all items specifically incidental to the loading system.
2. A means to insure flat, level (axial to test shaft), and solid concrete shaft top.
3. A drop weight of in the range of 1 to 2 percent of the anticipated drilled shaft nominal resistance or 20 tons, whichever is lower or as specified in the plans will be used. The impacting surface of the drop weight should have an area between 70 and 130 percent of the test shaft top area. The cross-sectional shape of the drop weight shall be as regular as possible (square, round, hexagonal, etc.).
4. A guiding frame allowing variable drop heights typically between 3 and 7 feet, or as determined by the High Strain Dynamic Load Testing Engineer (described herein as Testing Engineer) in consultation with the Department.
5. A top cushion consisting of new sheets of plywood with a total thickness of 2 to 6 inches, or as determined by the Testing Engineer in consultation with the Department.
6. A surveyor's transit, laser light or equivalent for measurements (precise to the nearest one-tenth inch) of test shaft set under each drop weight impact.
7. Dynamic testing shall be performed and/or supervised by a Licensed Professional Engineer in South Carolina with at least 2 years of dynamic testing experience.

**2.2** The Contractor shall supply any additional equipment and personnel to assemble, perform, disassemble, and move to next test site (if applicable). This equipment includes, but not limited to, the following:

1. Unloading and loading of the High Strain Dynamic Load Test supplier trucks during mobilization and demobilization.
2. Any necessary on-site mobilization of test equipment.
3. A level and firm surface surrounding the test drilled shaft to support the High Strain Load testing system.
4. A level and smooth drilled shaft top. The top of the test drilled shaft shall incorporate permanent casing length as indicated in the plans and have a minimum ½-inch wall thickness. There shall be at least 6 inches between the top of the test drilled shaft and the top of the casing left in place.

5. A crane, rigging and operator capable of lifting, unloading, assembling, disassembling, and packing all High Strain Dynamic Load Test equipment. The crane and rigging should be of sufficient size and strength to handle the required High Strain Load Test equipment.
6. Power source adequate for electronic equipment.
7. For over water tests only, welding equipment and welder for falsework platform.

### **3.0 PREPARATION FOR TESTING**

**3.1** The Contractor shall perform site and foundation preparation. Foundation preparation includes the cutting and cleaning of the surface of the test drilled shaft down to test elevation. The top of the test drilled shaft shall be smooth and level. The area around the test drilled shaft, on land, shall be leveled and compacted within a 15-foot radius. The top of the drilled shaft should be approximately 1-1/2 diameters above grade for axial testing. For over water or elevated work areas, the area provided shall be level and at the test elevation. The support falsework platform shall be assembled and installed by the Contractor at the test location.

**3.2** Prior to performing the load test, the Testing Engineer shall be provided with soil boring logs, test shaft installation records, concrete properties (strength, etc.) and details regarding the anticipated dynamic loading equipment. The Testing Engineer is required to perform wave equation analyses (using GRLWEAP or equivalent) to determine the suitability of the proposed dynamic load testing equipment and an acceptable range of drop weight heights so as not to cause damage in the test shaft during the test.

**3.3** For the test drilled shaft, proposed instrumentation location shall be provided to the Department a minimum of 7 days prior to the fabrication of the drilled shaft reinforcement cage. The Department will provide comments for the final instrumentation locations within 3 business days after receiving this information.

**3.4** Strain and pressure gage instrumentation, displacement transducers, CSL access tubes, High Strain Dynamic Load Testing devices and any other materials and equipment required by High Strain Dynamic Load Test supplier shall be installed on the reinforcing cage.

**3.5** Immediately prior to placement of the reinforcement cage, the dimensions and verticality of the drilled shaft excavation shall be determined by Contractor using a sonic calibration method approved by the Engineer.

**3.6** CSL testing will be performed by the Department personnel or a Department designated representative in accordance with Section 727 of the Standard Specifications.

**3.7** The Contractor shall perform the test drilled shaft excavation in accordance with Section 712 of the Standard Specifications.

**3.8** The Contractor shall use the utmost care in handling the test assembly so as not to damage the instrumentation during installation. The Contractor shall limit the deflection of the cage to 2 feet between pick points while lifting the cage from the horizontal position to vertical. The maximum spacing between pick points shall be 25 feet. The Contractor shall provide support bracing, strong backs, etc. to maintain the deflection within the specified tolerance.

## **4.0 PROCEDURE FOR LOAD TESTING**

**4.1** The Contractor shall assist the Testing Engineer as necessary during all aspects of the High Strain Dynamic Load Test. The following steps shall be taken in the performance of the High Strain Dynamic Load Test.

1. Preparation for testing as described in Section 3.0.
2. Prior to testing, the Contractor shall make the upper 1-1/2 diameters of the test shaft completely accessible to the Testing Engineer.
3. Four “windows” (approximate size of 6 by 6 inches) diametrically opposite of each other shall be located and removed from the casing, if appropriate, or an entire band of the casing removed to expose a smooth concrete surface for attachment of the sensors. Sensors are typically attached at least 1 diameter below the shaft top. Sensor locations will be determined by the Testing Engineer.
4. In areas where casing is not present, the Testing Engineer, or Contractor under the direction of the Testing Engineer, shall smooth (by grinding) areas around the test shaft circumference such that proper sensor attachment can be accomplished.
5. Sensors shall be attached by the Testing Engineer or under the direction of the Testing Engineer to the exposed concrete in a secure manner as to prevent slippage under impact.
6. Shaft top should be examined to insure having a smooth level surface.
7. Survey and record the shaft top elevation to a bench mark.
8. Apply plywood cushion and striker plate to the shaft top.
9. Two to four hammer impacts with varying drop heights should be applied to the top of the shaft. The first drop height should be minimal to allow the Testing Engineer to assess the testing equipment, the driving system and stresses on the shaft. Subsequent impacts can then be applied by utilizing sequentially higher drop heights until either stresses in the shaft are excessive or the shaft permanent set for the applied impact exceeds 0.1 inch.

## **5.0 INSTRUMENTATION**

**5.1** The intent of the load test instrumentation is to measure the test load and its distribution between side resistance and end resistance, load versus deflection, to provide information for design calculations and estimates, and to provide information for final design. The Contractor shall provide assistance when requested by the Testing Engineer during installation of any instrumentation supplied through this contract.

**5.2** The cost of all instrumentation, to be installed as directed by the High Strain Dynamic Load Test supplier, shall be included in the cost for High Strain Dynamic Load Testing. Instrumentation pertaining to the High Strain Dynamic Load Testing, and listed below, shall be provided by the High Strain Dynamic Load Test supplier in addition to any instrumentation outlined in ASTM D4945.

1. Pile Driving Analyzer<sup>®</sup> (PDA) manufactured by Pile Dynamics, Inc., model PAK, PAX or PAL or equivalent.

2. Four calibrated strain transducers.
3. Four calibrated accelerometers.

## **6.0 REPORTING OF RESULTS**

**6.1** Unless otherwise specified by the Department, provide a sealed, color electronic copy report for each load test, for each drilled shaft tested using the High Strain Dynamic Load Test device. Field results of the High Strain Dynamic Load Test shall be provided within 3 working days of test completion including an initial CAPWAP analysis. Submit a final report of the High Strain Dynamic Load Testing no later than 7 days after all High Strain Dynamic Load Testing is completed and accepted by the Department including a final CAPWAP analysis. A CAPWAP® analysis shall be completed for selected hammer impacts in the field and shall be performed by an Engineer that has achieved Advanced Level or better on the Foundation QC High Strain Dynamic Pile Testing Examination.

**6.2** The report must also provide the following:

1. Wave Equation analysis results obtained prior to testing.
2. CAPWAP® (or equivalent) analysis results.
3. The maximum measured force, maximum calculated tension force, transferred energy to the sensor location, corresponding stresses, and the Case Method bearing capacity for each impact.
4. Assessment of the test results both with respect to shaft capacity (including end resistance and friction resistance) and integrity.

## **7.0 METHOD OF MEASUREMENT**

**7.1** The quantity of the pay item “High Strain Dynamic Load Testing of Drilled Shafts” is measured by each (EA) completed and accepted by the Department. A completed High Strain Dynamic Load Test shall be 1 test conducted on a test drilled shaft using the High Strain Dynamic Load Testing.

**7.2** The High Strain Dynamic Load Test shall be considered as any material, labor, equipment, instrumentation, etc. required above. This item should include everything necessary to assemble, install, perform, collect data, and remove the High Strain Dynamic Load Test equipment; under the direction of the High Strain Dynamic Load Test supplier and others.

**7.3** All costs associated with the normal production of the drilled shaft are measured and paid for elsewhere in the contract documents.

## **8.0 DISPOSITION OF TEST SHAFT**

**8.1** After all testing and data collection has been completed, the test drilled shaft shall be cut off to a minimum depth of 2 feet below the ground surface. The cut-off portion of the shaft shall be properly disposed of by the contractor and the resulting hole shall be backfilled with soil in accordance with Section 205 of the Standard Specifications. The test area shall be graded smooth. In addition, the location of this test drilled shaft shall be indicated on the As-Built plans for this project.

## **9.0 BASIS OF PAYMENT**

**9.1** High Strain Dynamic Load Testing will be paid for at the contract bid price per each accepted test. The price and payment shall be considered full compensation for furnishing all materials, providing all tools, equipment, labor and incidentals, providing assistance to the production of the test shaft, performing the High Strain Dynamic Load Test, and disposing of the test shaft as described in Section 8.0 above.

## **10.0 PAYMENT**

**10.1** Payment shall be made under SCDOT Pay Item No. 712XXXX, "High Strain Dynamic Load Testing of Drilled Shafts".